What is happening in Sweden?

Sweden has witnessed significant, fast, and sustainable evolution in the optometry profession over the past 3 decades. We recommend a visit to the webpage of Sancta Lucia Gilles for a fantastic compilation of the history of optometry in Sweden — https://www.sanctaluciagille.se/optikeryrkets-historia. In this editorial we share some exciting news about the optometry education and extended responsibilities for optometrists.

After about 20 years of solid first-cycle bachelor education, Linnaeus University opened a new master program in optometry and vision sciences in 2021 (Linnaeus University, 2022). From September 2023 the bachelor education at Linnaeus University will be available from Campus Kalmar and Campus Gothenburg. That means an annual intake of about 75 first-cycle students and up to 25 second-cycle (masters) students per year. With an annual intake of 100 new students Linnaeus University will be a big player in optometry in the Nordic countries. In parallel, the responsibilities of Swedish optometrists are expected to be extended by the Swedish authorities. We aim to shed some light on the impact of these developments on optometry education in Sweden and the rest of the Nordic countries.

Recognising the evolving healthcare landscape and, probably, appreciating optometrists as a major asset for the chain of eye care, Socialstyrelsen (the Swedish National Board of Health and Welfare) is planning to extend optometrists responsibilities. Socialstyrelsen is an agency under the Swedish Ministry of Health and Social Affairs (Socialstyrelsen, 2019; 2020) and is responsible for ensuring the quality, accessibility, and equity of healthcare and social services.

From January 2024 the main planned changes to the law that controls optometric practice are: (a) optometrists will be allowed to perform eye exams and prescribe refractive correction to children of any age (currently Swedish optometrists cannot prescribe to children under the age of 8 years), (b) the text "optometrists cannot touch the eye" will be removed from the law, and (c) the "contact lens license" will cease to exist as a speciality, that is, all optometrists will be licensed to work with contact lenses. In addition, despite it not being mentioned in the law, the current consensus amongst all eye care professionals is that optometrists must be more selective when referring patients to hospital care. In many cases, optometrists can follow up their patients themselves instead of referring them to hospital. This seems particularly relevant for conditions such as non-exudative age-related macular degeneration and glaucoma (Landgren & Peters, 2021). The law will also include some updates about the vision assessment for driving licenses, but that has less impact on the scope of practice.

What does this mean for education?

The extended responsibilities for optometrists in Sweden represent a significant advancement in the profession's role within the healthcare system. However, the successful integration of these expanded responsibilities relies heavily on adapting the optometry education to equip current and future optometrists with the necessary knowledge and skills. Curriculum development, clinical training, continuing professional development, and interprofessional collaboration are key areas that require attention to ensure the optimal preparation of optometrists in meeting the evolving demands of eye care.

Now, more than before, standardising optometry education in the Nordic countries seems highly relevant. But why standardisation?

- Quality assurance — standardisation ensures a consistent level of quality across different optometry programmes. It establishes a baseline of knowledge and skills that all graduates should possess, ensuring that they are adequately prepared to provide high-quality care to patients. This consistency helps build trust among healthcare professionals, patients, and employers.
- Mobility and recognition — standardised education facilitates professional mobility across international borders. When education programmes follow similar curricula and standards, it becomes easier for optometrists to seek employment, pursue further education, or gain licensure in different Nordic countries. It also enhances the recognition of the profession both regionally and globally.
- Professional identity — standardised education helps shape a strong professional identity for optometrists. Consistent curriculum and training provide a common foundation of knowledge and skills, reinforcing the professional identity. This unity strengthens professional solidarity, collaboration, and advocacy efforts.
- Research and advancement — standardisation can foster collaboration and research initiatives among different optometry institutions. Common educational standards allow for easier sharing of knowledge, best practices, and research findings. This collaboration can contribute to advancements in the field, promote evidence-based practice, and drive innovation in optometry.
- Public health impact — optometrists play a crucial role in promoting public health through early detection and management of common eye conditions. Standardised education ensures that optometrists are equipped with the necessary skills to provide comprehensive services, including the detection of ocular diseases and timely referral to other healthcare professionals. Consistent training and competencies help optimise patient outcomes and public health impact.

While standardisation brings several benefits, it should also allow for flexibility to address regional variations, cultural aspects, and evolving healthcare needs. Striking a balance between standardisation and adaptability is crucial to ensure that optometry education meets the specific requirements of each Nordic country while maintaining a cohesive framework across the region. We urge the players, some authors in this editorial, at the education institutions to reflect about these points and start a dialogue — the sooner the better!

In this issue you can read about prevalence of keratoconus in Sweden (Binder & Sundling, 2023), as well as a new report from Swedish optometric practices that adds to the evidence that there appears to be no myopia epidemic in Scandinavia (Bro & Brautaset, 2023; Demir et al., 2022). You will also find further evidence for the need to use cycloplegic drops to ensure that hyperopia is detected in adolescents and young adults in Scandinavia (Hagen et al., 2023). Visual science is a scientific discipline that entails utilisation of quantitative methodologies, with qualitative methodologies only starting to emerge. A particular qualitative method, namely framework analysis, is presented in the context of optometry and visual science (Somerville et al., 2023).

The lecturers at the optometry education at Linnaeus University during graduation day, 2nd June, 2023, celebrating the qualification of 36 new optometrists. From left to right, Bertil, Peter G., Kabilan, Karin, Ida, Anna-Maria, Jenny, Ellen, Peter L., Carina, Pelsin, Karthikeyan, Antonio, Pablo, Maria, and Oskar. The photo was taken at Kalmar Castle, which is very symbolic because it was here that, in 1397, the Kalmar Union was formed — a union of Denmark, Norway, Sweden, and Finland, organised by Queen Margaret I of Denmark (Kalmar Castle, 2020; Kalmar Union, 2020). Maybe this can inspire us to the message of this editorial.

On behalf of SJOVS, we wish you all a Happy Summer!

Associate Editor António Filipe Macedo
Optometry program coordinator at Linnaeus University (Sweden) Oskar Johansson
Editor-in-Chief Rigmor C. Baraas

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NORGES OPTIKER FORBUND

SOPTI Società Optometrica Italiana

Prevalence and incidence of keratoconus in Sweden: A nationwide register study between 2010 and 2020

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Abstract

The purpose of this study was to estimate the prevalence and incidence of keratoconus in Sweden. The study had a cross-sectional descriptive design, using data from the Swedish Patient Register. Data about keratoconus registered from 1st January, 2010, to 31st December, 2020, were analysed. Prevalence was estimated from the total number of patients registered. Incidence was estimated from the number of first-time registrations per year for the age group 0 to 40 years and stratified by decades of age.

From 2010 to 2020, 16,055 patients were registered with keratoconus in the Swedish Patient Register, giving a total estimated keratoconus prevalence of 169.5 per 100,000 (95% CI: 144.9–194.1), 74.2% were male. The estimated annual incidence of keratoconus was 11.8 per 100,000 (95% CI: 5.1–18.5). The average annual incidence was highest in the decade 21 to 30 years, 26.1 per 100,000 (95% CI: 16.1–36.1). For the age group 0 to 40 years, the estimated incidence of keratoconus was 22.5 per 100,000 (95% CI: 13.7–32.3).

Keratoconus should not be regarded as an uncommon condition. The prevalence of keratoconus may be even higher because of under-registration among older citizens. The estimated prevalence and incidence of keratoconus in Sweden is comparable to estimated prevalence in Norway.

Keywords: Keratoconus, prevalence, incidence, epidemiology

Introduction

Keratoconus was first described in 1854 as a non-inflammatory and chronic corneal ectasia (Gordon-Shaag et al., 2015). It is characterised by progressive steepening and thinning of the cornea that can lead to visual impairment (Mukhtar & Ambati, 2018). Two decades ago, corneal collagen crosslinking (CXL) was introduced, revolutionising the treatment to prevent the progression of keratoconus (Gregor et al., 2003; Kankariya et al., 2013).

Keratoconus often presents unilaterally and patients are often asymptomatic in the early stages of keratoconus. However, within 16 years more than half of the unaffected eyes develop keratoconus (Kankariya et al., 2013; Mukhtar & Ambati, 2018). During the progression of keratoconus, myopia and irregular astigmatism develop causing decreased visual acuity, therefore keratoconus is often first detected in the course of an eye examination (Gordon-Shaag et al., 2015).

The number of detected new cases of keratoconus has increased in the last decade because of more advanced diagnostic tools available to monitor corneal ectasia (Flynn et al., 2016). The best and most sensitive method for the detection, diagnosis and follow-up of keratoconus is corneal topography (Gordon-Shaag et al., 2015). Previous studies estimate the prevalence of keratoconus to be 50 to 54 per 100,000 worldwide (Kennedy et al., 1986; Romero-Jiménez et al., 2010). However, a recent study from the Netherlands estimated a keratoconus prevalence of 265 per 100,000 (Godefrooij et al., 2017). In Scandinavia, the reported prevalence of keratoconus in Norway is 192.1 per 100,000 and in Denmark 44 per 100,000 (Bak-Nielsen et al., 2019a; Kristianslund et al., 2020). The annual overall incidence of keratoconus in Norway was found to be 19.8 per 100,000 and the highest rate of new cases, 36.7 per 100,000, was in the age group from 21 to 30 years (Kristianslund et al., 2020). In Denmark, the annual incidence of keratoconus was estimated to be 3.6 per 100,000 (Bak-Nielsen et al., 2019b). To our knowledge, no studies report the prevalence and incidence of keratoconus in Sweden. The aim of this paper is to present an estimated prevalence and incidence of keratoconus in Sweden between 2010 to 2020.

Methods

The study had a cross-sectional, descriptive design, analysing data obtained from the Swedish Patient Register administered by the Swedish National Board of Health and Welfare. Since the establishment of the International Classification of Disease and Related Health Problems (ICD-10) in 2011, it has been mandatory for Swedish healthcare practitioners to report diagnoses and treatment to the Patient Register. Further, in the same period, CXL has been introduced as a treatment for keratoconus.

The study population was all men and women with keratoconus in Sweden. The sample population was men and women registered with a diagnosis of keratoconus in the Swedish Patient Register between 2010 to 2020. Each patient has a unique patient identifier in the register. Information on age and gender was collected.

The present study analysed data for all patients registered with the ICD-10 code for keratoconus H18.6. Data were obtained for the period from 1st January 2010 to 31st December 2020. Further, the study used data on gender and age for the population of Sweden obtained from the open digital archive at the Central Bureau of Statistics (www.scb.se) for the analysis.

The prevalence of keratoconus was estimated based on the total number of patients registered with keratoconus between 2010 and 2020 (inclusively) and the average number of inhabitants in Sweden in the same period. The incidence was based on the number of new registrations of keratoconus each year and the number of inhabitants in Sweden each year. Further, the incidence was estimated for the age group 0 to 40 years, according to the likely age at onset of keratoconus and to allow for comparison with previous studies (Godefrooij et al., 2017; Kristianslund et al., 2020), and incidence was stratified for age groups 0–20, 21–30, 31–40, 41–50, 51–60, 61–70, 71+ years.

Data were analysed using the free software program R-commander (version 2.8.1) and estimates were presented per 100,000 inhabitants, with a 95% confidence interval (CI).

The study adhered to the Declaration of Helsinki. The Swedish Ethical Review waived the need for study approval. The Swedish National Board of Health and Welfare approved the use of anonymous data.

Results

From 2010 to 2020, 16,055 patients were registered with ICD-10-code H18.6 Keratoconus in the Swedish Patient Register, 74.2% were male. During the same time period, the average number of inhabitants of Sweden was 9,886,365. The estimated overall prevalence of keratoconus was 169.5 per 100,000 (95% CI: 144.9–

194.1). Table 1 presents the total and age-stratified prevalence of keratoconus. The prevalence was highest in the age group 21 to 30 years, 348.4 per 100,000 (95% CI: 313.2–383.6), and lowest among patients older than 70 years, 63.8 per 100,000 (95% CI: 48.8–78.8).

Table 1: *The estimated average and age-stratified prevalence of keratoconus.*

Age groups (years)	Prevalence per 100 000 (95% CI: lower to upper)
0–20	90.0 (71.8–108.2)
21–30	348.4 (313.2–383.6)
31–40	255.3 (225.2–285.4)
41–50	183.8 (158.3–209.3)
51–60	133.5 (111.8–155.2)
61–70	111.5 (91.7–131.3)
71+	63.8 (48.8–78.8)
All	169.5 (144.9–194.1)

Figure 1 shows the number of first-time registrations for each year. The estimated average annual incidence of keratoconus was 11.8 per 100,000 (95% CI: 5.1–18.5), ranging from 5.2 per 100,000 (95% CI: 0.8–9.7) in patients older than 70 years to 26.1 per 100,000 (95% CI: 16.1–36.1) in patients aged 21 to 30 years (see Figure 2). From 2010 to 2020, the average estimated incidence of keratoconus in the age group 0 to 40 years was 22.5 per 100,000 (95% CI: 13.7–32.3), with the annual incidence varying from 18.5% to 25.4% (see Figure 3).

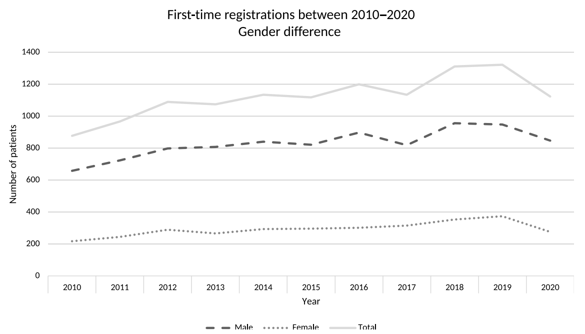

Figure 1: *Total number of first-time registrations by year from 2010 to 2020.*

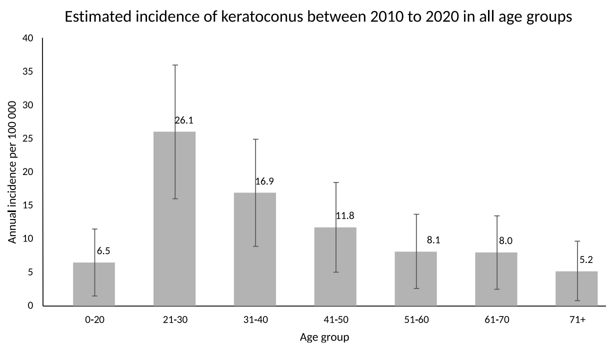

Figure 2: *The age-stratified average annual incidence of keratoconus from 2010 to 2020.*

Discussion

To our knowledge, the prevalence and incidence of keratoconus in Sweden have not previously been reported. The estimated prevalence of keratoconus in Sweden of 169.5 per 100,000 is three times higher than earlier reported estimates of 54 per 100,000 (Kennedy et al., 1986; Romero-Jiménez et al., 2010). Our findings reflect an increased prevalence of keratoconus similar to the estimated prevalence in Norway and the Netherlands, 192.1 per 100,000 and 265 per 100,000 respectively (Godefrooij et al., 2017; Kristianslund et al., 2020). In Denmark, the estimated prevalence of keratoconus for the period 1975 to 2015 was 44 per 100,000, reflecting previous estimates (Bak-Nielsen et al., 2019a). The increased prevalence in our study, and the Dutch and Norwegian studies, may be related to greater numbers of case findings of keratoconus in optometric practice, better access to eye care, better defined diagnostic criteria for keratoconus, improved diagnostic methods, increased availability of CXL treatment, as well as changes in the ethnical origin of the population. As Sweden, Norway and Denmark are countries with similar healthcare systems and populations, the discrepancies in prevalence of keratoconus may be due to differences in optometric practice, diagnostic criteria, and diagnostic methods in ophthalmic healthcare.

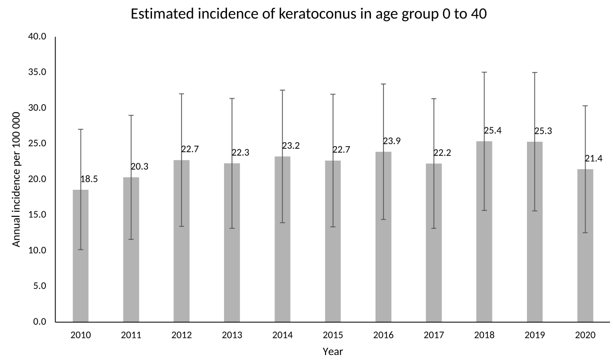

Figure 3: *Estimated annual incidence of keratoconus for the age group 0 to 40 years.*

Three out of four patients registered with keratoconus in Sweden were male, which is in line with current findings from Norway, Denmark, the Netherlands, and other studies showing a clear overrepresentation of keratoconus among male patients (Aylin & Orkun, 2008; Bak-Nielsen et al., 2019b; Godefrooij et al., 2017; Kristianslund et al., 2020). There are no clear explanations for the possible gender difference in keratoconus, although there is a hypothesis that hormonal factors may be an explanation (Gordon-Shaag et al., 2015). However, some studies have found no or only a small gender difference for prevalence of keratoconus (Hwang et al., 2018; Kennedy et al., 1986; Xu et al., 2012). For some of these studies, this may be due to a different ethnical background of the study population (Hwang et al., 2018; Xu et al., 2012).

The present study estimates an average keratoconus incidence of 11.8 per 100,000, with the highest incidence in the age group 21 to 30 years (26.1 per 100,000) and the second highest incidence in the age group 31 to 40 years (16.9 per 100,000). These results are supported by the study from Norway that presents similar distribution in the same age groups (Kristianslund et al., 2020). The lower incidence in the older age groups likely reflects that these patients were diagnosed before the implementation of the register. In the age group 0 to 20 years, the incidence was low compared to age groups 21 to 30 years and 31 to 40 years, and it is known that keratoconus debuts around puberty to young adulthood. The lower incidence in the youngest age group may reflect the fact that keratoconus takes some years to progress before it has an impact on vision. Moreover, suspected cases found in patients aged 20 to 40 years by optometrists may be related to visual requirements for driving or work. Nevertheless, it is important to screen for keratoconus in young patients as keratoconus can lead to reduced visual acuity, negatively affecting educational and social development (Mukhtar & Ambati, 2018).

It is assumed that the patients in our study with first-time registration of keratoconus in late adulthood have been undiagnosed in the greater part of their life, so to adjust for these aspects, a secondary estimation of incidence for patients aged 0 to 40 years was made. The estimated incidence in the age group 0 to 40 was 22.5 per 100 000, which is higher than the average incidence, and likely represents a more accurate incidence of keratoconus. This incidence is comparable to the estimated incidence in Norway and Netherlands, 19.8 per 100 000 aged 0 to 40 years and 13.3 per 100 000 aged 10 to 40, respectively (Godefrooij et al., 2017; Kristianslund et al., 2020).

In the present study, the number of first-time registrations of keratoconus has increased from 2010 to 2020, which is in line with reports from Norway (Kristianslund et al., 2020). This increase in incidence likely reflects greater awareness and improved diagnostic tests for keratoconus. Further, research about keratoconus has resulted in modern grading systems like Belin being implemented in diagnostic instrument software, which has made it easier to detect and follow progression in patients with keratoconus (Belin et al., 2020). This enhanced system of grading has also been implemented in diagnostic instrument software (Pentacam, Oculus GmbH, Wetzlar, Germany) to facilitate the grading of keratoconus (Belin et al., 2020).

In 2020, there was a slightly reduced incidence of keratoconus in Sweden, and we propose this was due to the Covid-19 pandemic leading to delayed diagnosis of keratoconus. Delayed diagnosis and management of keratoconus can lead to preventable reduction in visual acuity, and thereby reduction in quality of life. Therefore, it is important for clinicians, and policymakers allocating healthcare personnel, to prioritise appropriately, both during a pandemic and under normal circumstances. This is also highlighted as an important topic in a Norwegian population study (Kristianslund et al., 2020).

The study has some limitations. First, it does not explore ethnicity or immigration, which have been described as factors impacting the prevalence of keratoconus. In the Norwegian study, Kristianslund et al. (2020) suggested that the increased prevalence of keratoconus could be a result of immigration from regions with a higher prevalence of keratoconus, like Africa and Asia. The Danish study found a lower incidence of keratoconus when immigrants were excluded from the data analysis (Bak-Nielsen et al., 2019b). Further, the Dutch study presents a high prevalence and reports that approximately 22% of the general population was immigrants. Therefore, it is suggested that further epidemiological studies where information about ethnicity is included, should be carried out to improve the knowledge about keratoconus in Sweden. Second, the data were obtained by ICD-10 codes, specifically H18.6 keratoconus. There are other corneal ectasias with separate ICD-10 codes. Nevertheless, some of these cases may have been coded as keratoconus cases and included in our data. The number of these is low compared to the number of keratoconus cases, and therefore has a limited impact on the findings of the present study. Third, the diagnostic methods and diagnostic criteria (grading system) may influence the first-time diagnosis of keratoconus. To our knowledge, there are no general guidelines for diagnosis and management of keratoconus in Swedish healthcare. However, we believe the lack of general guidelines had limited impact on the data in the present study. Fourth, the study did not obtain first-time diagnostic outcome measurements such as pachymetry, keratometry or visual acuity that could have determined the stage of keratoconus at the time of diagnosis. A more in-depth study including this data could indicate if keratoconus was diagnosed at an early stage or if there is a need for improvement in detection and early management of keratoconus. Fifth, ICD-10 codes can be used by general practitioners or other health personnel suspecting keratoconus and referring patients to an ophthalmologist. The ophthalmologist may later contradict the diagnosis. This first ICD-10 code will be recorded in the Patient Register and contribute to an overestimation of keratoconus in the population. However, we believe this will have had limited impact on the data in the present study.

The results of the present study suggest an increase in keratoconus cases in Sweden between 2010 and 2020. The prevalence and incidence of keratoconus in Sweden are higher than reported in some review studies, but comparable to a recent Norwegian study. The true prevalence may be even higher due to under-registration in older age groups. The results of the present study indicate that keratoconus should not be regarded as an uncommon condition in Sweden.

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Prevalens og forekomst av keratokonus i Sverige: En nasjonal registerstudie for perioden 2010–2020

Sammendrag

Hensikten med denne studien var å estimere forekomst og antall nye tilfeller av keratokonus i Sverige. Studien hadde et deskriptivt tverrsnittdesign, og benyttet data fra det svenske pasientregisteret. Data om keratokonus registrert i perioden fra 1. januar 2010 til 31. desember 2020 ble analysert. Forekomst ble estimert fra det totale antallet registrerte pasienter. Insidens, antall nye tilfeller, ble estimert ut fra antall førstegangsregistreringer per år, tiårsklasse og for aldersgruppen 0 til 40 år.

Fra 2010 til 2020 ble 16 055 pasienter registrert med keratokonus i det svenske pasientregisteret, noe som ga en estimert total forekomst av keratokonus på 169,5 per 100 000 (95% KI: 144,9–194,1), 74,2% var menn. Estimert antall nye tilfeller av keratokonus per år var 11,8 per 100 000 (95% KI: 5,1–18,5). Gjennomsnittlig antall nye tilfeller var høyest i aldersgruppen 21 til 30 år, 26,1 per 100 000 (95% KI: 16,1–36,1). For aldersgruppen 0 til 40 år var estimert antall nye tilfeller per år 22,5 per 100 000 (95% KI: 13,7–32,3).

Keratokonus bør ikke ansees som en sjelden tilstand. Forekomsten av keratokonus kan være enda høyere på grunn av underregistrering blant eldre borgere. Estimert forekomst og antall nye tilfeller av keratokonus i Sverige er sammenliknbare med estimert forekomst og antall nye tilfeller i Norge.

Nøkkelord: Keratokonus, prevalens, insidens, epidemiologi

Prevalenza ed incidenza del cheratocono in Svezia: uno studio e registro nazionale tra il 2010 e il 2020

Riassunto

Lo scopo di questo studio e' di determinare la prevalenza ed incidenza del cheratocono in Svezia. Lo studio e' di tipo descrittivo considerando un disegno sezionale ed incrociato utilizzando dati del registro dei pazienti svedesi. Dati sul cheratocono registrati tra il primo Gennaio 2010 e il 31 Dicembre 2020 sono stati analizzati. La prevalenza e' stata stimata dal numero totale di pazienti registrati. L'incidenza e' stata stimata dal numero dei primi pazienti registrati per anno del gruppo di eta' dai 0 ai 40 anni e stratificati per ogni decade di eta'.

Dal 2010 al 2020, 16,055 pazienti sono stati registrati come cheratocono nel registro dei pazienti svedesi, dando una stima totale della prevalenza di cheratocono di 169.5 per 100,000 (95% CI: 144.9–194.1), di cui il 74.2% sono maschi. La stima dell'incidenza annuale di cheratocono e' 11.8 per 100,00 (95% CI: 5.1–18.5). La media annuale di incidenza e' la piu' alta tra la decade 21 a 30 anni, 26.1 per 100,000 (95% CI: 16.1–36.1). Per il gruppo di eta' 0 a 40 anni, la stima di incidenza del cheratocono e' stata del was 22.5 per 100,000 (95% CI: 13.7–32.3).

Il cheratocono non dovrebbe essere considerato una patologia non-comune. La prevalenza di cheratocono potrebbe essere addirittura piu' alta per via della sotto-registrazione tra i cittadini piu' anziani. La prevalenza stimata e l'incidenza del cheratocono in Svezia e' comparabile alla prevalenza stimata in Norvegia.

Parole chiave: Cheratocono, prevalenza, incidenza, epidemiologia

Refractive trends in 15-year-old adolescents attending optometric practices in southern Sweden between 2007 and 2020

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Abstract

The purpose of this study was to analyse the distribution of refractive errors in 15-year-old adolescents at optometric practices in southern Sweden between 2007 and 2020.

Refractive data were collected retrospectively from clinical records in five optometric practices in southern Sweden. The inclusion criteria were individuals visiting the practice at an age of 15 years between 2007 and 2020. The refractive errors were classified by the spherical equivalent (SE) (sphere + ½ cylinder) as follows: myopia (SE ≤ -0.5 D), hyperopia (SE ≥ 0.5 D), emmetropia (-0.5 > SE < 0.5 D). The astigmatism axis (-1.5 DC) was analysed as with-the-rule, against-the-rule and oblique according to traditional methods. To examine trends, the average refraction and distribution of refractive errors were compared between two selected time periods, 2007–2013 and 2014–2020.

During the time frame 500 adolescents aged 15 years were examined in the selected optometric practices. Myopia was found in 34%, emmetropia in 35% and hyperopia in 31%. Among 37 individuals with astigmatism, the most common axis was with-the-rule (41%), followed by oblique (32%) and against-the-rule (27%). No significant differences could be found in the distribution of different refractive errors between the periods 2007–2013 and 2014–2020. Nor could any significant difference in average refraction be found.

In contrast to the expected global rise in myopia as predicted by WHO and the high prevalence of myopia reported in some parts of the world, we could not find convincing changes in distribution between myopia and hyperopia in this cohort of Swedish adolescents.

Keywords: Myopia, incidence, prevalence, children

Introduction

Myopia occurs when the eyeball is too long relative to its refractive power (axial myopia) or if the refractive power is too strong in relation to the length of the eye (refractive myopia). The condition causes need for optical correction. Although high myopia carries the highest risk of complications, even low or moderate myopia increases the risk of cataract, glaucoma, retinal detachment, and myopic macular degeneration (Haarman et al., 2020). According to the World Health Organization (WHO), there has been an alarming increase of myopia the past few decades (WHO, 2017). The global prevalence is estimated to have increased from 23% to 28% between 2000 and 2010. However, there are considerable regional differences with a prevalence of 5% in east Africa and 49% in high-income Asia-Pacific countries (Holden et al., 2016). However, the significance of the global increase is complicated to judge due to a lack of standardised definitions. Furthermore, the diagnosis is strongly dependent on whether examinations are performed with or without cycloplegia, since myopia, defined as spherical equivalent (SE) ≤ 0.5 diopters, has been shown to disappear in 34–47% of cases after instillation of cycloplegic agents (Hu et al., 2015; Lundberg et al., 2018). However, the increase in the proportion of young children with myopia is a critical issue, as early debut of myopia is an important predictor of high myopia in later childhood (Chua et al., 2016).

Different causes of myopia progression have been discussed. A sibling of a myopic identical twin has an up to 90% risk of developing the condition, and several genes linked to myopia have been identified (Kiefer et al., 2013). However, the rapid global increase cannot be explained only by hereditary factors; other factors such as environment must be considered. A meta-analysis including 27 cohorts of children from almost all continents showed that more time spent on near work activities was associated with higher odds of myopia (Huang et al., 2015). Time spent outdoors has also been presented as an independent protective factor. In a study including 2000 children in Australia the odds ratio for myopia increased more than 3 times in the groups that spent only a small amount of time outdoors per week (French et al., 2013). In Asian children (e.g. from China and Singapore), there is much high-level evidence, including randomised controlled studies and meta-analysis, showing that time spent outdoors slows down the change of axial length and reduces the risk of myopia (Cao et al., 2020). Genetic observations suggest that the underlying mechanism for the outdoor effects is based on a light-dependent release of retinal dopamine, which controls scleral growth and remodelling (Tedja et al., 2018). Data concerning the effect of gender is conflicting, females are shown to have both more and less myopia than males (Xiang & Zou, 2020).

In the last few decades, children have become digital users at younger ages, with an increase in the use of computers, smart phones and tablets (OFCOM, 2022). In 2018, 78% of Swedish children had their own computer compared to 56% in 2008 (Statistics Sweden, 2019). In 2017, 24% of Swedish children aged between 12 and18 had a daily screen time (including computer, TV, smartphone and tablets) of at least three hours on weekdays, and at least ten hours during weekends (Statistics Sweden, 2017). Screen time has been argued to play a role in myopia development but consistent evidence for this hypothesis is still lacking (Lanca & Saw, 2020).

The trends for myopia prevalence in the Nordic population vary between the countries. Danish data have showed a decrease in myopia among conscripts in 2004 (12.9%) compared to 1964 (14.5%) (Jacobsen et al., 2007). However, no changes in prevalence of myopia could be demonstrated in a systematic literature search including nearly 140 years of research in Denmark (Hansen et al., 2021). A recent study of Norwegian adolescents has also shown low prevalence of myopia (13%), despite the fact that the study population had few daylight hours in the autumn-winter period, and high levels of indoor activity and near work (Hagen et al., 2018). In Finland, however, myopia is believed to have doubled from 11% to 22% among children aged around 15 during the 20th century (Pärssinen, 2012). Only a few Swedish studies have been published on the subject in the last 20 years. Myopia in cycloplegia (induced by tropicamide) was found in 50% of about a thousand children aged 12–13 years old in 1999 (Villarreal et al., 2000). Ten years later, 650 male conscripts aged between 17 and 23 years were examined. Myopia was found in 38%, but this study used no cycloplegia (Uhlin et al., 2009). An older smaller study of 143 children aged 4–15 years found myopia in cycloplegic refraction in 6% (Grönlund et

Table 1: *Distribution of myopia and hyperopia in previous comparable reports of refractive errors among adolescents in optometric populations.*

Country	Period	Author	Population	*n* (females %)	Ratio between myopia (SE ≤ -0.5) and hyperiopa (SE ≥ 0.5)	Ratio between number of myopic females and males
Sweden	2007–2020	Bro (current)	15 years	500 (59%)	1.0	1.4
Ireland	2015–2019	Longwill et al. (2022)	10–19 years	17 011 (57%)	1.8	1.4
South Africa	2017–2019	Wajuihian and Mashige (2021)	6–18 years	1080 (NR)	1.4	NR
Canada	2007–2008	Hrynchak et al. (2013)	15–19 years	349 (NR)	4.5	NR
Portugal	1999–2004	Queirós et al. (2009)	9–19 years	588 (65%)	1.4	1.6

Note: SE = Spherical equivalent; NR = Not reported for subgroup.

al., 2006). A more recent study found myopia (in cycloplegic refraction in the right eye) in 10% of 128 children aged 8–16 years. Parental myopia was associated with both the level of myopia and the length of the eye (Demir et al., 2021).

Besides conventional prospective studies of epidemiology of refractive errors, studies of records from optometric practices have also been shown to be useful. Although not representative of the population as a whole, such studies provide a reasonable representation of the distribution of symptomatic refractive errors, and serve as a baseline for future analysis. Previous retrospective reviews of records from adolescent patients at optometric practices have been performed in South Africa, Portugal and Canada, with proportions of myopia varying from 19 to 54% (Hrynchak et al., 2013; Queirós et al., 2009; Wajuihian & Mashige, 2021). Such studies usually require manual review of each case. Optometric practices with connected electronic patient databases enable larger studies in the same field (Longwill et al., 2022). Routinely collected data of government funded subsidies for spectacles for children are another valuable source for large amounts of data when available (Kearney et al., 2022). To the best of our knowledge, no previous studies of retrospective data from optometric practices have been performed in a Nordic population (see Table 1).

The purpose of this study was to analyse trends in refractive errors in a population that visited an optometrist at an age of 15 years in the period from 2007 to 2020 in the region of Småland in southern Sweden.

Methods

This was a retrospective study of computerised records from five optometric practices within Synsam Group AB in Småland Sweden (Eksjö, Nässjö. Sävsjö, Tranås and Vetlanda). All managers gave permission for data from their practice to be used in research. An average of 73 000 inhabitants lived in the region during the study time (SCB, 2021), but the included practices were not the only ones within the area. The refractive methods of the different practitioners were not standardised and not performed in cycloplegia. Refractive data were extracted from all youngsters examined at an age of 15 years between 2007 and 2020. This age was chosen as it usually implies a stabilisation of myopia (COMET Group, 2013) in both males and females (Qin et al., 2022).

The spherical equivalent (defined as sphere plus half the cylinder) for subjective refraction for the right eye was used for analysis, as there was no statistically significant difference in mean spherical equivalent between right and left eyes (mean −0.23 and −0.18 respectively) (p=0.08 with a paired t-test, Pearson's $r = 0.927$, $p < 0.001$). Myopia was defined as spherical equivalent (SE) ≤-0.5 D and hyperopia as SE ≥ 0.5 D. Eyes with an astigmatic refractive error ≤ -1.5 DC were considered astigmatic. Thereafter the proportion of, and the mean SE, for different refractive errors were calculated for the time period 2007–2013 compared to 2014–2020. Statistical significance was tested with t-tests and z-tests of proportions. The alpha level was set at 0.05. During the year 2020 the numbers of patients seeking optometric care and the reasons for attending may have been atypical because of Covid-19, therefore this period was analysed separately.

The study was approved by the Swedish National Ethical Review Agency (Dnr 2019-00562) and followed the tenets of the Declaration of Helsinki.

Results

During the time frame of 2007–2020, 500 children aged 15 years were examined in the selected optometric practices. The study group consisted of more females (59%) than males (34%). For the remaining 6% no information was given about gender. Myopia was found in 34%, emmetropia in 35% and hyperopia in 31% (see Table 2). The ratio between myopia and hyperopia was 1.0 and the ratio between myopic females and myopic males was 1.4 (see Table 1). Astigmatism was found in 7%. Among these, with-the-rule astigmatism (41%) was more common than against the rule (27%) (see Table 3). No significant difference was found in the distribution of different refractive errors when the period of 2007–2013 was compared with 2014–2020 (z-test). Nor could any significant difference in average refraction be detected (t-test) (see Table 2 and Figure 1). Myopia occurred in 40% of males and 29% of females. As for the total group, there were no significant differences in the distribution of different refractive errors or in the mean spherical equivalent refractive error between the two time periods in a gender separated analysis (see Tables 4 and 5). Even if the year 2020 may have caused differences in the numbers and reasons for seeking optometric care because of Covid-19, no significant difference in the proportion of myopia was seen during this period (38%) compared with 2014–2019 (31%) (p=0.44 z-test).

Table 2: *Refractive data in a cohort of 15-year-old adolescents seeking optometric care in Sweden between 2007 and 2020 (95% confidence intervals).*

	2007-2020	2007–2013	2014–2020	*p*
n	500	241	259	
Female	59%	62%	57%	
Male	34%	35%	34%	
Unknown	6%	3%	9%	
Proportions				
Myopia	34% (30–38%)	35% (29–41%)	33% (27–39%)	0.70
Emmetropia	35% (31–39%)	35% (29–42%)	34% (29–41%)	0.91
Hyperopia	31% (27–36%)	30% (24–36%)	33% (27–39%)	0.54
Mean SE in diopters				
Myopia	-2.1 (-2.3 – -1.8)	-1.9 (-2.2 – -1.6)	-2.2 (-2.6 - -1.8)	0.31
Emmetropia	0.1 (0 – 0.1)	0.1 (0 – 0.1)	0.1 (0 – 0.1)	0.94
Hyperopia	1.4 (1.2 – 1.6)	1.6 (1.3 – 1.9)	1.3 (1 – 1.5)	0.12

Note: SE = Spherical equivalent.

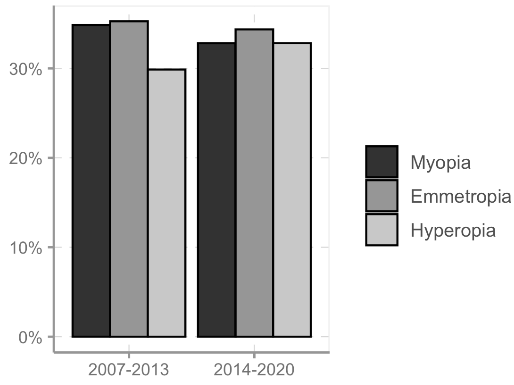

Figure 1: *Distribution of refractive errors in Swedish 15-year-olds seeking optometric care in Småland, Sweden for the time periods 2007–2013 and 2014–2020.*

Table 3: *Astigmatism in a cohort of 15-year-old adolescents seeking optometric care in Sweden between 2007 and 2020.*

	Females	Males	Unknown	Total
Astigmatism (≤ -1.5 D)	23 (8%)	10 (6%)	4 (13%)	37 (7%)
Astigmatic axis				
WTR	39%	30%	75%	41%
ATR	39%	10%	0%	27%
OBL	22%	60%	25%	32%

Note: WTR = with-the-rule (within 30° of vertical axis), ATR = against-the-rule (within 30° of horizontal axis), OBL = oblique (more than 30° from vertical or horizontal axis).

Table 4: *Refractive data in a cohort of 15-year-old females seeking optometric care in Sweden between 2007 and 2020 (95% confidence intervals).*

	2007–2020	2007–2013	2014–2020	*p*
n	297	149	148	
Proportions				
Myopia	29% (24–35%)	32% (25–40%)	26% (19–34%)	0.27
Emmetropia	38% (33–44%)	38% (31–47%)	39% (31–47%)	1.00
Hyperopia	33% (27–38%)	30% (22–38%)	36% (28–44%)	0.30
Mean SE in diopters				
Myopia	-1.9 (-2.2 – -1.6)	-1.8 (-2.2 – -1.4)	-2.1 (-2.5 – -1.6)	0.40
Emmetropia	0.1 (0 – 0.1)	0.0 (0.0 – 0.1)	0.1 (0.0 – 0.1)	0.63
Hyperopia	1.3 (1 – 1.5)	1.5 (1.0 – 1.9)	1.1 (0.8 – 1.4)	0.20

Note: SE = Spherical equivalent.

Table 5: *Refractive data in a cohort of 15-year-old males seeking optometric care in Sweden between 2007 and 2020 (95% confidence intervals).*

	2007–2020	2007–2013	2014–2020	*p*
n	172	84	88	
Proportions				
Myopia	40% (32-47%)	39% (29-51%)	40% (30-51%)	1.00
Emmetropia	28% (21-35%)	30% (21-41%)	26% (18-37%)	0.72
Hyperopia	33% (26-40%)	31% (22-42%)	34% (25-45%)	0.78
Mean SE in diopters				
Myopia	-2.1 (-2.5 – -1.8)	-2 (-2.6 – -1.5)	-2.2 (-2.7 – -1.7)	0.54
Emmetropia	0.1 (0 – 0.2)	0.1 (0 – 0.2)	0.1 (0.0 – 0.2)	0.98
Hyperopia	1.6 (1.3 – 2)	1.8 (1.2 – 2.3)	1.5 (1.0 – 2.0)	0.50

Discussion

In contrast to the expected global rise in myopia as predicted by WHO and the high prevalence of myopia reported in some parts of the world, this study, despite its limitations, did not indicate any convincing changes in the distribution between myopia and hyperopia over the last decade. The ratio between myopia and hyperopia of 1.0 is comparable to studies from Portugal and South Africa (both 1.4) (Queirós et al., 2009; Wajuihian & Mashige, 2021). However, it is lower than data from Ireland and Canada (1.8 and 4.5 respectively) (Hrynchak et al., 2013; Longwill et al., 2022). As in previous studies of adolescent optometric populations, females outnumber males both in total number and in myopic individuals (see Table 1).

To the best of our knowledge, this is the first published study using data from optometric practices in Sweden. Compared to population-based studies, our data probably have a skewed distribution towards myopia, as low to moderate hyperopes sometimes do not seek optometric care due to lack of visual symptoms. The proportion of myopic subjects may also be overestimated since cycloplegic drugs were not used. One way to address this issue is to define myopia as SE ≤ -0.75, which results in a proportion of myopia of 28% in 2007–2013 and 29% in 2014–2020 ($p = 0.93$ z-test). However, in our main results we prefer to use the recommended definition of SE ≤ -0.5 (WHO, 2017). Nevertheless, our results could be used as a basis to evaluate changes in the distribution of refractive errors in the two periods evaluated (2007–2013 vs. 2014–2020). During this period no change in the distribution of refractive error was found. This result is not in line with the global increase of the prevalence in myopia (WHO, 2017). However, it is in agreement with recent Nordic data (Demir et al., 2021; Hagen et al., 2018; Hansen et al., 2021). Thus, adolescents in the Nordic countries seem to defy the world-wide trend of increasing myopia, which challenges the picture of a ”myopia epidemic”.

Despite its limitations, this retrospective study of 15-year-old adolescents does not indicate any convincing changes in the distribution of myopia and hyperopia over the last decade.

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Trender for brytningsfeil hos 15-årige ungdommer som besøkte optikere i Sør-Sverige mellom 2007 og 2020

Sammendrag

Formålet med denne studien var å analysere fordelingen av brytningsfeil hos 15-årige ungdommer, mellom 2007 og 2020, som besøkte optikere i Sør-Sverige.

Data på brytningsfeil ble samlet retrospektivt fra kliniske journaler i fem optometriske praksiser i Sør-Sverige. Inklusjonskriteriene var personer som besøkte praksisen i en alder av 15 år mellom 2007 og 2020. Brytningsfeilene ble klassifisert etter den sfæriske ekvivalenten (SE) (sfære + 1/2 sylinder) og klassifisert som: myopi (SE ≤ -0,5 D), hyperopi (SE ≥ 0,5 D), emmetropi (-0,5 > SE < 0,5 D). Astigmatismeaksen (≤ -1,5 DC) ble analysert som med-regelen, mot-regelen og skrå etter tradisjonelle metoder. For å se på trender ble gjennomsnittlig brytning og fordeling av brytningsfeil sammenlignet mellom to utvalgte tidsperioder, 2007–2013 og 2014–2020.

I løpet av tidsrommet ble 500 ungdommer i alderen 15 år undersøkt i de utvalgte optikerpraksisene. Myopi ble funnet hos 34%, emmetropi hos 35% og hyperopi hos 31%. Blant 37 individer med astigmatisme var den vanligste aksen med-regelen (41%), etterfulgt av skrå (32%) og mot-regelen (27%). Det ble ikke funnet signifikante forskjeller i fordelingen av ulike brytningsfeil mellom periodene 2007–2013 og 2014–2020. Det kunne heller ikke påvises noen signifikant forskjell i gjennomsnittlig brytning.

I motsetning til den forventede globale økningen i nærsynthet som spådd av WHO og den høye forekomsten av nærsynthet rapportert i enkelte deler av verden, kunne vi ikke finne noen endringer i distribusjon mellom nærsynthet og hyperopi i denne kohorten av svenske ungdommer.

Nøkkelord: Myopi, insidens, prevalens, barn

Tendenze refrattive in adolescenti di 15 anni visitati in cliniche optometriche della Svezia meridionale tra il 2007 e il 2020

Riassunto

Lo scopo di questo studio e' stato quello di analizzare la distribuzione degli errori refrattivi in adolescenti di 15 anni visitati in cliniche optometriche della Svezia meridionale tra il 2007 e il 2020. I dati refrattivi sono stati raccolti retrospettivamente dalle cartelle cliniche in 5 cliniche optometriche della Svezia meridionale.

I criteri di inclusion sono stati individui visitati nelle cliniche con un eta' di 15 anni tra il 2007 e il 2020. Gli errori refrattivi sono stati classificati con l'equivalente sferico (SE) (sfera + ½ del cilindro) come segue: miopia (SE ≤ -0.5 D), ipermetropia (SE ≥ 0.5 D), emmetropia (-0.5 > SE < 0.5 D). L'asse dell'astigmatismo (-1.5 DC) e' stato analizzato come secondo regola, contro regola ed obliquo secondo i metodi tradizionali. Per l'esaminare le tendenze, la media della refrazione e distribuzione degli errori refrattivi sono stati comparati tra due periodi temporali selezionati, 2007–2013 e 2014–2020.

Durante questo periodo di tempo 500 adolescenti di 15 anni sono stati esaminati nelle selezionate pratiche optometriche. Miopia e' stata trovata al 34%, emmetropia al 35% ed ipermetropia al 31%. Tra 37 soggetti con astigmatismo, l'asse piu' comune e' stato quello secondo regola (41%), seguito da obliquo (32%) e contro regola (27%). Nessuna differenza significativa e' stata trovata tra i differenti errori refrattivi nei periodi 2007–2013 e tra 2014–2020. Ne e' stata ritrovata una differenza significativa nella media delle refrazioni. In contrasto a quanto e' stato predetto dal WHO per quanto riguarda l'aumento globale della miopia e l'elevata prevalenza della miopia riportata in alcune parti del mondo, non abbiamo trovato cambi convincenti nella distribuzione tra miopia ed ipermetropia in questo gruppo di adolescenti svedesi.

Parole chiave: Miopia, incidenza, prevalenza, bambini

The need for cycloplegic refraction in adolescents and young adults

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Abstract

Cycloplegic refraction is considered the gold standard method when examining children and for ensuring accurate refractive error assessment within epidemiological studies. Recent reports underline that cycloplegia is equally important for ensuring accurate refractive error assessment in Chinese adolescents and young adults (Sun et al., 2018). The aim of this study was to assess whether cycloplegia is of equal importance for refractive error assessment in Norwegian adolescents and young adults.

Non-cycloplegic and cycloplegic autorefraction (Huvitz HRK-8000A), and cycloplegic ocular biometry (IOLMaster 700), were undertaken in 215 Norwegian adolescents (101 males) aged 16–17 years. Topical cyclopentolate hydrochloride 1% was used for cycloplegia. Two years later, autorefraction and ocular biometry were repeated in 93 of the participants (34 males), both non-cycloplegic and cycloplegic.

Non-cycloplegic spherical equivalent refractive errors (SER = sphere + ½ cylinder) were more myopic (less hyperopic) than cycloplegic SER in 93.6% of the participants (overall mean ±*SD* difference in SER: -0.59 ±0.50 D, 95% limit of agreement: -1.58–0.39 D). Refractive error classification by non-cycloplegic SER underestimated the hyperopia frequency (10.4% vs. 41.4%; SER ≥ +0.75 D) and overestimated the myopia frequency (12.1% vs. 10.7%; SER ≤ -0.75 D), as compared with refractive error classification by cycloplegic SER. Mean crystalline lens thickness decreased and mean anterior chamber depth increased with cycloplegia, with the largest changes in the hyperopes compared with the emmetropes and myopes ($p \leq 0.04$). The individual differences between non-cycloplegic and cycloplegic SER varied by more than ±0.25 D between first and second visit for 31% of the participants.

Accurate baseline measurements — as well as follow-up measurements — are imperative for deciding when and what to prescribe for myopic and hyperopic children, adolescents, and young adults. The results here confirm that cycloplegia is necessary to ensure accurate measurement of refractive errors in Norwegian adolescents and young adults.

Keywords: Cycloplegia, refractive error, hyperopia, myopia, adolescents

Introduction

In epidemiological studies, cycloplegic refraction is the gold standard method for correct classification of refractive errors (Fotouhi et al., 2012; Morgan et al., 2015; Sun et al., 2018). Cycloplegia is also generally recognised as necessary when assessing refractive error in children to ensure that accommodation is relaxed — to reveal any latent hypermetropia and/or pseudo myopia (Major et al., 2020). The Norwegian Optometry Association's clinical guidelines reflect this by recommending that retinoscopy ought to be carried out after pharmacologically inducing cycloplegia at the first visit in all children aged 18 years and younger (Norges Optikerforbund, 2021). In comparison, the American Optometric Association recommends cycloplegic retinoscopy as the preferred procedure for the first evaluation of school-age children up to 20 years of age (AOA Evidence-Based Optometry Guideline Development Group, 2017). However, in an informal online questionnaire carried out in the spring of 2022, answered by 123 optometrists and one ophthalmologist who reported examining patients aged 16–20 years daily or weekly in Norway, only 15% reported to often (on at least every other patient) use pharmacological agents for assessing refractive error on the first visit in patients in this age group. The majority reported to rarely (67%) or never (18%) use a pharmacological agent on the first visit in 16–20-year-olds. See details in Supplementary Table S1.

Cycloplegic refraction with cyclopentolate 1% is reported to be critical for proper classification of refractive error in a study of Chinese young adults (Sun et al., 2018). The data showed that the difference between non-cycloplegic and cycloplegic spherical equivalent refractive error was 1.80 D, 1.26 D and 0.69 D for those with cycloplegic hyperopia, emmetropia and myopia, respectively (Sun et al., 2018). Similar findings have been reported from Australia and Israel (Mimouni et al., 2016; Sanfilippo et al., 2014), but with the use of eye drops that have a weaker cycloplegic effect than cyclopentolate 1% resulting in smaller differences between non-cycloplegic and cycloplegic refraction in the Australian study. Here, the aims were to evaluate the difference between non-cycloplegic and cycloplegic autorefraction and ocular biometry using cyclopentolate 1% — and to explore whether the difference between non-cycloplegic and cycloplegic refraction changed over a 2-year period — in Norwegian adolescents.

Methods

A representative sample of 16–19 year old Norwegian adolescents were enrolled in a study of cycloplegic refractive errors in Norway (Hagen et al., 2018). Non-cycloplegic and cycloplegic autorefraction, as well as cycloplegic ocular biometry, were undertaken in a subsample that consisted of 215 Norwegian adolescents (101 males; 87% European Caucasians) aged 16–17 years (mean ±*SD* age: 16.2 ±0.4 years). After 2 years, non-cycloplegic and cycloplegic autorefraction were re-measured in 93 (34 males) of these (Hagen et al., 2019). Both non-cycloplegic and cycloplegic ocular biometry were also repeated at the second visit. The study followed the declaration of Helsinki and was approved by the Regional Committee for Medical and Health Research Ethics in Southeast Norway. All participants gave written consent after being informed about the study.

For cycloplegia, topical cyclopentolate hydrochloride 1% (Minims single dose; Bausch & Lomb UK Ltd, England) was instilled in each eye. One drop of cyclopentolate 1% was instilled in eyes with blue and green irises, while two drops were instilled 1–2 minutes apart for eyes with brown irises.

Non-cycloplegic and cycloplegic autorefraction were measured in each eye at both visits with the same Huvitz HRK-8000A Auto-REF Keratometer (Huvitz Co. Ltd., Gyeonggi-do, Korea). Cycloplegic ocular biometry at the first visit, and both non-cycloplegic and cycloplegic ocular biometry at the second visit, were undertaken with the same Zeiss IOLMaster 700 (Carl Zeiss Meditec AG, Jena, Germany). Cycloplegic autorefraction and ocular biometry were undertaken 15–20 minutes after instillation of the last drop.

Since sphere and astigmatism were well correlated between the right and the left eye, cycloplegic sphere: Spearman rho (ρ) = 0.92; cylinder: ρ = 0.60; both $p < 0.001$, data of the right eye were used in the analyses. Spherical equivalent refractive er-

Table 1: *Non-cycloplegic and cycloplegic SER, sphere, and cylinder for 215 Norwegian 16–17-year-olds.*

	SER (D)		Sphere (DS)		Cylinder (DC)	
	Mean ±*SD*	Range	Mean ±*SD*	Range	Mean ±*SD*	Range
Non-cycloplegic	+0.00 ±0.98	-5.30 – (+5.22)	+0.25 ±1.06	-4.86 – (+6.50)	-0.49 ±0.68	-6.48 – 0.00
Cycloplegic	+0.60 ±1.17	-5.53 – (+7.71)	+0.85 ±1.25	-5.12 – (+8.58)	-0.50 ±0.65	-6.26 – 0.00
Paired difference	-0.59 ±0.50	-2.60 – (+0.24)	-0.60 ±0.50	-2.74 – (+0.25)	+0.01 ±0.16	-0.81 – (+0.56)
Paired t-test	$t(214) = 17.3$, $p < 0.001$		$t(214) = 17.4$, $p < 0.001$		$t(214) = -0.68$, $p = 0.49$	

rors (SER = sphere + ½ cylinder) from autorefraction data were used to categorise the participants as myopes (SER ≤ -0.75 D), emmetropes (-0.75 D < SER < +0.75 D), and hyperopes (SER ≥ +0.75 D). The cut-off values for myopia and hyperopia were chosen as in Sankaridurg et al. (2017).

The statistical analyses were performed by the statistical software R (version 4.4.2) (R Core Team, 2021). Significance level was set at $\alpha = 0.05$. Bland–Altman plots were used to assess the agreement between non-cycloplegic and cycloplegic autorefraction measurements at the first and second visits, and the mean difference and 95% limits of agreement (LoA) are presented. Histograms, QQ-plots and the Shapiro-Wilk test were used to test normality of data. Paired t-tests were used to test for individual pairwise differences. The effect of cycloplegia and refractive status on ocular biometry was analysed with a linear mixed model using the lmerTest package (Kuznetsova et al., 2017), that integrates the lmer function from the lme4 package (Bates et al., 2015), but adds p-values and degrees of freedom estimated using the Satterthwaite's correction. The model specification was as follows:

$$Y_{ij} = \beta_0 + b_p + \alpha_{1i} + \alpha_{2j} + \alpha_{12ij} + \epsilon_{ij}$$

where Y_{ij} was the dependent variable (i.e. LT), β_0 was the intercept, $b_p \sim N(0, \sigma_p^2)$ was a random intercept of participants, α_{1i} was a 2-level factor indicating the state of cycloplegia, α_{2j} was a 3-level factor indicating the refractive error category, α_{12ij} was the interaction between the state of cycloplegia and the refractive error and $\epsilon_{ij} \sim N(0, \sigma_\epsilon^2)$ was residual random error. The p-values were adjusted for multiple comparisons by the Holm method. Sensitivity, specificity, and positive and negative predictive values for identifying hyperopia by non-cycloplegic autorefraction are presented.

Results

Figure 1A presents data on non-cycloplegic and cycloplegic SER at the first visit for the sample of 215 Norwegian 16–17-year-olds. The mean ±*SD* difference in SER was -0.59 ±0.50 D, whereas the 95% limit of agreement (LoA) was -1.58 – 0.39 D. Compared with cycloplegic SER, non-cycloplegic SER values were more myopic (less hyperopic) in 96.3% of the participants. As shown in Table 1, the paired differences between non-cycloplegic and cycloplegic results were significant for the SER and the sphere, but not for the cylinder.

Figure 2 presents the frequency of myopia, emmetropia, and hyperopia based on non-cycloplegic and cycloplegic SER. Categorisation of refractive errors by non-cycloplegic SER underestimated the hyperopia frequency (10.7% vs. 41.4%) and overestimated the myopia frequency (12.1% vs. 6.0%), compared with cycloplegic SER. Only 64.2% of the participants were correctly categorised by non-cycloplegic data (100% of the myopes, 90.3% of emmetropes, 25.8% of hyperopes). The sensitivity to identify hyperopia from non-cycloplegic data was 25.8%, see further details in Table 2.

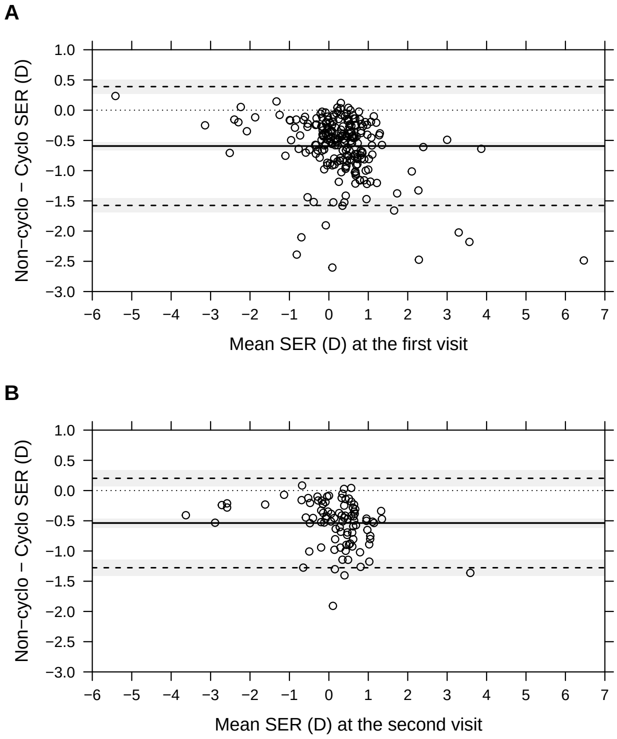

Figure 1: *Bland-Altman plots for comparisons between non-cycloplegic (Non-cyclo) and cycloplegic (Cyclo) autorefraction SER for the participants (A) at the first visit (n = 215; 16–17 years of age) and (B) at the second visit two years later (n = 93). The mean difference is shown as a solid line, while the 95% limits of agreement with the corresponding confidence intervals are shown as dashed lines with grey areas, respectively.*

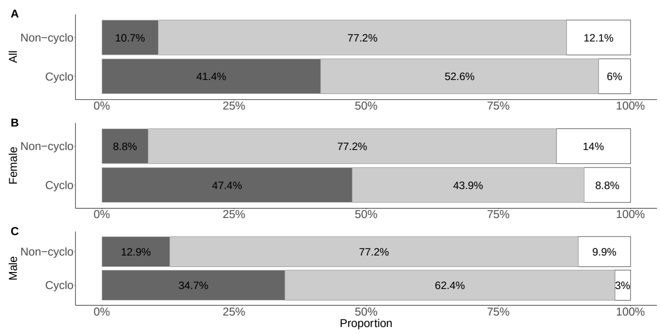

Figure 2: *Frequency of refractive errors based on non-cycloplegic (Non-cyclo) versus cycloplegic (Cyclo) autorefraction SER for (A) all, (B) females, and (C) males at the first visit (16–17 years of age). Bars in dark grey, light grey, and white illustrate hyperopia (SER ≥ +0.75 D), emmetropia (-0.75 D < SER < +0.75 D), and myopia (SER ≤ -0.75 D), respectively.*

There were significant differences between non-cycloplegic and cycloplegic SER in the hyperopes, ΔSER = 0.86 D, $t(212) = 18.2$, $p < 0.001$, $n = 89$, and the emmetropes, ΔSER = 0.43 D, $t(212) = 10.4$, $p < 0.001$, $n = 113$, but the difference did not reach significance in the myopes, ΔSER = 0.14 D, $t(212) = 1.2$, $p = 0.24$, $n = 13$. Note that the refractive errors of the participants were here categorised by cycloplegic SER. As illustrated in Figure 3, the differences between non-cycloplegic and cycloplegic SER were larger in the hyperopes compared with the emmetropes, $t(212) = -6.7$, $p < 0.001$, and the myopes, $t(212) = -5.4$, $p < 0.001$.

Table 2: *The frequency of hyperopia (SER ≥ +0.75 D) based on non-cycloplegic and cycloplegic data. Sensitivity, specificity, positive (PPV) and negative (NPV) predictive values for identifying hyperopia from non-cycloplegic autorefraction are presented.*

		Cycloplegic data		
		Hyperopia	No hyperopia	Total
Non-cycloplegic data	Hyperopia	23	0	PPV 100.0%
	No hyperopia	66	126	NPV 65.6%
		Sensitivity 25.8%	Specificity 100%	

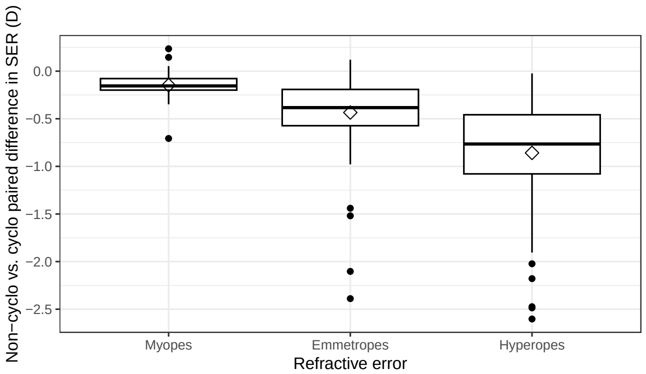

Figure 3: *Paired differences between non-cycloplegic and cycloplegic SER in myopes (n = 13), emmetropes (n = 113) and hyperopes (n = 89) at the first visit (16–17 years of age). Refractive errors were based on cycloplegic data. Horizontal line and diamond denote the median and the mean values, respectively.*

Ocular biometry was undertaken before and after administration of cycloplegia in 93 participants (34 males) at the second visit (18–19 years of age). Figure 4 illustrates the differences in SER, crystalline lens thickness (LT) and anterior chamber depth (ACD) as measured with and without cycloplegia grouped by cycloplegic refractive error. Mean LT decreased significantly with cycloplegia, $t(92) = -17.7$, $p < 0.001$. The decrease in mean LT with cycloplegia was larger in the hyperopes, $\Delta LT = -0.10$ mm, $t(90) = -16.2$, $p < 0.001$, compared with the emmetropes, $\Delta LT = -0.07$ mm, $t(90) = -12.3$, $p < 0.001$, and the myopes, $\Delta LT = -0.03$ mm, $t(90) = -2.1$, $p = 0.04$. Mean ACD increased significantly with cycloplegia, $t(92) = 26.4$, $p < 0.001$. The increase in mean ACD with cycloplegia was larger in the hyperopes, $\Delta ACD = 0.14$ mm, $t(90) = 23.1$, $p < 0.001$, compared with the emmetropes, $\Delta ACD = 0.10$ mm, $t(90) = 18.9$, $p < 0.001$, and the myopes, $\Delta ACD = 0.08$ mm, $t(90) = 5.3$, $p < 0.001$. Overall, cycloplegic ocular biometry showed shallower vitreous chamber and thicker central cornea compared with non-cycloplegic measurements, $\Delta VCD = -0.03$ mm, $t(92) = -12.8$, $p < 0.001$; $\Delta CCT = 0.002$, $t(92) = 4.2$, $p < 0.001$, with no significant interaction effect between cycloplegia and the category of refractive error. The data showed no significant difference between non-cycloplegic and cycloplegic measurements of mean corneal radius, $t(92) = 0.46$, $p = 0.65$.

Figure 1B presents data on non-cycloplegic and cycloplegic SER for the 93 participants at the second visit (18–19 years of age). The mean ±*SD* difference in SER was -0.54 ±0.44 D, whereas the 95% limit of agreement (LoA) was -1.33 – 0.25 D. The paired differences between non-cycloplegic and cycloplegic SER at the first visit were compared with the same results at the second visit for the 93 participants who were re-measured after 2 years (mean ±*SD* age at the first visit: 16.2 ±0.4 years). Figure 5 shows that the individual differences between non-cycloplegic and cycloplegic SER varied by more than ±0.25 D between the first and second visits for 31% of the 93 participants (data points outside the grey shaded area). The individual differences between non-cycloplegic and cycloplegic SER varied by more than ±0.5 D in 11%. The data points within the grey shaded area in Figure 5 represent the 69% of the participants in which the individual differences between non-cycloplegic and cycloplegic SER varied by less than ±0.25 D between the first and second visits.

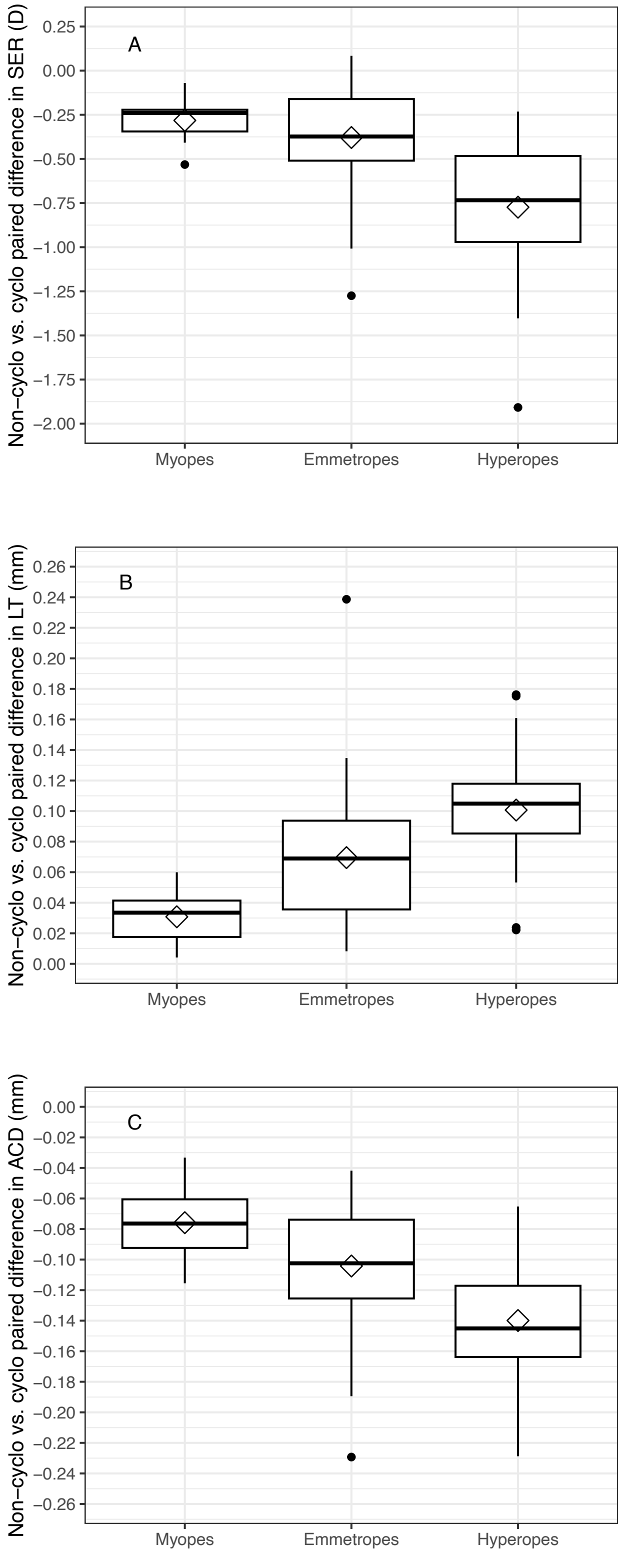

Figure 4: *Paired differences between non-cycloplegic and cycloplegic (A) SER, (B) LT, and (C) ACD in myopes (n = 7), emmetropes (n = 47) and hyperopes (n = 39) at the second visit (18–19 years of age). Refractive errors were based on cycloplegic data. Horizontal line and diamond denote the median and the mean values, respectively.*

Table 3: *Data from studies on differences between pre- and post-cycloplegic SER in myopic, emmetropic, and hyperopic adolescents and young adults. Classification of refractive errors was based on cycloplegic data except Sanfilippo et al. (2014), in which classification of refractive errors was based on pre-cycloplegic data.*

	Mean ±*SD* difference in SER (D)					
Age (yrs)	Myopes	Emmetropes	Hyperopes	Eye drop procedure	Autorefractor	Country
13–19	0.23 ±0.48		0.31 ±0.54	Cyclopentolate 1% (one drop). From 15 years of age: tropicamide 1% (one drop)	Humphrey-598 (Zeiss Meditech)	Australia (Sanfilippo et al., 2014)
16–17	0.15 ±0.23	0.57 ±0.43	1.48 ±0.74	Cyclopentolate 1% (blue-green iris: one drop; brown iris: two drops)	Huvitz HRK-8000A	Norway (present study)
18–19	0.28 ±0.15	0.37 ±0.29	0.77 ±0.37			
19–21	0.69 ±0.69	1.26 ±0.93	1.80 ±1.11	Cyclopentolate 1% (two or three drops) and tropicamide 0.5% (one drop)	Huvitz HRK-7000A	China (Sun et al., 2018)
17–22	0.35 ±0.31	0.73*	1.08 ±0.70	Cyclopentolate 1% (two drops)	Topcon KR-800	China (Pei et al., 2021)
18–21	0.46 ±0.68		1.30 ±0.90	Cyclopentolate 1% (two drops)	Speedy-K (Nikon Corp.)	Israel (Mimouni et al., 2016)
20–26	0.02 ±0.45		0.08 ±0.41	Tropicamide 1% (one drop)	Humphrey-598 (Zeiss Meditech)	Australia (Sanfilippo et al., 2014)

** SD not reported.*

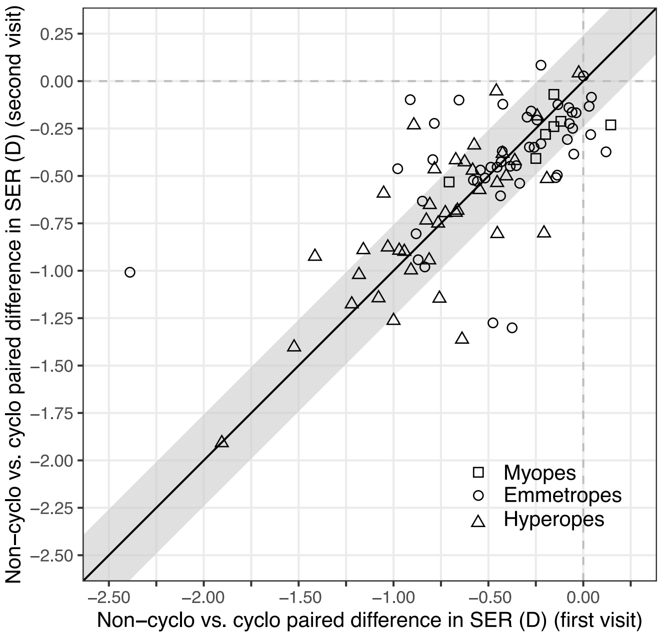

Figure 5: *Individual differences between non-cycloplegic and cycloplegic SER (D) at the first (x-axis) and the second visit (y-axis) for the 93 participants who were re-measured after two years. Mean ±SD age at the first visit was 16.2 ±0.4 years. The markers indicate the cycloplegic refractive error status for the participants at the first visit. The solid line represents the identity line (y = x), while the shaded grey area symbolises ±0.25 D from the identity line.*

Discussion

The results of this study emphasise the importance of pharmacologically inducing cycloplegia for the assessment of refractive error in adolescents and young adults, i.e. beyond the age range recommended by existing guidelines (Pei et al., 2021; Sankaridurg et al., 2017; Yoo et al., 2017). Several recent studies have reported that it is crucial to ensure that the eyes are sufficiently relaxed when measuring refractive error and deciding what to prescribe, also for patients in young adulthood (Mimouni et al., 2016; Sun et al., 2018). Studies claiming that cycloplegia is not needed for refraction have, in general, not used the recommended dosage of cyclopentolate 1%; some of those studies have used a pharmacological agent known to have a weaker cycloplegic effect, such as tropicamide 1% (Sanfilippo et al., 2014). Table 3 shows reported data on differences between pre- and post-cycloplegic SER in myopes, emmetropes, and hyperopes.

It is evident from Table 3 that the choice of pharmacological agent and number of drops play an important role in the cycloplegic depth attained. This is important when comparing the effect of the administered drops on the change in measured refractive error. Studies reporting refractive error with tropicamide or just one drop of cyclopentolate irrespective of iris pigmentation, show a considerably smaller difference between non-cycloplegic and cycloplegic refraction than studies that used the recommended dosage of cyclopentolate 1% (Table 3).

The data show differences in pre- and post-cycloplegic measurements of anterior chamber depth and lens thickness, as reported by others (Hashemi et al., 2020). There is clinical value in knowing which emmetropes have the thinnest crystalline lens as these are assumed to have a higher risk of developing myopia (Hagen et al., 2019; Mutti et al., 2012; Rozema et al., 2019). In Norwegian adolescents, it is expected that several emmetropes are at risk of developing myopia when they move into higher education (Fledelius, 2000; Jacobsen et al., 2008; Kinge & Midelfart, 1999). Indeed, there is a group of emmetropes who have a crystalline lens that is as thin as that observed in the myopes (Hagen et al., 2019).

The expected increase in myopia incidence in late adolescence and young adulthood indicates that there is a need to consider myopia control in this age group in Scandinavia and Europe – and cycloplegic refraction should be carried out at first time eye exam in adolescents and young adults who are in higher education. The measurement of cycloplegic refractive error is important information from which to assess the best treatment option. Treatment options other than standard single-vision spectacles or contact lenses carry an added burden on the patient, in terms of increased cost, compliance and sometimes side effects (Ha et al., 2022; Jonas et al., 2021; Liu & Xie, 2016; Polling et al., 2020; Sha et al., 2018). This challenges optometrists and ophthalmologists to ascertain the best solution for the patient, from among the many myopia control options available. Furthermore, to be able to assess the effect of the prescribed myopia control solutions, both ocular biometry and cycloplegic refraction are needed as baseline. Current standard of care for myopia management set out by the World Council of Optometry (World Council of Optometry, 2021) includes "regular comprehensive vision and eye health exams". Both cycloplegic refraction and ocular biometry results are recommended for baseline and as a means of follow-up to assess the effect of a given myopia control regime on the individual child and adolescent. Current advice for follow-up is that cycloplegic refraction is carried out at least once a year (Morton et al., 2019; Spillmann, 2020; Weng, 2020).

Clinicians may think that the degree of relaxation of the eyes is not important when measuring refractive errors and deciding what to prescribe in adolescents. This and other studies indicate the contrary (Mimouni et al., 2016; Sun et al., 2018), which is expected since average accommodation amplitude typically declines from 15 ±2 D in a 6-year-old to 12 ±2 D in a 16-year-old (Duane, 1922). The average 3 D decline in accommodation amplitude, combined with considerable between-individual variation, is not large enough to make cycloplegic refraction redundant. Another aspect to consider is that adolescents and young adults who have remained hyperopic from childhood, and who may have coped without correction, may, to a larger degree, need a corrective prescription to sustain the amount of near work required in higher education. The difference in SER between cycloplegic and non-cycloplegic data was larger in the hyperopes than in the emmetropes and myopes (see Figure 3), indicating that hyperopes accommodate more than emmetropes and myopes. It is clear from the data that without cycloplegia, hyperopes are prone to be misclassified and remain undetected. Thus, assessment of cycloplegic refraction is needed in adolescents to ensure that the clinician knows the correct baseline – with no influence from individual variation in accommodation – and uses this when assessing the type of solution for both myopes and hyperopes.

Limitations

It is possible that the depth of cycloplegia was not at maximum in this study as measurements were obtained as early as 15–20 minutes post administration of cyclopentolate 1%. A majority of the participants, however, had blue iris pigmentation, and there are indications that a sufficient cycloplegic depth was attained within this time (Manny et al., 1993). If sufficient cycloplegic depth was not reached, the difference between non-cycloplegic and cycloplegic refraction may be even larger than what we have reported here.

Conclusion

The results of this study underline the soundness of the recommendation by the Norwegian Optometry Association of pharmacologically inducing cycloplegia at the first visit in all patients aged 18 years and younger (Norges Optikerforbund, 2021), but the recommendation should also include young adults older than 18 years of age (AOA Evidence-Based Optometry Guideline Development Group, 2017) and follow-up measurements. Cycloplegic refraction is not only important for precise prescriptions, but also for proper myopia control treatment, in which the current advice for follow-up is at least annual cycloplegic refraction (Morton et al., 2019; Spillmann, 2020). This supports that good clinical practice is to perform cycloplegic refraction both at the first visit and in follow-up measurements in young adults as well as those aged 18 years and younger.

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Supplementary information

An informal online questionnaire on use of pharmacological agents for assessing refractive error on the first visit of patients aged 16–20 years was answered by 136 optometrists and 5 ophthalmologists in May 2022. Supplementary Table S1 shows responses from the 123 optometrists and one ophthalmologist who all reported to examine patients aged 16–20 years on a daily or weekly basis in Norway.

Table S1: *Frequency of use of pharmacological agents for assessing refractive error at the first visit of patients aged 16–20 years, as assessed from an informal online questionnaire. Data are the responses from 123 optometrists and one ophthalmologist, all of whom reported to examine patients aged 16–20 years on a daily or weekly basis in Norway.*

	Pharmacological agent		
Frequency	Cyclopentolate 1%	Tropicamide 0.5%	No eye drops
Always	2 (1.6%)	0 (0.0%)	
In more than half	16 (12.9%)	1 (0.8%)	
In fewer than half	78 (62.9%)	5 (4.0%)	
Never			22 (17.7%)

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Behovet for cykloplegisk refraksjon hos ungdommer og unge voksne

Sammendrag

Cykloplegisk refraksjon regnes som gullstandard-metoden ved undersøkelse av barn og for å sikre en nøyaktig utmåling av brytningsfeil i epidemiologiske studier. Nyere studier viser at cykloplegi er like viktig for å sikre nøyaktig utmåling av brytningsfeil hos kinesiske ungdommer og unge voksne (Sun et al., 2018). Målet med denne studien var å vurdere betydningen av cykloplegi for utmåling av brytningsfeil hos norske ungdommer og unge voksne.

Autorefraktor (Huvitz HRK-8000A) ble målt før og under cykloplegi, og okulær biometri (IOLMaster 700) ble målt under cykloplegi, hos 215 norske ungdommer (101 menn) i alderen 16–17 år. Cyklopentolathydroklorid 1% ble brukt for å oppnå cykloplegi. To år senere ble autorefraktor og okulær biometri målt på nytt hos 93 av deltakerne (34 menn), både før og under cykloplegi.

Sfærisk ekvivalent refraktiv feil (SER = sfære + ½ sylinder) målt før cykloplegi var mer myop (mindre hypermetrop) enn SER målt under cykloplegi hos 93,6% av deltakerne, samlet gjennomsnittlig $\pm SD$ forskjell i SER: -0,59 ±0,50 D, 95% grenseverdier (limits of agreement): -1,58–0,39 D. Klassifisering av brytningsfeil basert på SER målt uten cykloplegi underestimerte frekvensen av hypermetropi (10,4% vs. 41,4%; SER ≥ +0,75 D) og overestimerte frekvensen av myopi (12,1% vs. 10,7%; SER ≤ -0,75 D), sammenlignet med klassifisering av brytningsfeil basert på SER målt under cykloplegi. Ved cykloplegi ble gjennomsnittlig linsetykkelse tynnere og gjennomsnittlig fremre kammerdybde økte, de største endringene var hos de hypermetrope sammenliknet med de emmetrope og myope ($p \leq 0{,}04$). Individuelle forskjeller mellom SER målt før og under cykloplegi varierte mer enn ±0,25 D mellom første og andre besøk for 31% av deltakerne.

Nøyaktige førstegangsmålinger — så vel som oppfølgingsmålinger — er vesentlige for å avgjøre når og hva som skal foreskrives til myope og hypermetrope barn, ungdommer og unge voksne. Resultatene i denne studien bekrefter at cykloplegi er nødvendig for å sikre nøyaktig utmåling av brytningsfeil hos norske ungdommer og unge voksne.

Nøkkelord: Cykloplegi, refraktive feil, hypermetropi, myopi, ungdommer

La necessita' di refrazione cicloplegica in adolescenti e giovani adulti

Riassunto

La refrazione cicloplegica e' considerata un metodo "gold standard" quando si esaminano bambini e per assicurarsi che la rilevazione del difetto refrattivo all'interno degli studi epidemiologici. Comunicati recenti sottolineano come la cycloplegia sia ugualmente importante per assicurarsi che la rilevazione del difetto refrattivo in adolescenti e giovani adulti cinesi (Sun et al., 2018). Lo scopo di questo studio e' stato quello di verificare che la cicloplegia sia ugualmente importante per la rilevazione dell'errore refrattivo in adolescenti e giovani adulti norvegesi.

L'auto-refrattometria non cicloplegica e cicloplegica (Huvitz HRK-8000A), e la biometria cicloplegica (IOLMaster 700), sono state misurate in 215 adolescenti norvegesi (101 maschi) di eta' compresa tra 16 e 17 anni. Il farmaco topico-oculare hydrochloride 1% e' stato utilizzato per la ciclopegia. Due anni dopo, l'autorefrazione e la biometria oculare sono state ripetute in 93 soggetti (34 maschi), sia in cicloplegia che senza cicloplegia.

Gli errori refrattivi secondo l'equivalente sferico (SER= sfera + ½ del cilindro) sono stati misurati in non-cicloplegia e sono stati rilevati piu' miopici (meno ipermetropici) che in cicloplegia SER in 93.6% dei partecipanti (media generale $\pm SD$ con differenza in SER: -0.59 ±0.50 D, 95% limite di accordo: -1.58–0.39 D). La classificazione dell'errore refrattivo attraverso la non cycloplegia SER ha sottostimato la frequenza dell'ipermetropia (0.4% vs. 41.4%; SER ≥ +0.75 D) e sovrastimato la frequenza della miopia (12.1% vs. 10.7%; SER ≤ -0.75 D), cosi come comparato con la classificazione dell'errore refrattivo con ciclopegia SER. La media dello spessore del cristallino e' diminuita e la media della profondita' della camera anteriore e' aumentata in cicloplegia, con il piu' grande cambiamento negli ipermetropi in confronto agli emmetropi e ai miopi ($p \leq 0.04$). La differenza individuale tra i valori di SER non cicloplegici e quelli di SER cicloplegici e' cambiata di piu' di ±0.25 D tra la prima e la seconda visita tra il 31% dei partecipanti.

Misure accurate nella prima visita di base, cosiccome nelle misure di follow-up, sono perentorie per decidere quando e cosa prescrivere per bambini miopi ed ipermetropi, adolescenti e giovani adulti. I risultati di seguito confermano che la cicloplegia e' necessaria per assicurarsi che le misure degli errori refrattivi siano accurati in adolescenti e giovani adulti norvegesi.

Parole chiave: cicloplegia, errore refrattivo, ipermetropia, miopia, adolescenti

Framework analysis for Vision Scientists: a clear step-by-step guide

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Abstract
Vision sciences has traditionally been a quantitative discipline. However, to fully capture all aspects of clinical vision care, researchers increasingly need to be conversant in both quantitative and qualitative methodologies. This has resulted in qualitative methodologies becoming more common in vision sciences research literature. From the authors' perspective, vision researchers often struggle to identify suitable qualitative methodologies when coming from a tradition of a realist ontology, or the view that independent truth exists. This study explores the ontological and epistemological considerations when approaching qualitative research in vision sciences and proposes framework analysis as a qualitative methodology that is accessible for vision scientists. Framework analysis is a flexible and highly utilitarian qualitative analysis method which complements quantitative methodologies. This paper also presents a step-by-step guide for conducting framework analysis in a logical, transparent, and repeatable way that will provide a clear audit trail of how results are obtained from subjective data. This is done using a worked example from a recent eye care study.

Keywords: Qualitative, framework analysis, methodology, vision science

Introduction

Research can generally be divided into two distinct methodologies — quantitative and qualitative (Jolley, 2020). With increasingly sophisticated research techniques becoming available, researchers should select a methodology from their tool kit that is most appropriate for the research they are conducting. Vision sciences has traditionally been a subject dominated by quantitative research as the physical properties of light and its application lends itself well to quantitative measurement and exploration (Jones & Jefferis, 2017). Equally, measuring the success and impact of refractive procedures to correct refractive error (Ferreira et al., 2022), surgical interventions to manage cataracts (Louison et al., 2019) and glaucoma (Kuerten et al., 2015) is routinely undertaken by capturing quantitative research data including distance and near visual acuity (VA) (Chang et al., 2021), and intraocular pressure (IOP) at baseline and at defined time points following the intervention.

However, the application of light to the human experience, for example visual perception and the practice of optometry, requires that we understand more than the objective properties of light or the change in clinical parameters, but also how the entire world of sight and its place in healthcare is experienced by individuals. Such considerations are increasingly favoured by funding bodies such as the National Institute for Health and Care Research (UK) (2022) and the National Institutes of Health (USA) (2022). A number of studies that used qualitative methods have been published in major vision sciences journals such as Ophthalmic and Physiological Optics (Kumaran et al., 2021; Scheffer et al., 2022), Optometry and Vision Science (Narayanan et al., 2017) and Clinical and Experimental Optometry (Kandel et al., 2017; Moghimi et al., 2014).

Qualitative research is one way to collect such data to complement purely quantitative measurements. The necessity of qualitative research becomes apparent when research questions involving experience and belief are investigated (Green & Thorogood, 2018). Examples of these questions might include why patients refuse sight-saving interventions or why a new piece of optometric equipment is disliked by practitioners or patients. Experience and perception may initially appear to be relatively vague concepts, but are qualities best explored using an approach where the subjective experiences can be used as data. This can sit uncomfortably with clinicians or researchers coming from a traditionally positivist viewpoint who strive for objectivity in every step of their practice or research (Green & Thorogood, 2018). Qualitative research can also appear opaque without a robust set of guidelines and little indication of how the output of analysis was achieved from the raw data. The numerous qualitative research methods available can seem overwhelming as the terminology used for qualitative methodologies can be unfamiliar and can seem vague to those used to rigid definitions and transparency.

Framework analysis is one qualitative methodology that has proved popular with healthcare researchers (Ward et al., 2013). This paper argues that the framework analysis approach uses a research philosophy compatible with more traditionally realist ontology. It therefore provides an in-road into qualitative research for more quantitative-minded vision scientists although will require an appreciation of more subjectivist epistemologies. Using framework analysis, phenomena can be examined in great detail through a logical and repeatable series of steps, enhancing and improving the understanding of the application of vision to the human experience. This paper seeks to help researchers familiar with quantitative methodologies to understand the need for qualitative methodologies as another research tool. This paper also seeks to explore the relationship between a realist ontology and qualitative research, and proposes these are compatible, although a flexible approach to epistemology is required. Once the underpinning philosophical stance is understood, framework analysis is suggested as a user-friendly and robust method of qualitative analysis suitable for scientists with a realist ontology, and a step by step worked example is given. This paper aims to generate wider interest among vision researchers in exploring qualitative research methodologies and to stimulate future applications in mixed-methods studies to provide a more comprehensive evaluation of vision outcomes in patients. This paper proposes that the logical and repeatable nature of framework analysis lends itself well to mixed-methods research where quantitative and qualitative methodologies can complement each other in answering different aspects of larger research questions. The paper also lays out a step-by-step approach to analysis that vision scientists can refer to when conducting a piece of qualitative research.

Paradigm

Before a step-by-step approach is described to undertake any type of qualitative analysis, a thorough understanding of ontology and epistemology is required. Vision scientists coming from a traditionally realist and positivist background may need to take time to consider their philosophical stance before conducting qualitative analysis. Although it is important for all researchers to adapt their methods of research to the research question, the philosophical approach of the researcher is one element of research that may be difficult to change. This can be called the research paradigm and consists of the personal ontology and epistemology of the researcher (Kuada, 2012). Ontology refers to the researcher's personal opinion on the nature of reality or what we believe to be true. Epistemology refers to how we know the nature of reality. In research, ontology can often be boiled down to whether one believes that objective truth exists or not: if there is a truth that is independent of whether we believe it or not. In vision sciences, this is often the approach that clinicians and scientists take, that independent truth exists, also known as a realist viewpoint (Green & Thorogood, 2018). The epistemology is often positivist, meaning it is believed this objective truth can be observed and measured, for example in an experiment (Kuada, 2012). In studies with a positivist epistemology, researchers are careful not to introduce subjectivity or bias in observation or measurement that can cloud the reality they are trying to explore. This realist ontology along with a positivist or empirical epistemology is often a tacit assumption in the teaching of vision sciences: that we approach an objective world in an observable way and only what is proven by science is trustworthy (Bahari, 2012).

Some of the underlying concepts are described in the following paragraph. For readers unfamiliar with the terminology, a table with the most important definitions is provided (Table 1). A realist ontology is not something that necessarily needs to change in the course of our life or career. Our upbringing, our personal experiences, even theology come into our view of the world and subsequently our ontology, and it can be an essential part of who we are. Aspects of epistemology however, should be more flexible for researchers. Even if we believe that objective truth exists and that it can be measured and that subjective experience must be minimised to get as close to the truth as possible, what if the subject we seek to understand is itself a subjective experience? For example, a new intervention for myopia control has undergone extensive study and has proved effective but in the real world subjects are not completing treatment and practitioners are not adopting the techniques required. Knowing an intervention can work is not the same as it actually working. Understanding why human beings do certain things is essential to implementing ophthalmic interventions and is, by its very nature, not an objective phenomenon. Whether objective truth exists or not is not the issue at this stage, but a recognition that qualitative data is subjective in its telling and subjective in its interpretation by a researcher is essential (Hammersley & Atkinson, 1995). So, if the subject in question is by its very nature a subjective experience or what we may call a phenomenon, then it is impossible to approach this research with our traditional epistemology, i.e. that subjectivity must be eliminated. Instead, it is necessary to look at qualitative methodologies. The subjective telling may correlate with objective truth, if this exists, but either way the positivist notion of observing an objective truth cannot be achieved in qualitative research since participants cannot "objectivise" what is subjective in nature, i.e. the phenomenon in question (Kiernan & Hill, 2018). The data itself therefore cannot be criticised for being subjective because it is by its very nature just that. However, the analysis and inferences drawn from this data can be scrutinised for the subjectivity of the researcher shading the voice of the participant.

Vision scientists coming from a realist ontology can feel uncomfortable with qualitative methodologies because the philosophy underpinning much qualitative research is not realist. Instead, qualitative methodologies often approach knowledge relativistically, suggesting reality is socially constructed and there is no objective truth (Green & Thorogood, 2018). While rejecting the existence of truth may be unfamiliar for many vision scientists, this does not make all qualitative methodologies unapplicable to them. Approaching research from a realist (truth exists) ontology, does not mean one cannot explore subjective phenomena. Instead, researchers need to use a methodology that recognises epistemologically that this objective reality is viewed only as experienced subjectively by participants. It is the research question that must determine the most appropriate methodology. If the research question seeks an explanation of human behaviour or understanding of human reasoning, a flexible epistemology should recognise the subjective nature of the question and select an appropriate qualitative approach. This pragmatic approach does not require a paradigm shift in the researcher's personal view on the nature of reality (ontology) but requires an acceptance of the subjective nature of certain data and an understanding of how to approach it.

Table 1: *Table of key terms with meanings.*

Term	Meaning
Paradigm	The overall description of a worldview that involves both ontology and epistemology
Phenomenon	A subjective experience that is the object of qualitative research
Ontology	Philosophy regarding the nature of reality, i.e. does objective truth exist?
Epistemology	Philosophy regarding how we can discover truth, i.e. can truth be measured objectively?
Realism	A research ontology in which objective truth exists
Positivism	A research epistemology in which objective truth exists and can be measured by removing subjectivity from the research process
Empiricism	Philosophical approach in which only that which can be measured through science can be regarded as truth
Constructivism	A family of paradigms in which objective truth does not exist and cannot be measured as the phenomenon is only constructed through subjective processes
Framework analysis method	A method for analysing qualitative data that is flexible regarding ontology and attempts to explore phenomena in a robust and transparent way

This scrutiny of subjectivity in the process of analysis relates to the validity of the research. Policy makers must have confidence in the findings of research especially when it can be difficult for some to trust the validity of qualitative findings. As Kiernan and Hill (2018) put it, "If qualitative evidence is to be regarded seriously… it must be at the very least rigorous, systematic, and proportionate in its claims." This can be achieved using a combination of methods including reflexivity of the researcher and by using a qualitative analysis method that provides accountability for each step of the process. The data will always remain the subjective account of the participant, but transparency in auditing to show how data was recovered demonstrates validity in a way more in tune with realist ontology, producing a matrix-style output similar to that found in quantitative research (Pope & Mays, 2009). The validity is therefore not measured against an objective truth but should be measured against the accuracy in recording and transparency of inferences made. Reflexivity also helps to give an account of how the research process has influenced and been influenced by the researcher in order to show that subjective judgements are open to inspection. What is needed is an analysis method that demonstrates accuracy, repeatability, accountability and transparency.

Popular qualitative analysis methods include thematic analysis (Braun & Clarke, 2006), and qualitative content analysis and framework analysis (Ritchie & Spencer, 1994). A criticism of thematic analysis is that there is sometimes little transparency in the method of obtaining themes from the data (Herzog et al., 2019). When this process is not described in detail, it calls into question the trustworthiness of this method (Nowell et al., 2017). Equally, qualitative content analysis can be criticised for its reliance on intuitive actions of the researcher affecting its transparency (Elo et al., 2014). Framework analysis was developed for applied policy research to overcome some of these problematic areas, and it is therefore the transparency and potential repeatability of framework analysis that is attractive and aligns with traditional vision science perspectives. The ability to audit results based on the robust organisation of data and the production of a matrix-style output similar to that found in quantitative research makes it recommended for vision scientists (Pope & Mays, 2009) and potentially highly complementary when conducting mixed-methods research. Framework analysis is a suitable method for part time research because the analysis can, in fact, become more meaningful when over-immersion is not a factor (Smith et al., 2011; Ward et al., 2013). It is also largely pictorial, which may suit the personal data processing style of a researcher; it can be used both inductively and deductively, and is also relatively simple for novices (Gale et al., 2013; Smith & Firth, 2011; Srivastava & Thomson, 2009).

Framework analysis

Framework analysis, developed by Ritchie and Spencer in the 1980s (Ritchie & Spencer, 1994; 2002; Ritchie et al., 2013) is a qualitative analysis method from the same broad family as thematic analysis. Analysis methods from this family use themes as the output of the analysis. These are the broad concepts contained in the data and the meaning to participants of these concepts (Gale et al., 2013; Smith & Firth, 2011). Framework analysis also shares elements with grounded theory in that it uses a constantly comparative method, but unlike grounded theory does not seek to produce theory. Instead, it seeks to draw out explanatory conclusions from data centred around themes and has as its defining feature a matrix-style output where these themes are presented (Gale et al., 2013). It was first used in the context of Applied Policy Research for commissioned research projects with highly specific aims. This is important as it means this method was specifically developed for projects that begin with a focussed question. However, it has become popular in broader medical science research especially nursing and psychology, as it also allows for exploration of unexpected themes (Parkinson et al., 2016; Ritchie et al., 2013). The main benefit for researchers of framework analysis is the ability to explore phenomena in depth while creating a transparent audit trail, countering some of the arguments commonly made against other qualitative methods that they lack depth and transparency (Attride-Stirling, 2001; Smith & Firth, 2011; Ward et al., 2013). It also allows for rich description of a phenomenon whilst paying attention to the complex layers of meaning and understanding in the original context (Popay et al., 1998). Examples of healthcare studies using framework analysis include experiences of disease (Midgley et al., 2015), barriers to implementation of new health initiatives (Heath et al., 2012), and understanding of health promotion (Wood et al., 2010). It can be used for a variety of data including interviews, focus groups, and observational data (Goldsmith, 2021).

In order to provide this transparency in analysis, framework analysis utilises a robust method of cyclical analysis that can be followed step by step. This allows for the comprehensive interpretation of data whilst providing a process for analysis where the results can be traced back to the original data and are repeatable by another researcher. The process is similar to qualitative content analysis (Elo & Kyngäs, 2008; Graneheim & Lundman, 2004) in that it centres around themes or categories being lifted from the data and develops these into main themes and subthemes. It differs from other types of qualitative analysis in that it does not use codes or labels to do this, but synthesises material through summarising data and attempts to retain strong links to the original material. There are five steps involved in framework analysis as described by Ritchie et al. (2013), which are familiarisation, identifying a thematic framework, indexing, charting, and mapping and interpretation. Framework analysis in the context of vision science has been limited (Al-Attas et al., 2010; Lacey & Luff, 2009), but it was adopted recently as part of a mixed methods approach (Macfarlane et al., 2022). None of these studies detailed their experiences of conducting framework analysis in the context of vision science, although a number of other studies in the wider context of health research have (Gale et al., 2013; Parkinson et al., 2016; Smith & Firth, 2011; Ward et al., 2013). They have used varying nomenclature to describe the steps involved and the thematic output, but a summary of the steps and a suggested nomenclature are outlined here, along with practical examples of its use in a recent vision science study.

Steps in Framework Analysis with Worked Example from Vision Research

As indicated, framework analysis involves five steps: familiarisation, identifying a framework, indexing, charting, and mapping and interpretation. These steps can be easily followed in the context of the research process (see Figure 1). To assist vision researchers interested in the method, a detailed worked example will be described from a study undertaken in 2021 to address the problem of the lack of human resources for eye health in rural areas (unpublished data). The study involved a comparison between two countries with similar structures of eye care that both have issues in recruiting and retaining mid-level eye care workers. The World Health Organisation recommended that improving recruitment/retention and task-shifting were two ways to do this, but it was unknown what effect task-shifting and recruitment/retention may have on each other. To explore these phenomena in more detail, a qualitative study was conducted that used semi-structured interviews with 20 participants (10 in Scotland, 10 in Ghana) to explore experiences and perceptions of task-shifting and rural eye care working. Framework analysis was used on the transcripts of the interviews and examples of the process is detailed here.

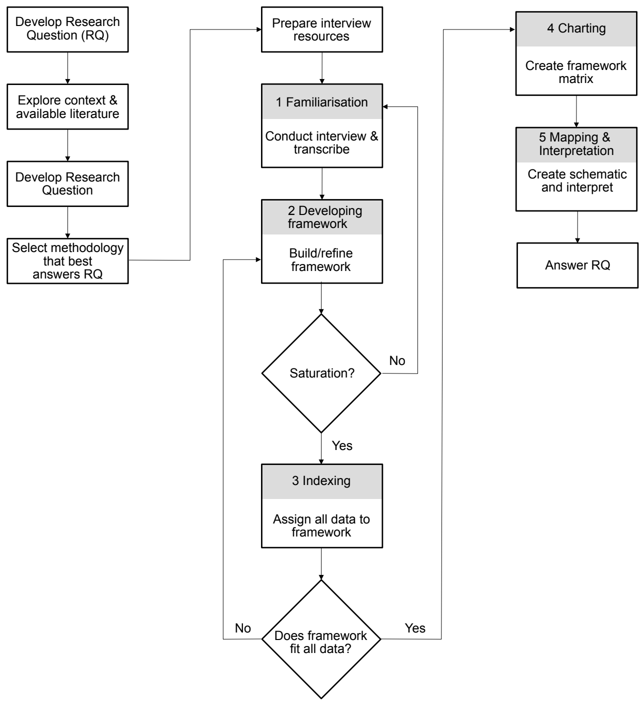

Figure 1: *Flowchart showing research process using Framework Analysis as the analysis method.*

Step 1: Familiarisation

Familiarisation involves immersing oneself in data in a similar way to other qualitative approaches with the purpose of getting an overall holistic sense of the phenomenon, i.e. what topics are the participants talking about? (Parkinson et al., 2016). Examples of how practically this can be done include conducting the interviews personally, the researcher typing their own transcriptions, re-listening to the interviews during transcription and reading and re-reading the transcripts (Silverman, 2006). It is also useful at this stage to note down initial thoughts and impressions as a way to develop the initial themes used in the next step (Parkinson et al., 2016). Gale et al. (2013) recommend the use of a tree diagram at this stage to cluster these initial ideas into initial themes in an attempt to begin the process of abstraction of the data.

In the eye care study, despite the large amount of data collected and the availability of automated transcription software, all transcripts were transcribed personally by the researcher. This fulfilled the purpose of changing the data from audio to text for analysis but also provided the researcher with the familiarity with all participants and the general tone of their experiences. It was possible to write notes on transcription and to provisionally highlight important passages in the text as the research question was kept in mind through the transcribing process. This was done by keeping an "analysis diary" where interesting points or questions were noted down for consideration at a later stage in analysis. Silverman (2006) describes transcription of data as an integral part of the research process as it aids familiarisation. Transcription by hand is therefore recommended as it aids the deep familiarity with the data required in framework analysis.

Step 2: Identifying a Framework

Identifying a framework is the second step in framework analysis. The purpose of this step is to develop a framework to organise or rearrange the data in a more useful and meaningful way (Gale et al., 2013; Parkinson et al., 2016). At this stage, interpretation of the data can be tempting, but the data should first be organised and rearranged. Instead of having the data structured by participant (e.g. a transcript containing all of participant 1's data) the goal is to have the data restructured by theme or topic. To do this, some initial, flexible themes must be decided upon, which is called the framework. Since framework analysis was developed specifically for research from organisations that came with a priori issues, for example a specific work-based problem, initial themes can be gained from these pre-determined issues (Srivastava & Thomson, 2009) but can also come from the results of a literature review or from the initial notes taken in step one. The idea at this stage is not to interpret the data but to manage it (Parkinson et al., 2016). A good way of developing the initial themes at this stage is to read transcripts and ask oneself, "what subject is the participant talking about here?". Since the data is not being interpreted yet, the themes are likely to change and therefore should be broad but robust. This can be done by beginning with flexible themes, testing them on transcripts, reviewing other transcripts in the light of emergent issues and reviewing again (Smith & Firth, 2011). If framework analysis is conducted as a team, it is important at this stage that regular team discussions are held so that flexible themes are agreed upon and the team embarks on the subsequent steps with a mutual understanding (Parkinson et al., 2016). Refining initial themes is critical whilst continuing to be grounded in the original data in order to demonstrate how the raw data is translated into themes (Smith & Firth, 2011; Srivastava & Thomson, 2009). This leaves the researcher with an initial thematic framework with the idea that this can now be applied to the data in the next stage.

In the example eye care study, the familiarity gained in the first step allowed this initial framework to be developed. It consisted of numerous initial, flexible themes decided upon by asking the question: "what were the participants talking about?" during the first phase of familiarisation by transcription and rereading. These were initially jotted down freehand, not in any order:

- contentment with scope of practice
- incentives
- salary
- impact of scope of practice on business
- financial security
- family commitments
- easier to find work in rural area
- out-of-pocket payments

The names of the initial topics were refined and improved and then organised under broader themes (see Table 2). For example, it was realised that when participants were talking about their experiences of out-of-pocket expenses, their salary, and their feelings on financial security, that these could all be broadly categorised as "finances". In this way, an initial, broad and basic framework was established. At this stage it was important that the themes be broad enough to incorporate as much of the topics as possible but streamlined enough to not make the initial framework overwhelming to work with. As more data was analysed, more themes and sub-themes were added until there was an initial matrix, in this case consisting of ten key themes, each with their own sub-themes.

Table 2: *Table showing extract from initial framework showing refining of topics into themes and sub-themes.*

Sub-themes	Key Themes
Salary	Finances
Remuneration from NHS (GOS fee)	
Out-of-pocket expenses	
Financial security	
Financial incentives	
Impact of SOP on stress	Scope of practice
SOP benefit to patients	
SOP impact on optics as a business	
SOP difficult to increase	
Enjoyment found in wider role	
Contentment with SOP	
Professional isolation	Isolation
Achieving CPD	
Logistic difficulties of isolation	
Personal isolation	

Step 3: Indexing

Once the framework of key themes with their own sub-themes has been created, indexing is the third stage in framework analysis and involves applying the framework developed in step 2 to the data in a systematic way (Gale et al., 2013). This is done by using a method called "indexing" where each initial theme is given a number and each transcript is read again. Each section of data (this may be anything from a phrase to a whole paragraph) is given a number based on which theme the participant is talking about. Again, at this stage there is no interpretation, the data is just being organised by theme. Occasionally some excerpts may be assigned two themes as they reflect on more than one issue, and it useful to have an "other" theme as recommended by Parkinson et al. (2016) in order to remain responsive to any data that was important but did not fit well with any of the initial themes. At this stage it is important to remain responsive to the data and refine the themes as the process is cycled back and forward. Themes can become merged or separated based on re-reading of the transcripts and new themes developed as understanding of the phenomenon deepens. At this stage, conducting framework analysis in a team is advantageous as discussion about where "difficult" themes should fit can improve accuracy (Parkinson et al., 2016).

In the eye care study, once the initial framework, consisting of themes with their own sub-themes was decided upon, indexing the data involved re-reading the transcripts and applying the framework to the data. This was done using NVivo software (version 1.5, QSR International Ltd, Denver, USA), but could also have been done by hand. In NVivo, colours can be assigned to each theme and sub-theme and text highlighted so that each piece of text can be linked to a sub-theme. The length of texts ranged from as short as a few words to as long as a paragraph. At this stage it was important that the themes were refined again and again as more transcripts were indexed, as it was vital to remain responsive to the data, i.e. open to new ideas emerging or paring down older ideas. For example, this meant that if a new passage was read that did not fit in with a current sub-theme, then a new one was added. During this stage themes were added, themes were combined, and themes were renamed. For example, "relationship with ophthalmologists" and "relationship with eye hospital" were originally two separate themes, but it became apparent the participants used these interchangeably as they viewed the hospital eye departments and the ophthalmologists in them as the same entity. The sub-theme "moving home" was renamed "home and rural upbringing." It was originally called "moving home" because many participants described the sense of "home" as a motivating factor in moving to a rural area. However other participants were found later whose home was in an urban area but who spent some formative years in a rural location. It was decided that both types of participants were describing the same phenomenon and the name of the sub-theme should be refined to accommodate both experiences. This study sought experiences from optometrists in two different cultures: Scotland and Ghana. Some themes applied only to one context, e.g. out-of-pocket expenses for consumables were a peculiarly Ghanaian theme. However, other themes that appeared context-specific were actually combined upon reflection. Ghanaian participants spoke about unreliable electricity and lack of accommodation as key problems with rural life. Scottish optometrists described difficulties with parcel delivery and long commutes. Although these problems were context-specific, they all described difficulties with rural life and were combined under the theme "rural living."

Step 4: Charting

Charting is the fourth step in framework analysis and is about organising the data in a more manageable chart format to aid the final step of the analysis, which involves interpretation. After each fragment of transcript has been assigned a colour or number, they are now grouped together according to theme rather than by participant. Computer software such as NVivo can do this easily, or it can be done physically by cutting out each excerpt and rearranging. Even though the software is able to group all the fragments together under each theme, this still involves displaying a large amount of data, as one excerpt may be as long as an entire paragraph. To assist the manageability, the original excerpts are instead summarised and placed into a chart so all the data can be looked at in one go in a more manageable way (Gale et al., 2013). Although summarising can mean the complexities of the participants' descriptions can become faded in this stage, the summarised data is always linked back to the original transcript, so original data will not be lost and can be easily accessed (Srivastava & Thomson, 2009). Where possible, it is best to summarise the data by a verbatim excerpt known as an in-vivo code that enhances the proximity of the analysis to the raw data (Smith & Firth, 2011). The end product then is the characteristic framework analysis chart or matrix where participants' pseudonyms are located in the left column and the themes are arranged across the top (see Table 3). This allows an observer to read down the chart to see each participant's contribution to a single theme or read across the chart to see a single participants' contribution to each individual theme (Gale et al., 2013). For example, in the eye care study, the chart can be read downwards to see what each participant said about "family and friends" or the chart can be read across the way to see "Coffie's" contribution to each theme.

Step 5: Mapping and Interpretation

Mapping and interpretation is the final stage in framework analysis. This stage moves beyond data management and finally into an attempt to understand and interpret the data. The matrix produced in the previous step provides the opportunity for the researcher to see patterns in the data in a simplified, more visual way, and enables interpretation of the "whole" from identifying the key characteristics in the matrix. Interpretation can be approached from a variety of phenomenological standpoints including hermeneutic phenomenology. Smith and Firth (2011) recommend starting by referring back to the original data to reduce the chance of misinterpretation. Srivastava and Thomson (2009) recommend at this stage that a schematic diagram of the phenomenon should be produced. The themes are now clarified and given descriptions. The "final themes" at this stage are the "interpretive concepts or propositions" that attempt to explain the data (Gale et al., 2013). The opportunity is also present at this point to create typologies, develop over-arching themes, establish relationships between themes, predict behaviours, and propose strategies for intervention or practice (Gale et al., 2013; Ritchie & Spencer, 2002).

In the eye care study, the matrix that was produced in the "charting" stage was scrutinised for mapping. This involved searching for patterns in the themes, relationships between themes and the characteristics of the participants who related different themes. For example, all Ghanaian participants described experiences of lacking technology in terms of basic equipment, whereas Scottish optometrists described the lack of network connection and software as more significant. Both Ghanaian and Scottish optometrists found that the isolation of rural life made continuous professional development more challenging. The importance of family in decision-making was discussed by both male and female participants but it was only female participants who described experiences of moving job because their spouse had found work elsewhere. At this stage, the aims and objectives were reviewed in light of the data in order to stay grounded in the purpose of the study. Various maps or schematics were considered by drawing them on a whiteboard in order to obtain the best visual representation of the most amount of data possible. It was decided that a "field" of themes was the best approach, with the location of the theme within the square corresponding to whether the theme applied to Ghana, Scotland or both, and whether the theme was highly motivating, highly demotivating, or neither. The schematic produced (see Figure 2) helps the viewer see at a glance the relative importance and impact of sub-themes and serves as a grounding connection between the aims of the study and the experiences of participants.

Interpretation involves interpreting the meaning behind the patterns in the data and interpreting the deeper meaning participants attached to themes in a wider sense. The first area of

Table 3: *Extract from framework matrix showing data organised by participant and by theme.*

	Theme	Collaboration and Teamwork			Family & Relationships	
	Sub-theme	Relationship with HES	Relationship to management	Inter-professional relationships	Family and Friends	Relationship issues
Participants (pseudonym)	Abina	Come to be "accepted" by other eye professionals	Management must provide the necessary working conditions — instruments and a good team — for motivation		"Moving to a rural areas would prevent "development" of family members. Proximity to family is a motivating factor"	"one of my fears in the rural area... am I able to meet a suitor?"
	Coffie	"That relationship is there. So, it makes the work much more easier"		Makes work easier. Mutual respect is important.	Being away from family life is difficult: "sometimes you miss your family. You really miss them"	
	Adjo	"once you are paired with an ophthalmic nurse or an ophthalmologist you are virtually limited in your scope of practice" "lack of recognition" exists		Motivated to stay by good interprofessional relationships at place of work	Being happy with location means having friends and family there. A better life for family is a motivating factor	"I met my wife at the hospital... So that's one advantage of working in a rural area!"

interpretation was given over to the a priori, or pre-determined issues arising from the literature review. For example, views on participants' scope of practice. If a funding body or a research aim demands the answer to a specific question, then this can first be addressed. In this study it was possible to see from the matrix and schematic that participants were content with their scope of practice. The important element of the interpretation phase is asking what does this really mean to participants in a deeper sense? Participants were content with their scope of practice because they felt it allowed them to fulfil their main motivational driver which was patient care. Without an increased scope of practice, participants felt a deeper ambiguity towards their existential purpose and felt the dissonance between being acutely aware of the needs of rural populations and not being able to solve many of the problems. A wide scope of practice on the other hand improved this dissonance and allowed optometrists to work towards solving the problem they identified.

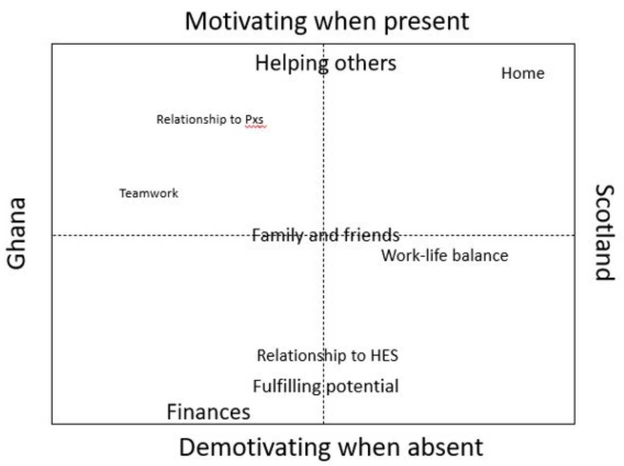

Figure 2: *Example schematic attempting to display relationship between subthemes, location and motivational category.*

Themes that were not a priori issues and that were discovered "organically" from the data are arguably a more important source of interpretation and discussion as they necessarily demonstrate the presence of themes in the originally data. Participants were not asked specifically about altruism or family relationships in interviews, but it became a recurring topic amongst the majority of participants in both countries. This gives weight to what was an unexpected theme and allows for consideration of this in the discussion. Unexpected answers to standard questions is another way to highlight important findings. Participants were asked indirectly about remuneration in all interviews and it was surprising that the vast majority of participants did not rank remuneration highly in their motivation in their profession. The discussion is therefore based on consideration of the interpretation phase of framework analysis.

Limitations of framework analysis

In qualitative research, there are a number of methods and approaches that can be taken for the analysis of data including thematic analysis, qualitative content analysis, and grounded theory (Green & Thorogood, 2018). Each method comes with its own set of strengths and weaknesses, and framework analysis is no different in this regard. As with any method and despite the many apparent benefits of framework analysis, there are limitations. It could be argued that framework analysis is more time consuming than other types of qualitative analysis as it involves more stages. The early stages can also be difficult for novice researchers when it is tempting to interpret from the beginning. Resisting the temptation to interpret and to solely organise data in the early stages reaps rewards of logical and accurate interpretation in the later stages. There is also a lack of theoretical underpinning that marks other approaches, like grounded theory or ethnography (Smith et al., 2011). However, these aspects must be weighed against the benefits of framework analysis, namely that it provides a novel depth of (subjective) data, which can add value by complementing quantitative data and by presenting patients' or practitioners' perspectives. From the authors' perspective, qualitative research approaches can provide meaningful and informative data in vision sciences, provided careful consideration is given to the analytical techniques employed.

Conclusions

Scientists should not ignore qualitative research, as qualitative methodologies can help to answer questions that are not adequately addressed by quantitative research approaches alone, and allow for in-depth exploration of issues that are by their very nature subjective and that are important to patients, clinicians, research funders, and policy makers (Green & Thorogood, 2018). Before conducting qualitative analysis, careful consideration of ontology and epistemology should be made, especially for vision scientists coming from a realist and positivist tradition. Having a realist ontology does not mean one cannot conduct qualitative research, as even though the data collected will be subjective in its telling and subjective in its interpretation, it can still be considered as a subjective representation of an objective truth. However, careful consideration of epistemology and the nature of subjective data should be given. It is not possible to eliminate subjectivity from qualitative data and therefore a positivist epistemology cannot be appropriate. Reliability can be demonstrated in other ways, including the use of a robust and repeatable method of analysis. Framework analysis is therefore proposed as a method which is suitable for scientists with a traditionally realist and positivist viewpoint as it is transparent, repeatable and helps fulfils the criteria of good quality qualitative research.

Conducting framework analysis involves five steps. The first four involve organisation of the data with the final step involving interpretation. Researchers must bear in mind that although framework analysis concentrates a great deal of time to data organisation, the ultimate aim of analysis is the important final step of interpretation of the phenomenon. Although time-intensive, framework analysis is robust, flexible and provides for investigation of a priori and unexpected topics. The use of qualitative software can significantly simplify the process of indexing and charting. The example given demonstrates how to conduct each step using real data from the field of vision science. Using this step-by-step approach, vision scientists can conduct framework analysis which will add to their catalogue of evidence and leave a transparent audit trail of how the final output was achieved from the raw data.

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Rammeverksanalyse for synsforskere: en enkel steg-for-steg metode

Sammendrag

Synsvitenskap har tradisjonelt vært en kvantitativ disiplin. For å fange alle aspekter av klinisk synshelsetjeneste fullt ut, må forskere imidlertid i økende grad være kjent med både kvantitative og kvalitative metoder. Dette har resultert i at kvalitative metoder har blitt mer vanlig i synsvitenskapelig forskningslitteratur. Fra forfatterne av denne studiens perspektiv sliter synsforskere ofte med å identifisere egnede kvalitative metoder når de kommer fra en tradisjon med en realistisk ontologi, eller oppfattelsen om at det finnes en uavhengig sannhet. Denne studien utforsker de ontologiske og epistemologiske betraktninger når man nærmer seg kvalitativ forskning innen synsvitenskap, og foreslår rammverksanalyse som en kvalitativ metodikk tilgjengelig for synsforskere. Rammeverksanalyse er en fleksibel og nyttig kvalitativ analysemetode som utfyller kvantitative metoder. Denne artikkelen presenterer også en trinnvis veiledning for å utføre rammeverksanalyse på en logisk, transparent og repeterbar måte som vil gi en tydelig endringslogg for hvordan resultater oppnås fra subjektive data. Dette gjøres ved å bruke et bearbeidet eksempel fra en fersk øyehelse studie.

Nøkkelord: Kvalitativ, rammeverksanalyse, metodologi, synsvitenskap

Strutta dell'analisi per scienziati della visione: una chiara guida passo dopo passo.

Riassunto

La scienze della visione ha tradizionalmente un approccio alla disciplina di tipo quantitativo. Ciononostante, per comprendere pienamente tutti gli aspetti della cura della visione dal punto di vista clinico, i ricercatori devono incrementare anche il lato quantitativo come quello qualitativo nei metodi. Questo e' risultato per i metodi qualitativi in divenire piu' comuni all'interno della letteratura scientifica della scienze della visione. Dal punto di vista degli autori, i ricercatori nel campo delle scienze della visione spesso fanno fatica ad inviduare le metodologie qualitative quando si sono sempre basati su una tradizionale ontologia realista, o sulla visione che la verita' indipendente esiste. Questa ricerca esplora che le considerazioni ontologiche ed epistemiologiche quando si approcciano alla ricerca qualitativa nelle scienze della visione e propongono una struttura di analisi come metodologia qualitativa accessibile agli scienziati della visione. L'analisi strutturale e' flessibile e i metodi qualitativi di analisi altamente utilitaristici per condurre un approccio strutturale sono logici, trasparenti, e ripetibili in modo da garantire una traccia chiara di come i risultati sono ottenuti da dati soggettivi. Questo e' stato fatto considerando un esampio ottenuto da un recente studio di salute dell'occhio.

Parole chiave: Qualitative, analisi strutturale, metodologia, scienza della visione

SOPTI Meeting 2023: Abstracts

The 28th National Conference of the Italian Optometric Association (SOPTI) was held in Rimini on May 7–8, 2023. This year the conference title was "ABC in Optometry" and it was divided into three sessions: ametropias, binocular vision and correction. A *lectio magistralis* in "Clinical uses of fixation disparity testing" was held by Prof. Bruce Evans, Institute of Optometry, London, UK. The abstracts from accepted posters and free papers are presented here.

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Development of a psychometric questionnaire about progressive addition lenses adaptation: a preliminary study

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Abstract

The purpose of this study was to develop a survey for optometrists and opticians who have experience in prescription, dispensing and supplying progressive addition lenses (PALs), in order to select questions that can later be included in a psychometric questionnaire to measure the degree of patients' adaptation to PALs.

After a bibliographic search and consultation with a panel of experts, an online survey was created using Google Forms. The survey was distributed to opticians and optometrists through Facebook groups and IRSOO (Institute for Research and Studies in Optics and Optometry). The selection of the questions was made based on the score obtained.

According to the professionals interviewed, the most significant activities undertaken by PAL users were walking, using computers and smartphones, and day- and night-driving. The symptoms to investigate were dizziness, distance and near blurred vision, double vision, difficulty perceiving distances, wish to return to the previous spectacles, and anomalous positions and movements of head or eyes. The most interesting general features of the users were age, occupation, ametropia, near addition, and anomalous posture. The psychological aspects to investigate were the need for clear vision at all distances, confidence or insecurity towards the use of PALs, and perfectionism or tolerant attitude. The technical aspects were pantoscopic and wrap angle, back vertex distance, prescription and prescription changes, and prescriber.

In this preliminary phase, we have created two separate questionnaires: one for wearers of PALs, which focuses on quantifying, on a scale from 0 (not at all) to 4 (very much), the comfort when performing certain activities, and on a scale from 0 (never) to 4 (always), the frequency of experiencing certain symptoms of discomfort while wearing PALs; and a technical form for the optician. The two questionnaires will now need to be validated by administering them to a sample of subjects.

Comparison, inter- and intra-operator repeatability of three different subjective phoria tests

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Abstract

There are several tests that evaluate phorias. The purpose of this study is to compare three tests widely used in clinical practice to assess if there are clinically significant differences among tests and whether the operator can affect the repeatability.

The sample consisted of 36 participants with normal binocular vision that can be correctly dissociated with every test. The Maddox test, the Facchin test, and subjective cover test were assessed. Each test was performed three times (both for distance and near) on every participant in order to collect enough data to assess short term repeatability and make a statistically valid comparison between the tests. For data analysis repeated measures analysis of variance was used, which allows the comparison of multiple measurements obtained with different tests, instruments and operators. The Maddox test tended to give more esophoric values, subjective cover test provided more exophoric values, and the Facchin test provided intermediate values between the two.

Repeatability among the tests was optimal for distance and near. The only statistically significant (but not clinically significant) difference emerged in inter-operator repeatability of near Maddox test. These results allow us to assert that in clinical practice, the three tests work completely linearly with each other, and therefore, they are interchangeable.

Correlation between digital eye strain and dry eye in remote workers

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Abstract

The purpose of this research is to assess the presence of Computer Vision Syndrome (CVS) and dry eye in remote workers, in relation to the hours spent on the computer, age, gender, and type of correction used.

The sample consisted of 70 participants (40 males, 30 females), with a mean age of 36 years (median 32; *IQR* 26–45; range 18–66). The CSV_Q questionnaire for measuring Computer Vision Syndrome symptoms and the SPEED questionnaire for dry eye symptoms were administered online to a sample of smart working operators.

The average CVS_Q score was 7.6 (median 8; *IQR* 4–10; range 0–18), with 37 subjects affected by CVS. The average SPEED questionnaire score was 6.3 (median 6.5; *IQR* 3–8; range 0-17), with 12 subjects symptomatic for dry eye, 11 of whom were also affected by CVS. There was a positive correlation between the scores of the two questionnaires ($R = 0.638$; $p < 0.05$). The only statistically significant difference found was between the genders, where females had higher scores compared to males on both questionnaires. The data demonstrate a correlation between symptoms of digital fatigue and dry eye. Almost all subjects symptomatic for dry eye were also symptomatic for CVS. However, it cannot be concluded that a subject presenting with

symptoms of digital fatigue must necessarily have a dry eye condition.

The two questionnaires, although correlated, are not interchangeable. The SPEED questionnaire, freely available in Italian, unlike the CVS_Q, cannot be used to diagnose CVS but can be proposed to individuals experiencing digital fatigue to understand if the cause of the symptoms is primarily related to an ocular surface imbalance.

Comparison between monocular and binocular prismatic lenses anteposition in open field test execution

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Abstract

The purpose of the study was to compare the values of fusion vergences, and dissociated and associated phorias obtained by adding prismatic lenses monocularly and binocularly in open field. Also, the possible influence of gender and monocular/binocular performance mode on the tests performed was studied.

Seventy-seven subjects between the ages of 19 and 30 years were examined, of whom 54 were female and 24 were male. Each subject examined was asked to report any use of ophthalmic correction or contact lenses and was then balanced by the Humphriss method. The tests considered were the fusion vergence jump test with Berens' cues, dissociated heterophorias by Thorington's test (modified Maddox test), and associated heterophorias at 6 m by the needle test (from Haase's sequence) and at 40 cm by the Wesson Card. All tests were performed at 6 m and of 40 cm.

The data collected showed significant differences between the tests for fusional vergences, while there were no significant differences for dissociated and associated phorias. Comparing the monocular and binocular test modes, the differences were significant for negative fusion vergences breaking at distance and for positive fusion vergences breaking at near.

The results obtained provide a starting point for subsequent studies and research, given the paucity of data and reference values, as there are studies in the literature comparing the various tests without reference to monocular/binocular modality. At a clinical level, the presence of greater differences in near vergences than in distance vergences appears to be relevant in the assessment of phorias. In fact, the most frequently disturbing phorias are near phorias. Vergence data were detected differently depending on whether they were measured monocularly or binocularly and this would avoid phorias compensation, leading to improvement of the subject's visual comfort.

Epithelial thickness changes during orthokeratology treatment

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Abstract

Orthokeratology is a contact lens treatment that involves the use of rigid gas permeable (RGP) lenses with reverse geometry design. They are designed to be worn during sleep to allow the wearer to improve their visual acuity without the use of spectacles or contact lenses. Additionally, orthokeratology is used to control myopia progression. The use of this particular type of contact lens leads to changes in thickness of the corneal epithelium (Qu & Zhou, 2022). The purpose of this research is to analyse variation in epithelial thickness during overnight orthokeratology treatment by comparing thickness before treatment and after 30 nights, centrally, at 6 mm and at 8 mm from the corneal apex.

For this research were enrolled 11 patients (22 eyes), aged between 14 and 62 years with an average spherical equivalent refraction of -2.50 D (range -1.00 to -4.75 D). All participants underwent an eye test, a slit lamp examination to assess the centration and fluorescein pattern of the contact lens, and optical coherence tomography of the anterior segment (CSO MS-39) to measure epithelial thickness before and after the 30th night of treatment. At the follow up, all participants had a visual acuity equal to or greater than 6/6 without the need for any optical correction. Epithelial thickness data were extracted from the tomography: centrally and at four different locations: nasal, temporal, superior and inferior (at both 6 and 8 mm from corneal apex).

From data analysis it was found that central epithelial thickness decreased on average by 7.4 $\pm$3.7μm. At 6 mm eccentricity, epithelium increased in thickness for all locations except in temporally, where no significant change was found. At 8 mm eccentricity, an increase in epithelial thickness was found in the nasal, temporal, and inferior zones, with no significant changes in the superior zone.

During orthokeratology treatment, the corneal epithelial thickness undergoes two different types of changes. In the central zone, the epithelium tends to reduce in thickness, while in the lens reverse zone (6 and 8 mm from corneal apex) it tends to thicken.

References

Qu, D., & Zhou, Y. (2022). Post-Ortho-K corneal epithelium changes in myopic eyes. *Disease Markers*, *2022*.

Case report: High monocular astigmatism compensated using a toric scleral lens

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Abstract

The correction of anisometropia, especially astigmatic anisometropia, can be challenging with spectacles due to adaptation difficulties. Often, contact lenses are the most comfortable and efficient solution for patients. If astigmatism is high, scleral lenses can offer comfort and stable vision.

Mrs GP (51 years old) has scleral and corneal toricity that cause an astigmatism of 5.00 D in her RE (VA 1.0 logMAR). In the LE she has astigmatism of -0.50 D VA (0.04 logMAR). She has never previously used correction, and only now, with presbyopia, she reports blurry near vision, constant fatigue, and headaches.

The first lens fitted (ΔS 100μm; $\oslash$16.80; BC 8.00; SAG 4200μm) had excessive sagittal height that caused the formation of air bubbles and excessive lift at the edge in the steeper meridian. Proceeding by steps, the sagittal height of the lens was progressively reduced, and the sagittal difference between the two meridians was increased. The final lens had the following parameters: ΔS 540μm; $\oslash$15.30 BC 8.30; SAG 3680μm; Sph: +1.43 Cyl: -2.59 Ax: 6 (VA 0.14 logMAR); Optimum Infinite DK 185 (3DLAC, Pa).

In her LE, a frequent replacement soft lens was tried, but this was not tolerated due to insufficient comfort. Therefore, the astigmatism was corrected with spectacles. Presbyopia was managed with a monofocal ophthalmic lens (Add: +1.75). After the initial adaptation, the patient wears only the scleral lens in her right eye throughout the day and has resolved the problems of fatigue and headaches.

In cases of high astigmatism, toricity often extends to the sclera, making the application of scleral lenses more complex. The analysis of the scleral profile can be carried out through the fitting of trial scleral lenses, evaluating the interaction with the sclera, and increasing the sagittal difference until proper fitting is achieved in all meridians.

How long does it take to fit and manage contact lens properly?

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Abstract

Specialty contact lens (CL) practice is considered fascinating and it is often asked: "How does one start a specialty contact lens practice?". There are numerous factors to consider, and some cannot be properly investigated. The purpose of this research is to investigate the time needed to fit and manage patients with contact lenses in a specialty contact lens practice.

Over a 3-months period, the time dedicated to each patient was registered. 554 activities were measured (85 first fitting, 424 scheduled follow-up, 45 unscheduled follow-up) conducted by two optometrists with different level of experience. The timeframe of each activity was divided into three periods. The first period (t_1), the evaluation, includes history and symptoms, reason for visit, measurement of the anterior segment (using tomography), the conditions of ocular surface lubrication (using a slit lamp and diagnostic dyes), measurement of objective refraction (using ocular aberrometry), and subjective refraction including assessment of binocular vision. The second period (t_2), the communication, includes the communication with the patient, the selection and sharing of the treatment plan, including risks, benefits, and necessary activities involved. The third period (t_3), the instructions, includes insertion of the trial lens, evaluation of the fit (using slit lamp), measurement of visual performance (objective refraction with aberrometer, subjective refraction and binocular balancing), and lens removal and care. An additional period (t_{add}) was measured, dedicated to the repetition of instructions during the appointment for the lens collection.

The average time for t_1 was 10 ±2 minutes (95% CI [9, 11]), for t_2 10 ±6 min (95% CI [9, 12]), for t_3 13 ±3 min (95% CI [12, 14]), and for t_{add} 22 ±19 min (95% CI [18, 26]). The average total time for each patient was 56 ±23 min (95% CI [51, 61]; minimum 28 and maximum 137). For any follow-up the average time was 8 ±4 min (95% CI [7, 9]). Statistically significant differences were found between the four fitting protocols ($p = 0.001$, ANOVA): soft 48 ±16 min, corneal rigid gas permeable 49 ±18 min, orthokeratology 65 ±24 min and scleral rigid gas permeable 70 ±30 min. No statistically significant difference was found between age groups (group 1: 5–12 years, group 2: 13–18 years, group 3: 19–60 years, group 4: over 60 years).

Effective and safe contact lens practice is based upon experience, expertise, and methodology, as in many other professional activities. Moreover, any activity should be sustainable for both the practitioner and the patient to ensure its continuous delivery. The time devoted to speciality contact lens practice measured in this study serves as reference model for the investment of necessary resources in terms of time and minimum personnel required.