THE ROLE OF OPTOMETRISTS IN PAEDIATRIC EYECARE IN ENGLAND

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DECLARATION

I, Salma Wilson, confirm that the work presented in this thesis is my own.

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COVID-19 IMPACT STATEMENT

COVID-19 Impact Statement

This statement is provided for the aid and benefit of future readers to summarise the impact of the COVID-19 pandemic on the scope, methodology, and research activity associated with this thesis. The academic standards for a research degree awarded by City, University of London and for which this thesis is submitted remain the same regardless of this context.

Title of the research project: The role of optometrists in paediatric eyecare in England.

Summary of how the research project, scope or methodology has been revised because of COVID-19 restrictions.

1. Summary of how research activity and/or data collection was impacted because of COVID-19 restrictions, and how any initially planned activity would have fitted within the thesis narrative.

The study titled "To determine if non-cycloplegic refraction is ever an appropriate alternative for infants under seven years" was affected due to the COVID-19 restrictions. This study aims to establish a clinical situation where certain refractive levels can be appropriately managed with non-cycloplegic refraction in under-sevens. Data was being collected during the clinics held at City Sight University of London clinics. However, the impact of the pandemic affected clinic visits and the ability to collect enough data. As a result, data collection had to come to a halt, and the study had to be abandoned.

A retrospective review of 250 clinical records for all patients under seven years old attending the paediatric clinic was going to be conducted. The notes were going to be reviewed after every clinic weekly. The principal researcher will use the data from the battery of clinical tests minus cycloplegic refraction to decide whether each patient requires further investigation with cycloplegic refraction.

The outcomes of the initial tests were going to be compared against a gold standard eye test which includes cycloplegic refraction, to determine the sensitivity and specificity of the initial vision screening tests.

The following summarises the methods that were going to be used for this study.

The initial tests that are conducted prior to the installation of cycloplegic refraction are as follows;

- History and symptoms taking.
- Measurement of vision (monocular).
- Binocular assessment: cover test, prism fusion range, motility, convergence and, stereopsis.
- Non-cycloplegic autorefraction.
- Pupil reaction and colour vision (if possible).
- Dry retinoscopy.
- Dynamic retinoscopy (if possible).

Data collection will be done retrospectively. The clinical data that will be reviewed are as follows;

- Child's age.
- Non-cycloplegic autorefractor readings.
- Cycloplegic retinoscopy results. (1.0% or 0.50% Cyclopentolate Hydrochloride depending on what dosage is suitable for the child)
- Further notes for any risk factors or binocular vision anomalies (reduced vision in one or both eyes that cannot be corrected with a refractive correction or a loss of coordination of movement between the two eyes).
- Dry retinoscopy.
- Dynamic retinoscopy.

The Royal College of Ophthalmologists recommends the use of 1.0% Cyclopentolate Hydrochloride. For children under the age of 6 months, 0.5% should be used to reduce the risk of toxicity (Royal College of Ophthalmologists, 2012).

A Bland and Altman analysis would help determine levels of agreement between refractive errors measured by cycloplegic retinoscopy and non-cycloplegic retinoscopy. As well as the agreement between autorefraction and cycloplegic retinoscopy. The patterns found in dynamic retinoscopy results would have been examined to see if the accommodation status influences the refractive error measurements agreement.

2. Summary of actions or decisions taken to mitigate for the impact of data collection or research activity that was prevented by COVID-19.

The decision taken due to COVID-19 was to stop data collection and conduct a systematic review and meta-analysis on currently published data on non-cycloplegic and cycloplegic refraction.

3. Summary of how any planned work might have changed the thesis narrative, including new research questions that have arisen from adjusting the scope of the research project.

The planned work would have helped fill the gap currently visible in literature which has been supported by the findings from the systematic review and meta-analysis conducted as part of this thesis. Further work is required exploring the agreement between non-cycloplegic and cycloplegic refraction in young children in relation to different visual assessments results.

Date of statement: 09/04/2021

EXECUTIVE SUMMARY

Existing literature suggests that primary eyecare services in community settings are not easily accessible for young children. However, there is little information that can explain why community practices are selective when offering eye examinations to young children. An eye examination during the early stages of a child's life is essential to determine that the child's vision is developing as expected.

This research aimed to investigate the extent of primary eyecare services available to young children among community practices and explore the barriers and the corresponding enablers to optometrists providing paediatric eyecare. A mixture of methodological approaches were used. Qualitative and quantitative data were obtained via questionnaires (telephone survey and Delphi technique), focus group discussions, and a systematic review and meta-analysis were also performed.

A telephone survey (*Study One*) was conducted to investigate the accessibility of eye examinations for young children and children with autism (a child aged 1, 3, 5 years and a 13-year-old with autism). A total of 400 optometric practices were selected and telephoned to establish the availability of an eye examination for the child of concern (100 different practices for each scenario). A total of 397 optometric practices reported they examine children. However, out of the 400 practices, 14% of them were willing to examine a child of any age. The median age at which practices declared they would start to examine children was four years. However, all children under the age of 16 years are eligible for a National Health Service funded eye examination.

When examining children, objective tests are performed using cycloplegic drugs to ensure accurate refractive error measurements. Cycloplegic retinoscopy is the gold standard for assessing refractive errors. In the present study (*Study Two*), an agreement between non-cycloplegic and cycloplegic refractive error measurements was assessed. Bland and Altman's plots demonstrated that non-cycloplegic refraction is not sufficiently sensitive. The results indicate a significant difference between non-cycloplegic and cycloplegic conditions with the various types of autorefractors (Plusoptix, Retinomax and Canon) and the refractive error measurements obtained. An overall comparison of non-cycloplegic and cycloplegic autorefractors and agreement between non-cycloplegic autorefraction and cycloplegic retinoscopy demonstrated ≥0.50 Dioptres or more myopic findings in non-cycloplegic conditions.

Globally, uncorrected refractive error is a leading cause of visual impairment. By exploring paediatric eyecare in England and its potential limitations, clinical guidelines were reviewed to establish their possible impact on eyecare services. The clinical guidelines on prescribing refractive error in young children were appraised using the AGREE II Tool to establish the quality of existing guidelines (*Study Three*). In addition, the clinical appropriateness of the selected guidelines was evaluated via the Delphi methodology. The Delphi technique is a robust method for gaining autonomous opinions amongst a panel of experts. This combined approach of using the AGREE II Tool and the Delphi study resulted in an assessment of quality and identification of gaps in existing guidelines on prescribing refractive correction. The appraisal of the identified guidelines highlighted several key areas that require improvement, particularly the domains 'Stakeholder Involvement, 'Rigour of Development', 'Applicability', and 'Editorial Independence'. The Delphi technique has facilitated in highlighting the gap and need to develop prescribing refractive error guidelines for practitioners.

Focus group discussions (*Study Four*) were undertaken to explore the perspective of optometrists working in community optometric practices. The barriers and enablers to providing paediatric eyecare within a community setting were explored using a topic guide. Findings suggest improvements are required to enhance primary eyecare services for young children. In addition, gaps in knowledge and awareness have been identified among primary eyecare providers and parents of young children. Moreover, funding problems have become apparent and need to be further investigated.

To conclude, these studies highlight various gaps and accessibility concerns within paediatric eyecare in a primary care setting. Children tend not to report their symptoms. Therefore, any visual problem that occurs during their development should be assessed to allow better prognoses during the sensitive period of the visual development process. Children learn primarily through the visual input they receive; therefore, it is paramount that their development is not hindered. Based on these research findings, several recommendations were identified to improve paediatric primary eyecare. Moreover, the findings may help optometrists examine more

young children and inform future practitioners, the public, professional and educational bodies regarding paediatric eyecare in optometry.

1. RESEARCH OVERVIEW AND INTRODUCTION

RESEARCH OVERVIEW

This thesis comprises of six chapters, including this introductory chapter, four empirical chapters, together with a concluding chapter including recommendations for future work. Chapters two to five are presented as separate studies with a brief introduction, detailed methods, results, and a discussion section.

Chapter two presents the details of Study One. This study looks at the accessibility of primary eyecare across England for young children and children with autism. The aim was to establish a snapshot of how accessible eyecare is for children within primary care and compare whether things have improved since existing findings in the literature. Data was collected via a telephone survey to determine the accessibility of primary eyecare for children in England using simulated realistic scenarios of daily patient encounters. Four hypothetical scenarios were used during the survey, including a child who is autistic aged 13 years and children with typical development aged one, three, and five years.

Chapter three presents a systematic review and meta-analysis that was conducted to explore the agreement between cycloplegic and non-cycloplegic refraction in children. This chapter describes the findings from existing literature investigating cycloplegic and non-cycloplegic refraction. The results highlight a gap in the current literature when assessing types of refraction. This study involves determining whether the disparity between cycloplegic and non-cycloplegic refraction is large enough to justify the inclusion of cycloplegic refraction in every child. The refractive error measurements were analysed to assess the agreement between refraction performed with or without cyclopentolate hydrochloride, allowing a meaningful conclusion to be obtained regarding the use of cycloplegia in children under 12 years of age.

Chapter four describes a systematic appraisal used to identify the best available evidence for prescribing refractive error correction in children (*Study Three*). Firstly, a literature search collates all the available guidelines and resources. Subsequently, an internationally validated quality assessment tool, the Appraisal of Guidelines for REsearch and Evaluation (AGREE II), was used to systematically perform critical appraisals on clinical practice guidelines. Finally, the Delphi methodology was used to assess the clinical appropriateness of guideline recommendations and turn opinions across a panel of experts into group consensus. The panel of experts consisted of paediatric ophthalmologists, optometrists, and orthoptists.

Chapter five investigates the barriers and enablers community optometrists experience in relation to examining young children's eyes in a primary setting. The grounded theory approach was used to find barriers preventing optometrists in England from performing eye examinations on young children and the corresponding enablers. Barriers were identified using focus groups consisting of registered optometrists recruited from various locations and practice types (independent and multiple) across England. Focus groups were moderated in an unbiased format based on a topic guide and were conducted until data saturation was reached, with no new information arising. Data from the focus groups were categorised into subject matters and then grouped into enabling factors and barriers.

Chapter six summarises how the different studies collectively address the role of optometrists and the provision of paediatric eyecare. The chapter concludes with a proposal for further research, and information on publications and conference presentations that were achieved as part of this PhD are also included.

INTRODUCTION

Optometry is defined as *"the science or practice of testing visual acuity and prescribing corrective lenses"* (Collins, 2021). This has evolved and optometry also entails specialising in areas of optometry and treating and managing patients alongside ophthalmologists in hospital settings and clinics (National Health Service, 2022a). Optometrists in the United Kingdom (UK) are healthcare professionals who have been trained to examine eyes and detect visual problems as well as signs of ocular diseases or secondary complications (i.e., general health), offer clinical advice, prescribe refractive correction to improve the clarity of sight, and refer patients to secondary eyecare services (e.g., hospitals) when needed (College of Optometrists, 2021a). The optometrists role in the UK has undergone changes over the years in both community (local high-street optometric practices) and hospital settings, including aspects such as referral criteria and amendments to the Medicines legislation. (Samia-Aly et al., 2015; Marks et al., 2012; Ho and Vernon, 2011; Hau et al., 2007; Banes et al., 2000, Oster et al., 1999). Optometrists can now undergo additional training in the UK to qualify them to supply, administer, or prescribe drugs in partnership with an ophthalmologist once obtaining independent prescribing qualifications (Padilla and Stefano, 2009).

In 1958 the General Optical Council (GOC) was created through the Opticians Act legislation (General Optical Council, 2021a). The GOC are the regulators for the UK's optical profession and set standards for optical education, training, and professional conduct (General Optical Council, 2021b). The GOC aim to protect the public and maintain high standards within the profession. All registered and practising optometrists must meet a standard of practice (General Optical Council, 2020).

In order to become a qualified and practising optometrist in the UK, a pre-registration year must be successfully completed. This must demonstrate a range of competencies related to paediatric eyecare and binocular vision (*Table 1.1*) (College of Optometrists,2021b).

Table 1.1. *A list of some competencies relating to children's eyecare that must be achieved during the pre-registration year (College of Optometrists,2021b).*

Stage of pre-registration	Core-competencies
1	Uses appropriate diagnostic drugs (e.g., cyclopentolate hydrochloride 1.0% and 0.5%) to aid refraction.
1	Assesses children's visual function using appropriate techniques.
1	Understands the techniques of the assessment for infants.
1	Understands the special examination needs of patients with learning and other disabilities.
1	Assesses binocular status using objective and subjective means.
1	Manages children at risk of developing an anomaly of binocular vision.
1	Manages children presenting with an anomaly of binocular vision.
2	Optical appliances - One paediatric dispensing (aged four years or under).
2	Assessment of visual function - One appropriate cycloplegic examination of a child.
2	Assessment of visual function - One refraction of a child aged four years or under.
2	Assessment and management of binocular vision - A child (seven years or under) with a binocular vision anomaly (anomaly preventing good visual input into one or both eyes).
2	Assessment and management of binocular vision - A child (seven years or under) at risk of developing a binocular vision anomaly

In 2015 the College of Optometrists introduced the learning outcomes for the 'Professional Certificate in Paediatric Eyecare', which was compiled in collaboration with a panel of experts from hospital and community settings (College of Optometrists, 2021b). This postgraduate module aimed to provide further training for optometrists lacking confidence in dealing with children as well as optometrists wanting to improve their expertise in paediatric eyecare. The College of Optometrists later introduced further training opportunities with a Higher Certificate in Paediatric Eyecare. The Professional Certificate covers the following topics (College of Optometrists, 2021c):

- Visual development (refractive error [longsightedness (hyperopia), short-sightedness (myopia) and astigmatism], acuity [ability to see with refractive correction], binocular vision, and accommodative

function [eyes ability to adjust focus to see objects at various distances]) and common abnormal visual outcomes.
- Vision screening pathways (national and local).
- Assessment of infants and children visual function.
- Strengths and limitations of different tests and techniques.
- Infants and children with developmental disabilities.
- Dispensing and management plans.
- Safeguarding children.

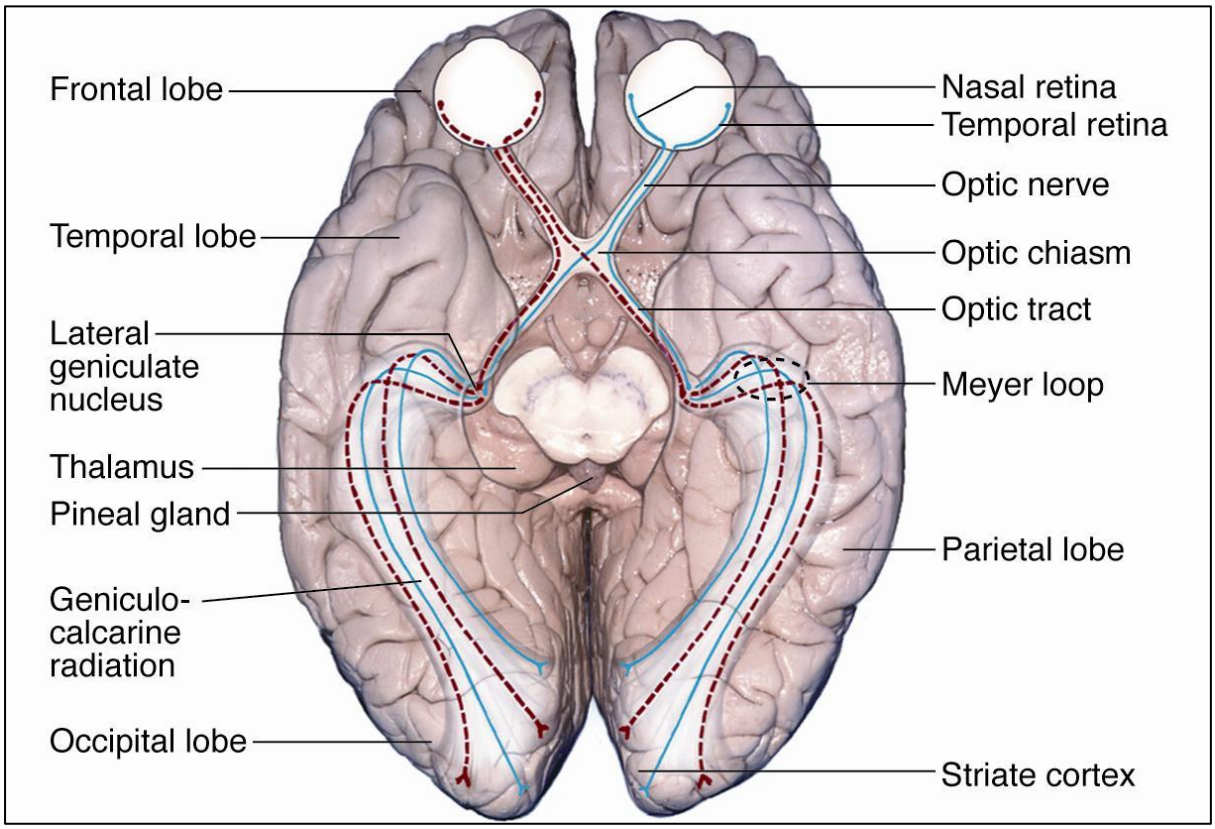
The 'Higher Certificate' expands on the knowledge obtained from the 'Professional Certificate' and develops skills used in formulating evidence-based management plans and examining children with developmental disabilities (College of Optometrists, 2021c). The main difference is the development of skills to formulate evidence-based management plans and to examine children with both typical and atypical development. The Higher Certificate covers the following topics (College of Optometrists, 2021c):

- Evidence on current clinical practice in paediatric eyecare.
- Impact of visual impairment on childhood development.
- Causes of developmental disability.
- Communication skills amongst parents/carers and children.
- Skills to assess children.
- Formulating an evidence-based management strategy for children's eyecare.

In addition, the College of Optometrists has set out professional guidance on examining young children, including key information on aspects of a paediatric eye examination (College of Optometrists, 2021d). Advice is also given on prescribing refractive correction in young children, safeguarding children, and protecting professionals from litigation (College of Optometrists, 2021e).

Examining young children is important as a child's vision is still developing, and therefore paramount to establish whether the development process is being hindered by any unforeseen factors. Therefore, it is valuable to understand the visual development process. The neural pathway from retina to brain is illustrated in *Figure 1.1* (Jangra and Grover, 2016). The visual pathway develops both before and after birth, as the retina is activated by external stimuli (Braddick and Atkinson, 2011). However, the function and the quality of a baby's visual system differs from that of an adult due to retinal immaturity and organisation of the visual receptive fields (Spillmann, 2014; Martinez and Alonso, 2003). Visual receptive fields are regions within the retina where light energy influences the activity of retinal and post-retinal cells (Spillman, 2014). Youdelis and Hendrickson (1986) revealed that at birth, the fovea is an extensive area populated by rod photoreceptors, with cone cells being absent at this stage. The foveal cones have a large inner segment and do not have an outer segment containing photopigment (Youdelis and Hendrickson, 1986). These retinal immaturities account at least in part for reduced visual function in early life. The large inner segments of the cones force them apart, reducing spatial resolution (Hendrickson et al., 2008; Yuodelis and Hendrickson,1986). As the cones develop, they become thinner and more extended, but more closely spaced. This improves spatial resolution by approximately 45 months of age (Hendrickson et al., 2008; Yuodelis and Hendrickson,1986).

Figure 1.1. *Diagram displaying the visual pathway from the retina to the occipital lobe (American Academy of Ophthalmology, 2021).*[†]



[†]Permission obtained from the American Academy of Ophthalmology to use the image.

The development of various sensory and motor visual functions over the first year of life happens in a coordinated manner. As vision develops, changes occur throughout the visual system (Hubel, 1988). Maturation of which is influenced by visual experience during periods of neural plasticity in the early stages of life (Baroncelli et al., 2010; Berardi et al., 2004). Plasticity allows the brain to undergo functional and structural changes depending on the environment (May et al., 2007). Plasticity may be considered as synaptic (changes in activity at the junction of nerve cells) and structural (changes in shape and size of axons, dendrites and, dendritic spines and suppression and creation of synapses) (Fernandez-Espejo and Rodriguez-Espinosa, 2011).

New-borns have rudimentary vision at birth. Four days from birth, a new-born can discriminate their mother's face from that of a stranger when the hairline is visible (Pascalis et al., 1995). From two weeks to three months from birth, the infant's ability to focus improves (Banks, 1980), but the infant is unable to make eye contact until approximately two months of age (Otsuka, 2014; Maurer and Salapatek, 1976). It has been reported that infants less than six months of age can detect contours, but this ability is not adult-like until the teenage years (Otsuka et al., 2008). Infants at the age of three to six months demonstrate depth perception and the response to shape, shadings, and contours of objects which develops up to seven months of age (Corrow et al., 2011; Tsuruhara et al., 2010). There is some form of perception of motion from birth (Simion et al., 2008) which develops up to and including the teenage years (Hadad et al., 2011). Infants can discriminate whether an object is expanding or contracting at the age of two months, and this ability improves by eight months (Brosseau-Lachaine et al., 2008). Research has shown that a child's resolution acuity reaches adult levels by around five to six years (Ellemberg et al., 1999; Birch et al., 1983: Mayer and Dobson, 1982) while recognition acuity is still developing at between seven and eight to 10 years (Drover et al., 2008). The development of acuity in an infant can be explained by the changes in the size, shape and distribution of photoreceptors and cortical development (Banks and Bennett,1988). *Table 1.2* shows approximate levels of visual acuity from birth to early childhood. Shimojo and Held (1987) found that Vernier acuity (ability to detect alignment or misalignment) is poorer than grating acuity

in infants at the age of 11-12 weeks, whereas in adults, the converse is true. This is due to retinal (Banks et al., 1991) and cortical factors (Levi et al., 1985).

***Table 1.2**. Table demonstrating a change in acuity with age using various acuity chartsł*

Age	Test	Visual Acuity (Snellen equivalent)
30-35 months	HOTV (Pan et al., 2009)	6/19 or better
36-47 months		6/15 or better
48-59 months		6/12 or 6/9.5
60-72 months		6/9.5
1 month	Teller acuity cards (Mayer et al., 1995)	6/180
6 months		6/30
48 months		6/7
60 – 72 months	Teller acuity cards (Hargadon et al., 2010)	6/7.5
< 36 months	HOTV (Leone et al., 2014)	6/7.5
36 to < 42 months		6/7.5
42 to < 48 months		6/6
48 to < 54 months		6/6
54 to < 60 months		6/6
60 to < 66 months		6/6
66 to < 72		6/6
< 36 months	ETDRS LogMAR Chart (Leone et al., 2014)	6/12
36 to < 42 months		6/9.5
42 to < 48 months		6/9.5
48 to < 54 months		6/7.5
54 to < 60 months		6/7.5
60 to <66 months		6/7.5
66 to < 72 months		6/7.5
6 to < 9 months	Teller acuity cards II (Leone et al., 2014)	6/30
9 to < 12 months		6/30
12 to < 15 months		6/30
15 to < 18 months		6/24
18 to < 21 months		6/24
21 to < 24 months		6/19
24 to < 27 months		6/15
27 to < 30 months		6/15
30 to < 33 months		6/12
≥ 33 months		6/12

ł HOTV test chart consists of the letter's "H", "O", "T" and, "V" in varying sizes and is conducted at a distance of 40cm. Teller acuity cards include a section with gratings and a blank section and is a form of preferential looking test and can be conducted at multiples testing distances depending on the age of the young child. Early Treatment Diabetic Retinopathy Study (ETDRS) chart is a form of LogMAR chart and letters reduce in size in a logarithmic progression the test can be conducted at various distances.

Visual responses and milestones

From birth to six years, the eye and visual functions continue to develop (Zimmermann et al., 2019). The table below (*Table 1.3*) explains how visual function develops over the first six years of life (Zimmermann et al., 2019).

***Table 1.3**. Changes in visual function with age (Zimmermann et al., 2019).*

Age (months)	Visual function
0-1	As the eyes receive light they respond by being able to be innovated and respond independently.
	Eyes move towards the light stimuli but cannot hold in position.
1-3	Optic never fibre myelination increase (insulating sheath to increase the efficiency of electrical transmission), foveal maturation, pupillary reaction, eye-eye contact, eye movement development, people recognition, facial expression imitation, visual tracking for objects.
3-6	Fixation, discriminant perception of colours, ability to move eyes quickly and search, begins to accommodate reflex, binocular vision, and voluntary eye movements.
6-10	Developed binocular vision and sensitivity to contrast.
10-16	Optic nerve myelination is complete, voluntary control of eye movements. Perception and discrimination of light, dark and colour. Able to maintain good eye contact.
16-24	Focusing and fixing on objects at different distances. Perception and discrimination of different sizes of objects.
24-36	Good visual-motor perception and coordination. Full development of visual accommodation.
48-72	Complete binocular vision, full capacity for spatial perception.

As the visual functions develop, different milestones (Table 1.4) occur during a child's development (Swaminathan et al., 2019), impacting a child's learning and communication if development is hindered.

Table 1.4. *Visual milestones of infants (Bowman, 2019; Swaminathan et al., 2019).*

Age (Months)	Milestone
1	Visual interest and attains awareness to movement, patterns, and faces. Able to give brief eye contact and imitate adult facial expressions.
3	Ability to maintain attention to faces (10-20cm away) and smile in response to people coming toward the infant. Awareness of the environment increases, and things are explored with hands.
6	The child moves towards objects out of reach and imitates, waving and clapping. Ability to recognise family members based on facial features. Blinks in response to threat.
9	Able to look for familiar objects and people. Some understanding of changes in height and surfaces while moving around.
12	The child enjoys and can recognise familiar objects and people.

Contrast sensitivity

Contrast sensitivity is the ability to detect subtle differences in luminance. This improves at all spatial frequencies between birth and ten weeks of age (Norcia et al., 1990). Improvement at high spatial frequencies is rapid until the age of four, whereas development at low spatial frequencies is slower and continues until nine years of age which was detected using a psychophysical card procedure (Adams and Courage, 2002). Some psychophysical tests are designed to measure the lowest stimulus level at which the observer can perform the task correctly 50% or 75% of the time (Jones et al., 2015). Studies using alternative methods of measuring contrast sensitivity (Hiding Heidi test, LEA low contrast symbols, vertical sine-wave gratings, and Vistech Contrast Sensitivity Distance Chart (VCTS 6500)) have found contrast sensitivity to be adult-like by the age of approximately seven years (Leat and Wegmann, 2004; Ellemberg et al., 1999; Scharre et al., 1990).

Stereoacuity

Stereoacuity is the ability to perceive depth binocularly as the eyes align corresponding points of each retina receive the same image, and a slight difference in the location of each image can allow depth to be judged (O'Connor and Tidbury, 2018). Stereoacuity starts to develop at four to six months when interocular retinal image disparities are detected (Birch et al., 2008; Ciner et al., 1996). Stereoacuity then quickly reaches a plateau, followed by slow development until adult levels have been reached (Kiorpes, 2015). Since stereopsis appears rapidly no earlier than about four months after birth, it is unnecessary to measure stereoacuity until about six months of age (Birch et al., 1982). Before this point, the eyes may be misaligned due to a lack of binocularity as the eyes have no incentive to align (Birch et al., 1982).

Accommodation

Accommodation is the fast and adaptive ability to change lens focus due to the contraction of the ciliary muscles in the eye (Ostrin and Glasser, 2004). Numerous investigations have studied the development of accommodation, with some suggesting infants can accommodate accurately around two months of age and the ability to accommodate as well as an adult by four months or after 10 months of age (Haynes et al., 1965; Braddick et al., 1979; Banks 1980; Brookman, 1983; Howland et al., 1987). However, it has been reported that infants have a larger depth of focus than adults, meaning that their ability to detect blur and, therefore, the need to accommodate (which would lead to accurate accommodation) is poor (Banks, 1980). Banks (1980) assessed accommodation development during early infancy and found that it is accurate in children but less so in young infants as they over accommodate for distances further away but do not accommodate for short

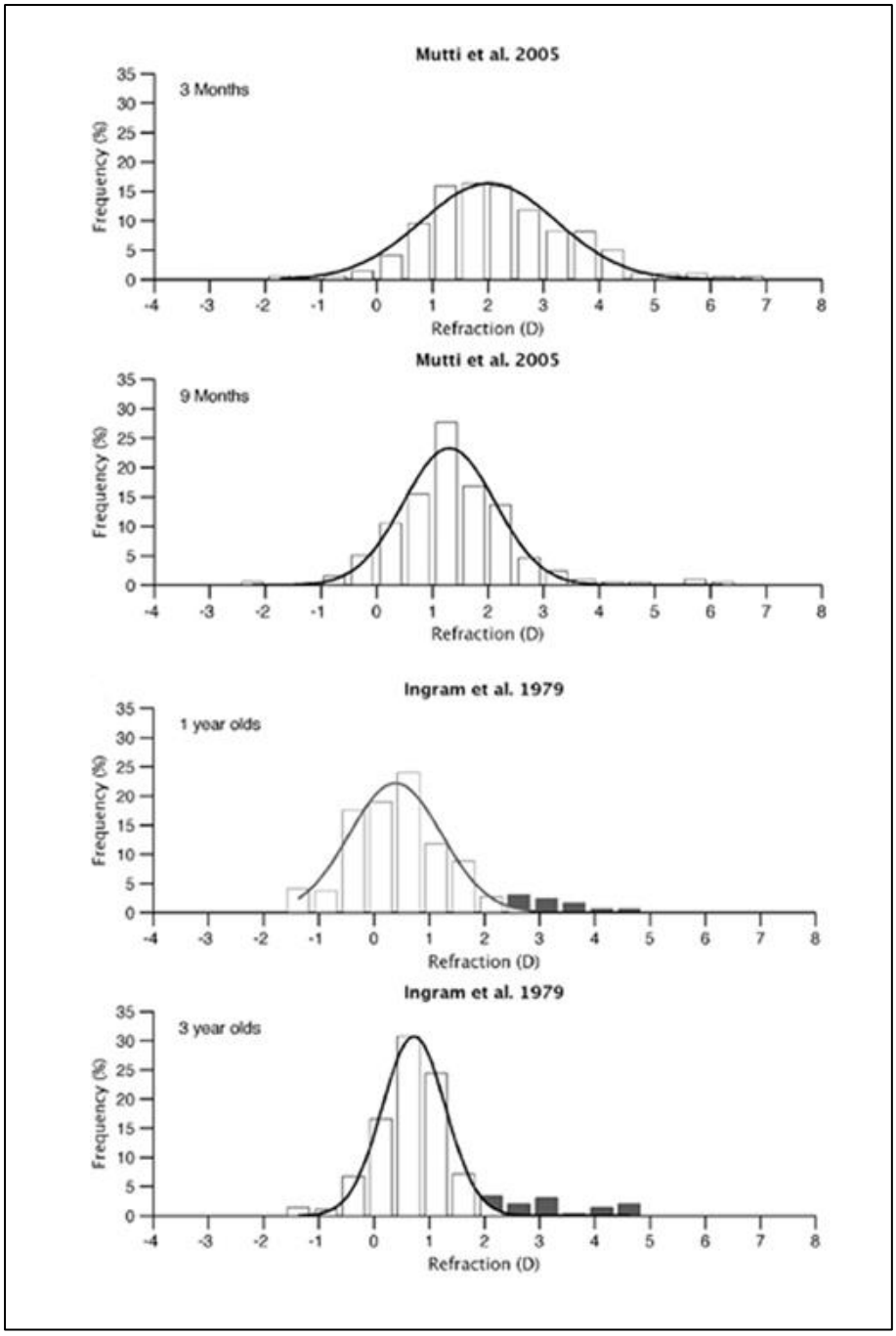
distances due to a poor focusing ability. The two components that underlie accommodative development are: motor elements (that implement change in lens shape needed to maximise image sharpness) and the sensory element (evaluation of the clarity and sharpness of retinal images to determine whether accommodation is required) (Banks, 1980). As the sensory element of detecting blur and proximity develops, motor control (control of eye movements and positions) improves, resulting in more accurate accommodation (Currie and Manny, 1997).

The rate of development of accommodation, as previously stated, varies among infants, and is affected by the presence of hyperopia (Currie and Manny, 1997). A typical three-month-old infant can accommodate within ± 0.50 Dioptres (D) of their average lag (difference between accommodative demand and accommodative response) (Candy and Bharadwaj, 2007). However, when examining infants and children who have a cycloplegic refractive error of at least +4.00D of hyperopia, it has been found that those children have a larger and more variable accommodative lag than children with smaller amounts of refractive error (Tarczy-Hernoch, 2012; Ingram et al., 1994). More recent work exploring accommodation in uncorrected hyperopic children with no strabismus has found children between the age of 0-10 years are able to accommodate in a similar manner to those children who are not hyperopic in nature (Neupane et al., 2021; Sreenivasan et al., 2017). In addition, there is some evidence that infants who are poor accommodators will develop strabismus (ocular misalignment) (Somer et al., 2014; Ingram et al., 1994). Furthermore, to this evidence, research has also explored the accommodation in children who are amblyopic and have found that the severity of amblyopia us associated with the child's ability to accommodate (Chen et al., 2018). Those who are poor accommodators are less likely to emmetropise (emmetropisation section below) (Ingram et al., 2009; Mutti et al., 2009).

Emmetropisation

The process of emmetropisation is indicated by the shift in refractive error from hypermetropia (long-sightedness) to emmetropia (refractive status of the eye when light rays focus precisely on the retina and give perfect vision) (Brown et al., 1999). Emmetropisation occurs due to retinal feedback obtained regarding the image quality resulting in the eye changing its size and optical power (Brown et al., 1999). A review suggested that refractive error is around +2.00D in early infancy, reducing to around emmetropia (refractive state of the eye where light rays are focused upon the retina accurately with no additional assistance) by early childhood (Flitcroft, 2014). This supports earlier work by Mayer et al., 2001, showing early hyperopia and a general trend towards emmetropia during childhood. Mayer and colleagues showed that refractive error plateaus in the teenage years and a significant level of astigmatism in infancy is normal. The distribution of refractive error during childhood is illustrated in Figure 1.2.

***Figure 1.2**. Distribution of refractive error during childhood (Mutti et al., 2005; Ingram et al., 1979).*



In addition to the changes that have been reported to occur in hyperopic children those that are myopic have shown have an increase in their refractive error during their teenage years (Flitcroft, 2014). A study collated data from four population-based studies of multi-ethnic children aged between six to 72 months found that 3.2% of children have hyperopia > 4.00D (Jiang et al.,2019). Between the ages of one and a half to three years is the peak onset of developing refractive esotropia (misalignment of the eye [deviating inwards]) (Olitsky et al., 2016; Parks, 1958). Therefore, hyperopic children should be examined vigilantly during this period. Hyperopia from +2.00D is a risk factor for esotropia, and when there is more than 3.00D of hyperopia, the risk is greater (Cotter et al., 2011). Uncorrected hyperopia causes children to accommodate so their eyes can focus, which results in convergence of the eyes and, over convergence can lead to a loss of binocular control and development of an esotropia (Vivian et al., 2002). Mutti (2007) explored the refractive error (spherical equivalent) change with age by exploring the findings from three longitudinal studies (Berkeley Infant Biometry Study (BIBS), Orinda Longitudinal Study of Myopia (OLSM), and the Collaborative Longitudinal Evaluation of Ethnicity and Refractive

Error (CLEERE) study) and found that by 18 months most infants have a refractive error ranging from Plano (0.00D) to +3.00D. When examining young children, consideration should therefore be made as to whether they will fully or partially emmetropise or whether the process will not occur. This can be assessed by observing the rate of reduction of refractive error through follow-ups (Candy et al., 2009; Mutti et al., 2005; Atkison et al., 2000).

An interocular difference in refractive error has been found in infants (anisometropia). Practitioners should be aware that 20-30% of neonates can be found to have anisometropia of > 1.00D (Varghese et al., 2009; Zonis and Miller, 1974); however, over the age of one year, if anisometropia of >1.00D is only present in 2-8% of infants (Afsari et al., 2013; Huynh et al., 2006; Blum et al., 1959). Semeraro et al. (2019) explored how refraction at birth changes during the first year of life and found the prevalence of anisometropia (> 2.00D) decreased in the first six months after birth. However, anisometropia has also shown to increase in prevalence between the ages of 5 and 15 years, therefore, a child can possibly develop anisometropia over time (Deng and Gwiazda, 2012). A review conducted by Saunders in 1995 explored astigmatism > 0.75D from birth to five months of age, and it has found that approximately 60% of infants will have astigmatism > 0.75D, which typically tends to be with the rule (WTR) and against the rule (ATR) during infancy.

As emmetropisation occurs, a child's visual function changes and develops. Therefore, assessing a child's visual function will depend on their age and developmental progress. As a child grows and develops, there are different ways to measure their vision. A brief description of some tests suitable for assessing children's vision are highlighted in *Table 1*.5.

***Table 1.5**. A selection of tests that can be used to measure different aspects of a child's visual function (Directorate of Optometric Continuing Education and Training,2020; American Optometric Association, 2017).*

Visual function assessment	Test	Brief description
Distance visual acuity (Preferential looking)	Teller (US)	A preferential looking test. A set of cards which include a blank section and gratings section. Each card contains a peephole in the centre.
	Keller Acuity Card (UK)	A preferential looking test based on a child's preference for patterned stimuli. A set of cards with gratings on one side and next to a blank space with equal luminance to the gratings. Each card contains a peephole in the centre.
	Cardiff Acuity Test	A set of preferential looking cards which have pictures designed to measure a child's vision. The grey cards either have the pictures at the top or bottom.
Distance visual acuity	Kay Pictures (Single, Crowded format and matching cards)	A book that contains single pictures that are crowded or a line of pictures that are crowded by a box outlined around the picture.
	Lea Symbols	A distance chart based on common shapes that children would identify.
	Letter Acuity Chart	A distance chart consisting of letters reducing in size.
Near visual acuity	Peter Rabbit	A reading test type with print sizes of varying sizes (N.48, N.36, N.24, N.18, N.12, N.10, N.8, N.6, N.5).
	Thomas the Tank Engine	A reading test specifically for children with print sizes from N.24 to N.5.
	The Maclure test	A reading chart designed to differentiate between sight and reading difficulties with images of the word of various sizes.
Contrast sensitivity	Cardiff Contrast Test	Cardiff Acuity Test can also be used to measure contrast sensitivity.
	Hiding Heidi Test	A preferential looking test with pictures of faces of varying contrast.
Refraction	Cycloplegic retinoscopy	Retinoscopy conducted after the installation of cycloplegic drugs has taken effect.
	Near retinoscopy	Retinoscopy conducted in a darkened room at 50 cm with a dim retinoscope light as the fixation target.
	Static Retinoscopy	Retinoscopy is conducted as the patient fixates on a distance target, and the practitioners' working distance is considered when measuring refractive error.
	Subjective refraction	A form of refraction where the refractive error is refined, and the best visual acuity is obtained by demonstrating a combination of lenses in front of the patients' eyes.
Binocular function	Cover test	A test to determine the type and size of ocular deviation by covering each eye at a time while the patient fixates on a suitable target.
	Hirschberg test	A corneal light reflex is assessed whether the corneal reflexes are symmetrical or not.
	Krimsky test	The Hirschberg test with a prism is employed to quantify the eye's misalignment.
	Bruckner test	The light of a direct ophthalmoscope is used to obtain a red reflex to ensure there is no media opacity (e.g., cataract), refractive error, or manifest strabismus.
	Versions	A test used to assess the movements of the ocular muscles while a child fixates and follows an illuminated object.
	Near point of convergence	The ability of the eyes to converge is assessed using a small target that moves closer to the child until the practitioner sees an eye drift outward.
	Positive and negative fusional vergences	Base-in and base-out prisms are used to measure vergences while the patient fixates on an object, and the point with double vision occurs, and single vision is regained is recorded.
	Stereopsis	Various tests can be used with or without polarised glasses to assess if the child can create a 3-dimensional interpretation of the image presented to them.
Accommodation	Monocular Estimate Method (MEM) retinoscopy	An objective test that can be used to measure accommodation. Retinoscopy is conducted at a near working distance where a near fixation target is used, and one meridian is corrected with the corresponding dioptric spherical lenses needed.

Vision screening in children

The UK National Screening Committee recommends that local authorities provide vision screening in schools for children aged between four to five years. Evidence suggests that local authorities have a haphazard response to vision screening resulting in variable coverage at school ages (Clinical Council for Eye Health Commissioning, 2016). Variability in school screening could be due to this service not being mandatory. More recent findings report that 94% of local authorities provide some form of vision screening; however, only 47% of vision screening programs are compliant with the Public Health England (PHE) specifications (Clinical Council for Eye Health Commissioning, 2020; Public Health England, 2017). This is concerning because children are likely to be asymptomatic despite poor vision impacting their learning and social development (Bruce et al., 2016; Thurston, 2014). Vision screening is not mandatory and depends on the local authority of the area who commission the services therefore those schools undertaking vision screening which are not complaint with the PHE specification are not monitored. These variations have been identified and the Clinical Council for Eye Health Commissioning (CCEHC) have recently provided a report for commissioners and policy makers regarding requirements to deliver a high level of service and post-vision screening to allow standardisation (Clinical Council for Eye Health Commissioning, 2022).

After failing vision screening (detection of reduced vision), the pathway ranges from being referred to a community/hospital optometrist, orthoptist, or ophthalmologist. There is a lack of information provided to parents/carers/guardians about what happens next (Clinical Council for Eye Health Commissioning, 2016). Public Health England has provided a vision screening pathway, such that those involved are aware of the appropriate steps (GOV.UK, 2019). Su et al. (2013) and Kimel, (2006) found that the most common reason for not seeking further eye assessment post failing vision screening was lack of knowledge of the screening results, suggesting that the results were not communicated effectively. It has been reported that only 15% of parents stated that strabismus between the ages of one to seven years is not normal (Donaldson et al., 2018). This shows that there is a gap in parental awareness regarding eye health. In 2015, the UK College of Optometrists launched their' Eyes on our Future' campaign to help raise awareness of children's eyes and their visual development amongst parents and carers to identify vision-related signs and symptoms (College of Optometrists, 2015). It has been reported that children from deprived and lower parental income, or socioeconomic backgrounds are more likely to fail vision screening due to a visual anomaly (O'Colmain et al., 2016; Williams et al., 2008).

Irrespective of school screening, a full eye examination is of immense importance as the school vision screening services are only designed to detect visual anomalies such as vision worse than 0.20 LogMAR (O'Donoghue et al., 2012). Research conducted to help produce population-based normative vision readings in children has resulted in the referral threshold of 0.20LogMAR or worse in one or both eyes to be used (Leone et al., 2014). The 0.20LogMAR threshold used for vision screening at school has shown good sensitivity (70.4%) and specificity (82.2%) for detecting strabismus or a significant refractive error (hyperopia ≥ +4.00Ds, myopia ≤ -0.50DS, astigmatism ≤ -1.50DC, and anisometropia ≥ +1.50DS) (McCullough and Sanders, 2019). School vision screening only assess a children distance vision with the use of a Keeler crowded logMAR chart this is done unaided if however, the child does wear correction (spectacles/ contact lenses) it is undertaken with the child's refractive correction (Public health England, 2019).Therefore, it is vital that an optometrist examines the child in conjunction with the school screening to ensure the child has been checked for all risks of abnormal visual development. Children are not aware of what normal vision should be; hence, they may not report symptoms to their parents as they do not know any better.

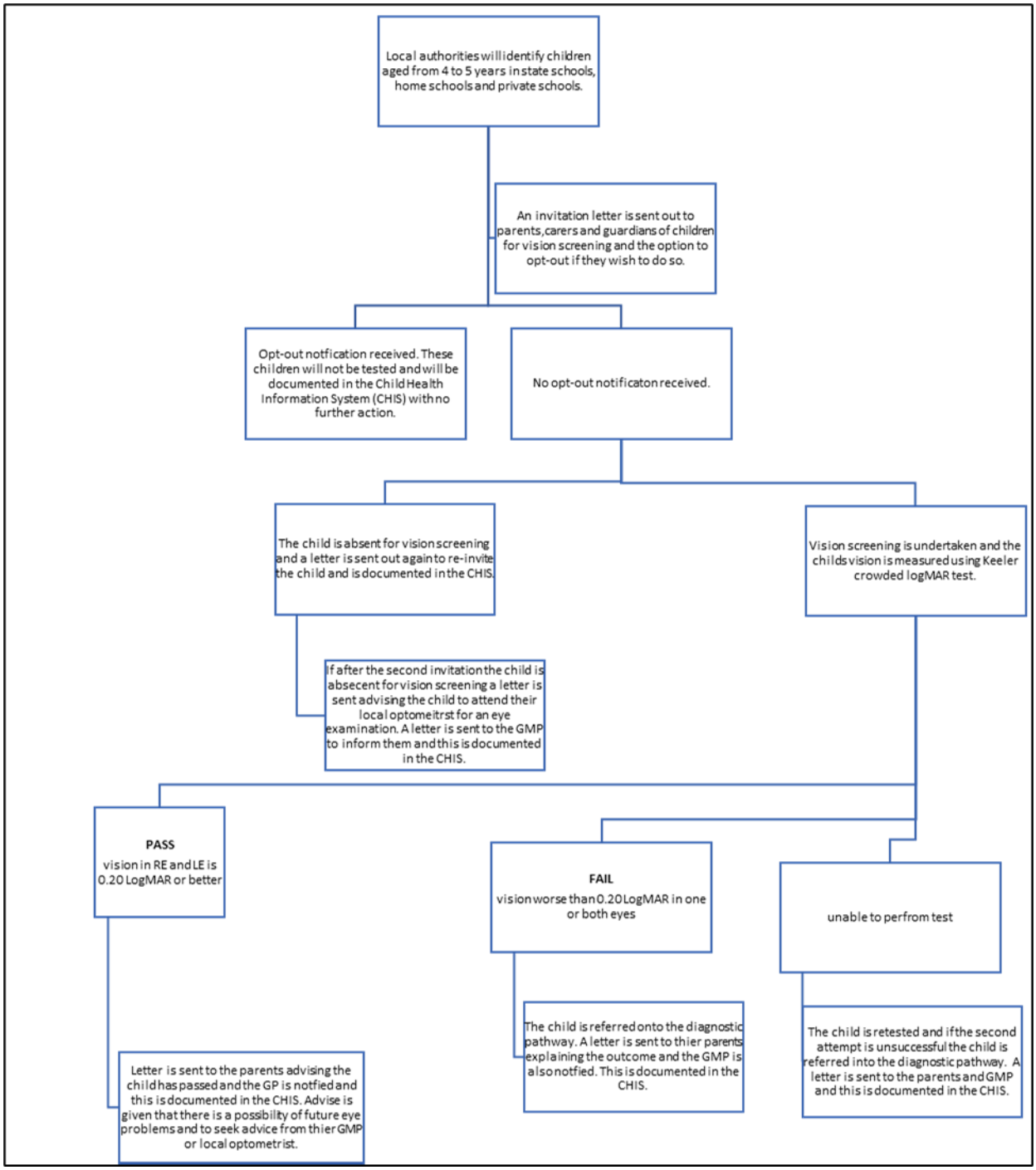
Owing to the visual system's plasticity, it is imperative that both eyes receive clear, equal visual input and that any disruption to this is detected and treated as early as possible (Sansevero et al., 2020; Bishop, 1991). Optometrists in the UK can refract and use appropriate drugs if indicated for refraction to aid accurate measurements of refractive error. Additionally, an optometrist can conduct further tests with equipment that may not be available during screening to ensure any chance of a visual anomaly being present or developing can be detected and managed accordingly (Lee, 2019; Robinson et al., 1999; Bishop, 1991). Therefore, an optometric eye examination is essential in childhood, particularly for children referred from a vision screening.

After a comprehensive eye examination, a child may require further assessments and management under a hospital. Most hospital eye service (HES) referrals in England originate from community optometrists as they are the main primary eyecare providers. Around 99.9% of NHS funded eye examinations are carried out by optometrists (National Health Service Digital, 2020). An audit on ophthalmic referrals from community optometrists looking at all ages of the population has indicated that the most referred conditions are cataracts/posterior capsular opacification and glaucoma/ suspect glaucoma (Evans et al., 2020).

Community-based models have previously been explored and have shown that the use of an optometrist working in conjunction with an orthoptist helps to facilitate appropriate referrals to the HES and improves the accessibility of paediatric eyecare (Karas et al., 1999). This is important as the current accessibility of primary paediatric eyecare could be improved by addressing any barriers that may hinder optometrists from examining young children in a community setting which could help reduce the burden on the HES. Donaldson et al. (2002) revisited this type of model and found that children could be managed in community settings and may not need to be referred to a HES. This finding highlights the importance of a full eye examination in conjunction with vision screening services. Vision screening services offered to school children across England are described in *Figure 1.2 (more detail enclosed in Chapter Two)*. The cost and effectiveness of vision screening conducted in schools across the UK has recently been explored (Horwood et al.,2021). An orthoptic led school vision screening as specified by PHE in school children between the ages of 4-5 years has found to be highly cost effective (reporting false positives 6.5%) (Horwood et al., 2021; Carlton et al., 2008). If a child has a comprehensive eye examination, this can help reduce referral rates to the HES as Donaldson et al. (2002) found that after conducting a comprehensive eye examination on children, only 16% (n=211) of them required referral to a HES for additional management of which 61% (n=141) would have needed a referral without an eye examination due to the apparent turn in the eye (strabismus). An assessment of workload within the HES paediatric department found that 40% of children were referred due to amblyopia (reduced visual acuity due to abnormal visual development), with an anisometropic or bilateral refractive error being the primary cause (Stewart et al., 2016). Referrals to the HES paediatric department could be reduced potentially as refractive error can be managed within a community setting by local optometrists. Despite this, data from the Childhood Eye Cancer Trust (CHECT) indicated that in 2017, 50% of optometric practices declined parents' requests for eye examinations for their children (due to the child's young age). Of those optometric practices that were contacted 11 children were subsequently diagnosed with retinoblastoma, a cancer of the retina (Childhood Eye Cancer Trust, 2018).It has been reported that one new-born each week is diagnosed with retinoblastoma in the UK (Childhood Eye Cancer Trust, 2018). Therefore, it is paramount for an optometrist to play a role in primary eyecare for young children.

Health visitors are predominantly involved in providing ante and post-natal support to help parents care for their baby and assess growth and developmental needs as the baby grows (National Health Service, 2021). However, when a parent reports concerns about their child's vision, the child is directly referred to the HES, which has resulted in a high false-positive rate of referrals (Donaldson et al., 2002). This could lead to a significant waste of resources.

Figure 1.3. *A flow chart describing the vision screening programme established to screen school children (RE= Right Eye, LE= Left Eye) (Public Health England, 2019b).*



Teachers' awareness of common childhood vision problems

Teachers have a gap in knowledge and training regarding vision problems that commonly cause challenges to a child in a classroom (McClelland et al., 2018). It has been reported that children with uncorrected refractive error and other causes of visual impairment are disadvantaged in educational achievement (Doyle et al., 2016). Refractive error has been demonstrated to be associated with reduced academic performance and reading ability (Doyle et al., 2016; Orlansky et al., 2015; Dusek et al., 2010), whereby uncorrected hyperopia is linked to underachievement amongst children in educational assessment (Williams et al., 2005), and children with

uncorrected myopia have also shown more unsatisfactory academic performance (Doyle et al., 2016; Ma et al., 2014). Children with a visual impairment that has not been addressed are at risk of developmental delay in terms of sensorimotor understanding, verbal comprehension, and social development (Levtzion-Korach et al., 2000; Cass et al., 1994). Teachers and special educational needs coordinators receive limited training in children's eyecare (McClelland et al., 2018; Dewhirst et al., 2014). This is an important issue as poor communication between eyecare professionals, and the education department can lead to specific vision-related issues left unaddressed at schools (Little and Saunders, 2015). Reassuringly, children with a recognised visual impairment have qualified teachers trained to work with their visual impairment (McClelland et al., 2018).

Amblyopia

Around 97% of children with a significant bilateral reduction in vision are diagnosed during childhood due to carers concerns, or the routine Universal New-born and Infant Physical Examinations (Rahi et al., 2010). Amblyopia is reduced visual acuity in one or both eyes due to disruptions to visual development, leading to an interocular difference in visual acuity of two or more lines (Braverman, 2015; Birch, 2013; Holmes and Clarke, 2006). The prevalence of amblyopia varies with population due to the definition used for amblyopia more recent finding has indicated that the total prevalence of amblyopia in children worldwide is 4.3% (95% CI: 2.6-7.0%) (Mostafaie et al., 2020).

Children with unilateral amblyopia have relatively poor development of vision in one eye which, they may be unaware of, and the condition may remain undetected unless the child is examined (Solebo et al., 2015). Unilateral poor vision results in a loss of depth perception (Stewart et al., 2013). Mild levels of uncorrected short-sightedness (myopia) or long-sightedness (hypermetropia) are less likely to be detected through vision screening as they tend to be associated with reasonable distance vision (Afsari et al., 2013). The Northern Ireland Childhood errors of Refraction (NICER) Study indicated the changes in astigmatic refractive error in children is difficult to predict and due to the nature of refractive error is important for a child to have regular eye examination as the astigmatic refractive error does not remain stable and may be overlooked during vision screening (O'Donoghue et al., 2015a).The highest level of evidence for any vision screening programme at present is the Rotterdam Amblyopia Screening Effectiveness (RAMSES) longitudinal cohort study in which 77% of amblyopic children had improved vision by the age of 7 by spectacles being prescribed or with the use of occlusion therapy (patching) (Groenewoud et al., 2010). However, this model is not directly comparable with the UK programme as the starting age for this scheme is nine months (*UK vision screening explained in Chapter Two*).

Uncorrected refractive error and untreated visual anomalies can impair a child's learning and lead to permanent vision loss if not detected and treated within the critical period (Ibironke et al., 2011; Wen et al., 2011; Roche-Levecq et al., 2008; Atkinson et al., 2002). The critical period consists of various overlapping periods of visual system development within the first nine years of childhood (Daw, 1986; Harwerth et al., 1986). This is when visual experience is required during the developmental period to prevent abnormal vision (Hooks and Chen, 2007). Furthermore, visual function is a significant predictor of school-age children's academic performance (Basch, 2011; Maples, 2003). It has also been reported that vision disorders can affect health and wellbeing throughout the adult years (Davidson and Quinn, 2011).

AIM OF THESIS

This research aimed to determine the age at which optometric practices across England examine young children and understand the role of qualified and practising optometrists in paediatric eyecare by exploring the barriers and enablers to examining young children in community practices.

Aim of study one (chapter 2): To determine how accessible primary eye care is for young children and children with autism in England within community settings.

Aim of study two (chapter3): To conduct a systematic review and meta-analysis to determine the agreement between non-cycloplegic and cycloplegic refraction in children (12 years of age and below).

Aim of study three (chapter 4): To evaluate the level of variability in the quality of selected guidelines for refractive correction prescribing in children, and to establish expert consensus on guideline recommendations that are clinically appropriate.

Aim of study four (chapter5): To understand the barriers and corresponding enablers when examining young children within a primary care setting from the perspectives of qualified practising optometrists in the UK.

HYPOTHESIS

It is hypothesised that current accessibility for primary eyecare for young children is limited due to optometrists lacking confidence in examining young children. In addition, the time constraints in examining young children, conducting cycloplegic refraction, and managing refractive error in a community setting are also contributing factors. This is based on current findings in the existing literature, which will be explained in each chapter in the background section.

2. TO DETERMINE THE CURRENT ACCESSIBILITY OF PRIMARY EYECARE FOR YOUNG CHILDREN AND CHILDREN WITH AUTISM IN ENGLAND

BACKGROUND

CHILDREN AND VISION

The National Health Service (NHS) recommends that children should have their eyes examined at specific intervals as described below (National Health Service, 2018).

a. Within 72 hours of birth.

The newborn's eyes are checked for any apparent ocular conditions (e.g., cataracts) during the newborn physical examination. All parents are offered a physical examination for their baby within the first 72 hours of giving birth. This initial screening is usually undertaken at the hospital before the mother and child go home. On some occasions, it can be undertaken at a community clinic, General Medical Practitioner (GMP) surgery or home. This examination can be undertaken by a suitable medical doctor, midwife, nurse, or health visitor. The health professional will examine the newborn's eyes with an ophthalmoscope to check how the eyes look and move. It has been reported that 2 or 3 in 10,000 babies are born with problems with their eyes that need treating (National Health Service, 2018). The newborn physical examination is highly recommended for the baby but is not compulsory. The health professional conducting the examination will give the parent the results on completion of the assessment and document the findings in the baby's personal child health record (red book). Interestingly, the red book given to parents as a logbook of their child's development and vaccinations has no reference to primary eyecare services for children funded by the NHS and provided by community optometrists (Legislation.gov, 2008).

b. Between six and eight weeks old.

This is a follow-up to the initial physical examination to ensure that nothing obvious was missed on the first screening. The same screening tests are conducted as the first 72 hours after birth to ensure no apparent problems with the baby's eyes. A normal red reflex however does not exclude an underlying ocular disease (Subhi et al., 2020). A meta-analysis exploring the diagnostic test accuracy of the red reflex test suggests that 25.3% of infants who have an ocular disease but show a normal red reflex (Subhi et al., 2020). Therefore, there is a need to conduct the red reflex twice.

c. Around one year to two and half years.

At this stage, parents may be asked if they have any concerns about their child's eyes during their health and development review. If there is a concern, an eye examination can be arranged at a hospital though a referral is required. Health visitors offer parents regular health and development checks until the baby is two years of age. This assessment is conducted either at home, at a GMP surgery or at a baby clinic. During the baby's checkup, the health visitor will discuss the baby's health and development and any concerns the parents may have.

d. About four or five years old.

Around the age of four to five years, the child's eyes are examined soon after they start school. This is conducted via school vision screening which checks for reduced vision in either eye or both eyes. The screening program aims to detect reduced vision so that treatment can be undertaken as early as possible.

Young children are at greater risk of visual impairment due to factors such as premature birth or low birth weight (Cumberland et al., 2010; Rahi and Cable, 2003), being brought up in an economically deprived environment (Cumberland et al., 2010; Rahi and Cable, 2003), or having some form of learning difficulty (Woodhouse et al., 2014). In 2019 it was reported that 12,681 children had visual impairment identified as their primary special educational need, which was an increase of 397 children from the previous year (Keil, 2019). Visual anomalies left undetected can have a negative impact, and it has been reported that children with visual impairment have a considerably lower quality of life (Chadha and Subramanian, 2010).

Thirteen per cent of children in the UK have an undiagnosed visual anomaly (e.g., refractive error and amblyopia) (Thurston, 2014). In amblyopia, the vision through one or both eyes is reduced due to untreated refractive error, strabismus, or form deprivation (congenital cataract) (Elflein, 2016; Birch, 2013). Amblyopia can be successfully treated before eight years of age and less successfully later due to reduced neural plasticity (Simons, 2005; Mitchell and MacKinnon, 2002). Therefore, it is important for young children to have access to eyecare, allowing early detection and treatment if required.

Evidence suggests that uncorrected childhood vision anomalies can double the risk of bilateral visual impairment (van Leeuwen et al., 2007; Rahi and Cable, 2003). Moreover, reduced visual acuity can impact visual function and potentially affect educational attainment (Bruce et al., 2016). A visual anomaly or a reduction in vision due to uncorrected refractive error or untreated amblyopia can impact a child's learning and social development and leave the child with suboptimal monocular and binocular vision (Zheng et al., 2011; Chua and Mitchell, 2004). Due to the impact vision has on a child's visual, educational, and social development, the accessibility of primary eyecare for children ought to be investigated.

NATIONAL HEALTH SERVICE

Most of the health care in the UK is provided by the NHS, which is the largest publicly funded health care system in the world (Thorlby et al., 2019). The NHS was established in 1948 to make free accessible health care services available to the entire population, which is funded by general taxation (Harker, 2011). The NHS primary eyecare services provided by community-based optometric practices are referred to as the General Ophthalmic Services (GOS). The GOS aims to provide eyecare for children, adults over sixty, those on a low income, diabetics, and those at risk of an ocular disease (National Health Service, 2017). The groups of patients who are eligible for an NHS funded eye examination in England, Wales, and Northern Ireland are highlighted in *Table 2.1* (National Health Service, 2017).

Table 2.1. *Table describing various groups of individuals who are eligible for an NHS funded eye examination.*

Age	Ocular condition	Low income	Other
Children under the age of 16 years.	Individuals at risk of glaucoma.	Individuals claiming benefits (income support, jobseeker's allowance).	A patient with diabetes.
Individuals aged 16, 17 or 18 years and in full-time education.	Close relatives that are diagnosed with glaucoma and the patient is 40 years old or over.	Individuals on low income and named on an HC2 or HC3 certificate.	A prisoner on leave from prison.
Individuals aged 60 years or above.	Registered blind or partially sighted.	A patient receiving employment and support allowance, pension credit or tax credit.	
	Individuals that are eligible for an NHS Complex Lens Voucher.		

Optometrists, dispensing opticians, and ophthalmic medical practitioners (OMP) are the three primary eyecare providers. The role of optometrists and OMPs in a primary care setting is to examine the eyes by checking the

health, testing the sight, and prescribing spectacles or contact lenses. Dispensing opticians fit and supply spectacles following the prescribing of a refractive error correction by the optometrists. Those who have taken further training as dispensing opticians may also fit contact lenses (qualified contact lens opticians).

Optometrists are the main providers of primary eyecare in England. The GOS contractual terms state that optometrists "shall provide mandatory services under the contract to any eligible person if the request is made for such services" (General Ophthalmic Services, 2008). This suggests that optometrists should not exclude categories of patients. Optometrists are trained to be adaptable when performing eye examinations and understand patient care implications concerning the Mental Capacity Act 2005 and Disability and Equality Act 2010 (College of Optometrists, 2019). Therefore, optometrists should not decline requests for eye examinations from patients who may present with specific challenges, such as young children or children with learning difficulties. The College of Optometrists guidance states that an optometrist must have a suitable justification for refusing to see a patient (threat to safety, practices, and public members). If the patient is an NHS patient, the optometrist is "prohibited from unreasonably restricting a patient's access to their preferred practice and practitioner" (College of Optometrists, 2020a).

New Public Health England Guidelines were issued in January 2018 to improve children's eyecare awareness and importance. Specific information on vision screening was developed to allow screening to be conducted correctly (Department for Health and Social Care, 2019). Vision screening conducted at school is limited in what visual problems it can detect, and an optometrist should also examine a child to enable hypermetropia, convergence problems, or pathology to be identified (O'Donoghue et al., 2012). However, this differs from the advice given by the Royal College of Ophthalmologists and British and Irish Orthoptic Society, who state that vision screening is sufficient, and a full eye examination is not required (Royal College of Ophthalmologists, 2015a).

ENGLAND'S EYECARE MODEL

In England, eyecare is funded nationally and locally (College of Optometrists, 2020b). The GOS in England are contracted and funded by NHS England. The Clinical Commissioning Groups (CCGs) are clinically-led NHS bodies that are responsible for planning and commissioning health care services for a local area. There are more than 200 hundred CCGs in England. The CCGs were established as part of the Health and Social Care Act in 2012 (National Health Service, 2021a). It has been reported that the CCGs are responsible for approximately 60% of the NHS budget; they commission both secondary and community health services (National Health Service, 2021a). In addition, they allocate funds for the Hospital Eye Services (HES) and supplementary eyecare services beyond the scope of an essential GOS eye examination.

In May 2014, NHS England invited the CCGs to come forward and increase their role in the commissioning of the primary care services (National Health Service, 2018). This was to allow the local CCGs to enhance primary care services for patients. In April 2018, approximately 90% of CCGs had fully delegated commissioning arrangements for primary health services (National Health Service, 2018).

LOCAL OPTICAL COMMITTEE SUPPORT UNIT

The Local Optical Committee Support Unit (LOCSU) has developed a children's visions pathway. This support unit was established to provide training and policies and develop clinical pathways to help deliver primary care services (Local Optical Committee Support Unit, 2020). As a result, this extended paediatric service occurs in some regions of England (*Table 2.2*) (Local Optical Committee Support Unit, 2020).

***Table 2.2**. Areas in England where the Local Optical Committee has developed children's eyecare pathways.*

Local Optical Committees	Clinical Commissioning Groups	Additional information
Bolton	Bolton	
Calderdale & Kirklees	Greater Huddersfield	
Durham	County Durham Tees Valley	Tees Valley is not completed covered
Essex	Basildon and Brentwood Castle Point and Rochford Mid Essex North East Essex Southend Thurrock	
Gloucestershire	Gloucestershire	
Herefordshire	Herefordshire and Worcestershire	
Northumberland, Tyne, and Wear	Newcastle Gateshead North Tyneside Northumberland South Tyneside Sunderland	
Sheffield	Sheffield	
Shropshire	Shropshire Telford and Wrekin	
Suffolk	North East Essex	
Tees	Tees Valley	The entire area is not covered
Wakefield	Wakefield	
Worcestershire	Herefordshire and Worcestershire	

These eyecare pathways developed by the LOCSU are provided by community optometrists to allow early intervention for children who have been suspected of having amblyopia following school vision screening (Local Optical Committee Support Unit, 2020). Further examination and management are conducted at one's local optometric practice, allowing parents to choose where they prefer to be seen, which would help accessibility and compliance with attending the next appointment. In turn, this will help reduce the burden on the HES and allow more time to treat more complex clinical scenarios. The children's eyecare pathway also allows the development of community optometrists' roles and skills as they participate in this pathway.

ACCESSIBILITY

Given the well-established need for normal visual stimulation during periods of visual development, it is a concern that 2 in 100 practices would not carry out an eye examination on a child younger than seven years of age (Shah et al., 2007). Moreover, the earliest age at which an optometric practice would examine a child was reported to range from one to seven years, with a mean of 3.1 ± 1.7 years (Shah et al., 2007). This is a concern, as there is a need for normal visual stimulation during visual development periods. When exploring the impact of the practice settings, 66% of optometrists who work in either an independent, multiple, hospital, academia, locum, or domiciliary setting reported they do not test children aged two years or younger (Doyle et al., 2019). Further work is required as the sample size Doyle et al. (2019) investigated was small (n=1000 with a 31% response rate), and those practitioners who did not examine children of a specific age were excluded. Doyle et al. (2019) conducted a survey and asked 310 optometrists. There is no information as to whether these professionals worked in the same practice but also information regarding professional not examining children was excluded. When participants are aware that they are undertaking a survey there is a likelihood of the Hawthorne effect whereby the participants give a response that they expect the researcher to want rather than what happens on a day-to-day basis in practice settings. Therefore, to get a broader snapshot of what the accessibility is like for parents of young children further investigation needed to take place. More recently, the median age of a child's first eye examination in Essex is found to be at the age of six years (Swystun and Davey, 2020). Evidence suggest that children between the age of 3-5 years should have their eyes examined as they are old enough to cooperate with the various tests that are conducted during an eye examination (US Preventative Services Task Force, 2011; US Preventative Services Task Force et al., 2017). However, if there are concerns

regarding a child's eyes at a younger age they should be seen as soon as possible. The only test recommend for children between 4-5 years in the UK is vision screening (National Screening Committee, 2019). Full sight tests are only recommended when there is another factor for example family ocular history or a learning disability (National Screening Committee, 2019). Following on from this, it is important to find out what the current accessibility of eyecare for young children is across England and if changes have occurred because diagnosing a visual concern in a child is essential and should happen during the visual development period. In addition, as school vision screening is not mandatory, it is important to explore children's primary eyecare services as less than half of vision screening programs are compliant with the PHE specifications (Clinical Council for Eye Health Commissioning, 2020; Public Health England, 2019b).

Some research on the accessibility of eyecare focuses on the area's economic status (Shickle and Farragher, 2014) and the socio-economic factors and not age per se. (Knight and Lindfield, 2015). For example, it has been reported that families with low income are less likely to access children eyecare within Southwest England (Majeed et al., 2008). In addition, the prevalence of eye conditions is higher in minority ethnic groups (William et al., 2008). However, this does not help us understand nor explain the variability in the accessibility of eyecare for young children.

OPTOMETRISTS

To practice as a qualified optometrist in the UK, graduate optometrists must complete a pre-registration year. Upon qualification, optometrists are deemed competent in paediatric eyecare (College of Optometrists, 2019b). Optometrists are trained and have the knowledge and skillset to manage amblyopia, strabismus, and other forms of binocular vision anomalies using sound evidence-based therapy (Kiely and Slater, 2015).

However, if optometrists were to refer all children under the age of seven to the HES without first examining, this is likely to increase the burden on the HES significantly. A retrospective study was conducted over a period of 64 months that investigated methods of optimising an optometrist's skills, which can help reduce unnecessary referrals to the HES as management can take place within community practices (Donaldson et al., 2002). The study conducted by Donaldson et al. 2002 focused on children referred to the HES by GMPs, health visitors, and school nurses. The results showed that 43% of the children did not need to be seen at the HES as there were no visual or binocular concerns (Donaldson et al., 2002). Therefore, if an optometrist examines a child before referring them to secondary eye services (HES), this could reduce the number of children needing to be seen at the hospital, which could positively impact the HES. The findings from Donaldson et al. (2002) emphasise that optometrists play a key role in children's eyecare and highlight the effectiveness of the eyecare system enabling children to receive additional examinations where needed.

AUTISM SPECTRUM DISORDER

Autism spectrum disorder (ASD) is a lifelong and nonprogressive condition characterised by repetitive and restricted behaviour that affects social communication skills (National institute of neurological disorders and stroke, 2018). ASD is referred to as a spectrum due to the various symptoms and the range in severity in behaviour and social interaction (National institute of neurological disorders and stroke, 2018).

Asperger syndrome, on the other hand, also results in behaviour and social interaction issues but is less severe, and the individual has no impact on their language or cognitive skills (Autism Society, 2016). Pervasive developmental disorder (PDD-NOS) is used to describe individuals on the autistic spectrum but do not meet the criteria to be diagnosed as autistic or having Asperger syndrome (Autism Speaks, 2019). "Doctors do not diagnose anyone with Asperger's syndrome anymore however, if in the past you one was diagnosed with it will stay on their clinical record (National Health Service, 2022).

It has been reported that in 2018 there were approximately 700, 000 people in the UK on the ASD spectrum (The National Autistic Society, 2021). This suggests that more than 1 in 100 people in the UK have ASD (The National Autistic Society, 2021). Males are five times more likely to be diagnosed with ASD than females; this is said to be due to the variation in symptoms resulting in females being underdiagnosed, and 44-52% of individuals with ASD have a learning disability (The National Autistic Society, 2021). There are different ways of helping

individuals with ASD, such as improving communication skills, sensory integration therapy, speech and language therapy (The National Autistic Society, 2021).

Studies that have looked at the prevalence of refractive error and strabismus amongst individuals with ASD are variable, with some studies not specifying how participants have been selected and on what basis preventing generalisability of the results (Kabatas et al., 2015; Black et al., 2013; Ikeda et al., 2013). Even so, these studies indicate that refractive error and strabismus are more prevalent in individuals with ASD than those without ASD, but their reliability is questionable because of factors such as small samples sizes, selection bias during recruitment, and inconsistent criteria for autism. The prevalence of refractive error has been reported as 22%, 27%, 29%, and for strabismus, 8.6%, 41% and, 21%, respectively (Kabatas et al., 2015; Black et al., 2013; Ikeda et al., 2013). Moreover, children with ASD may be expected to have normal visual acuity but may have visual problems ranging from reduced near point of convergence to retinal structural anomalies (Little, 2018). Children with autism are more likely to have accommodative problems (significant lag of accommodation) than typically developing children, resulting in reduced near visual acuity (Anketell et al., 2018).

There have been some recommendations for eyecare professionals when performing an eye examination on patients with ASD to modify their approach when performing an eye exam (The National Autistic Society, 2017). It has been recommended that clear and concise instructions are used in the syntax format with a timer if possible (The National Autistic Society, 2017). In addition, guidelines have been developed for those working with children with ASD (Coulter et al., 2015). An ASD toolkit has been developed by the Royal College of General Practitioners (2019) that advises practitioners on dealing with individuals with ASD. Moreover, for primary eyecare settings, a form is available for patients to fill in before their consultation. This allows the practitioner to make adjustments and have valuable information for the eye examination (SeeAbility, 2019). Professionals that encounter children with ASD should undergo training (Le Couteur et al., 2003). Evaluation of a training program aimed at increasing practitioners' awareness of possible ocular problems amongst individuals with autism was conducted by Long and colleagues in 2016. Common themes such as knowledge and confidence of practitioners understanding atypical individual needs were demonstrated (Long et al., 2017). There has been an indication that education programs are useful and play a vital role in facilitating awareness of specific health needs amongst practitioners (Long et al., 2016).

It is known that children with ASD have incredible difficulty accessing health and social care (Grinker, 2009) due to their difficulty interacting with others. The NHS funds primary eyecare for children under 16 years of age through the GOS, and children with ASD are entitled to an NHS eye examination. There is a requirement for optometrists to complete a full eye examination for every service user, which includes all the following elements: refraction, internal eye examination and external eye examination (Royal College of Ophthalmologists, 2015b). Research has explored the experiences of children with ASD in primary eyecare (Gow, 2015). Children with varying degrees of ASD may have a poor experience in primary eyecare due to the service providers' lack of awareness and adaptability (Gow, 2015). Research is yet to be conducted to determine how accessible eyecare services are for children with ASD.

AIM

This study aimed to determine "How accessible is primary eyecare for young children and children with autism in England?" By exploring this question, I aimed to get a snapshot of the proportion of optometric practices offering an eye examination for young children and children with ASD within community settings. It has been hypothesised that an eye examination for a young child is not as readily accessible within primary care and is influenced by the child's age. This hypothesis is based on previous research by Shah et al. (2007) and more recent data collected from Doyle et al. (2019) and Swystun and Davey, (2020).

METHODS

Ethical approval for this study was obtained from the City, University of London's Senate Research Ethics Committee (Appendix 2.0). All procedures performed in this study followed City, University of London's Research Ethics Committee's ethical standards.

This study used a telephone survey to collect quantitative and qualitative data and took place within the Division of Optometry and Visual Science at City, University of London. The researcher SW (Salma Wilson) recruited 400 optometric practices between August - September 2019.

The method chosen has been used successfully previously (Shah et al., 2007), and when deciding on the current approach, other methods were also considered. The first method that was considered was collecting data of this kind by using an anonymous written survey. Bias would be reduced using this approach due to the anonymous nature of the survey. However, it was anticipated that the response rate would be low due to "survey fatigue" (Porter et al., 2004) and, based on low response rates in comparable research; 7.8% (Suttle et al., 2011) and 16.2% (Lawrenson and Evans, 2013). In addition, those responding to the survey may be interested in children's eyecare, have time to respond, or may be more likely to respond than most survey recipients due to other factors. Therefore, the results may not provide an accurate representation of the accessibility of eyecare within the country. The second option considered was collecting data by asking parents about their experiences of making an appointment for their child. This approach would have been limited due to logistical issues in identifying parents who recently had this experience and can recall the details. Therefore, it was felt that conducting a telephone survey would give the best view on the accessibility of eyecare for children in the most realistic manner (using a scenario where a parent is calling up an optometric practice to arrange an eye exam). The telephone survey highlights what information parents are likely to receive when enquiring about booking an eye exam for their child.

To minimise bias, the practices contacted were not aware that a study was being conducted. The study did involve the participant being led to understand that the researcher calling the practice is a parent and not a person conducting research to minimise the risk of bias. Additionally, there was no risk of humiliation to any person, or the practice being contacted because the questions that were asked during the telephone call were those that a parent would usually ask. The practices were not identified in any dissemination from this study, and the only information about the practice which was recorded for analysis of the research data is the type of practice (multiple or independent) and the first three elements of the postcode (though the postcode information will not be disclosed). The names of all the practices contacted were held in a different password-protected spreadsheet containing the data gathered as part of the survey. Once the data was collected, the document containing the practice names was deleted. All data gathered has been kept anonymised. This approach helped enhance the validity of the results by avoiding informed responses (Masling, 1966). The Windsor Deception Checklist was used to look for potential concerns (Pascual-Leone et al., 2010). This approach helped justify the chosen methodology (to minimise bias), cites previous comparable research (Shah et al., 2007), considers possible risks and involves no emotional impact, humiliation, denigration, or other negative impacts on the participants.

The telephone survey was conducted at City, University of London. The design of the telephone survey was based on each of the following four scenarios:

1. A child aged one year. Mother is concerned that the child may have an eye turn (strabismus).
2. A child aged three years. Mother is concerned as she and her husband are short-sighted (myopic).
3. A child aged five years. The mother is concerned as the school has advised her to test her child's eyes with an optometrist.
4. A child aged 13 years. Who is autistic and finds being in new environments and communicating at times challenging.

The research team formed the scenarios based on literature, professional knowledge, and experiences working in practice. The literature reviewed indicates parents seek eyecare for children when there is a visible problem if it is recommended by a paediatrician, required for school entry, for preventative reasons to ensure eye problems get picked up, especially if they as a parent themselves have problems with their eyes (Frazier et al., 2008). In addition, it has been highlighted that if a family member wears spectacles, this increases the likelihood of children having an eye examination arranged by their parents (Sukati et al., 2018). Also, parents seek eyecare for their children due to a manifest condition or when there is a family history of an ocular condition or if the

child reports not seeing the school board and their eyes hurting (Ebeigbe et al., 2018; Balasubramaniam et al., 2013).

Data was gathered via a telephone survey where the researcher (SW) acted as a public member and asked whether the practice would carry out an eye examination on a child. The scripted questions can be found in Appendix 2.1. The scripted questions were piloted by calling City Sight (The University's Eye Clinic) anonymously by trialling out scenario one. This helped highlight any flaws in the questioning. One hundred different practices were telephoned for each of the four scenarios to ensure that each practice was only contacted once.

When each optometric practice was contacted, the information was taken from the practice staff member who answered the phone, reflecting what happens realistically when an enquiry is made. The researcher (SW) recorded how the information was provided by the person who answered the phone and how it was obtained (e.g., a staff member had to confirm with the practice manager). Any additional relevant information was also documented. No appointments were physically made, but the member of staff was thanked for the information they provided.

STUDY PARTICIPANTS

Community optometric practices that conduct eye examinations in England were eligible for selection. Community practices that only dispensed spectacles or were outside England, and the hospital eye services were excluded from the sample selection. Community optometric practice types were classified as being multiples or as independents.

Optical businesses that are sole practitioners, small practices or partnerships have been classified as an independent. Optical businesses that are a franchise, joint venture, or single corporations with multiple nationwide branches have been classified as multiples. These definitions (*Table 2.3*) are derived from the 2018 business regulation final report for the General Optical Council (GOC) (Europe Economics, 2013).

***Table 2.3**. Definition of optical practice types.*

Type of optical practice	Definition
Sole practitioner	Practices that are run by a single registered optometrist providing either private or NHS services or both.
Small practices or partnership	This type of practice tends to be owned by an optometrist or a dispensing optician and offer either NHS or private services or both.
Franchise	Optical practices that are privately owned but are a part of a broader brand (e.g., Boots Opticians). The host brand helps the practice with IT infrastructure, merchandise, and administration.
Joint venture	This kind of optical practice is owned with an agreement between the practice director and the wider brand companies partnering group. The partnering group has more oversight of the practices compared to a franchise.
Single corporation	This is a type of optical business that has multiple nationwide branches (e.g., Asda Opticians).

Various sampling methods were considered before settling on a strategy in which postcodes were randomly selected. When designing the study, enquiries were made to see if there was data on all the current existing optometric practices with the GOC, Local Optical Committee (LOC) and Association of Optometrists (AOP), but to no avail. Each optical practice is given a code (Organisation Data Service (ODS) code) by Primary Care Support England (PCSE), and NHS Digital uses these codes to produce reports on the number of optical practices as well as GMP practices and dentists. However, it was found that there is considerable duplication in the list because old codes are not being deleted when branches closed or ownership changed (for example, a new contractor taking over, or the business being sold to one of the chains). NHS Digital is working on improving the data set as part of their work to introduce electronic referrals.

Valid postcodes in England were randomly selected using an online postcode generator https://www.doogal.co.uk/UKPostcodes.php. Each selected postcode was entered into an online search engine. Once the postcode was entered into the search engine, the first three search results were selected. To ensure this chosen sampling method was appropriate, pilot work was conducted. It was found that the database chosen

provided a combination of multiple and independent practices in its 'first three' results. If a practice appeared in the search more than once and had already been included in the study, then the next optometric practice from the search result list was contacted. If there was no answer on two attempts of trying to contact a practice, then the next optometric practice on the search results list for that postcode was contacted. The sample was monitored during the selection process to ensure that independent and multiple practices were similarly represented.

SAMPLE SIZE CALCULATION

A prior power statistics analysis revealed that a sample size of 280 optometric practices was required as a minimum. This was calculated using G*power 3.1 with 95% power $Z\alpha/2= 1.96$, $Z\beta=1.64$. The number of optometric practices contacted was oversampled to 400 optometric practices, whereby 100 different optometric practices were selected. This was done to help obtain more information regarding the population of interest and help reduce the possibility of selection bias from the chosen method.

An appropriate sample size calculation had to be undertaken to ensure that there was a reasonable representation of the number of practices in the country that will be survey. In addition, due to several scenarios been chosen to stimulate real life situations, there needed to be a fair number of practices for each scenario. When the G* power software was used the F-test (ANOVA: Fixed effects, omnibus, one way) was choices as there were four scenarios, and the minimum number of practices needed to produce a significant effect on the variable age was required.

STATISTICAL ANALYSIS

Data was stored on a password protected Excel spreadsheet. All statistical analyses were performed using SPSS (version 25.0) (IBM, 2017). The Wilcoxon Signed-Rank test was used to compare responses obtained for each scenario before and after the concern raised by the parent (e.g., an 'eye turn'). The Mann-Whitney test was used to compare the results obtained from different practice types. In addition, an analysis was conducted that compared the accessibility of eyecare for young children in relation to the level of deprivation of the practice's location. Additional statistical analysis using chi-square and Kruskal Wallis have been added. A Pearson correlation was also undertaken to explore the correlation between IMD score and age of a child's first eye examination.

Qualitative analyses were undertaken with the additional responses obtained during the telephone survey by coding the information (labelling processes) and assigning themes (grouping data into relevant categories). A verbatim transcript was not obtained as the telephone call was not audio recorded. Notes were made on the additional information that was obtained during the telephone call. The researcher (SW) read through the anonymised notes obtained during the telephone survey multiple times before coding the information. Data were first coded and then categorically arranged into themes. To ensure the validity of coding, the data were checked independently by another researcher (supervisor Catherine Suttle) agreement on the codes was ensured.

RESULTS

Three hundred and ninety-seven out of 400 optometric practices contacted stated that they perform eye examinations on children. The 397 practices were asked at what age they start testing children in their practice, followed by scripted questions from one of the four pre-allocated scenarios. The results in *Table 2.4* showed the combined responses from all; 400 optometric practices when those that examined children were asked the following question in the survey, "At what age do you start testing children at your practice?" and the change in response once practices were informed of the concern in the pre-allocated scenario. Thirty of the 200 practices contacted for Scenarios one and two changed their response relating to the age at which they examine children after they were made aware of the scenario. These differences are stated as comments in *Table 2.4*. This has been further explored for each scenario, and the median age at which a practice would examine a child after an

explanation of the concern in each scenario is illustrated in *Table 2.5.* Detailed analysis (*Table 2.4*) highlighted that 56/400 (14%) practices would examine a child of any age, and 125/400 (31.25%) practices reported that they examine children from four years and 136/400 (34%) from, 5 years of age. The median age at which the optometric practices stated they started to examine children was 4 years (Inter- Quartile Range (IQR) 3-5 years). As 100 different practices were contacted for each case scenario, the type of practices in each group could result in variability. A statistically significant difference was found in the sample practice types used for the scenarios. These differences were particularly noticeable for scenarios one and four, scenarios one and three, scenarios two and four and scenarios two and three ($H(3) = 30.39$, $p < 0.001$). Statistically significant differences were found for the practice type used for each scenario, indicating variability in the practice type chosen for each scenario, whereby some practices were more likely to see young children than the total sample. A summary of the telephone survey for each scenario is illustrated in *Table 2.6.*

Table 2.4. *The earliest age at which practices stated they would examine a child in response to the question, "At what age do you start testing children at your practice?", as well as the ages at which the practices stated they would examine the child once they were informed of the scenario[ǂ] and comments to explain the differences in responses.*

Age (years)	Number (%) response to question 2	Number (%) response following presentation of scenario	Comments
Any age	56 (14.0)	53(13.25)	3 practices from the sample for scenario 1 initially said any age to question 2; however, once informed of the child and age, they declined to examine the child at any age.
1	3 (0.75)	13(3.25)	10 practices of the 100 contacted for scenario 1 that initially gave an older age for question 2; however, they changed their response when they were willing to offer services after the presentation of a 1-year-old child.
2	6 (1.5)	6(1.5)	No change in responses.
3	61 (15.25)	81(20.25)	20 of the 100 contacted for scenario 2 initially gave an older age for question 2; however, changed their response when they were willing to offer services after presenting a 3-year-old child.
4	125 (31.25)	103(25.75)	22 practices of the 200 practices contacted for scenarios 1 and 2 who initially answered question 2 with the age of 4 years and then changed their responses in light of the scenario.
5	136 (34.0)	133(33.25)	3 of the 200 practices contacted for scenarios 1 and 2 who initially answered question 2 with the age of 5 years and then changed their responses considering the scenario.
6	10 (2.5)	8(2.0)	2 of the 200 practices contacted for scenarios 1 and 2 initially answered question 2 with the age of 6 years and then changed their responses considering the scenario.
Do not examine children	3 (0.75)	3 (0.75)	The scenarios were not presented as they do not examine children.

[ǂ] Scenario 1= 1-year-old with an eye turn, Scenario 2= 3-year-old with a family history of myopia, Scenario 3= 5-year-old with advice from school to get an eye examination and, Scenario 4= 13-year-old with autism.

Table 2.5. *The median age at which practices would examine children in each scenario once the concern relating to the relevant scenario was explained (IQR=inter- quartile range).*

Scenario	Median age practices would examine a child (Years)
1 year old	4 (IQR 1-4)
3-year-old	3 (IQR 3-4)
5-year-old	4 (IQR 4 -5)
13-year-old	5 (IQR 3-5)

*T**able 2.6.** A summary of the results for each telephone survey scenario (IQR=inter- quartile range).*

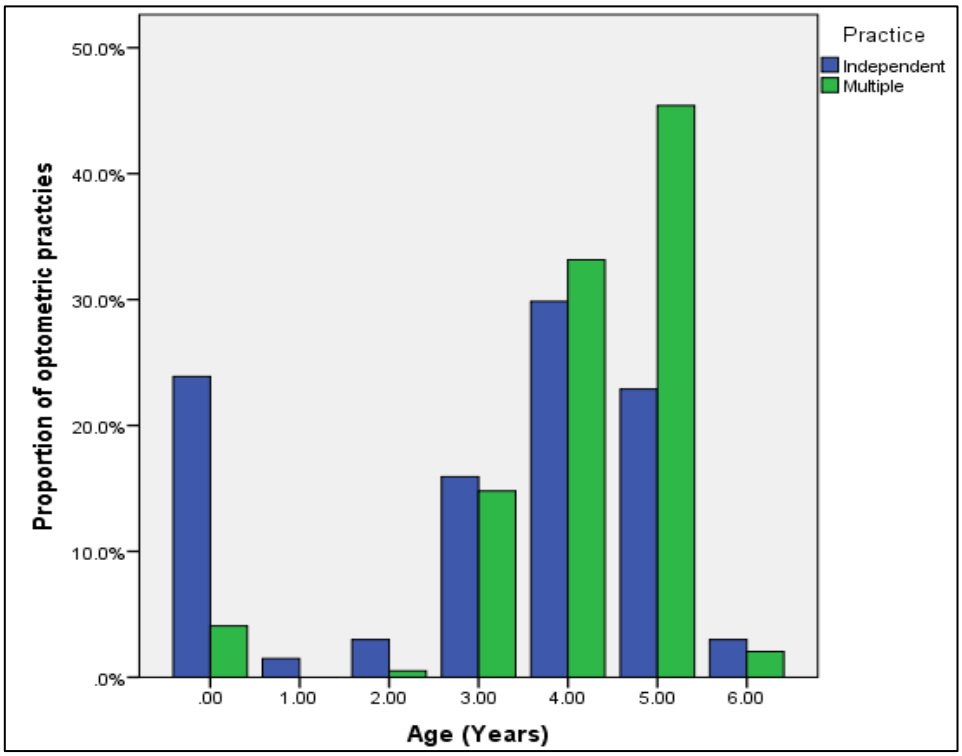
	Scenario 1: 1-year-old	Scenario 2: 3-year-old	Scenario 3: 5-year-old	Scenario 4: 13-year-old
Number of multiples	44	45	51	58
Number of independents	56	55	49	42
Q1. Do you test children? (n=100)	100%	99%	99%	99%
Q2. At what age?				
Multiple practice type (Median)	4 years (IQR 3-5 years)	4 years (IQR 4-5 years)	4.5 years (IQR 4-5 years)	5 years (IQR 4 -5years)
Independent practice type (Median)	3 years (IQR 0-4 years)	4 years (IQR 3-4 years)	4 years (IQR 3-5 years)	3 years (IQR 0-5 years)

Independents and multiples

A total of 198 multiples and 202 independents were contacted. When addressing the accessibility of primary eyecare within a community setting, the type of practice was analysed to see if there is a difference between multiple and independent practices. The median earliest age at which a multiple or independent practice offered an eye examination to a child was four years in both cases, with a notable difference in the IQR (4-5 years and 1-5 years, respectively). This difference was statistically significant (U =26198, p<0.001). *Figure 2.1* illustrates the answers received in response to question two of the telephone survey indicating the youngest age practices examine children prior to introducing the scenario-specific information. This finding was taken with caution with verification of variance in the sample (homogeneity of variance) (Levene's test, P> 0.05). The age at which examinations are offered in young children varies, as seen in *Figure 2.1* (ages rounded to nearest year)

A statistically significant difference was noted between multiple and independent practice types, whereby independent practices were more likely to offer an eye examination for a child instead of recommending that the child is seen elsewhere (chi-squared test, p<0.005). Of the multiple and independent practices that declined to examine the one-year-old and three-year-old, the median age at which those practices would examine children was 4 years (IQR 3-5 years) and 4 years (IQR 4-5 years), respectively.

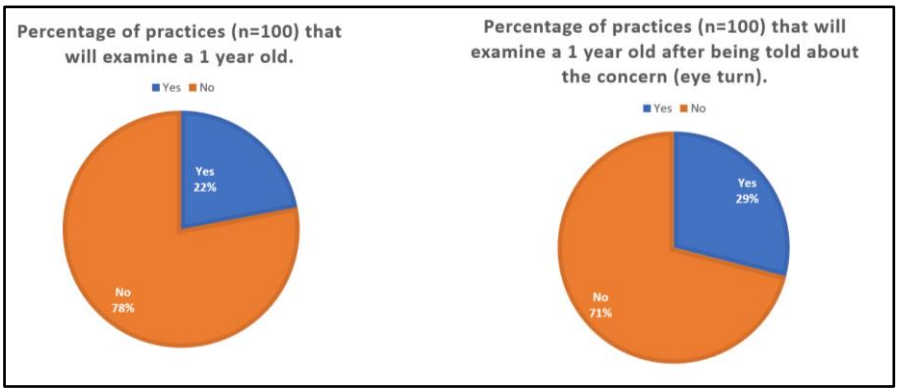
Figure 2.1. *The earliest age (rounded to the nearest year) at which the independent and multiple practices in this sample offered an eye examination to children (0 = any age; there was no age restriction).*



Scenario one

Of the 400 practices, 100 were contacted for scenario one. Practices were first asked whether they performed eye examinations on children and the earliest age they would examine children. The scenario-specific questions were then asked. The results obtained from the 100 optometric practices contacted regarding scenario one as to whether they would examine a 1-year-old child's eyes followed by a one-year-old child with a concern of a turn in the eye are highlighted in *Figure 2.2*.

Figure 2.2*. Responses from the 100 optometric practices contacted and their responses when asked if they would offer an eye exam to a one-year-old and how the practices who initially said no changed their responses once informed of the parent's concern.*

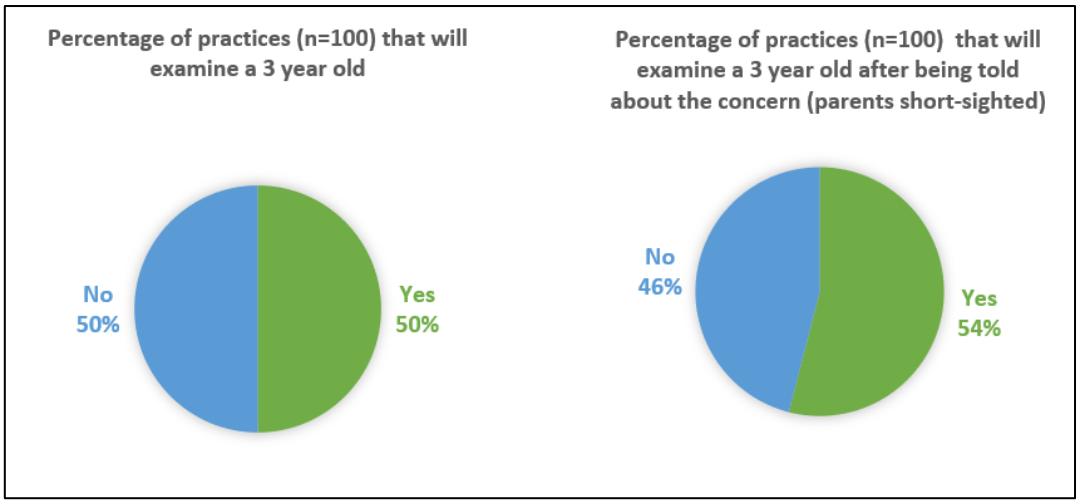


Some optometric practices (n=71) simply said no, and some practices (n=7) changed their response, considering the concern regarding the child's eyes. The difference between the responses obtained from both questions was statistically significant (Wilcoxon signed-rank test, Z = -2.646, p=0.008, with a small effect size (r= 0.11)). Further information obtained from the telephone survey is illustrated in *Table 2.6*.

Scenario two

In this scenario, the overriding question was whether practices would examine a three-year-old child's eyes. The second part of this question included examining a three-year-old child with a concern as both parents are short-sighted. The results are illustrated in *Figure 2.3*.

Figure 2.3*. Responses from the 100 optometric practices contacted and asked if they would offer an eye exam for a three-year-old and how practices who initially declined changed once informed of the parent concern.*

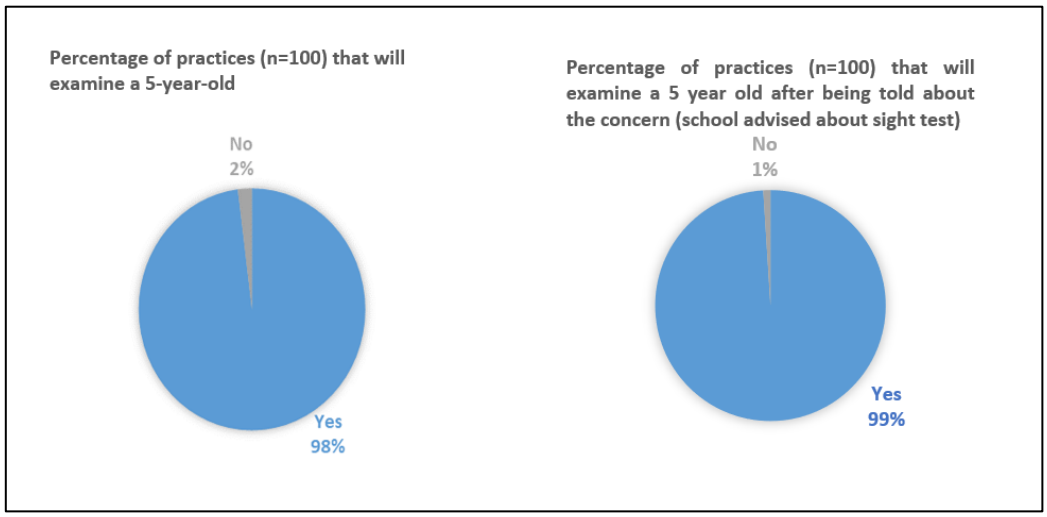


The 4% (n=4) change in response from first asking if the practice would examine a three-year-old and then once informing the practice that there is a family history of myopia was found to be statistically significant (Wilcoxon signed-rank test, Z= -2.000, p= 0.046, with a small effect size (r=0.20)). The results from scenario two have been tabulated in *Table 2.6*.

Scenario three

Scenario three explored the accessibility when a child is of five years. *Figure 2.4* shows the results obtained from asking optometric practices to examine a five-year-old child's eyes, followed by examining a five-year-old child when the concern is that their school has advised the parent to get their eyes examined.

Figure 2.4. *Responses from the 100 optometric practices contacted and asked if they would offer an eye exam for a five-year-old. The response changed once obtaining further details regarding the child's eyes for those practices that initially declined.*

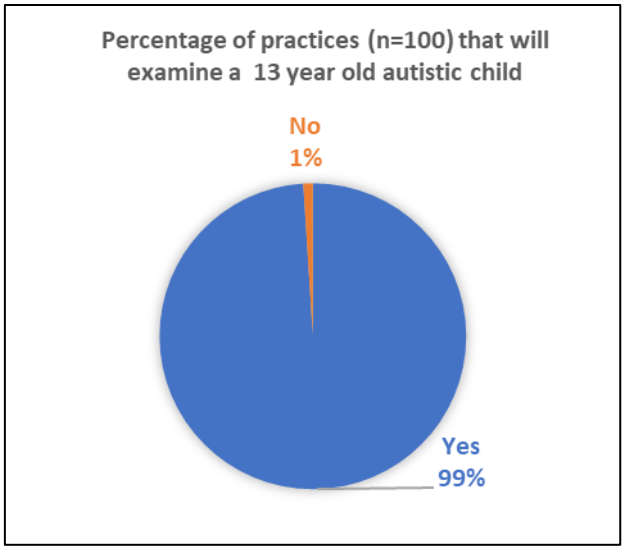


The Wilcoxon signed-rank test revealed no significant difference between the responses obtained from the optometric practices when questioned about examining a child aged five years and then relaying the concern about the child's eyes (Z= -1.000, P=0.317, with a small effect size (r=0.10)). The results obtained from the telephone survey for scenario three can be found in *Table 2.6*.

Scenario four

In the final scenario, optometric practices were asked to examine a child of 13 years who had autism; the results are illustrated in *Figure 2.5*. The overall responses that were obtained from scenario four can be found in *Table 2.6*.

Figure 2.5*. Responses from the 100 optometric practices that were contacted and asked if they would offer an eye examination for a 13-year-old with autism.*



Eye examination fee

Of the 400 practices contacted as part of this survey, 397 stated they see children for eye examinations; however, only 281 were willing to offer eyecare services to the child in question. Of those practices that offered an eye examination service, 279 practices would perform an NHS funded eye examination for the child in question. Two practices offered private services as they did not provide GOS services. Of these, one practice offered to do the eye examination for free of charge as a goodwill gesture, and the other practice would charge £50.

Declining to offer an eye examination

A total of 119 practices declined to offer an eye examination for the child in the scenario. However, all the practices that declined to examine the child recommended contacting different healthcare services to ensure the child's eyes were examined. The frequency of each service for each scenario is documented in the table below (*Table 2.7*). Of the practices that declined to examine the one-year-old and three-year-old, the median age at which those practices would examine children is 4 years (IQR 3-5 years) and 4 years (IQR 4-5 years), respectively.

Table 2.7. *Healthcare services[ǂ] that were recommended in each scenario ('other' in scenario one = call 111 (telephone service when one needs advice or medical treatment quickly) and in scenario two = wait for school screening). GMP= General Practitioner.*

Referred to another service:	**Scenario**			
	Scenario 1 (1-year old)	**Scenario 2 (3-year-old)**	**Scenario 3 (5-year-old)**	**Scenario 4 (13-year-old)**
GMP or Health Visitor	67	34	0	0
Hospital	6	8	0	0
Another optometric practice	4	3	1	1
Other	1	1	0	0

[ǂ] There were seven optometric practices that recommended multiple options to the parent.

Index of Multiple Deprivation (IMD)

The Index of Multiple Deprivation (IMD) 2015 measures the level of deprivation for areas in England. The IMD ranks areas in England from 1 (most deprived) to 32,844 (least deprived area) (Department for Communities and Local Government, 2015). Analysis based on the IMD score was considered in relation to the age at which practices start to examine children. Statistical analysis was conducted using the Kruskal-Wallis test, which indicated no statistical difference between the age at which practices start to examine children in relation to the location's deprivation level (H (6) = 5.419 p= 0.491). The practices that were contacted varied in location. *Figure 2.6* demonstrates the locations that were contacted to determine the accessibility of eyecare for children. A Pearson correlation coefficient was computers to assess the relation between the IMD score of an area and the age of child at their first eye examination. There was a small strong negative correlation between the two variables, r=-0.11, n=397, p=0.02. The higher the IMD score associated with younger ages of a child's first eye examination.

Figure 2.6. *A map showing the geographical locations of the practices contacted during this survey.*

Qualitative data

One hundred and eighty-nine comments from respondents were coded and categorised into eight themes. Not all the information was obtained directly from the respondent. Of the 400 optometric practices, 30 practices confirmed the information with another staff member before informing the parent of which, 16 optometrists, two dispensing opticians, one supervisor, 11 unknown staff members were asked by the respondent regarding the telephone enquiry. This information was categorised into enablers and barriers to accessing eyecare. Factors facilitating access to eyecare were categorised as enablers, while those indicating limitations to access were categorised as barriers. Themes and codes alongside the additional notes and frequency of the code are shown in *Tables 2.8* and 2.9. Additional information relating to scenario three was not obtained and is therefore not included in the qualitative data.

Table 2.8. *Enablers in accessing eyecare for children with examples summarising the information provided. Note that verbatim comments are not provided as the call was not recorded.*

Theme	Code	Frequency	Example summary of a telephone conversation
Eye examination	Access	7	We can book an eye test but also go and speak to your health visitor or the hospital as they have age-related tests.
Professional skills	Professional skill	3	We are happy to see the child due to the concern, and there is a certain optometrist we recommend who would be best for the child's sight test.
Adaptability	Adapting	13	We can adapt to make the child feel more comfortable and book two-time slots.
	Preparation	9	We will inform the optometrist, so they are aware.
	Familiarisation	1	We advise you and the child to visit the practice, so the child adapts to the environment before booking an eye test.
	Trained	6	We are all trained to see people with autism.
Appointment time	Specific day	7	Sundays are better for children as it is quieter.
	Longer appointment	10	Extra time will be given to the child to make them feel at ease.

Table 2.9. *Barriers to accessing eyecare for children with an example (GMP= General Practitioner).*

Theme	Code	Frequency	Example summary of a telephone conversation
Communication	Age	25	They are too young to be seen by an optometrist.
	Alphabet	2	The child may not know their letters.
	Speech	1	The child needs to be able to communicate.
Equipment	Cycloplegia	9	See your GMP as we will need to put drops in his eyes so we can refer to a clinic.
	Equipment type	6	Go and see your GMP as we do not have the equipment.
Monitor child	Monitor child	1	Watch the child to see if he squints.
Type of eye examination	NHS contract	3	We do not see children as we do not have an NHS contract.
Management	Refer to a GMP or health visitor	63	See your health visitor or GMP due to the concern you have.
	Refer to a hospital or another optometric practice	11	Go to the hospital and also visit *** optometric practice they will see a child of that age.
	Referral needed	2	The child may need a referral if there is strabismus present.
	Professional skill	6	Optometrists do not see children at that age.

Further analysis of the management theme was undertaken with those practices that justified the need for a referral, which is detailed in *Table 2.10*.

Table 2.10. *Classification of the management theme for scenario one (one-year-old child) and scenario two (three-year-old child) with an example (GMP= General Practitioner).*

Scenario	Theme	Reasons	Frequency	Example summary of a telephone conversation
One	Management	Communication	11	See a GMP as the child is too young to be seen by an optometrist.
				See your GMP as the child is too young and will not understand the test.
		Equipment	3	Go see your GMP, who can refer to a hospital eye service who have tests for children at that age.
		Professional skills	3	You should visit your GMP if concerned, as we cannot do much at this optometric practice.
		Time	3	It would be a quicker pathway to see a specialist at the hospital.
		Responsibility	3	Your GMP or health visitor should be the first point of contact.
		Strabismus	1	The child may need a referral if there is strabismus present.
Two	Management	Professional skills	3	Go to another optometrist that sees children from the age of 2 years.
		Equipment	3	Go to the hospital as they can do a more accurate test.

DISCUSSION

Accessibility to paediatric eyecare is influenced by several factors, including eye health education, conflicting family needs, socio-cultural background, economic conditions, and lack of awareness from parents about the importance of eye examinations. Optometrists are the leading providers of primary eyecare and have been trained to be adaptable when performing eye examinations and understand patient care implications concerning the Mental Capacity Act 2005 and Disability and Equality Act 2010 (College of Optometrists, 2019c). One of the first things this study sought to determine was how accessible eye examinations are for children. It is reassuring that 99.3% (397/400) of optometric practices in this sample were willing to examine children's eyes, though 85% would not examine children below a certain age (median four years). Our findings are in line with earlier studies that reported that some optometrists are reluctant to examine very young children (Swystun et al., 2020; Shah et al., 2007).

It is of some concern that there is a restriction to eyecare depending on the child's age. This restriction in services is of concern as the GOS aims to provide eyecare for children, adults over 60, those on a low income, diabetics, and those at risk of an ocular disease (National Health Service, 2017). The GOS terms of contract state, “the ophthalmic services contractor… shall provide mandatory services under [their] contract to any eligible person if a request is made for such services” (Legislation.gov, 2008). A previous survey on the availability of NHS funded eye examinations for children found that 54% of practices effectively excluded young children (aged one year), and 2% of practices did not see children under the age of seven years (Shah et al., 2007). The current study results show that 85% of the practices would exclude a child from a GOS eye examination based on their age, and 2.5% of the practices would not examine a child under the age of six years.

The results from scenario one revealed that only 22% of practices would offer an eye examination to a one-year-old. This is of concern because, at this age, the visual system is still developing with additional concerns around the presence of strabismus; this increases the importance for the child to be seen as this can hinder their visual development. The results show that the advice from the respondents predominantly consisted of visiting a GMP or health visitor. An optometrist is better equipped to examine a child as they have the skills and knowledge to test young children when they qualify as an optometrist but often lack experience testing very young children as they do not often present in community practice. Health visitors with concerns about children’s eyes refer them to the HES rather than a community optometrist. In addition, the ‘red book’ also tells parents that they should speak to their GMP or Health Visitor, where they have concerns about their child’s eyes. Children eye

examinations and binocular vision anomalies are not critical areas of specialities for GMP's and health visitors. The Vision of Britain report stated that 32% of GMPs feel "de-skilled" in diagnosing eye conditions, and 44% of GMPs felt less confident with eye conditions than other parts of the body (Optegra Eye Health Care, 2015). This, furthermore, highlights the fact that optometrists are better suited in this situation to be the ones offering eyecare to young children. The practices that advised the child should be taken to the hospital to get their eyes examined could potentially be causing unnecessary referrals being made, which could have cost implications on the hospital eye service.

In contrast, for scenario two, when seeking an eye examination for a three-year-old as both parents are short-sighted, interestingly, only (54%) of practices telephoned would examine the child. Even at a slightly older age, where the child can name colours correctly, count and identify everyday objects and match things (Sharma and Cockerill, 2014), 46% of optometric practices declined to offer a child an eye exam. The caller was advised to see the child's GMP or health visitor (34/100) regarding the concern. A few practices (8/100) thought the child should be seen at the hospital despite the child's age. The results show that all practices appreciate the need for an eye examination due to the family history of refractive error; however, nearly half of the optometric practices felt the child needed to be seen elsewhere. This is worrying as optometrists are best placed when it comes to measuring one's refractive error. Hospital optometrists refract those children that do get seen in practice with the same equipment (retinoscope). This can, therefore, be undertaken in a primary setting and, therein, reduce referrals into the HES system. Examining children when there is a family history of myopia is essential. It has been reported that children who have one myopic parent are three times more likely to become myopic in the UK (O'Donoghue et al., 2015b). If both parents are myopic, the child is seven times more likely to develop myopia (O'Donoghue et al., 2015b). Research has shown that the prevalence of myopia in the UK is rising (McCullough et al., 2016); therefore, children who are at higher risk of developing myopia must be seen earlier, and advice regarding environment and lifestyle should be given to parents of the child to help delay the onset of myopia.

When investigating the accessibility of eyecare for a child of five years whose mother has been advised by the school to get their eyes tested, the results show a significant change in response in the proportion of optometric practices that offer an eye examination. Only one practice declined to see the five-year-old and was advised to go elsewhere as the practice did not examine children because they do not have an NHS contract. The results from a recent survey found that 97% of optometrists see children between the age of five to seven years at least once a week (Doyle et al., 2019).

The accessibility of eyecare for autistic children was explored using a scenario of a 13-year-old child where the mother informs the practice of the child's challenges when in a new environment and how this may impact communicating with him. Only one optometric practice declined to offer an eye exam as they reported that they do not examine children and are not sure if the optometrist would see them. The researcher was advised to check with another practice. It is reassuring that most optometric practices are willing to adapt and accommodate autistic children with behavioural challenges, particularly because individuals with autism are more likely to have a visual problem. Approximately 75% of individuals with autism also have a learning difficulty therefore, caution should be taken as they could also have an eye problem (Turner et al., 2013). Evidence suggests that individuals with autism are more likely to have a visual problem such as reduced near the point of convergence and strabismus (Ludlow et al., 2008; Milne et al., 2005).

Moreover, in this present study, when looking at independent practices and multiples offering eye examinations, the results show that independent practices are willing to see children at a younger age. The results show that some multiples are willing to examine a child irrespective of their age, but there are more independents than multiples that do not restrict their services due to age. This is an interesting finding as the type of practice should not affect the accessibility of a service. Practices within the same chain would give various age restrictions there was no one set rule for each multiple. Each practice had their own age restriction. Most practices offer state-funded eye examinations for children. There were only two independent practices that would offer private services. This difference in services between the types of practices supports research that has recently reported differences in eyecare services between multiples and independents. When exploring practice type and eye examination outcomes, children under 16 were more likely to be referred to secondary care or prescribed a new or changed prescription by a multiple compared to an independent practice (Swystun and Davey, 2020).

The qualitative analysis of additional comments has allowed the identification of factors limiting (barriers) or facilitating (enablers) children's access to community eyecare. Investigation of the qualitative data from scenario one (one-year-old) and scenario two (three-year-old) highlights *communication* and *equipment* as the two key potential barriers for children of one and three years of age accessing eyecare. The key enablers primarily associated with the autism scenario (scenario four) were *adaptability* and *appointment times*. No barriers were found in the scenario regarding a child with autism.

A key concern reported by the optometric practices during the telephone survey related to the *management* theme as a barrier to accessing primary eyecare. This theme explored how the practice would manage examinations for young children in their practice of a certain age or with a particular concern. The practices stated that the management of children of one and three years would be a challenge due to *communication, equipment, professional skills, time*, and perceived *responsibility*. Scenario one (one-year-old with a possible eye turn) generated more codes under the *management* theme (n=47) compared to scenario two (three-year-old with a family history of myopia), which is consistent with the fact that more practices declined to offer services for the younger child. Interestingly, further analyses of these data highlighted those practices in England believe that a child of one year or three years with visual concerns should be examined by a GMP or in a hospital setting as such examinations are not performed by an optometrist in a community setting due to the potential need for a cycloplegic examination. Doyle et al. reported that most optometrists (77%) are not concerned about using cycloplegia (Doyle et al., 2019). Qualified optometrists know the appropriate usage, practice, and contraindications of cycloplegic drops and have the skills to use an ophthalmoscope and retinoscope (General Optical Council, 2015). When the theme of *management* was explored further, it was noted that the common reason for the need for a referral in scenario one was communication between the child and the optometrist. In contrast, for scenario two, the need for a referral as management was related to the professional's skills and equipment.

Optometrists undergo university-based pre-registration training, and paediatric optometry is an element that needs to be achieved before qualifying. At the time of qualification, optometrists have the fundamental skills required to examine children though confidence is likely to increase with experience. The College of Optometrists has introduced the professional and the higher certificates in paediatric eyecare in response to registrants concerns regarding their experience and expertise in this area (College of Optometrists, 2020a). The qualitative data revealed that in some cases, the access to eyecare for the child might be dependent on whether the optometrist was willing to examine the patient based on their confidence in related skills. For example, in three situations, the optometrist was happy to see the child due to the parent's concern compared to four cases where the optometrist reported that they do not see children at that age. The current undergraduate requirement with the GOC is a minimum of eight patients experience, at least two of which are paediatric with at least one of these under 7 years of age (General Optical Council, 2022). Current training requirements needs to be modified to allow optometrists to have more exposure examining young children and potential further training to become a specialist if logistically adding more patient experiences during the undergraduate course is challenging. There may be a need for greater emphasis and publicity of this additional training for optometrists who do not feel confident in examining young children.

The availability of paediatric eye examination in England can be limited by barriers experienced by optometrists when examining children whilst working within a primary care setting. Kemper and Clark, in 2006, found the barriers to examining paediatrics were due to; the level of cooperation from the child, time and, lack of training for testing younger patients. In the present study, *communication* between the child and the optometrist was a significant barrier in preventing optometrists from providing eyecare services. While objective techniques are available for some aspects of the paediatric eye examination, the child's age, ability to communicate and their knowledge of the alphabet impacted the accessibility of eyecare for young children, suggesting that at least part of the process would involve subjective testing. Communication is a professional skill and could be viewed in the same light as the skills and competencies discussed above and could perhaps be enhanced with additional training and clinical experience.

Previous research reports that patients at different ends of the autism spectrum have a very poor experience of primary eyecare despite the severity of their autism (Gow, 2015). More recently, qualitative research explored

healthcare experiences from the clinicians' perspective and that of individuals with autism (Mason et al., 2021). Individuals with autism reported challenges with processing information during their medical appointment or providing information to the healthcare practitioner, and expressing their needs (Mason et al., 2021). Clinicians have reported barriers such as constraints with appointment times, in particular, sight test appointments and financial constraints with the optometric practice when accommodating individuals with autism and the disconnect between various healthcare services (Mason et al., 2021). In the present study, the accessibility of eyecare for autistic children was facilitated by advising a longer *appointment time*. The sample information illustrates the need to ensure the child is at ease, attending the practice at its quietest periods to remain calm and relaxed. The additional time helps to achieve this. The staff and the practitioner's *adaptability* were highlighted by confirming the individuals in practice trained in dealing with individuals with ASD. This is encouraging as this shows optometrists have been trained to be adaptable when performing eye examinations and can accommodate all types of patients.

Other factors influencing the accessibility of eyecare for children include *equipment* and whether the eye examination was funded by the NHS or private. Some practices suggested that they do not have the resources to conduct eye examinations on young children but did not specify the missing resources. All optometrists either have their own or have access to a retinoscope and ophthalmoscope to conduct key elements of the eye examination. In addition to this, the optometrist would need access to an age-appropriate vision test, and stereopsis test which the practice would generally provide. All children under the age of 16 years are eligible for an NHS-funded eye examination. The GOS contract does not stipulate which form of vision testing equipment is required for measuring vision however does stipulate what procedures should be undertaken in an eye examination as it is the contractor who needs to ensure the equipment is suitable (Legislation.gov, 2008). This may have influenced resources available in practices and therein resulting in practices declining to see young children due to not having the appropriate equipment to accommodate young children. Furthermore, due to a potential need for a cycloplegic examination, the parent was advised to visit their GMP or be seen in a secondary care setting instead. There may be a need for community optometric practices to invest in age-appropriate tests to allow optometrists the relevant resources to examine young children. The theme *type of eye examination* was classified as a barrier as some practices did not hold a GOS contract to offer NHS funded eye examinations for children or did not examine children limiting the accessibility of eyecare among some community practices. The optometry profession as a whole could enhance the inter-referrals between optometrists through frequent use of this strategy. In addition, increasing the awareness among professionals and the public which optometrists have additional paediatric accreditations and feel confident in examining young children and the location of these practices.

Recent studies highlight a gap in accessibility of eyecare for children (Swystun and Davey, 2020; Doyle et al., 2019; Shah et al., 2007), and concerns have been raised around school screening not meeting the PHE specifications (Clinical Council for Eye Health Commissioning, 2020; Public Health England, 2017). Data were obtained from the Freedom of Information (FOI) request in 2019 highlighted that out of the local authorities that responded, 94% of local authorities provide vision screening; however, only 47% of the screening services comply with the PHE specifications (Clinical Council for Eye Health Commissioning, 2020; Public Health England, 2019). In light of the current findings, the British and Irish Orthoptic Society (BIOS) have an action plan to ensure compliance with the PHE specifications (Clinical Council for Eye Health Commissioning, 2020). Moreover, it has been evident that children with a learning disability have problems accessing eyecare (Pilling and Outhwaite, 2016). One of the main reasons for underdiagnosing visual impairment in those with learning difficulties is that at times visual signs and symptoms may be incorrectly considered as an untreatable part of their disability (Royal College of Ophthalmologists, 2015a). Developments to improve eyecare pathways for people with learning difficulties are underway in parts of England (SeeAbility, 2021). Research has shown that children in special education benefit visually, and their behaviour within the classroom improves when a refractive error or visual anomalies are corrected (Black et al., 2019). Therefore, it is paramount for any child presenting with an eye concern to be offered an eye examination. Following this initial primary care investigation, a referral should be instigated if further assessment is required in a secondary care setting. This would help reduce the burden of secondary care services by reducing the number of children being referred when the optometrist can undertake the management (e.g., refractive amblyopia) (Stewart et al., 2016). Furthermore, optometrists have a duty of

care towards the wider public. If a particular patient is beyond their scope of practice, the optometrist should refer the patient to an appropriate professional.

These results suggest that the child's age influences the accessibility of primary eyecare. The project has provided a significant opportunity to advance the understanding of accessible eyecare for young children in England. This has been done by updated data on what the accessibility of eyecare is like within primary care. A possible explanation for these results might be that there are barriers amongst community practices that lead parents of children to visit their GMP, health visitor or hospital. The reasoning for this will require further investigation. A recent study found that some of the clinical barriers experienced when examining young children are due to children losing their attention quickly, hence a possibility of an incomplete assessment resulting in multiple visits (Cassetti et al., 2019). Further work is required to explore the barriers amongst optometrists in community practices when examining young children.

Primary eyecare for children at an early age is essential, especially with a family history of strabismus, refractive error, or other visual anomalies. Unfortunately, the current study findings are in line with a similar previous survey (Shah et al., 2007) which concluded that optometric practices exclude children of a certain age from a GOS eye examination. This is a concern because of the prevalence of refractive error and binocular vision anomalies in children.

The Directorate of Optometric Education and Training (DOCET) have focused their training on paediatric optometry to help UK-registered optometrists feel more confident and competent in examining children. Despite these efforts, there still seems to be a gap. There may be clinical and commercial reasons why certain optometric practices decline to examine children of a certain age. This area needs to be investigated to assess the barriers and potential enablers to improve the accessibility of eyecare within the country. Moreover, the importance of this has been further highlighted during the current Coronavirus Disease (COVID-19) pandemic. There have been major interruptions in education and child health services resulting in vision screening services that have been delayed, postponed, or cancelled for some of the children who started reception in 2019 (Clinical Council for Eye Health Commissioning, 2021). The Clinical Council for Eye Health Commissioning have stipulated that the responsibilities of optometric practices are to provide NHS funded eye examination for children, assessing visual acuity with crowded LogMAR letter chart, provide GOS-2 statement of outcome and, refer to the local HES were warranted in line with local guidance (Clinical Council for Eye Health Commissioning, 2021).

STRENGTHS AND LIMITATIONS

A major strength of the study is the relevance of the scenarios used during the telephone survey. The scenarios used during the telephone survey were based on professional experiences of optometrists and the literature available (Ebeigbe, 2018; Sukati et al., 2016; Balasubramaniam et al., 2013; Frazier et al., 2008). However, these findings cannot be extrapolated to all optometric practices in England, as only a sample of 400 practices were surveyed. It is noteworthy that some practices did confirm their responses with an optometrist. However, most of the responses came from staff members who regularly answer the telephone, which may not give an accurate representation of the optometrists' perspectives on the scenarios used during the survey. The questions relating to each scenario were scripted and piloted to ensure that the telephone enquiry process was smooth and consistent. Additionally, to ensure consistency and standardisation, all practices were contacted by the same researcher.

The Windsor Deception Checklist was used to assess any potential ethical concerns (Pascual-Leone et al., 2010). This was to help justify the methodological approach by citing previous comparable research (Shah et al., 2007) and considering risks. While care was taken in designing the telephone survey script, scenarios, and data collection, there may have been variations in individual responses. Depending on who answered the telephone and how much experience and knowledge they have in this area, there may have been a difference in the interpretations of the necessity for an eye examination. The nature of the telephone survey data represents optometric practices' opinions and those who work within the shop floor and reception proximity and who regularly answer the telephone. Therefore, it may not represent the clinician's actual response at what age they might choose to examine young children. While the present study does not highlight the responses, one would obtain from the optometrist regarding examining young children. Some practices confirmed with their

optometrist before advising on obtaining eyecare for a young child. While there was a positive finding from optometric practices accommodating autistic children for an eye examination, additional information could have been obtained by specifying what end of the spectrum the child was on or two different autistic scenarios. A limitation exists in the manner in which the qualitative data were collected. No prompt questions were used; hence, a talkative staff member may have biased the results by giving more information than requested. Moreover, qualitative analysis was not conducted for scenario three due to insufficient data because most of the practices contacted were willing to accommodate the five-year-old. Therefore, additional information was not gained during the telephone conversations.

The chosen sampling method may introduce some limitations in the results as even though the postcodes were randomly selected, businesses pay additional fees to appear within the top three searches. Nevertheless, these scenarios and practice type findings cannot be extrapolated to all optometric practices across England because a sample of only 400 practices across the country were surveyed. There was also no record of the total number of optometric practices in England as it is not mandatory for optometric practices to be registered with the GOC at the time of data collection.

CONCLUSION

In summary, this study has identified variability in how parents of children can access eyecare in a primary care setting. The research has shown that an eye examination is more accessible to older children (five-year-old and a 13-year-old) than younger children (one-year-old and a three-year-old). Optometrists are trained in paediatric eyecare and therefore have the skills and aptitude to examine children. Yet approximately 30% of practices that declined to examine the child advised that the child should see their general medical practitioner or health. Key themes identified that play a role in the accessibility of eyecare for children in England include *communication, equipment, professional skills, adaptability, and appointment time*. Although the findings from this research project will not directly benefit the optometric practices included in the survey, they indicate the need for further research to investigate the optometrists' perspective in community settings regarding the barriers and the corresponding enablers to examining young children. This will provide further evidence and help improve our understanding of the barriers in paediatric eyecare in primary care settings and support developing an effective plan to improve eyecare for young children in England.

3. SYSTEMATIC REVIEW AND META-ANALYSIS ON THE AGREEMENT OF CYCLOPLEGIC AND NON-CYCLOPLEGIC REFRACTION IN CHILDREN

BACKGROUND

Cyclopentolate Hydrochloride is a synthetic antimuscarinic cycloplegic agent (a drug that dilates the pupil) and is available in 0.5% and 1.0% concentrations (National Institute for Health and Care Excellence, 2020). It is widely used and accepted as the first choice for providing excellent short-term paralysis of accommodation (*see Chapter One*), termed *cycloplegia*, for refraction (Patel, 2015; Farhood, 2012). Cycloplegic refraction is an effective way of reducing fluctuation in accommodation or spasm of the ciliary muscle (Hopkins et al., 2012; Fotedar et al., 2007; Zhao et al., 2004). The temporary paralysis of accommodation is useful when refracting young children as their accommodative system is vigorous, leading to inaccurate measurements (Major et al., 2020). Furthermore, inaccuracies in refractive error measurements can occur during non-cycloplegic refraction in children by overestimating myopia and underestimating hyperopia (Sankaridurg et al., 2017).

Young children are routinely administered Cyclopentolate Hydrochloride (0.5 % or 1.0%) to improve the accuracy of refractive error measurements when hyperopia is suspected or when there is a binocular vision anomaly present, and the full hyperopic prescription needs to be attained (Royal College of Ophthalmologists, 2012). Moreover, cycloplegic refraction is also important in diagnosing and monitoring myopia progression (Morton et al., 2019). However, cycloplegia does not impact the astigmatic component of a refractive error (Doherty et al., 2019). The Royal College of Ophthalmologists recommends that children under the age of 12 years require cycloplegic refraction (Royal College of Ophthalmologists, 2012). In addition, the College of Optometrists advises optometrists to consider performing cycloplegic refraction when examining young children to obtain accurate refraction and the best possible view of the fundus but do not quantify the age range as to when this is appropriate (College of Optometrists, 2021f).

However, Cyclopentolate Hydrochloride can result in several ocular side effects, including irritation, lacrimation, allergic blepharoconjunctivitis, conjunctival hyperaemia, and systemic side effects such as drowsiness, disorientation, incoherent speech, and visual hallucinations (Rengstorff and Doughty, 1982). From a clinical perspective, cycloplegic refraction is considered the gold standard for measuring refractive errors due to the accuracy in the refractive error measurements obtained (Morgan et al., 2015). However, cycloplegic refraction is an invasive procedure involving eye drops which many patients find uncomfortable, potentially causing distress, particularly amongst younger children (Zhu et al., 2016). Furthermore, many parents and children refuse cycloplegia due to the effect of blurred vision and other side effects (Jin et al., 2021; Zhu et al., 2016). Hu et al. (2015) reported a 5% refusal rate due to the effects of blurred vision and light sensitivity due to cycloplegia. It has been reported that a brief stinging sensation of the eye that is felt on the instillation of cycloplegic drops causes distress in children (Ruttum and Smith, 1994). The cycloplegic effects begin at 25 to 75 minutes after the administration of the drug, and recovery occurs 24 hours later (Sani et al., 2016; Bartlett, 1978). This has been reported to be a time-consuming process (Yilmaz et al., 2015), potentially resulting in up to a 75-minute wait depending on when the cycloplegic drops take effect, which could be a limitation as to how long a parent and child may be able to wait. Children with very dark irides have been found to demonstrate 23% of the pupil dilating on an average of 24 minutes after a round of Cyclopentolate Hydrochloride and Phenylephrine Hydrochloride (topical anaesthetic) drops being instilled twice with a 10–15-minute separation, further highlighting a lot of time is required to achieve maximum cycloplegia (Llewellyn et al., 2018). The use of

diagnostic drops does have cost implications, and shortages in supply can occur due to various reasons, such as the shortages in February 2020 due to problems with the active ingredient contained in Cyclopentolate Hydrochloride (Royal College of Ophthalmologists, 2021). Furthermore, the barriers amongst parents accessing eyecare for their children has been established (Donaldson et al., 2018), and the use of diagnostic drops could potentially deter them from regular eye examinations.

Retinoscopy provides an objective measure of a patient's refractive error. Measuring refractive error via retinoscopy is performed using a retinoscope (an instrument used to illuminate the eye's inside and observe the light reflected from the retina) at the practitioner's preferred working distance. The light from the retinoscope is shone into the patient's pupil, and the reflex obtained is neutralised with concave or convex lenses (Elliott, 2007). Retinoscopy, however, can only be performed by a trained practitioner as it requires a few years of training to become skilful in measuring refractive error using a retinoscope. Cycloplegic retinoscopy is the gold standard method for measuring refractive error in young children (Morgan et al., 2015). Autorefractors are machines that can objectively measure refractive error and can be found in both primary care and secondary care settings. Autorefractors are relatively quick, and refraction can be performed by an appropriately trained non-healthcare professional. Autorefractors work in one of two ways; a closed-view type where the internal fixation target is viewed via a fogging lens system to relax accommodation, or the open-view type, where the patient views an external fixation target which is presented at a specific distance (Elliott, 2007).

Differences between cycloplegic and non-cycloplegic retinoscopy and autorefraction have previously been identified in new-borns as early as one to six days of age and children from six to 12 years (Chen et al., 2011; Fotedar et al., 2007). Guha et al. (2017) reported that the mean difference in refractive error (spherical error) in children under six years of age when comparing cycloplegic autorefraction and cycloplegic retinoscopy was -0.24 dioptres (D)± 0.56D, unlike those children over six years of age with a mean difference in a spherical error of -0.10D± 0.41D was detected. These findings were found to be statistically significant (p-value= 0.01) (Guha et al., 2017).

In 2014 Kirschen and Isenberg reported that cycloplegia might not be necessary when there are no risk factors such as a binocular vision anomaly or family history of any visual anomaly being present (Kirschen and Isenberg, 2014). However, the sample size was small and consisted of 88 participants, of which only 27 were under the age of eight years (Kirschen and Isenberg, 2014), and the range of refractive error within the sample was not enclosed just the prevalence of myopia, hyperopia, and astigmatism. The variability found between small levels of refractive error in non-cycloplegic and cycloplegic autorefraction may not be the same as exploring a wider range of refractive errors. The 27 children under eight years had a spherical difference in non-cycloplegic autorefraction and cycloplegic retinoscopy by -1.48 D ± 1.13D (Kirschen and Isenberg, 2014). Krischen and Isenberg (2014) reported that the non-cycloplegic autorefraction gave a reading of 0.29D ± 0.75D less hyperopic than the manifest refractive error. It has been suggested from the literature that non-cycloplegic autorefraction results of children under eight years of age and non-cycloplegic retinoscopy results of children aged between three and a half to five years can be used to calculate cycloplegic findings without the need for cycloplegic drops (Kirschen and Isenberg, 2014; Chan and Edward, 1994). However, the amount of error between non-cycloplegic and cycloplegic refraction differs from one individual to another (*Table 3.1*). Therefore, there is no way of adjusting non-cycloplegic refraction to approximate the potential cycloplegic refraction as a child's ability to accommodate can impact the precision of measuring refractive error (Morgan et al., 2015).

Furthermore, the age at which children do not require cycloplegic refraction is still undefined (Morgan et al., 2015). Recent literature has explored non-cycloplegic and cycloplegic retinoscopy and autorefraction and has found more myopic / less hyperopic measurements during non-cycloplegic assessments, therefore attempts to forgo cycloplegia could lead to considerable errors in refractive error measurements (Ilechie et al., 2021). Therefore, more evidence-based information is required regarding the type and level of refractive error where cycloplegic refraction is paramount in young children.

Table 3.1. *Difference between non-cycloplegic refractive error measurements and estimated cycloplegic measurements.*

Formula (X= spherical refractive error)	Study	Non-Cycloplegic refraction (DS= Dioptres Sphere)	Estimated cycloplegic refraction (DS= Dioptres Sphere)
X*0.84 + 1.55	Kirschen and Isenberg, 2014	+2.00 DS	+3.23 DS
		+5.00 DS	+5.75 DS
X*1.45 + 0.39	Chan and Edwards, 1994	+2.00 DS	+3.29 DS
		+5.00 DS	+7.64 DS

Some studies report that hyperopia is underestimated, and myopia is overestimated when children are refracted with autorefractors and nil cycloplegia (Zhu et al., 2016; Hu et al., 2015). In addition, there are suggestions that there may be a difference in the diagnostic agreement of non-cycloplegic and cycloplegic refraction based on either type of refractive error (Sankaridrug et al., 2017), the level of refractive error (Zhu et al., 2016; Hu et al., 2015), the patients' age (Morgan et al., 2015) or the type of refraction (Ilechie et al., 2021; Kirschen and Isenberg, 2014). Research generally suggests that older patients were less likely to show significant differences in refractive error measurements with or without cycloplegia (Sanfilippo et al., 2014; Kearns et al., 2010).

Child-friendly autorefractors such as the non-cycloplegic Plusoptix (A09) have been shown to play a useful role in screening for refractive errors in non-cycloplegic conditions (Bogdanici et al., 2016). Yalcin et al. (2016) found consistency with the spherical error found when using a non-cycloplegic Plusoptix when compared against cycloplegic retinoscopy. Literature suggests that the non-cycloplegic Plusoptix has high sensitivity when detecting myopic and astigmatic prescriptions (Payerols et al., 2016; Paff et al., 2010), and a good agreement has been found between non-cycloplegic Plusoptix and cycloplegic retinoscopy where retinoscopy was performed by a paediatric ophthalmologist (Peterseim et al., 2014).

Uncorrected refractive error is a leading cause of moderate to severe visual impairment and the second most common cause of blindness (Bourne et al., 2013). In addition, a refractive error that is uncorrected or not appropriately corrected can be a risk factor for amblyopia when uncorrected anisometropia is present or when this can lead to the development of strabismus resulting in permanent loss in binocular function (Al-Haddad et al., 2019; Birch and Holmes, 2010; von Noorden and Campos, 2002). Therefore, measuring refractive error accurately is essential to ensure that children are given the correct amount of refractive correction for the best visual acuity and binocular vision status. As highlighted previously, if refractive error is underestimated, this can lead to a manifest strabismus, amblyopia, and permanent loss of binocular functions. Despite ample research investigating non-cycloplegic versus cycloplegic refraction, the inclusion criteria, results, and quality of research is variable. Therefore, further research is needed to extrapolate non-cycloplegic and cycloplegic refractive error measurements at different age groups and different levels and types of refractive error. In addition, more guidance is required as to when cycloplegic refraction is necessary to obtain an accurate measurement of refractive error and when it is safe to forgo when refracting young children.

While comparisons have been made between cycloplegic and other refraction methods in children, there are no clear indications of the need for cycloplegia in children, based on age, type, or level of refractive error. It has been reported that NHS ophthalmology is financially strained and under-resourced (Hingorani, 2019) therefore, resources and time need to be used clinically appropriately. The use of cycloplegic agents and their cost-effectiveness has been explored, and it has been reported that the median total cost for cyclopentolate was £2.08 when examining 78 children (Ebri et al., 2007). The present review aims to provide guidance on the need for cycloplegic refraction in children. To date, there are only individual studies that have looked at cycloplegic and non-cycloplegic refraction. Synthesising existing knowledge and exploring the agreement between cycloplegic and non-cycloplegic refraction will help researchers and clinicians better understand both techniques, which will help design appropriate clinical policies when refracting children's eyes. In addition, a meta-analysis is better suited to answer this research question than exploring each study individually, as this will allow more precision to answering the research question and yield more conclusive results.

OBJECTIVES

To determine the diagnostic agreement of non-cycloplegic and cycloplegic refraction in children (12 years of age and below). Refractive error in this review was defined as follows; myopia ≤ -0.50D (Flitcroft et al., 2019), hyperopia ≥ +0.50D (Althomali, 2018) the definitions are defined as spherical equivalent. The astigmatism cylinder power was defined as a power of ≤ -0.50D (Hashemi et al., 2016).

AIM

This study aimed to systematically review current research and extract data to perform a meta-analysis to determine the agreement between non-cycloplegic and cycloplegic refraction in children (12 years of age and below). This age range was chosen based on the Royal College of Ophthalmologist guidelines regarding cycloplegic refraction.

METHODS

PROTOCOL AND REGISTRATION

A scoping search was conducted to investigate if a systematic review had already been performed on the topic of interest, in addition to ensuring there was sufficient literature on the topic to perform a systematic review. The following resources were searched on the 26th August 2020: PROSPERO, Cochrane Library, NICE evidence, TRIP, EBSCOhost, and OVID online. No current review protocol existed under the topic (https://www.crd.york.ac.uk/PROSPERO/). The methodology of this review protocol has been registered and published on the PROSPERO database (reference number: CRD42020208201).

ELIGIBILITY CRITERIA

The inclusion criteria were as follows:

- No restriction on the year of publication.
- Only publications in the English language were eligible.
- Participants' age must be equal to or less than 12 years.
- Any degree of refractive error.
- Either sex.
- Participants with no co-morbidities, with no restriction on ethnicity, socio-economic status, or geographical area.
- Any form of refraction technique (retinoscopy, autorefractor).
- Studies - including participants who have undergone refraction with or without cycloplegia (any type of autorefractor or retinoscopy).
- Studies using cyclopentolate hydrochloride only as a cycloplegic agent.
- Studies comparing more than one method were included (comparative studies).

The exclusion was based on:

- Publications in a language other than English.
- Publications including participants over 12 years of age.
- Participants with ocular or binocular vision anomalies.
- Conference abstracts or posters.

SEARCH METHODS FOR IDENTIFICATION OF STUDIES

The PRISMA guidelines for reporting a meta-analysis were followed (Page et al., 2020). The electronic databases that were searched are listed below (*Table 3.2*).

Table 3.2. *List of the electronic databases that were searched and the date of the search.*

Electronic Database	**Date of search**
Cochrane Central Register of Controlled Trials (CENTRAL)	8th September 2020
Health Technology Assessment Database (HTAD)	8th September 2020
Ovid Online	
Allied and Complementary Medicine (AMED)	January 1985 to 9th September 2020
Embase	January 1974 to 9th September 2020
Global Health	January 1973 to 10th September 2020
Medical Literature Analysis and Retrieval System Online (MEDLINE)	January 1946 to 10th September 2020
Elton Bryson Stephens Company (EBSCO)host	
Academic Search Complete	January 1887 to 14th September 2020
Medical Literature Analysis and Retrieval System Online (MEDLINE)	January 1857 to 14th September 2020
Biosciences Information Service (BIOSIS)	January 1969 to 15th September 2020
Scopus	15th September 2020
Science direct	15th September 2020
System for Information on Grey Literature in Europe (OpenGrey)	January 1992 to 15th September 2020
Bielefeld Academic Search Engine (BASE)	16th September 2020
Google Scholar	16th September 2020
Web of Science	January 1970 – 17th September 2020
US National Institutes of Health Ongoing Trials Register- Clinical Trails.gov (https://clinicaltrials.gov/)	17th September 2020
International Standard Randomised Controlled Trial Number Registry (ISRCTN Registry) (https://www.isrctn.com/)	17th September 2020
UK Clinical Research Network (http://www.ukcrc.org/research-infrastructure/clinical-research-networks/uk-clinical-research-network-ukcrn/)	17th September 2020
UK Clinical Trials Gateway (https://bepartofresearch.nihr.ac.uk/)	17th September 2020
World Health Organization International Clinical Trials Registry Platform (https://www.who.int/ictrp/en/)	17th September 2020
National Institute for Health and Clinical Excellence (NICE) (https://www.nice.org.uk/about/what-we-do/evidence-services/journals-and-databases)	17th September 2020
NIHR website (https://www.nihr.ac.uk/health-and-care-professionals/search-our-evidence.htm)	17th September 2020

To increase sensitivity, electronic searches were conducted using both thesaurus controlled and text terms (*Table 3.3*). A search on the electronic databases listed above was conducted during September 2020 (date of the last search: 17th September 2021). The electronic search followed the steps below:

1. Perform a subject heading search (MeSH).
2. Perform a keyword search.
3. Merge searches.
4. Repeat steps for other parts of the research question.
5. Combine the final search for each concept using "AND".
6. Make a note of any parts of the research question where a MeSH term is not available (e.g., non-cycloplegic).

Table 3.3. *Search terms used with the relevant MeSH (e.g., for MEDLINE) and Emtree terms (e.g., for EMBASE).*

OR (any of the following terms)	**OR (any of the following terms)**	**OR (any of the following terms)**	**OR (any of the following terms)**	**AND (a combination of one or more terms from the OR columns)**
Child* Infan* P?ediatric* Minor Young people	Cycloplegic Wet Cyclopentolate	Non-cycloplegic Dry	Refraction Retinoscopy Autorefractor	
Child Infant Preschool child School child Toddler	Cycloplegic agent Cycloplegic Cyclopentolate	Non-cycloplegic	Refraction Refractive error Retinoscopy Autorefractor	

The principal researcher (SW) conducted a detailed search. Published and unpublished journals were searched. The reference lists from studies that were retrieved and classed as relevant were included in the search process. In addition, citation alerts were used to ensure that the more recently published studies were included. Duplications (the same publication sourced from different databases) were removed.

SELECTION OF STUDIES

All the eligible studies were organised into a table, including the title of the publication and abstract. All the identified publications were shared with the second reviewer (Supervisor Miriam Conway) so that screening of the search results could be conducted independently. Two researchers (SW and MC) independently assessed the titles and abstracts of all the studies the electronic searches obtained to help exclude irrelevant publications. This was conducted using RefWorks, which allowed all the search results to be in one place, and identification of duplications could be made with ease. The studies were marked as "definitely relevant", "possibly relevant", or "definitely not relevant". Those studies that got marked as "definitely not relevant" by both review researchers were excluded. Those studies that got marked as "definitely relevant" or "possibly relevant" by both review researchers were independently assessed against the inclusion criteria as to whether they are relevant to this review. This was done by obtaining full copies of the relevant papers. Any disagreement during the selection stage was solved through a discussion until consensus was met. If necessary, a third researcher was contacted to help resolve the disagreement. If necessary, the study investigators were contacted to gain more information to help decide the studies eligibility. The study authors details can be found in the manuscript, and a two-week time frame was given for each response. If a response could not be obtained, then a decision was made with the available information.

DATA EXTRACTION AND MANAGEMENT

The two researchers (SW and MC) independently extracted data from the studies that met the inclusion criteria. Extraction of data was conducted with the use of a standardised data collection form (Appendix 3.0). Studies were excluded if they were re-analysis or republication from an initial data set to ensure that duplication of results does not occur. The data were entered into Review Manager 5 (RevMan 5) (Nordic Cochrane Centre, The Cochrane Collaboration., 2014). The second review author verified the entered data. If any disagreements arose during this process, they were resolved through discussion until consensus was achieved. If needed, the study investigators were contacted to provide missing information to help clarify data.

ASSESSMENT OF METHODOLOGICAL QUALITY

The researchers (SW and MC) independently assessed each eligible study for risk of bias and assessed the quality of the body of evidence using the QUADAS-2 tool (Whiting et al., 2011). This assessment tool has undergone evaluation to ensure validity and usefulness (Whiting et al., 2011; Whiting et al., 2006). If there were any discrepancies between the reviewers, this was resolved through discussion until consensus had been obtained. Alternatively, a third researcher (member of the research team) was consulted, which was not required during this process.

QUADAS-2 consists of four domains:

1. Patient selection.
2. Index text (non-cycloplegic refraction).
3. Reference standard (cycloplegic refraction).
4. Flow and timing.

The QUADAS-2 tool consisted of four distinct stages (University of Bristol, 2020). First, the researchers agreed upon the signalling questions and piloted the questions independently on one of the included studies and made a final decision before independently commencing the assessment of methodology quality.

Stage 1: Review question

The researchers reported the review question regarding patients, index test(s), reference standard and target condition.

Stage 2: Review specific tailoring

This stage consisted of modifying the signalling questions to help assess the risk of bias in the most appropriate way. Once the review researchers had agreed upon the content, a specific rating guideline was developed. This was then piloted independently by the two researchers to ensure good agreement and appropriateness of the signalling questions. *Table 3.4* below summarises the QUADAS-2 signalling questions, risk of bias and applicability rating questions.

Stage 3: Flow diagram

A flow chart was made, which helped facilitate judgment of risk of bias and provide information on recruitment of patients, order of tests conducted and the number of patients undergoing the index test and reference standard. This was done during the process of answering the signalling questions to make the task simpler.

Stage 4: Judgments on bias and applicability

The risk of bias was judged using signalling questions which were answered as either “yes”, “no”, or “unclear”, whereby “yes” indicated a low risk of bias. The risk of bias assesses the following domains: patient selection, index test, reference standard, flow and timing. The applicability of a study was assessed by the researchers answers from the signalling questions for all three domains (patient selection, index test and reference standard), which allowed a judgment to be made regarding applicability. The concern regarding applicability is rated as “low”, “high”, or “unclear”. For each question, the researchers answered them independently. Any discrepancies in the quality assessment procedure the researchers discussed until consensus was obtained.

***Table 3.4**. Risk of bias and applicability assessment questions for each QUADAS-2 domain.*

Domain	QUADAS-2 questions	Researchers' judgment
Patient selection	Did the study avoid inappropriate exclusions? (yes/no/unclear)	
	Did the study avoid inappropriate inclusion? (yes/no/unclear)	
	Were the same patient selection criteria used for those assigned to the non-cycloplegic test? (yes/no/unclear)	
	If the children received the non-cycloplegic test, was the decision made before the children were recruited? (yes/no/unclear)	
	Did the study avoid using prior tests as inclusion criteria that were correlated with the non-cycloplegic refraction test? (yes/no/unclear)	
	Risk of bias Could the selection of children have introduced bias? (yes/no/unclear) = (High risk/ low risk/ unclear risk)	
	Concerns regarding applicability Are the concerns that the included children in the study do not match the review questions? (yes/no/unclear) = (High concern/low concern /unclear concern)	
Index test	Were the non-cycloplegic test results conducted and interpreted without knowledge of the results of the cycloplegic refraction? (yes/no/unclear)	
	Did the study avoid using index test thresholds that are likely to advantage some of the index tests? (yes/no/unclear)	
	Risk of bias Could the conduct or interpretation of the non-cycloplegic refraction test have introduced bias? (yes/no/unclear) = (High risk/ low risk/ unclear risk)	
	Concerns regarding applicability Are the concerns with the non-cycloplegic test, its conduct, or interpretation differing from the review question? (yes/no/unclear) = (High concern/low concern /unclear concern)	
Reference standard	Is the cycloplegic refraction likely to correctly classify the target condition? (yes/no/unclear)	
	Were the cycloplegic refraction results conducted and interpreted without knowledge of the results of the non-cycloplegic refraction? (yes/no/unclear)	
	Risk of bias Could the cycloplegic refraction, its conduct, or its interpretation have introduced bias? (yes/no/unclear) = (High risk/ low risk/ unclear risk)	
	Concerns regarding applicability Are there concerns that the target condition, as defined by cycloplegic refraction, does not match the review question? (yes/no/unclear) = (High concern/low concern /unclear concern)	
Flow and timing	Was there an appropriate interval between the non-cycloplegic refraction and cycloplegic refraction? (yes/no/unclear)	
	Did all children receive cycloplegic refraction? (yes/no/unclear)	
	Did all children receive the same cycloplegic refraction method? (yes/no/unclear)	
	Were all children included in the analysis? (yes/no/unclear)	
	Risk of bias Could the patient flow have introduced bias? (yes/no/unclear) = (High risk/ low risk/ unclear risk)	

STATISTICAL ANALYSIS AND DATA SYNTHESIS

Statistical analysis and data synthesis were conducted in accordance with Chapter 10 of the Cochrane Handbook for Systematic Reviews of Diagnostic Test Accuracy (Macaskill et al., 2010). The aim was to extract and analyse the data available for each test (non-cycloplegic and cycloplegic refraction) to ease the interpretability of the summary measures of accuracy.

We included studies that evaluate only one eye of each participant, randomly selected or studies where both eyes were included. Those studies that included both eyes were in the review as, at times, there can be anisometropia present, leading to the refractive error findings being considerably different between both eyes. However, an acknowledgement will be made regarding the unit of analysis when the analysis is concluded (overestimation).

The main outcome measure was to look at the agreement between non-cycloplegic and cycloplegic refraction. The difference in the mean change in refractive error and 95% limits of the agreement were calculated (Williamson et al., 2002). The outcome measure that is important as correcting refractive error can improve vision and help with a child's learning experiences and educational attainment (Zheng et al., 2011). As the refractive error is the main outcome, which is continuous, the mean differences (MD) with the corresponding 95% confidence interval (CI) were calculated. The means and standard deviation (SD) were then averaged to calculate the effect estimates for the analyses (non-cycloplegic refraction versus cycloplegic). The 95% LoA interval was calculated for each study from a pooled estimate of the MD between a non-cycloplegic and cycloplegic refraction. The additional outcomes were uncorrected vision (distance and near), adverse events (ocular or systemic) from the use of cycloplegic agents, and patient-reported outcomes (comfort or stress of using drops).

Meta-analysis was attempted, and the results have been reported. The primary outcome agreement was assessed by calculating summary 95% limits of agreement (LoA) (Williamson et al., 2002). The 95% LoA was calculated for each refraction technique from pooled estimates of the mean difference between the non-cycloplegic and cycloplegic refraction. Pooled estimates of mean difference and random error were calculated using the DerSimonian and Laird random-effects method (DerSimonian and Laird, 1986). The LoA were calculated to allow Bland and Altman analysis and direct comparison. The confidence intervals were calculated and included as recommended by literature as to when reporting the agreement and precision the LoA are only estimated (McAliden et al., 2011).

An approximate 95% prediction interval was calculated for the MD and the SD of different parameters using the estimated tau (τ) (SD of the study level distribution) to quantify the impact of between-study heterogeneity. This provides a range of plausible values for future work based on the current studies (pooled parameters estimate ± 1.96 X τ). An additional analysis was conducted to correct repeated measurements using reported estimates of within-participants variation (Bland and Altman, 1999).

INVESTIGATION OF HETEROGENEITY

Investigation of heterogeneity started with a visual assessment of the results by observing the nature of the forest plot before conducting statistical analysis (Bossuyt et al., 2013). Heterogeneity was evaluated by assessing the forest plot and examining if the confidence intervals overlapped or by conducting statistical tests such as the Cochrane Q test and I^2 index (Huedo-Medina et al., 2006). Due to the expected degree of heterogeneity, various factors contribute to clinical and methodological diversity (age and type of refractive error). Analyses based on the type of refractive error was not possible with the data available. In addition, there was a lack of studies defining the types of refractive error.

SENSITIVITY ANALYSES

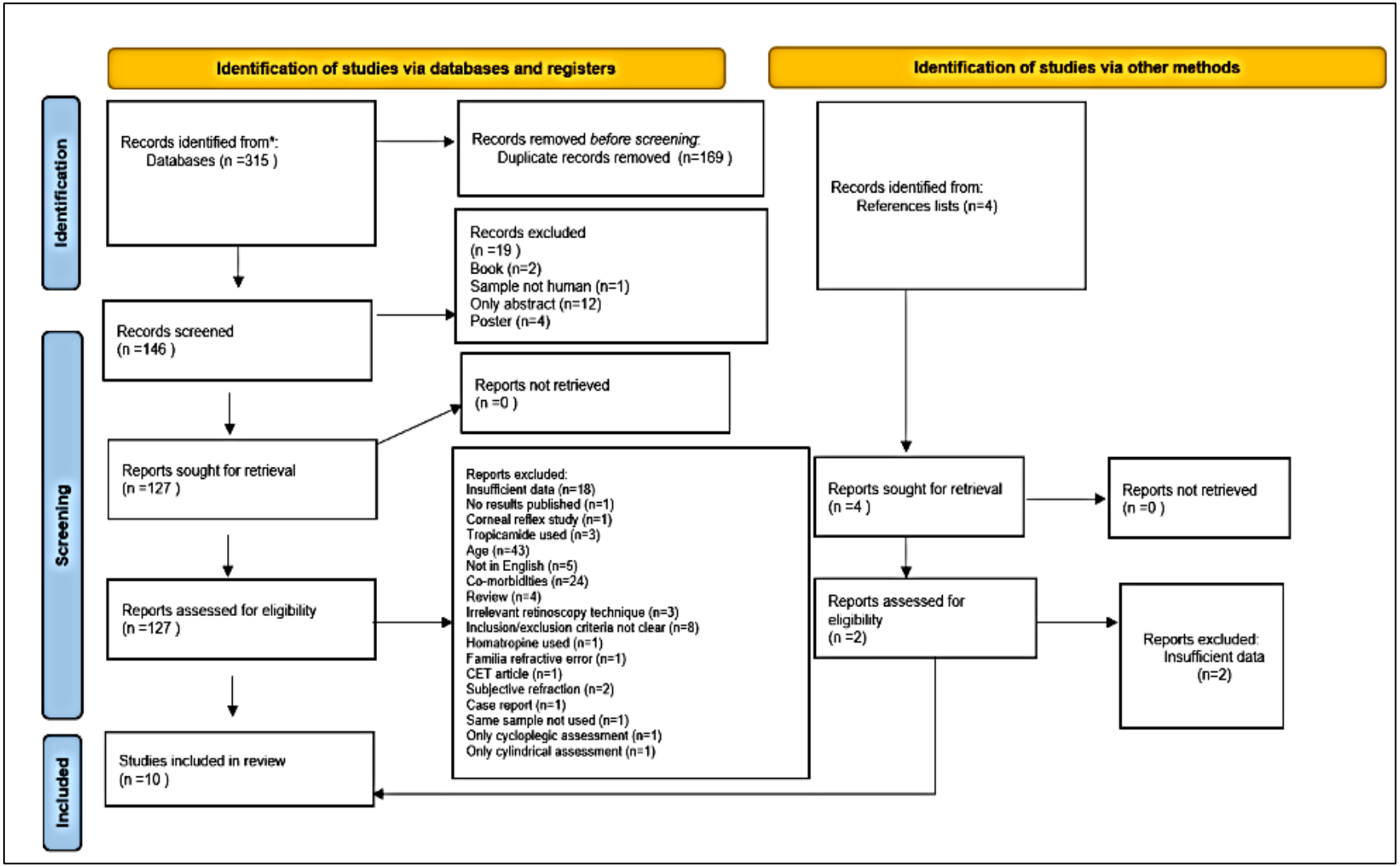
The sensitivity analysis were conducted to assess the impact of risk of bias on test accuracy by repeating the analysis after removing the studies with a high risk of bias. In addition, sensitivity analyses looked at the impact of excluding studies that used suboptimal methods according to our quality assessment. Possible reasons for heterogeneity were explored with subgroup analysis, such as the impact of autorefractor manufactures.

RESULTS

STUDY SELECTION

Of 150 potential titles, 131 full test manuscripts were obtained, with 10 publications meeting the inclusion criteria. The process for selecting studies, screening the results, and identifying eligibility for inclusion in the meta-analysis is illustrated in *Figure 3.1* below. After the results were obtained, screening of titles, abstracts against inclusion criteria were initially performed.

Figure 3.1. *PRISMA flow diagram illustrating the screening process (Page et al., 2020).*



STUDY CHARACTERISTICS

The exclusions were based on the study design and the data available and were not based on the quality of the published study. Reasons for the exclusion for each study has been documented in *Table 3.5*.

Table 3.5. *Characteristics of the excluded studies.*

Title	First author and year	Reason for exclusion
Comparison of Refraction Measurements in Children Under General Anaesthesia, With and Without Cycloplegic Drops.	Gur, 2015	No results were published for the clinical trial.
Performance of 2WIN Photoscreener With Corneal Reflex Compared to School Bus Retinoscopy by AAPOS Guidelines.	Alaska Blind Child Discovery, 2018	Investigated photoscreener with or without corneal reflex.
A New More Efficient Cycloplegia Scheme.	Pontificia Universidad Catolica de Chile	Tropicamide used.
Is noncycloplegic photorefraction applicable for screening refractive amblyopia risk factors?	Rajavi et al., 2012	Children aged from 1-14 years.
Clinical evaluation of an eccentric infrared photorefractor: the PowerRefractor.	Abrahamsson et al., 2003	No data to extract.
The influence of cycloplegia in objective refraction.	Jorge et al., 2005	Investigated 18-34-year of age.
What is the appropriate age cut-off for cycloplegia in refraction?	Sanfilippo et al., 2014	Investigated 13-26-year of age.
Availability of Cycloplegic Refraction in Children and Adolescents.	Kim and Lee, 2020	Not in English.
Harley's pediatric ophthalmology.	Leonard et al., 1998	Book.
A Comparison of Refraction Defects in Childhood Measured Using Plusoptix S09, 2WIN Photorefractometer, Benchtop Autorefractometer, and Cycloplegic Retinoscopy.	Yalcin et al., 2017	Age range 1-18 years.
Photoscreener for preschool children visual screening.	Lavezzo et al., 2010	Not in English.
Objective vision screening using Plusoptix for children aged 3–11 years in rural Turkey.	Ugurbas et al., 2019	Insufficient data.
Effectiveness of the Welch Allyn suresight Autorefractor as a Screening Tool in a Sample of Children Aged 3-69 Months.	Vricella, 2002	Insufficient data.
The usefulness of the Retinomax autorefractor for childhood screening validated against a Danish preterm cohort examined at the age of 4 years.	Fledelius et al., 2015	Comorbidities in the sample (retinopathy of prematurity).
Repeatability and Validity of Peripheral Refraction with Two Different Autorefractors.	Morrison and Mutti, 2020	Investigates refractive error measurements in adults.
Comparison of the Retinomax and Palm-AR Autorefractors: A Pilot Study.	Ciner et al., 2011	Comorbidities in the sample (possible amblyopia or strabismus).
Refractometers, the New Standard in Studies on Refraction.	Fledelius, 2017	Insufficient data.
Measurement of the refractive state using streak retinoscopy and the" Sure Sight™" autorefractor in dogs.	Sivagurunathan, 2011	Study on dogs, not humans.
Pediatric ophthalmology	Lee, 2010	Book.
Accuracy of the Retinomax K-plus3 in measuring refractive error in a pediatric population.	Peng et al., 2014	Age range 5 months- 17 years.
Inter-tester Agreement in Refractive Error Measurements.	Huang et al., 2013	Comorbidities in the sample (amblyopia and strabismus present in the sample).
Near retinoscopy and refractive error.	Bullimore et al., 1988	The age range of 18-29 years.
Pediatric vision screening using the plusoptix A12C photoscreener in Chinese preschool children aged 3 to 4 years.	Huang et al., 2017	Comorbidities in the sample (strabismus and persistent pupillary membrane).
The use of the plusoptix photoscreener for vision screening.	Tidbury et al., 2012	Literature review and screening.
Critical evaluation of the NR-1000F Auto Refractometer.	Ghose et al., 1986	Age range 6 to 75 years.
Performance of Glow Fixation gocheck Kids and 2WIN Photoscreeners and Retinomax to Uncover Hyperopia.	Levitt et al., 2020	Age range 0.1 to 18 years.
Cycloplegic Evaluation of the Powerrefractor.	Arner, 2003	Poster.
Refraction in Children: A Comparison Between "Naive" Refraction to the Plusoptix A12 Portable Auto-Refractometer and Refraction at the Fixed Auto-Refractometer in Cycloplegia: About 52 Cases.	Iferkhass et al., 2018	The age range of 3-16 years.
Naked Autorefraction in Children: Pitfalls and Perils.	Silverberg et al., 1999	Age range 2-16 years.
Reliability and Reproducibility of a Handheld Videorefractor.	Ogbuehi et al., 2015	Adults were aged 20-25 years.
Comparison of cycloplegic refraction between Grand Seiko autorefractor and Retinomax autorefractor in the Vision in Preschoolers–Hyperopia in Preschoolers (VIP-HIP) Study.	Ying et al., 2017	Comorbidities in the sample (strabismus and suspected amblyopia).
Cycloplegia in Children: An Optometrist's Perspective.	Major et al., 2020	Review on the use of mydriatic for cycloplegic refraction.
Refracting children without cycloplegia.	Cockerham, 1969	Review.
Influence of fogging lenses and cycloplegia on open-field automatic refraction.	Queirós et al., 2008	Age range 18-26 years.
Habits and attitudes towards retinoscopy and the relative accuracy of dedicated and combined retinoscopes.	Dustone, 2014	Spot and steak retinoscopy explored.

Accuracy of noncycloplegic refraction performed at school screening camps.	Khurana et al., 2018	The age range of 6-16 years.
Cycloplegia and spectacle prescribing in children: attitudes of UK optometrists.	Doyle et al., 2019	Insufficient data.
Simple retinoscopic screening.	Olver, 1988	Insufficient data.
Calibration and validity of an eccentric photorefractor.	Chan et al., 1996	Comorbidities in the sample (strabismus).
Comparison of refraction with or without cycloplegia using Retinomax® or Plusoptix® devices.	Quoc et al., 2017	Not in English.
A longitudinal study of cycloplegic refraction in a cohort of 350 Japanese schoolchildren. Cycloplegic refraction.	Watanabe et al., 1999	Insufficient data.
Upper Age Limits for Cycloplegic Refraction at Mayo Hospital Lahore.	Alvi et al., 2017	Age range 7-18 years.
Accuracy of Noncycloplegic Autorefraction in School-Age Children in China.	Zhao et al., 2004	Age range 7-18 years.
Evaluation of the svone Handheld Autorefractor in a Pediatric Population.	Rosenfield and Ciuffreda, 2017	Age range 5-17 years.
Accuracy of the Nidek ARK-900 objective refractor in comparison with retinoscopy in children ages 3 to 18 years.	Wood, 1998	Age range 3-18 years.
Agreement and Repeatability of Noncycloplegic and Cycloplegic Wavefront-based Autorefraction in Children.	Rauscher et al., 2019	Comorbidities in the sample (strabismus, amblyopia, and nystagmus).
Wave-front analysis as screening technique for amblyogenic ametropia with and without cycloplegia.	Schimitzek and Schworm, 2003	Age range 1 -81 years.
Comparison of subjective and objective refraction in children with and without using cycloplegics.	Ganger et al., 2017	Age range 7-14 years.
Comparison between two hand-held autorefractors: the Sure-Sight and the Retinomax.	Cordonnier and Maertelaer, 2004	Age range 6 months to 16.5 years.
Validity of Noncycloplegic Retinoscopy, Retinomax Autorefractor and suresight Vision Screener for Detecting Significant Refractive Errors.	Kulp et al., 2011	Abstract only.
Screening for Refractive Errors with the Topcon PR2000 Pediatric Refractometer.	Williams et al., 2000	Comorbidities in the sample (strabismus, lens opacities, corneal scarring, iris coloboma, and pseudophakia).
The reliability of Mohindra's near retinoscopy in human infants (0-2 years).	Chia and Samek, 1987	Study on near retinoscopy.
Identification of Infants with Significant Refractive Error and Strabismus in a Population Screening Program using Noncycloplegic Videorefraction and Orthoptic Examination.	Anker et al., 2003	Comorbidities in the sample (e.g., developmental delay and strabismus).
Accuracy of non-cycloplegic refraction in primary school children in southern Thailand.	Funarunart et al., 2009	Age range 6-13 years.
A comparison of non - cycloplegic and cycloplegic autorefraction of African children aged 5 - 1 5 years in Kwazulu-Natal.	Naidoo and Govender, 2005	Age range 5-15 years.
Comparison between Manifest vs Cycloplegic Photorefraction with MTI Photoscreener in Prematurity.	Rhee et al., 2000	Only abstract.
The use of non-cycloplegic autorefraction vs Non-cycloplegic retinoscopy in children during eyecare missions: A literature.	Peel and Negoita, 2002	Literature review.
Accuracy of noncycloplegic retinoscopy, retinomax autorefractor, and suresight vision screener for detecting significant refractive errors.	Kulp et al., 2014	Comorbidities in the sample (strabismus and amblyopia).
Comparison of on-and off-axis photorefraction with cycloplegic retinoscopy in infants.	Hamer et al., 1992	Insufficient data.
The manifestation of noncycloplegic refractive state in preschool children is dependent on autorefractor design.	Suryakumar and Bobier, 2003	Unclear inclusion and exclusion criteria.
A non-cycloplegic refraction technique for infants and young children.	Mohindra, 1977	Abstract only.
Comparison of open-field autorefraction, closed-field autorefraction, and retinoscopy for refractive measurements of children and adolescents in Taiwan.	Kuo et al., 2020	Tropicamide used.
Clinical Performance of the Spot Vision Photo Screener before and after Induction of Cycloplegia in Children.	Yakar, 2019	Insufficient data.
Screening for refractive errors at age 1 year: a pilot study.	Ingram et al., 1979	Insufficient data.
Reproducibility and accuracy of measurements with a handheld autorefractor in children.	Harvey et al., 1997	Subjective refraction was performed.
Compared performance of Spot and SW800 photoscreeners on Chinese children.	Qian et al., 2019	Comorbidities in the sample (strabismus).

Screening for refractive errors in children: The plusoptix S08 and the Retinomax K-plus2 performed by a lay screener compared to cycloplegic retinoscopy.	Paff et al., 2010	Comorbidities in the sample (strabismus, nystagmus, and developmental delay).
Cycloplegic refraction in preschool children: comparisons between the hand-held autorefractor, table-mounted autorefractor and retinoscopy.	Prabakaran et al., 2009	Unclear inclusion and exclusion criteria.
Comparison between near retinoscopy and cycloplegic retinoscopy in the refraction of infants and children.	Saunders and Westall, 1992	Study on near retinoscopy.
Cycloplegic refractive error in young children: poster #54.	Moore, 2001	Poster.
Cycloplegic refractive errors in children: comparison of a standard and a hand-held refractor.	Kallay et al., 1998	Age range.
Comparison of the Retinomax hand-held autorefractor versus table-top autorefractor and retinoscopy.	Tuncer et al., 2014	Age range.
Comparison of the Plusoptix S04 binocular autorefractor with cycloplegic refraction performed by an ophthalmologist.	Gilmartin, 2010	Comorbidities in the sample (strabismus).
A comparison of manifest refractions, cycloplegic refractions and retinoscopy on the RMA-3000 autorefractometer in children aged 3 to 15 years.	Rotsos, 2009	Age range.
Comparison of Plusoptix S12R photoscreener with cycloplegic retinoscopy and autorefraction in pediatric age group.	Saini et al., 2019	Use of homatropine 2%.
Correlations between familial refractive error and children's non-cycloplegic refractions.	Guo et al., 2000	Abstract only.
Correlations between familial refractive error and children's non-cycloplegic refractions.	Hui et al., 1995	Familial refractive error.
Noncycloplegic autorefraction in infants and young children	Adams et al., 2001	Abstract only.
Preschool screening for refractive errors: comparison of two non - cycloplegic methods.	Buchner et al., 2003	Insufficient data.
Preschool vision screening: comparison of two autorefractors and traditional subjective methods.	Shankar and Bobier, 2003	Abstract only.
Accuracy of the grand Seiko autorefractor in children.	Clifford et al., 2003	Abstract only.
Use of a non-cycloplegic autorefractor to perform vision screening in preschool children.	Clarke et al., 2004	Insufficient data.
Variability of autorefractor measurement in infants, children and adults: The Welch Allyn suresight.	Courage et al., 2004	Abstract only.
Cycloplegic influence on the accuracy of autorefractometer in myopic and hyperopic children.	Prabhakar et al., 2016	Age range.
Objective measurement of refractive errors: Comparison of Plusoptix s08 with a standard autorefractometer.	Demirel et al., 2013	Age range.
Cycloplegic refraction and non-cycloplegic refraction using contralateral fogging: a comparative study.	Yeotikar et al., 2007	Age range.
Screening for Refractive Errors in Preschool Children with the Vision Screener.	Ehrt et al., 2007	Comorbidities in the sample (microtropia, strabismus less than 10 degrees°).
Examination of preschool children for ametropia: First experiences using a new hand-held autorefractor.	Büchner et al., 2004	Unclear inclusion and exclusion criteria.
Retinoscopy in infancy: cycloplegic versus non-cycloplegic.	Bonci and Lupelli, 2012	CET‡ article.
Comparison of cycloplegic and manifest refraction of children and adolescents in Campinas, Brazil.	Sobrinho et al., 2017	Insufficient data.
Retinoscopy under cycloplegic and non-cycloplegic conditions in children comparison of measurements of three examiners.	Bujara et al., 1981	Not in English.
A comparison of cycloplegic and manifest refractions on the NR-1000F (an objective Auto Refractometer).	Nayak et al., 1987	Age range.
Screening for refractive errors in children: accuracy of the hand-held refractor Retinomax to screen for astigmatism.	Cordonnier and Dramaix, 1999	Comorbidities in the sample (strabismus).
A Comparison of Different Autorefractors With Retinoscopy in Children.	Oral et al., 2012	Age range.
Comparison between binocular, open-field auto ref/keratometer and conventional autorefractor.	Wan et al., 2012	Not English.
Cycloplegic autorefraction versus subjective refraction: the Tehran Eye Study.	Hashemi et al., 2016	Age range.
Comparison of retinoscopy results with and without 1% cyclopentolate in school-aged children.	Doherty et al., 2019	Inclusion criteria were unclear.
Performance of Plusoptix A09 Photo Screener in Refractive Error Screening in School Children Aged between 5 and 15 Years in the Southern Part of India.	Prabhu et al., 2020	Age range.
Precision in automated refraction.	Salvesen and køhler, 1991	Age range and atropine ad strabismus in the sample.

Automated refraction. A comparative study of automated refraction with the Nidek AR-1000 autorefractor and retinoscopy	Salvesen and køhler, 1991	Sample with comorbidities and age range 6 to 29 years.
Results of photorefractometric screening for amblyogenic defects in children aged 20 months.	Angi et al., 1992	Comorbidities in the sample (strabismus and media opacities).
Comparison of the techniques of videorefraction and static retinoscopy in the measurement of refractive error in infants.	Hodi and Wood, 1994	Inclusion criteria were unclear.
Screening of infants for significant refractive error using videorefraction.	Hodi, 1994	Insufficient data.
Screening for abnormal levels of hyperopia in children: a non-cycloplegic method with a hand held refractor.	Cordonnier and Dramaix, 1998	Possible comorbidities in the sample (family history of strabismus or amblyopia, and suspect visual anomaly).
Non-cycloplegic screening for refractive errors in children with the hand-held autorefractor Retinomax: Final results and comparison with non-cycloplegic Photoscreening.	Cordonnier and Kallay, 2001	Insufficient data.
Non-cycloplegic screening for amblyopia via refractive findings with the Nikon Retinomax hand held autorefractor in 3 year old kindergarten children.	Barry and König, 2001	Comorbidities in the sample (amblyopia).
Comparison of computer-photoscreening with non-cycloplegic retinoscopy for amblyopiogenic risk factors in children.	Guo et al., 2000	Comorbidities in the sample (strabismus and media opacities).
Testing young infants with the Welch Allyn suresight non-cycloplegic autorefractor.	Russell et al., 2002	Exclusion criteria are not clear.
Noncycloplegic photorefractive screening in preschool children with the "powerrefractor" in a pediatric practice.	Schaeffel et al., 2007	Comorbidities in the sample (nystagmus, ptosis, or Down syndrome).
Plusoptix Vision Screener: the accuracy and repeatability of refractive measurements using a new autorefractor.	Dahlmann-Noor et al., 2009	Comorbidities in sample (strabismus).
Effect of cycloplegia on the refractive status of children: the Shandong children eye study.	Hu et al., 2015	Age range.
Cycloplegic refraction is the gold standard for epidemiological studies.	Morgan et al., 2015	Age range.
Difference between manifest and cycloplegic refraction in healthy non-presbyopic patients.	Buey et al., 2016	Abstract only.
Comparison of the Plusoptix A12 and the 2WIN with the Retinomax K-plus 3 in a pediatric population.	Bouvier et al., 2016	Age range.
Accuracy of Plusoptix A09 distance refraction in pediatric myopia and hyperopia.	Payerols et al., 2016	Comorbidities in the sample (strabismus or amblyopia).
Does astigmatism alter with cycloplegia?	Asharlous et al., 2016	Age range.
Pre- and Postcycloplegic Refractions in Children and Adolescents.	Zhu et al., 2016	The inclusion criteria were not clear.
The difference between cycloplegic and non-cycloplegic autorefraction and its association with progression of refractive error in Beijing urban children.	Lin et al., 2017	Age range.
Effect of cycloplegia on the measurement of refractive error in Chinese children.	Li et al., 2019	Tropicamide used.
Comparison of Two Wavefront Autorefractors: Binocular Open-Field versus Monocular Closed-Field.	Carracedo et al., 2020	Age range.
Comparison of the welch allyn suresight to the Nikon Retinomax: poster #87.	Walsh et al., 2001	Poster.
Comparing Plusoptix A09 photorefractometer results with autorefractometer using Bland-Altman analysis.	Bilg and Simsek, 2017	Age range.
THE ACCURACY OF NON-CYCLOPLEGIC AUTO REFRACTOR VERSUS RETINOSCOPY IN A PEDIATRIC POPULATION: Poster #52.	Joachmin et al., 2002	Poster.
Validity of retinomax autorefraction in young children.	Hsiao et al., 1999	Abstract only.
Evaluation of a hand-held autorefractor in children younger than 6.	El-Defrawy et al., 1998	Abstract only.
Clinical evaluation of the Nidek AR autorefractor.	Helveston et al., 1984	Abstract only.
Variations in refractive change induced by cyclogyl upon children with differing degrees of ametropia.	Shultz, 1975	Age range.
Comparison of cycloplegic and non-cycloplegic refractions of Eskimos.	Young et al., 1971	Age range.
Do all children need a cycloplegic refraction? A comparison of Mohindra's versus cycloplegic refraction.	Kauser et al., 2020	Comorbidities in the sample (amblyopia).
Case of extremely high refractive error misdiagnosed as normal by plusoptix S09 photoscreener.	Demirci et al., 2015	Case report.
Comparison of Measurements of Refractive Errors Between the Hand-held Retinomax and On-table Autorefractors in Cyclopleged and Noncyclopleged Children.	Liang et al., 2003	Comparison of non- cycloplegic and cycloplegic was not of the same sample.

Intra- and inter- examiner repeatability of cycloplegic retinoscopy among young children.	Mccullough et al., 2012	The inclusion criteria are not clear.
Clinical evaluation of the Shin-Nippon SRW-5000 autorefractor in children.	Chat and Edwards, 2001	Insufficient data.
A comparison of the Plusoptix S08 photorefractor to Retinoscopy and cycloretinoscopy.	Mirzajani et al., 2013	Insufficient data.
Cycloplegic Autorefraction Results in Preschool Children Using the Nikon Retinomax Plus and The Welch Allyn suresight.	Steele et al., 2003	Insufficient data.
A comparison of two automated devices that measure refractive error.	Jacobs, 2017	Age range.
Accuracy of the Welch Allyn SureSight for measurement of magnitude of astigmatism in 3- to 7-year-old children.	Harvey et al., 2009	Cylindrical assessment only.
Overestimation of hyperopia with autorefraction compared with retinoscopy under cycloplegia in school-age children.	Hashemi et al., 2018	Cycloplegic refraction compared against cycloplegic.
Comparison of Findings of Autorefraction and Retinoscopy with Subjective acceptance between Rural and Urban School going Children in Northern India.	Bhat et al., 2021	Subjective refraction.
Comparing School-Aged Refraction Measurements Using the 2WIN-S Portable Refractor in Relation to Cycloplegic Retinoscopy: A Cross-Sectional Study.	Liu et al., 2021	Age range.

[i] Continuous Education and Training (CET)

The included studies represented a varied geographical spread, including the Middle East, North America, and East Asia (Li et al., 2021; Seymen et al., 2019; Vasudevan et al., 2016; Won et al., 2016; Akil et al., 2015; Yilmaz et al., 2015; Demirci et al., 2014; Ozdemir et al., 2005; Iuorno et al., 2004; Harvey et al., 2000). All the included studies were published between 2000-2021, and the sample size ranged from five to 1803 children. The summary characteristics of the studies included for meta-analysis can be found in *Table 3.6*.

Table 3.6. *Description of the Included studies.*

Study	Country	Number of participants	Age	Refractive error range (D=Dioptres)	Range of spherical equivalent refractive error of sample (D= Dioptres)	Refractive error definition given	Type or refraction NC= Non-Cycloplegic C=Cycloplegic
Akil 2015	Turkey	112	Range 2 – 12 years Mean 6.78± 2.61 years	No restriction	The range was not disclosed.	No	NC Canon RK-F1 NC Retinomax K-plus 3 C Canon RK-F1 C Retinomax K-plus 3 C Retinoscopy
Demirci 2014	Turkey	118	Range 1-12 years Mean 4.9± 2.6 years	Spherical range -7.00D to +5.00D Cylindrical range -7.00D to +5.00D	Plusoptix (-5.38D to +2.75D) Topcon (-5.38D to +2.50D) Retinoscopy (-3.88D to +2.75D)	No	NC Plusoptix S08 (PS08) C Topcon RM8800 C Retinoscopy
Harvey 2000	North America	36	Range 3.6 - 5.6 years Mean 4.7 years	No restriction	Retinoscopy (-3.75D to +3.50D)	No	NC Retinomax K+ C Retinomax K+ C Retinoscopy
Iuorno 2004	North America	91	Range 37 - 107 months (3.1 – 8.9 years) Mean 97 months (8.1 years)	No restriction	Welch Allyn Sure Sight (WASS) (-3.375D to +4.375D) Nidek AR-820 (NAR) (-3.50D to +6.75D) Retinoscopy (-3.50D to +6.875D)	No	NC Welch Allyn SureSight (WASS) C Nidek AR-820 (NAR) C Retinoscopy
Ozdemir 2015	Turkey	98	Range 12- 60 months (1 – 5 years) Mean 28.8 ± 18.5 months (2.4 ± 1.5 years)	Spherical range -7.00D to +5.00D Cylindrical range -7.00D to +5.00D	The range was not disclosed.	No	NC Plusoptix A09 C Plusoptix A09 C Refraction (Retinoscopy /WASS)
Seymen 2019	Turkey	194	Range 3- 34 months (0.25-2.8 years) Mean 16.65 ± 10.04 months (1.4±1.3 years)	Spherical range -7.00D to +5.00D Cylindrical range -7.00D to +5.00D	Plusoptix (-3.38D to +5.88D) Retinomax (-2.88D to +6.50D) HandyRef-K (-3.00D to +6.63D)	No	NC Plusoptix A09 C Retinomax K-Plus 3 C HandyRef-K
Vasudevan 2016	North America	5	Range 5-12 years	Exclude: Anisometropia > 2.00D Spherical refractive more than ±4.00D or cylindrical component more than 1.00D	The range was not disclosed.	No	NC WAM-5500 C Retinoscopy
Won 2016	Korea	40	Range 2-10 years	Spherical range -7.00D to +5.00D	The range was not disclosed.	No	NC Plusoptix S09 NC Canon RK-F1 C Canon RK-F1
Yilmaz 2015	Turkey	200	Range 4-12 years Mean 6.2± 2.8 years	Spherical range -7.00D to +5.00D Cylindrical range -7.00D to +5.00D	The range was not disclosed.	No	NC Plusoptix A09 C Retinomax K-Plus3 C Retinoscopy
Li 2021	China	1830	Range 5.89–10.32 years Mean 6.38 ± 0.46 years	No restriction	Non-cycloplegic (-8.63D to +8.94D) Cycloplegic (-8.50D to +8.63D)	Yes	NC KR-800 Topcon C KR-800 Topcon

ASSESSMENT OF METHODOLOGICAL QUALITY

A graphical representation can be found in *Figure 3.2* and *Figure 3.3,* which summarise the level (high, unclear, low) of risk of bias and applicability. Three of the included studies were judged to have a high risk of bias, and of which, they all demonstrated to occur in the index test domain. Two studies had a high risk of bias for the patient selection and flow and timing domain. Five studies were categorised as having an unclear risk of bias due to poor reporting. When addressing applicability concerns, four studies were found to have a low concern when assessing the relevance of the study based on the domains: patient selection, index test and reference standard. Only one study reported having unclear judgment regarding applicability due to how the authors selected participants for their study and decided suitability for refraction.

Figure 3.2. *Risk of bias and applicability concerns graph: researchers' judgements about each domain presented as percentages across included studies.*

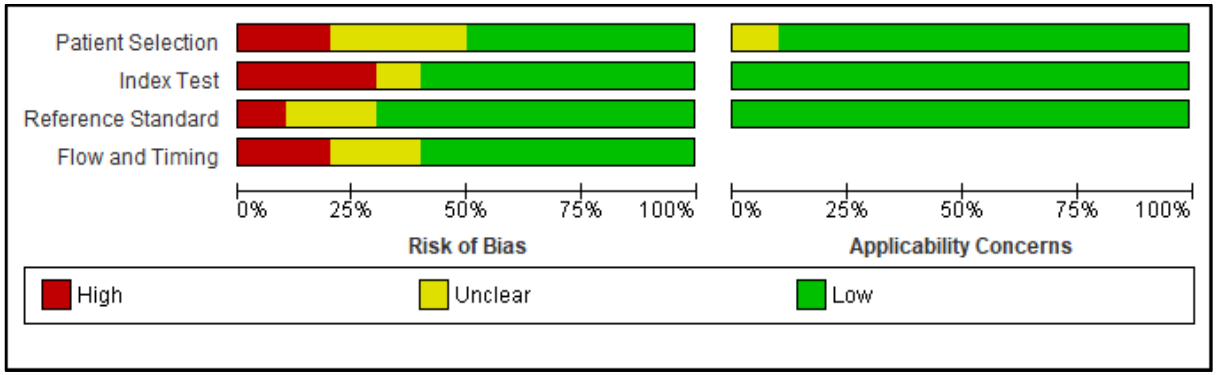
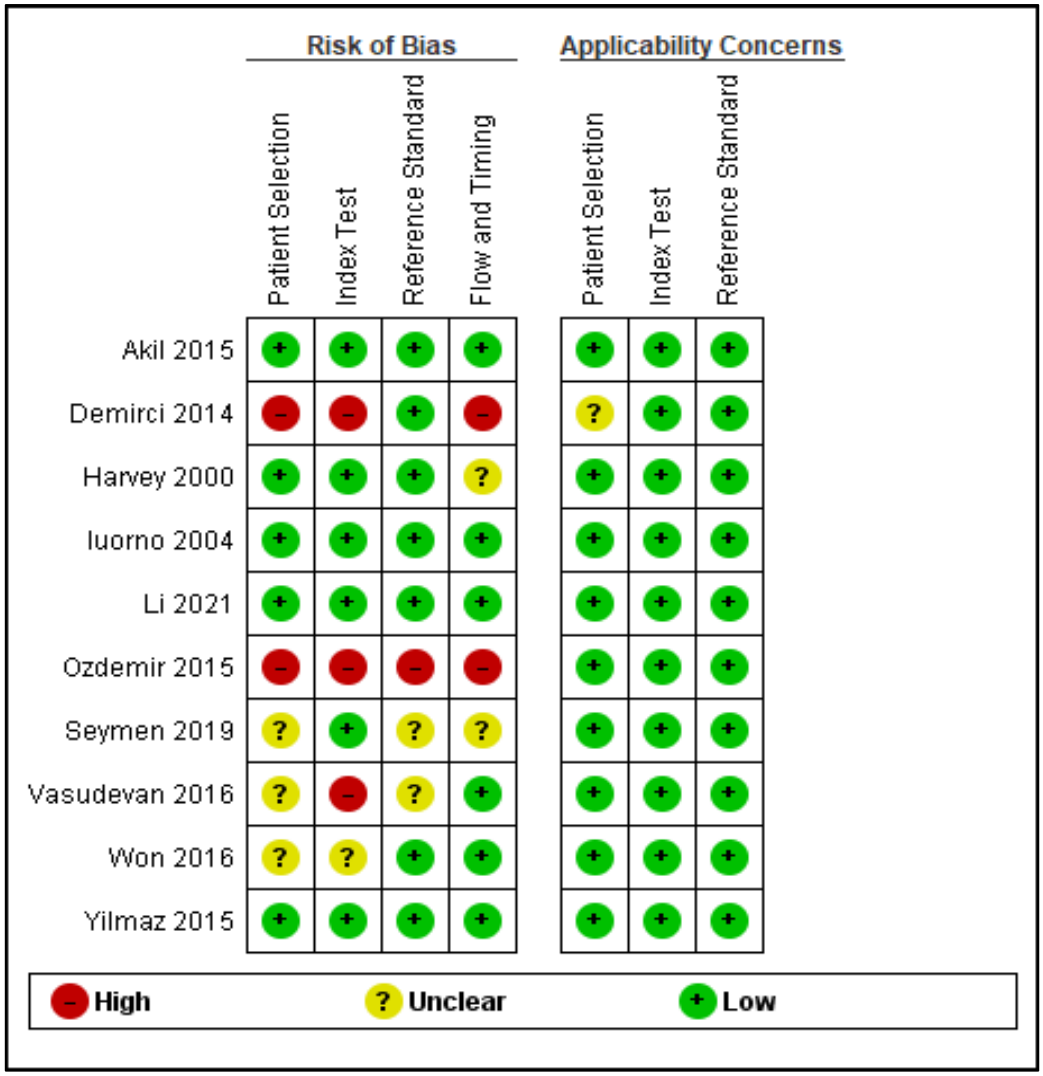


***Figure 3.3**. Risk of bias and applicability concerns summary: researchers' judgements about each domain for each included study.*



QUANTITATIVE DATA SYNTHESIS

The included studies are represented within the forest plots (*Figure 3.4, 3.5, and 3.6*). Each observation from the eligible studies is presented line by line. A random-effects model has been used. Pooled estimates and weighting were given to each study to describe each study's level of contribution, which is indicated by the size of the box presented in the forest plot. More weighting was given to studies with a greater sample size or smaller confidence intervals which are illustrated with a larger sized box, which influenced the pooled results more. On the forest plot, the width of the lines emanating from the box is the 95% confidence interval (CI) of each study. The diamond shape represents the overall effect. Each study may be found on either the left-hand side or right-hand side of the forest plot. If the study is found to be on the left-hand side this means the mean difference (non-cycloplegic refraction – cycloplegic refraction) in refractive error was found to be negative and if found on the right-hand side the mean difference in the refractive error was found to be positive.

The test for the overall effect is not significant in the non-cycloplegic Plusoptix (Z= 0.34, p=0.74) (*Figure 3.4*). However, the non-cycloplegic Retinomax and non-cycloplegic Canon subgroup illustrates a significant overall effect (Z=9.79, p< 0.00001) and (Z=4.61, p< 0.00001), respectively. Therefore, these subgroups and not all completely identical. The subgroup difference indicates a significant difference between the subgroups (Q= 17.93, df= 2, p=0.0001). The prediction interval is the index of dispersion which highlights how widely the data varies in an infinite population. The prediction interval for the non-cycloplegic Plusoptix autorefractor is -1.72D to +1.56D, indicating that in almost 95% of all populations, the true effect size will fall in this range.

When analysing non-cycloplegic refraction and cycloplegic refraction in relation to age (*Figure 3.5*), the test for overall effect is not significant in the under-five year's subgroups (Z= 1.51, p=0.13). However, for the over five years, the overall effect was significant (Z=2.14, p=0.03). Therefore, these subgroups are not completely identical. However, this model suggests there are no differences between the age subgroups (Q=0.22, df= 1, p=0.64). The I^2 value is high in both subgroups, indicating there is most likely another covariant that is causing heterogeneity. For under five years, the T^2 is the variance of the true effect sizes, which is 0.41, and the SD of the true effects is T which is 0.64. The prediction interval is -3.60D to +2.60D. It would be expected that in 95% of all populations, the true effect size will fall in this range. Therefore, in a population, the difference will be very substantial. In the over five years group, T^2 is 0.51, and the SD of the true effects (T) is 0.71. The prediction interval is -3.25D to +1.79D. It would also be expected that 95% of all populations, the true effect size will fall in this range. Therefore, in a population of this age group, the difference will also be quite substantial.

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Figure 3.4. *Forest plot synthesis studies that compared non-cycloplegic autorefraction to cycloplegic autorefraction with the use of different autorefractors.*

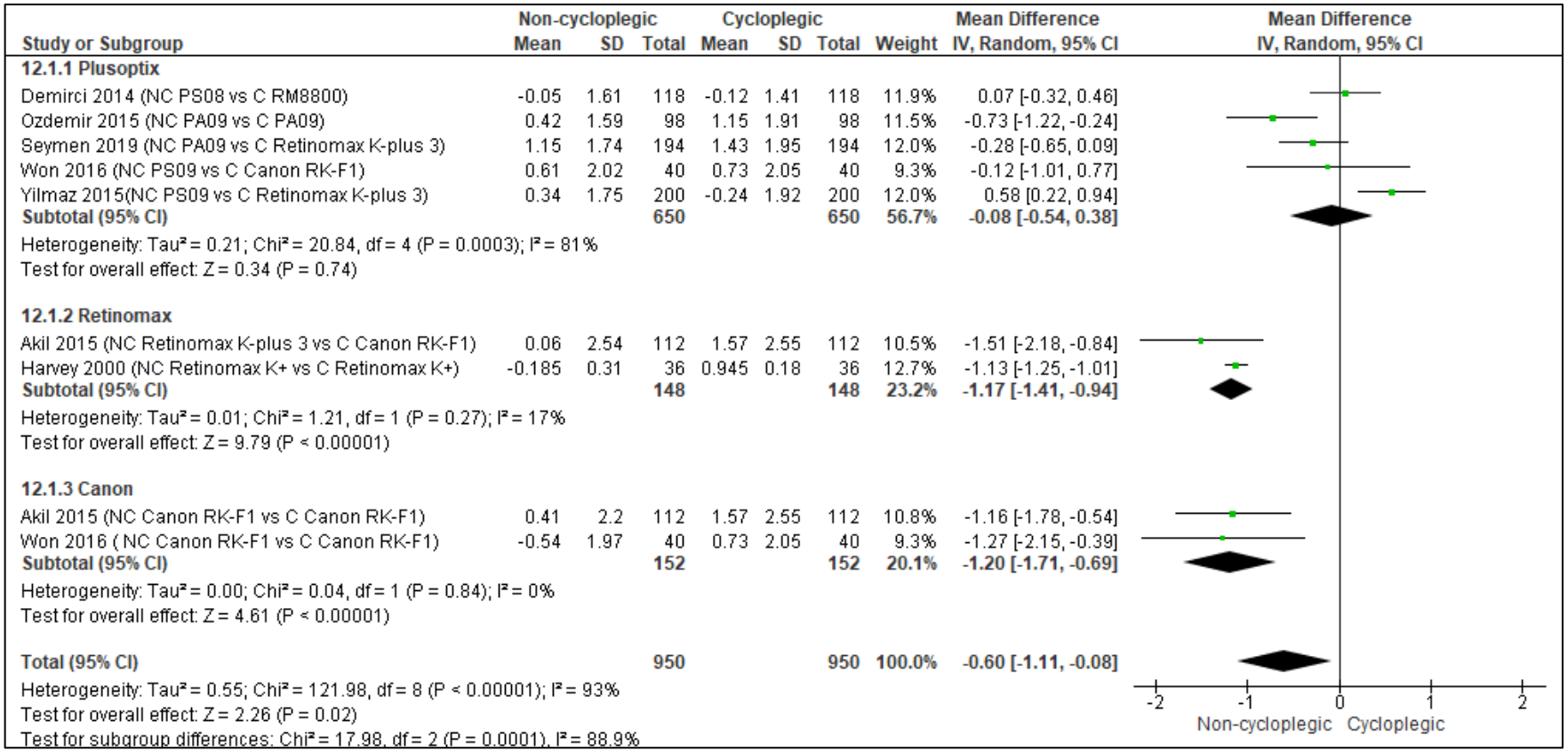
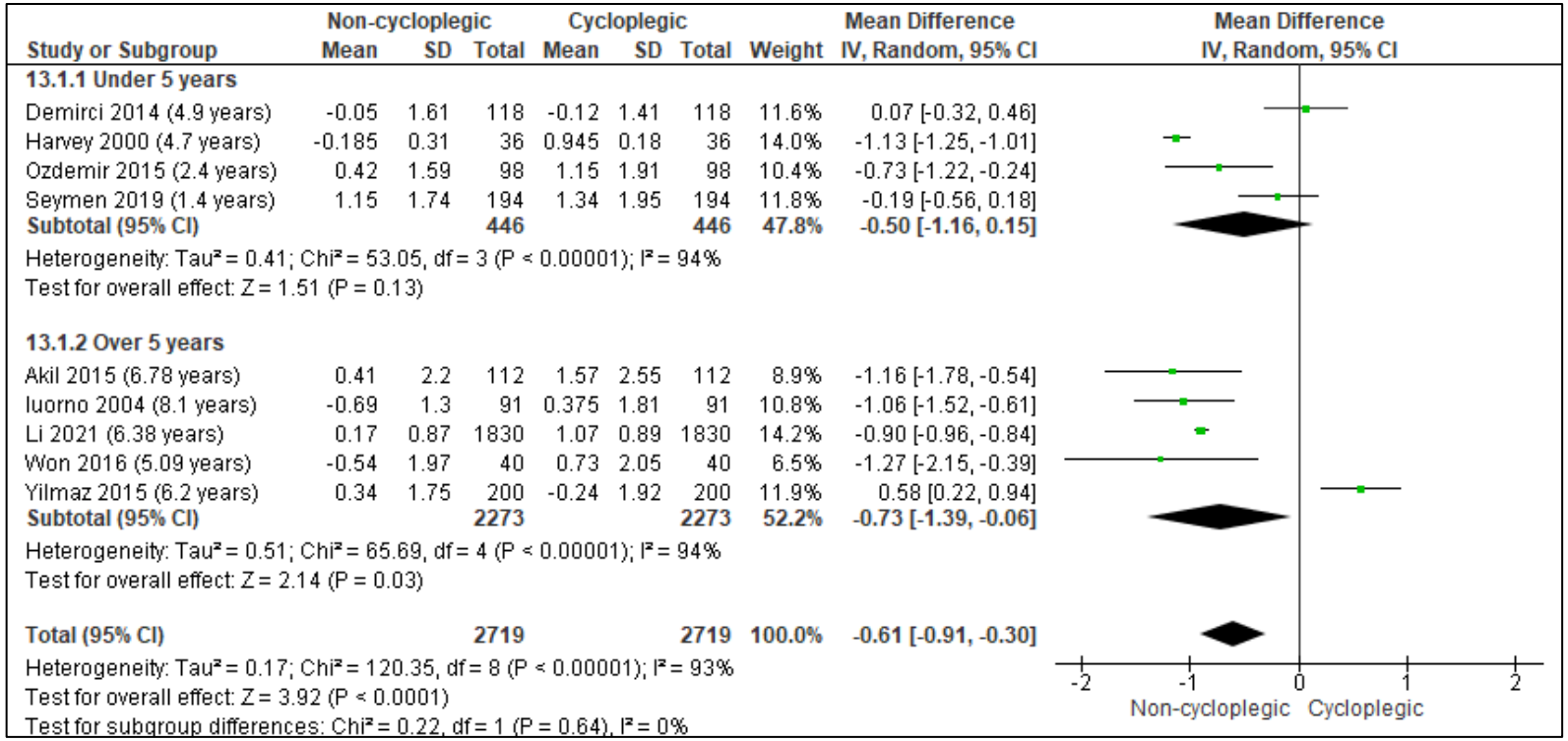
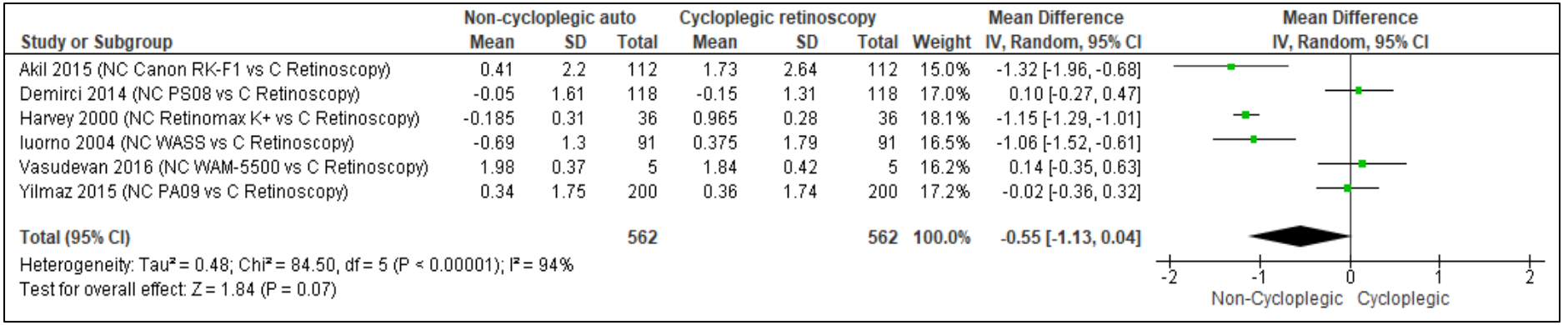


Figure 3.5. *Forest plot demonstrating the difference in non-cycloplegic and cycloplegic autorefractionł in relation to age.*



ł Demirci 2014 (NC PS08 vs C RM8800), Harvey 2000 (NC Retinomax K+ vs C Retinomax K+), Ozdemir 2015 (NC PA09 vs C PA09), Seymen 2019 (NC PA09vs C HandyRef-K), Akil 2015 (NC Canon RK-F1 vs C Canon RK-F1), Iuorno 2004 (NC WASS vs C Nidek AR-820), Won 2016 (NC Canon RK-F1 vs C Canon RK-F1), Yilmaz 2015 (NC PAO9 vs C Retinomax K+) (NC = Non-cycloplegic C=Cycloplegic).

Figure 3.6. *A forest plot exploring non-cycloplegic autorefraction in relation to cycloplegic retinoscopy.*



The Forest plot in *Figure 3.6* explored non-cycloplegic autorefraction versus cycloplegic retinoscopy. The effect size is the MD, and the overall effect is -0.55D with a 95% confidence interval of -1.13D to +0.04D. Therefore, on average, a child is diagnosed more myopic under non-cycloplegic conditions than cycloplegic conditions (~0.50D). The overall effect is 1.84, with a corresponding p-value of 0.07. Therefore, the null hypothesis (there is no difference between non-cycloplegic autorefraction and cycloplegic retinoscopy) can be rejected.

The Q-value is 84.50 with 5 degrees of freedom and $p < 0.00001$. Therefore, the true effect size is not identical in all studies. The I^2 static tells us that the proportion of the observed variance reflects differences in the true effect size rather than sampling error (I^2=95%). The variance of the true effect size (T^2) is 0.48, and the SD of the true effects (T) is 0.69. The prediction interval is -2.65D to +1.55D. It would be expected that in 95% of all populations, the true effect size will fall in this range. Subgroup analysis could not be performed due to the number of studies. In addition, analysis exploring non-cycloplegic retinoscopy and cycloplegic retinoscopy/autorefraction could not be undertaken as none of the eligible studies explored non-cycloplegic retinoscopy.

SENSITIVITY ANALYSIS

The meta-analysis was repeated by changing the number of studies included (*Figures 3.7, 3.8, and 3.9*). This was to investigate whether the review findings are dependent on the decisions made during the review process and the data included in the review. Sensitivity analysis were based upon the assessment of the risk of bias and applicability. Once the studies with a high risk of bias were removed (Demirci 2014, Ozdemir 2015, Vasudevan, 2016) there was still a significant difference in almost all types of autorefractor used during refraction (Q=13.14, df=2, p=0.001) apart from the non-cycloplegic Plusoptix, which was still not significantly different (*Figure 3.7*). There was no significant difference in relation to over and under five years (Q=0.01, df= 1, p=0.93) (*Figure 3.8*).

Figure 3.7. *A forest plot synthesising studies that compared non-cycloplegic autorefraction to cycloplegic autorefraction, excluding studies with a high risk of bias*

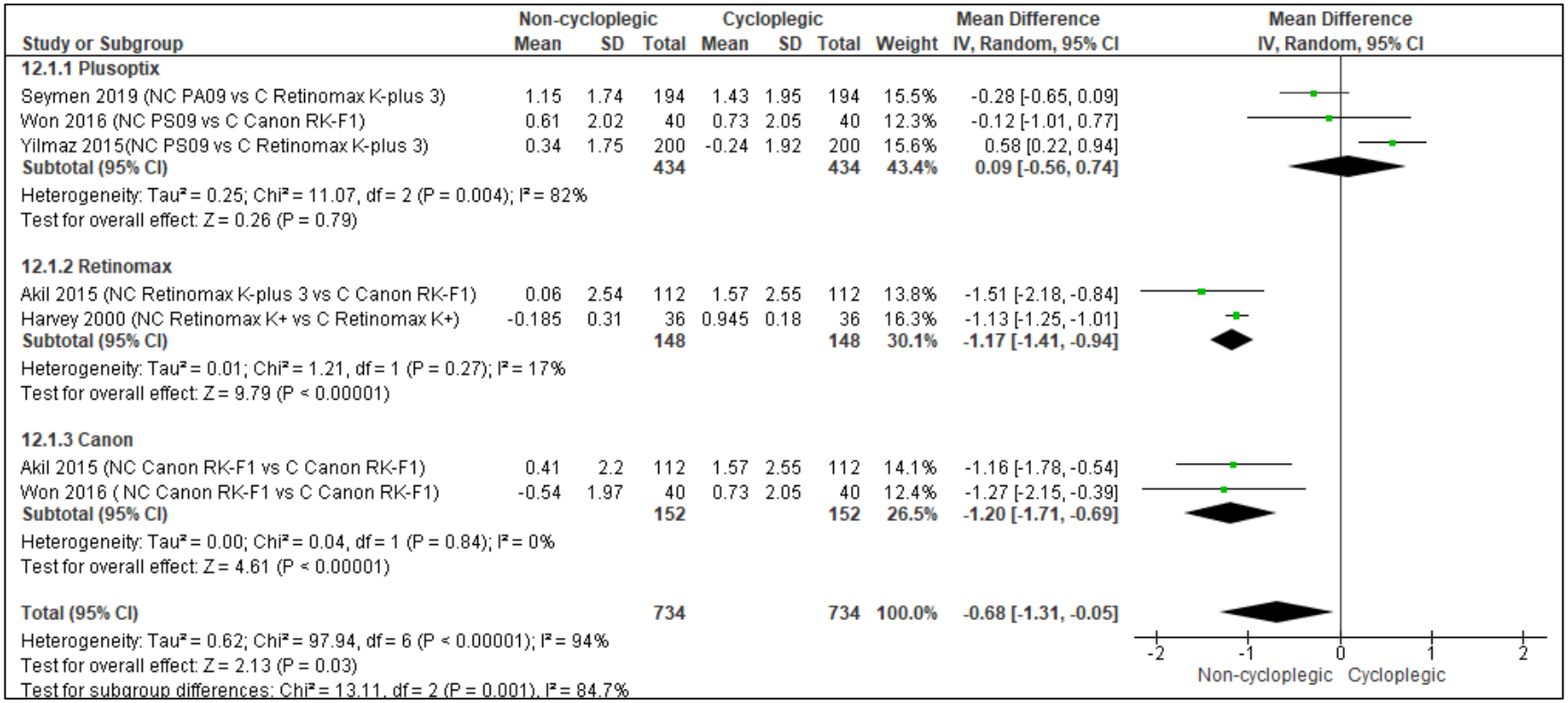


Figure 3.8. *The forest plot demonstrates the difference in non-cycloplegic and cycloplegic autorefraction compared to age, excluding studies with a high risk of bias.*

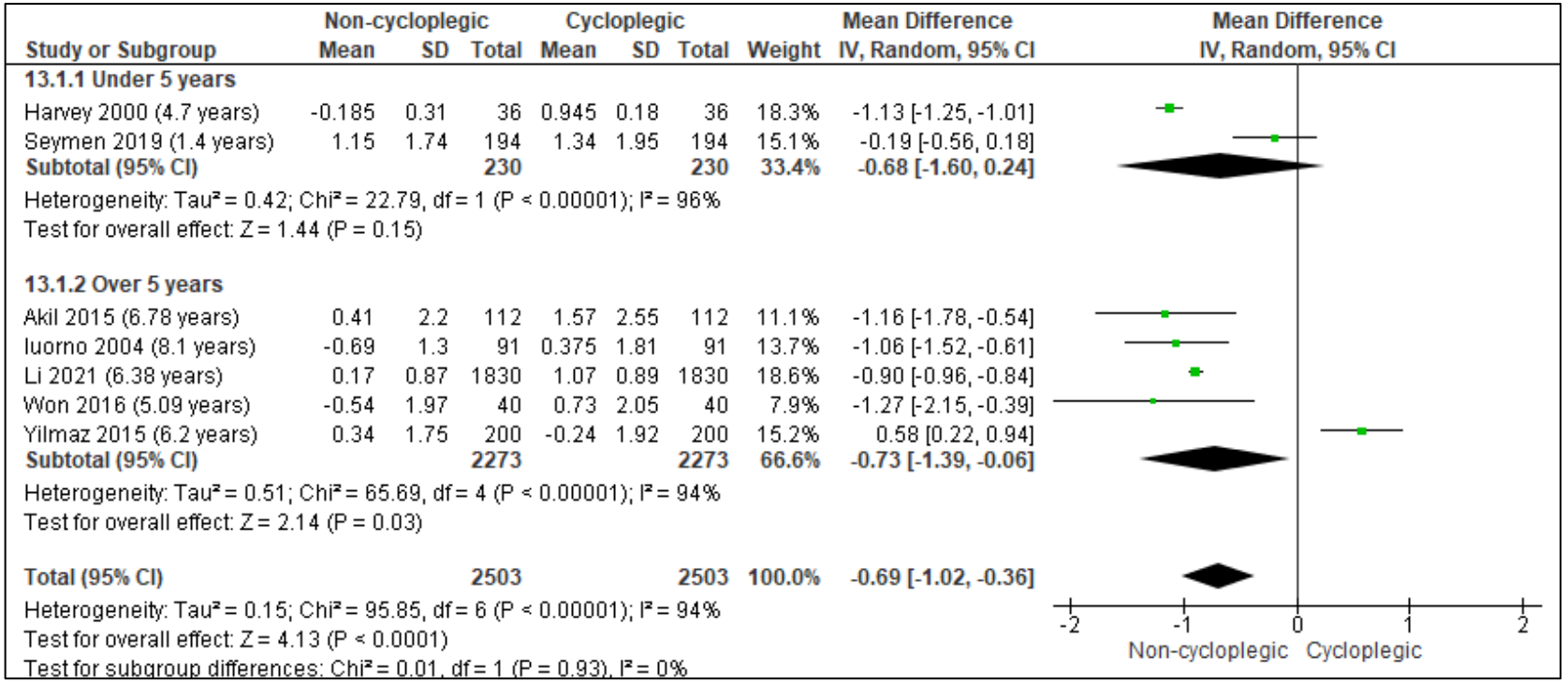
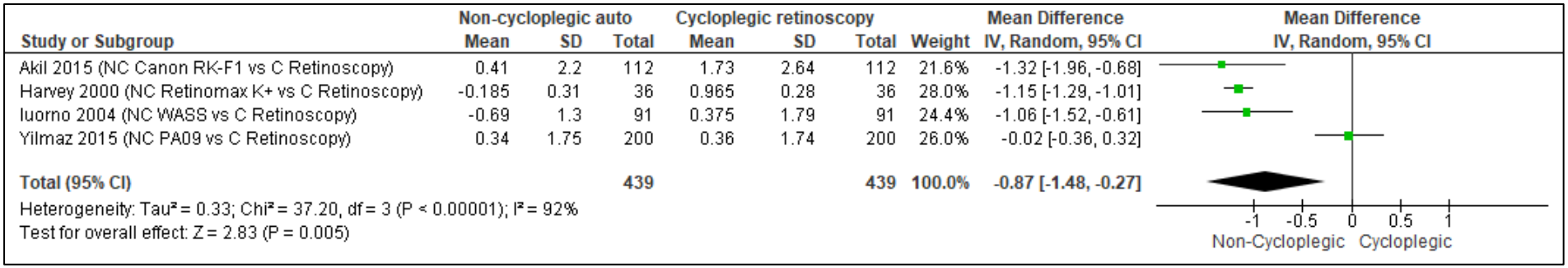


Figure 3.9. *A forest plot exploring non-cycloplegic autorefraction in relation to cycloplegic retinoscopy with the exclusion of studies with a high risk of bias.*



After removing the studies with a high risk of bias (*Figure 3.9*), the test for overall effect size appears to remain significant when addressing non-cycloplegic autorefraction and cycloplegic retinoscopy (Z=2.83, p=0.005).

LIMITS OF AGREEMENT

The protocol specified that a Bland and Altman analysis would be undertaken to compare non-cycloplegic and cycloplegic refraction. Due to the limited number of studies and individual patient data for all participants not being available this analysis was abandoned. The eligible studies reported means for their sample and therefore would not provide a fruitful outcome (Tipton and Shuster, 2017). In addition, only four studies (Li et al., 2021; Seymen et al., 2019; Yilmaz et al., 2015; Akil et al., 2015) reported using Bland and Altman analysis therefore, a comparison of all the eligible studies could not be undertaken or tabulated to report limits of agreement and bias.

DISCUSSION

To our best knowledge, this is the first systematic review and meta-analysis that has been conducted on non-cycloplegic and cycloplegic refraction. The present review found 10 studies that assessed non-cycloplegic and cycloplegic refraction on children up to 12 years of age and met the eligibility criteria. Subsequently, we analysed a total of 2724 participants from 10 studies. This review found non-cycloplegic Plusoptix to be the most useful autorefractor for estimating refractive error in young children with low to moderate levels of hyperopia. Results also suggest that cycloplegic refraction must remain the test of choice when measuring refractive error ≤ 12 years.

In this review, the mode of refraction from each study was compared in non-cycloplegic and cycloplegic conditions to help establish the suitability for measuring refractive error in routine clinical practice in young children. This was to help establish if cycloplegic refraction could potentially be replaced in a certain age group or level of refractive error. Our findings are only directly relevant to the autorefractors included in this review, limiting the conclusion that can be made about non-cycloplegic and cycloplegic refraction with autorefractors. Moreover, other autorefractors that exists may be considered relevant by other clinicians.

To establish if the difference between non-cycloplegic and cycloplegic refraction was clinically acceptable, the limits of maximal acceptable differences were based on earlier research (McCullough et al., 2017; Doherty et al., 2019). If these limits are exceeded, then the results suggest that non-cycloplegic refraction is not a suitable alternative. The value of ±0.85 D has been published as the intra-examiner limits of repeatability for cycloplegic retinoscopy in 4 year-olds (McCullough et al., 2017; Doherty et al., 2019; MacKenzie, 2008). Having reviewed previous research in this area the intra-examiner limits of repeatability for cycloplegic refraction were rounded up to 1.00D as refractive error is measured in 0.25D steps (Smith, 2006). As the limits of agreement were significantly greater non-cycloplegic refraction (autorefractors; Plusoptix, Retinomax and, Canon) was found to be not sensitive enough.

This meta-analysis has highlighted some interesting findings regarding the non-cycloplegic Plusoptix autorefractor. The non-cycloplegic Plusoptix autorefractor shows reasonable agreement with cycloplegic retinoscopy and autorefraction and the least variability in the refractive error measurements with a mean difference of -0.08D with a 95% CI (-0.54D to +0.38D) (Z= 0.34, p=0.74) indicating that relative effect size was virtually zero. As the 95% confidence intervals fall within the intra-examiner limits of repeatability for <1.00D cycloplegic retinoscopy this suggests that the non-cycloplegic Plusoptix would be a good screening tool to assess a child's refractive error in non-cycloplegic conditions before instilling cycloplegic drops. If the non-cycloplegic Plusoptix indicated a level of refractive error that is not significant enough to warrant causing any visual or binocular problems, there would be no need for cycloplegic refraction to be performed. In this manner, the non-cycloplegic Plusoptix can help identify those children that would require refraction with cycloplegic drops. However, these results should be taken with caution as the total sample size for the studies that explored the

non-cycloplegic Plusoptix was small (650), and hyperopia only up to +5.00DS was investigated, which could have potentially led to an underestimation in the agreement between non-cycloplegic and cycloplegic refraction. The prediction interval shows that if it were possible to predict the wider distribution of effects to the entire population then the average effect size would lie between -1.72D to +1.56D. These findings suggest that the non-cycloplegic Plusoptix should not be used exclusively due to the potential variability being significantly larger than 1.00D. Factors that we expect to lead to an important difference between non-cycloplegic and cycloplegic refraction were type and level of refractive error. There was limited data to provide evidence to suggest that differences in the type of refractive error would lead to a difference in conclusions. Additional data regarding the patients' refractive error could explain these discrepancies, but due to a lack of data available across the studies, this made it difficult to explore. Attention to the clinical history, vision, and binocular vision tests must also be considered when measuring and prescribing refractive error. Hypermetropia and anisometropia increase the risk of developing amblyopia and strabismus (Pascual et al., 2014; Ingram and Barr, 1979; Phelps and Muir, 1977) therefore when there is an indication of a binocular vision anomaly, cycloplegic refraction would be essential to ensure there is an accurate prescription for the management of the binocular anomaly. These findings do not allude to the fact that cycloplegic refraction is not required in specific clinical situations. The unexplored covariants (level and type of refractive error) would have given more information on when cycloplegia is necessary and when non-cycloplegic refraction can be sufficient. However, the findings demonstrate that using a non-cycloplegic Plusoptix autorefractor on young children is the most appropriate method out of the three autorefractors in this review for detecting refractive error without cycloplegia. The prediction interval for the Plusoptix however, exceeded the limits of maximum acceptable difference (1.00D), suggesting that non-cycloplegic Plusoptix cannot be substituted for a full cycloplegic refraction. Binocular open-field autorefractors were developed to avoid myopia that a monocular closed-field autorefractor would generate without cycloplegia (Carracedo et al., 2020). Research has shown less myopic findings with the binocular open-field than monocular closed-field (Bharadwaj et al., 2013) autorefractor, which may explain the agreement between the NC Plusoptix and C retinoscopy. Estimating refractive error with eccentric infrared photorefraction depends on the calibrations of luminance slopes in the pupil (conversion of the distribution of light reflected across the pupil to refractive error), and research has shown that better agreement can be found with low refractive error levels and significant errors can arise as the refractive error increases (Chen et al., 2011). These findings suggest that the NC Plusoptix should not be used exclusively due to the potential variability being significantly larger than 1.00D.

The reported mean difference and 95% confidence interval in refractive error using a non-cycloplegic Retinomax (-1.17D, 95% CI -1.41D to -0.94D) indicated poor agreement. A negative mean effect size indicates that on average this method provides a higher estimate of myopia under non-cycloplegic conditions. As the 95% confidence intervals for the non-cycloplegic Retinomax (-1.41D to -0.94D) fall outside the intra-examiner limits of repeatability for >1.00D cycloplegic retinoscopy, these results suggest that the Retinomax autorefractor is an inaccurate method for measuring refractive error under non cycloplegic conditions. Non-cycloplegic and cycloplegic refraction conducted with a Canon autorefractor showed little agreement (-1.20D 95% CI -1.71D to -0.69D), which was greater than 1.00D, indicating similar findings to the Retinomax autorefractor and that cycloplegic refraction cannot be forgone. This is in line with previous findings reporting non-cycloplegic autorefractors tend to over and under estimate myopia and hyperopia respectively (Fotedar et al., 2007; Chen et al., 2011; McCullough et al., 2017). Therefore, when refracting young children, caution should be taken when conducting non-cycloplegic autorefraction with either the Canon or the Retinomax. Consequently, conducting non-cycloplegic autorefraction with either the Canon or the Retinomax should be avoided when refracting young children.

Non-Cycloplegic autorefraction versus cycloplegic retinoscopy reveals an effect size -0.55D with a 95% confidence interval of -1.13D to +0.04D. Findings therefore again suggest that non cycloplegic autorefraction when compared against cycloplegic retinoscopy is an inaccurate method of measuring refractive error as it often results in an over-estimate of myopia and a wide range of effect sizes. A comparison between non-cycloplegic retinoscopy to cycloplegic autorefraction or cycloplegic retinoscopy was not possible as the relevant data were not available from the included papers. Future studies should attempt to examine this relationship as practitioners may find it easier to obtain an accurate reading via retinoscopy because younger children like to

move around. In addition, a practitioner has some control over accommodation during non-cycloplegic retinoscopy, unlike an autorefractor with its inherently inflexible design. Moreover, in one comparison of cycloplegic retinoscopy, it was reported that 80% of intra and inter-examiner repeatability of cycloplegic retinoscopy falls within ± 0.50D (McCullough et al., 2017). Autorefractors can be limited with the range of refractive error they can measure for example, the PlusOptix A09 -7.00 to +5.00D (Payerols et al., 2016). Therefore, it is important to explore non-cycloplegic retinoscopy so children with refractive errors that are beyond the range of an autorefractor can also be included.

Rosenfield and Benzoni (2007) found a considerable decline in the amplitude of accommodation (5.02D) between the age of five to 10 years suggesting that inaccuracy of non-cycloplegic refraction is particularly likely in younger children. A child's ability and range of focus is linked to the need for cycloplegic drops as the level of accommodation declines with age. Most of the evidence on refraction in children <12 years old indicates that myopia is higher in non-cycloplegic than cycloplegic autorefraction (Fotedar et al., 2007; Chen et al., 2011, McCullough et al., 2017) with higher differences in younger children, particularly those with hyperopic eyes (Fogel-Levin et al., 2016). These findings suggest that younger children on average should have larger effect sizes with increased variability. However, the results indicated less variability in the refractive findings for those children under five years of age (-0.50D, 95% CI -1.16D to +0.15D) than in those over 5 years old (-0.73D, 95% CI -1.39D to -0.06D). This unusual finding could be due to the type of autorefractor differed between the studies. Despite the changes in accommodation the overall amplitude of accommodation for a 10-year-old was still around 15D (Rosenfield and Benzoni, 2007) which may explain the effect size between children under and over 5 not being different. This possibility is supported by the high I^2 value suggesting that there is significant heterogeneity between the groups. The prediction intervals were also extremely large in both groups indicating that the effect size is hard to predict due to the large amount of heterogeneity. Unfortunately, due to the low numbers of studies included we were unable to carry out a meta-regression to verify this.

Similarly, our findings and previously published data suggest that non-cycloplegic refraction outcomes in young children are inaccurate. It can lead to misdiagnoses on the type of refractive error present (long-sighted prescription can be diagnosed as being short-sighted). Our findings indicate that there is poor agreement between non-cycloplegic and cycloplegic refraction when conducted with autorefractors. Although cycloplegic refraction takes time and is an uncomfortable, invasive procedure for young children, it is likely to remain the standard for obtaining an accurate, objective reading of refractive error in children. For this reason, determining which autorefractors in non-cycloplegic conditions is close to cycloplegic refraction is useful. However, due to the variability of different autorefractors, the choice of equipment during non-cycloplegic refraction in children is essential. The non-cycloplegic Plusoptix autorefractor has shown to be the closest instrument in screening for refractive error; however, it still requires refractive measurements to be refined by cycloplegic retinoscopy.

An important finding of the review was the level of heterogeneity between the results of individual studies. The meta-analysis quantified the degree to which the findings differed between studies and showed inconsistencies and variation in the published literature. There are several limitations in the individual study findings that limit the extent to which we could accurately represent the evidence and explore reasons for heterogeneity. Unfortunately, many studies averaged all types and levels of refractive error measurements into one overall figure. As a direct result, we were unable to investigate how types and levels of refractive error influenced the differences between cycloplegic and non-cycloplegic refraction. In addition, several studies included more than one eye per child, which resulted in the clustering of data within-person (Murdoch et al., 1998) because of this, extracting data for just one eye alone was not feasible. Factors, such as accommodation and type and level of refractive error, can influence refractive error measurements and potentially the agreement between non-cycloplegic and cycloplegic refraction, which could not be formally investigated because of the limitations with the data reported in the published literature. Recent data published has shown that a clinically significant change in spherical equivalent (≥ 0.50D) between non-cycloplegic and cycloplegic autorefraction is more likely to occur in children who have a lag of accommodation less than 1.15D (Jin et al., 2021). However, further work is required to produce guidance on the application of cyclopentolate and when it can be avoided.

Due to the low number of studies, this review could demonstrate an underestimation of the actual relationship. There was only one study that had reported the difference between non-cycloplegic and cycloplegic

astigmatism. Due to only one study reporting these findings, analysis could not be undertaken, and the study was excluded. The included studies all gave spherical equivalents for their average population. Moreover, a comparison of non-cycloplegic retinoscopy to cycloplegic autorefraction or cycloplegic retinoscopy could not be made. Nevertheless, this relationship would have been of use. At times, a practitioner may find it easier to obtain an accurate reading via retinoscopy than an autorefractor, where the practitioner needs to ensure the child remains still. In addition, a practitioner can control accommodation during non-cycloplegic retinoscopy, unlike with an autorefractor, despite their design; therefore, exploring this mode of refraction could have been valuable.

Moreover, there is a need to explore children who have no risk factors but have a refractive error greater than +5.00D to ensure bias is not introduced. The findings suggest that more work is required with an appropriate sample size that explores non-cycloplegic and cycloplegic refraction related to age, the type and level of refractive error, and other possible ocular concerns highlighting that there is a gap in the literature despite many studies that have explored cycloplegic refraction in children. The implications for further work can help inform researchers and policymakers regarding refracting children in primary and secondary care settings. Further research of sufficient quality is needed to allow analysis to be conducted to find the agreement of non-cycloplegic and cycloplegic refraction in relation to the type and level of refractive error concerning a child's age.

STRENGTHS AND LIMITATIONS

The strengths of this review include the methodological rigour. A comprehensive search strategy was used to identify as many potential studies for inclusion as possible, with no clinical setting, study design, or publication year restriction. All titles and abstracts were independently screened by two researchers. The researchers independently extracted the data and conducted a quality assessment study using the QUADAS-2 Tool.

There are several limitations, as many studies had a high or unclear risk of bias in at least one domain, and substantial heterogeneity was observed between studies. This should be taken into consideration when interpreting the review findings. In addition, we are unable to conduct the planned sensitivity and Bland and Altman analysis. A lack of data from various degrees and types of refractive error might have affected the overall estimate in this review. Therefore, the findings should be interpreted with caution until more data is available. The assumptions made from this review is restricted to only the autorefractors included in this study. In addition, the analysis of low to moderate hyperopia can only be established, and agreement for hyperopia greater than +5.00D is yet to be explored.

Data was selected carefully from studies which had multiple comparisons of an autorefractor and repeated observations. This ensured that data duplication did not skew the results and artificially inflate precision, leading to false conclusions. In future studies, bias should be minimised by ensuring that all subjects, irrespective of their level and type of refractive error, are randomised into either arm of the trial. When undertaking non-cycloplegic refraction, thresholds should be avoided as there should not be a limit on the level of refractive error. All levels of refractive error should be included to examine the amount of agreement between types and severities of refractive errors. Some of the studies had assigned a criterion such as refractive error before the child was assigned to undergo non-cycloplegic autorefraction. Moreover, studies should be transparent regarding how long of an interval was allowed before cycloplegic refraction was performed after instilling cycloplegic drops.

CONCLUSION

The present systematic review and meta-analysis highlight substantial gaps in refracting young children under non-cycloplegic conditions. Future investigations should report the type and degree of refractive error and must include children with refractive errors > +5.00D. Unfortunately, as most studies averaged different types and levels of refractive error, we were unable to determine whether cycloplegia is needed for all children or whether it can be safely administered to children with specific types or levels of refractive error. This could be addressed by a large primary study or potentially by a meta-analysis of individual patient data obtained from all study authors. In conclusion, many different forms of autorefractors can be used to help evaluate refractive error

objectively. However, cycloplegic refraction is the standard, and the non-cycloplegic Plusoptix autorefractor seems to achieve the closest measurement to cycloplegic refraction in children with low to moderate hyperopia. yet, cycloplegic retinoscopy is still advised to ensure accurate measurements of the refractive error present.

4. GUIDELINES FOR PAEDIATRIC SPECTACLE PRESCRIBING: APPRAISAL USING THE AGREE II TOOL AND A MODIFIED DELPHI APPROACH

BACKGROUND

Spectacles prescribing for children is of great importance as uncorrected refractive error can impact a child's visual development (*see Chapters One and Two*) and is a common risk factor for strabismus and/or amblyopia (*see Chapter One*) (Pascual et al., 2014). About 4% of children in Europe have amblyopia (*defined in Chapter One*), and uncorrected refractive error is a common cause of correctable visual impairment in children globally (Maduka-Okafor et al., 2021; Wang et al., 2021; Mostafaie et al., 2020). Thus, spectacle prescribing in children has a vital role in reducing these anomalies and their impact on children's visual and other aspects of development.

While refractive error changes with age from birth (Mayer et al., 2001) (*see Chapter One*), it may require correction or monitoring in children. When prescribing refractive correction in children, a clinician needs to consider emmetropisation (*see Chapter One*), whether the clinical findings (vision, visual acuity, and stereopsis) are typical for age, and whether the correction improves the child's visual function (Leat, 2011).

Optometrists working in primary and secondary settings in the UK prescribe refractive error correction to children differently, indicating a need for comprehensive, evidence-based resources to help practitioners decide when and how to prescribe (Doyle et al., 2019; Farbrother, 2008). Leat (2011) published guidelines for optometrists based on the available research. In addition, guidelines from the Royal College of Ophthalmologists and the American Academy of Ophthalmology are based on professional knowledge and experience (American Academy of Ophthalmology, 2017; Royal College of Ophthalmologists, 2012). However, to date, the quality of these guidelines has not been appraised, so their robustness remains untested.

Clinical guidelines (defined in *Table 4.1*) help guide healthcare professionals in evidence-based practice, reduce clinical practice variation (Carlsen and Norheim, 2008), and improve the quality and resources of healthcare (Harrison et al., 2010; Dahm et al., 2009; Vlayen et al., 2005; Woolf, 1992). In addition, there is evidence to suggest that healthcare practitioners who use guidelines have a better understanding of the condition and treatment than those who do not use them (Corriere et al., 2014; Wollersheim et al., 2005).

Table 4.1. *Definition of a clinical guideline.*

Source	Clinical Guideline Definition
National Institute for Health Care Excellence (NICE) (National Institute for Health Care Excellence, 2012)	Evidence-based recommendations on a topic including preventing and managing specific conditions, improving health, and managing medicines in different settings.
World Health Organisation (WHO) (World Health Organisation, 2020)	A document containing recommendations about health interventions, whether these are clinical, public health or policy recommendations.

The Appraisal of Guidelines for REsearch and Evaluation (AGREE) Collaboration states that high-quality guidelines provide "*confidence that the potential biases of guideline development have been addressed adequately and that the recommendations are both internally and externally valid and are feasible for practice*" (The AGREE Collaboration, 2003). Variation in guideline quality is a universal phenomenon (Hoffmann et al.,

2009), and criteria for quality have been suggested (McAlister et al., 2007; Shiffman et al., 2003; Grimshaw and Russell, 1994).

Within optometry, paediatric spectacle prescribing habits vary (Doyle et al., 2019; Farbrother, 2008), suggesting that guidelines may be inconsistent or are not being applied consistently. These findings indicate a need to understand the quality and applicability of guidelines for spectacle prescribing in children.

AIM

This study aimed to evaluate the level of variability in the quality of selected guidelines for refractive correction prescribing in children and to establish expert consensus on guideline recommendations that are clinically appropriate.

METHODS

DECIDING ON AN APPRAISAL TOOL

It has been reported that there are 40 appraisals tools available for guideline quality appraisal, 38 of which are published in English (Siering et al., 2013). The tools differ in the criteria used (e.g., number of domains, rating scale, number of appraisers required). A systematic review by Siering et al. (2013) compared various such tools, which indicated that the AGREE II tool was the most robust tool to use compared to the other tools available when comparing appraisal tools characteristics and domains and items of each tool were explored. In addition, the manner in which current literature has undertaken appraisal of guidelines, and the frequency of which tools are used has also helped to decide which appraisal tool to choose (Gyawali et al., 2021; Lawrenson et al., 2019; Chiappini et al., 2017; Yao et al., 2017). Subsequently with the findings obtained from the systematic review and how researchers have conducted appraisals of guidelines led to the use of the AGREE II tool, which was consolidated with the fact that this tool has undergone testing to ensure validity (Brouwers et al., 2010a) and reliability (Brouwers et al., 2010b), making it appropriate for this study. The AGREE II tool consists of 23 items and six domains described in *Table 4.2*.

Table 4.2. *The grading criteria for each item and domain used in the AGREE II tool instrument (Brouwers et al., 2016) and the maximum and minimum scores on guideline appraisal by two appraisers.*

Domain and Items	Criteria[t]	Maximum score	Minimum score
Domain 1: Scope and purpose			
1. Objectives	Health intention. The expected outcomes or benefits. Target patient population.	42	6
2. Questions	Target patient population. Intervention. Comparisons. Outcome. Health care setting.		
3. Population	Sex and gender of the population of interest. Clinical condition. The severity of the condition. Comorbidities. Exclusion of population.		
Domain 2: Stakeholder involvement			
4. Group members	Details of group members; name, discipline, institution, location, and role.	42	6
5. Target population preference and views	Target patient population views- method, outcomes and, how the information is used.		
6. Target users	Guideline audience. How the guideline will be used.		
Domain 3: Rigour of development			
7. Search methods	Name of database used, time, and search terms.	112	16
8. Evidence selection criteria	Inclusion and exclusion criteria.		
9. Strengths and limitations of the evidence	Looking at evidence and study methodology.		
10. Formulation of recommendations	Process of how the recommendations were developed and the outcomes.		
11. Consideration of benefit and harms	Data supporting the benefits and harms of the recommendations that have been produced.		
12. The link between recommendations and evidence	Information on how the recommendation that has been developed have used evidence and how they have been linked.		
13. External review	Information on how the recommendation and guidelines were reviewed externally and the outcomes.		
14. Updating procedure	Information on how and when the guidelines will be updated.		
Domain 4: Clarity of presentation			
15. Specific and unambiguous recommendations	A statement on the recommendation and the purpose.	42	6
16. Management options	Description of the management options for relevant clinical situations.		
17. Identifiable key recommendations	Recommendations are easily visible in a summary box, bold lettering, or presented as a flow chart.		
Domain 5: Applicability			
18. Facilitators and barriers to application	Mention of the facilitators and barriers considered when making the recommendations and how the information was obtained	56	8
19. Implementation advice/tools	Additional information to help support and allow the guidelines to be implemented.		
20. Resource implications	Additional resources and the cost and practicality of performing the guideline line recommendations.		
21. Monitoring/auditing criteria	Criteria for assessing implementation and impact of guidelines.		
Domain 6: Editorial independence			
22. Funding body	Details of the funding body and statement recharging any influence on the content of the guidelines.	28	4
23. Competing interests	Information on any competing interests and a description of how they were dealt with and their influence on the guidelines.		

[t] Criteria for each item has been explained in detail in the AGREE II manual, highlighting what the appraisers need to look for (AGREE Trust, 2017).

The AGREE II tool focuses on the methodological aspects of the guideline's development. It does not evaluate its clinical appropriateness (if a specific management plan is suitable given the signs and symptoms of the patient) (Brouwers et al., 2010a). Therefore, after assessing the guidelines, a Delphi study (as described below) was conducted to gain expert consensus on their clinical appropriateness.

DELPHI TECHNIQUE

The Delphi technique was selected to gain expert consensus after considering alternative approaches, including the Nominal Group Technique and focus groups. These methods do not provide anonymity and may allow dominant individuals to influence results (Fern, 2001; Delbecq and Van de Ven, 1986; Riggs, 1983; Linstone and Turoff, 1975). There are over 20 variations of the Delphi technique (Mullen, 2003), which do not produce definitive recommendations but evaluates potential decisions that aid decision-making processes (Sackett et al., 1996). Using a series of rounds of questionnaires aiming to achieve consensus (McKeena, 2004; Dalkey and Helmer,1963), this technique assumes that consensus is more important than individual opinion, and its anonymity allows participants of high or low status to freely express ideas (Keeney et al., 2011; Adler and Ziglio, 1996). A web-based format allows the inclusion of geographically and otherwise diverse participants (Donohoe et al., 2008; Adler and Ziglio, 1996). In the present study, a three-round modified Delphi approach was used as this version of the Delphi study has also developed competencies and specifications within the profession (Kotecha et al., 2018; Davey et al., 2017; Campbell et al.,2012; Myint et al., 2010) and deemed to be appropriate in obtaining maximum engagement with the participants with unnecessarily lengthening the technique.

ETHICAL APPROVAL

Ethical approval for the study was obtained from the Optometry Research and Ethics Committee at City, University of London on the 1st March 2020 (Appendix 4.0). Furthermore, written, and informed consent was obtained from all participants, conforming to the tenets of the Declaration of Helsinki.

SEARCH FOR GUIDELINES

A search for guidelines was conducted using the following electronic databases and sources:

1. Ovid Online.
2. Elton Bryson Stephens Company (EBSCO) host.
3. National Institute for Health and Clinical Excellence (NICE).
4. Guidelines for Management of Strabismus in Childhood 2012 (Royal College of Ophthalmologists, 2012).
5. Pediatric eye evaluations: Vision screening in the primary care and community setting II Comprehensive ophthalmic examination (American Academy of Ophthalmology, 2017).

The search was based on keywords relating to paediatrics, prescribing and refractive error with no date restriction (*see Appendix 4.1 for detailed search terms*).

The search results underwent a screening process based on the inclusion criteria listed below. Two researchers (SW and CS) screened the studies to assess eligibility.

1. Includes a clear recommendation specific to paediatric prescribing.
2. No restriction to the geographical location of the guideline. This is because decision making for refractive prescribing does not depend on location, and similar rules should be adopted regardless of the professional's geographical location.
3. Published in English.

The researchers (SW and CS) agreed on which guidelines met the above criteria. If there was a disagreement between the two researchers, their opinions were discussed, and a consensus was reached. A third party

(another research team member) would have been consulted if consensus could not be obtained regarding a specific guideline. However, there was no need for a third member to be consulted.

GUIDELINE APPRAISAL PROCESS

The clinical guidelines were evaluated by two researchers (SW and IC) using the AGREE II tool. Each appraiser had a copy of the AGREE II manual (AGREE Trust, 2017) and undertook an online training exercise before appraising the eligible guidelines (AGREE Trust, 2019). The appraisal process was undertaken on the AGREE PLUS platform (https://www.agreetrust.org/resource-centre/agree-plus/). When appraising each guideline, each item (*Table 4.1*) is rated on a scale from 1 (lowest quality/strongly disagree) to 7 (highest quality/strongly agree) in accordance with the AGREE II collaboration manual (AGREE Trust, 2017). If an item did not apply to the guideline under appraisal, it was allocated a score of 1, indicating missing information and low quality. The maximum and minimum scores that could be obtained are described below and tabulated in *Table 4.2.*

Maximum possible score

Example for Domain One:

	Item 1 Objectives	Item 2 Questions	Item 3 Population
Appraiser 1	7	7	7
Appraiser 2	7	7	7

Maximum possible score= 7 (strongly agree) x (number of items) x (number of appraisers)

Maximum Possible Score= 7 x 3 x 2 =42

Minimum possible score

Example for Domain One:

	Item 1 Objectives	Item 2 Questions	Item 3 Population
Appraiser 1	1	1	1
Appraiser 2	1	1	1

Minimum possible score= 1 (strongly disagree) x (number of items) x (number of appraisers)

Minimum Possible Score= 1 x 3 x 2 =6

After each domain had been scored, the appraisers then gave their overall judgement on the quality of the guideline and if whether they would recommend using the guideline, whether it requires modification first or whether it should not be used.

To assess the quality of the guideline, a score for each domain was calculated by summing individual item scores using the format below, producing a percentage score for each domain. The percentage score for each domain was then used to assess the quality of the guideline, which is described below (*see section: Classifying guidelines as high or low quality*).

$$\textbf{Domain score (\%)} = \frac{\textbf{Obtained score} - \textbf{Minimum possible score}}{\textbf{Maximum possible score} - \textbf{Minimum possible score}} \times 100$$

Example for Domain One:

	Item 1 Objectives	Item 2 Questions	Item 3 Population	Total
Appraiser 1	5	7	4	17
Appraiser 2	3	6	5	14
Total				31

$$\textbf{Domain score (\%)} = \frac{31 - 6}{42 - 6} \times 100 = 69.44\%$$

CORRELATION CRITERIA

The agreement between the appraisers was verified using an intraclass correlation coefficient (ICC) for all six domains (Shrout and Fleiss, 1979). The agreement was expected to be at least moderate (ICC= 0.41 - 0.60; Michaelov et al., 2018; Ou et al., 2011). If lower, or if the appraisers disagreed on their overall recommendation, a discussion would occur to reach consensus; however, this situation did not arise. The AGREE II tool does not give an overall score for each guideline, so correlation was determined for each domain.

CLASSIFYING GUIDELINES AS HIGH OR LOW QUALITY

High-quality guidelines recommended by both appraisers were included in the Delphi study. All items regarding prescribing refractive error from the guideline which was classified as high quality were included into the Delphi process. Previous literature suggests that a score of 60% or more on four of the six domains, including the domain 'rigour of development', indicates high quality (Hayawi et al., 2018). The threshold for 'rigour of development' (domain three) was kept as 70%, as recommended by the AGREE II manual (AGREE Trust, 2017).

High quality = Domain Three (70% or more) and three other domains (60% or more)

PILOT DELPHI STUDY

A pilot Delphi study was conducted to identify and address any potential methodological flaws. The pilot study consisted of a single round with one online questionnaire asking for feedback on the approach, including framing of the questions (Appendix 4.2). The questionnaire contained statements on refractive error correction recommendations from existing high-quality guidelines, and participants were required to score each using a scale from 1 (strongly disagree) to 9 (strongly agree) (Holmes and Myint, 2018; Myint et al., 2010). The questionnaire was generated using Qualtrics Survey Software (https://cityunilondon.eu.qualtrics.com) which allowed qualitative and quantitative data to be collected.

The pilot study participants were two optometrists and one orthoptist from the City, University of London's eye clinic (City Sight) who were invited to participate in the pilot study only. The participants were emailed an invitation letter and information sheet (Appendix 4.3 and 4.4). The study commenced after the participants expressed interest and signed the consent form. A two-week timeframe was given to allow the participants to decide whether to participate and if no response was obtained, another participant was invited. Once consent was obtained from all participants, they were emailed a questionnaire link to complete the online questionnaire via any electronic device and were given four weeks to complete the questionnaire, with reminders provided on the 14th and 21st days after this.

The pilot questionnaire consisted of 68 multiple choice questions (obtained from the guideline 'Pediatric Eye Evaluations Preferred Practice Pattern') and 12 notes sections to allow participants to justify answers or make comments based on the participant's knowledge and expertise.

THE MAIN DELPHI STUDY

There is little evidence suggesting that large samples are required to achieve consensus (Murphy et al., 1998), and previous studies using the Delphi technique have included a range of sample sizes (range 7 to 38 participants). These findings helped to inform our decision to include 10 participants (Holmes and Myint, 2018; Kotecha et al., 2018; Davey et al., 2017; Campbell et al., 2012; Myint, 2010). This small sample helps to avoid complexities and difficulties in collecting data, reaching consensus, and conducting analysis. On the other hand, a very large sample size would result in more time required to obtain consensus from the experts and therefore requiring more than three rounds of the Delphi study, which could lead to fatigue, poor response rate and participants dropping out with the potential of not obtaining fruitful findings.

The inclusion criteria were as follows:

Practising, registered ophthalmologists with a subspecialty of paediatrics were selected. Practising, registered optometrists were selected based on the research team's knowledge of optometrists working in hospital and community practices, specialising in paediatric eyecare. Practising registered orthoptists routinely work with children and were selected based on the research team's knowledge (to ensure they have good exposure and experience working with very young children). Clinicians working in private and NHS settings were selected.

An expert panel was formed via purposive sampling, and to minimise bias, the sample included participants from a range of work settings (e.g., hospital and community practice) to ensure that different perspectives were gathered. The expert panel members were selected from an unrestricted pool of professionals. Before the participants were contacted, the principal researcher (SW) checked that the potential participant was registered with their professional body.

At the time of recruitment, some obstacles were experienced due to the pandemic (COVID-19), resulting in participants being unavailable. For this reason, experts were recruited via the paediatric listserv mailing platform (used to circulate information to paediatric ophthalmologists in the UK, https://www.rcophth.ac.uk/) with the assistance of the chair of the Royal College of Ophthalmologists paediatric subcommittee, and the British and Irish Orthoptic Society (BIOS) mailing system e-zine (https://www.orthoptics.org.uk/membership-levels/). After obtaining consent, each participant was given a code to track their responses through the different Delphi rounds (described below) with anonymity.

DELPHI ROUNDS

The questionnaire was presented in the same manner as the pilot Delphi study, however, it consisted of three rounds of questionnaires. Disagreement on specific statements (prescribing statement not obtaining consensus and meeting criteria described below) was explored by including the statement in the subsequent round (round 2 then round 3 if required) by the researcher (SW) giving feedback on the groups and participants opinions (participants own score and median score for the panel as a whole) (Dajani et al., 1979). This allowed the participant to reconsider their opinion if appropriate. The attrition rate was minimised by following up with non-respondents, giving prompt feedback to prevent fatigue and not unnecessarily lengthening the study.

During round one, consenting participants were sent the online questionnaire with instructions. The online questionnaire included questions about the participant's demographic factors and paediatric refractive error prescribing recommendations (Appendix 4.5). Rounds two and three consisted of additional instructions and feedback from the previous round alongside a revised questionnaire. Questions were removed after each Delphi round if consensus (criteria described below) was achieved. Statements that did not achieve consensus were carried through each Delphi round and excluded after the final round.

CONSENSUS CRITERIA

The Delphi technique does not stipulate the level at which consensus must be reached. Some previous studies have used the "mean score" rather than median when developing a consensus criterion (Holmes and Myint, 2018; Myint et al., 2010; Myint, 2013). Due to the sample size in this study, the median score was deemed more appropriate as mean values are likely to be skewed by extreme scores. In addition, many authors have strongly favoured using the median score as it would reflect the level of consensus better (Keeney et al., 2011; Hill and Fowles, 1975). For this study, if a statement had a median score (scoring explained in the pilot study using scale 1 to 9) of six or more from a least 60% of the participants, this meant consensus had been obtained indicating the prescribing statement was appropriate. If 60% of the participants scored the prescribing statement 5 or below the statement was excluded and classified as being an inappropriate prescribing recommendation.

DATA ANALYSIS

The data obtained from the questionnaire were exported out of Qualtrics. The demographic data collected during round one were analysed to look for any association between participants' expertise and their prescribing opinion. As stated above, averages were expressed as medians and interquartile ranges. In addition, the reliability of the response rates (consistency within the panel of experts and their responses) was reviewed by calculating Cronbach's alpha and the correlation between responses from each participant with the average ICC value.

RESULTS

GUIDELINE SEARCH

The guideline search conducted in November 2019 yielded 65 records (*Table 4.3*) in total, including resources identified from reference lists of relevant resources.

Table 4.3. *Search results.*

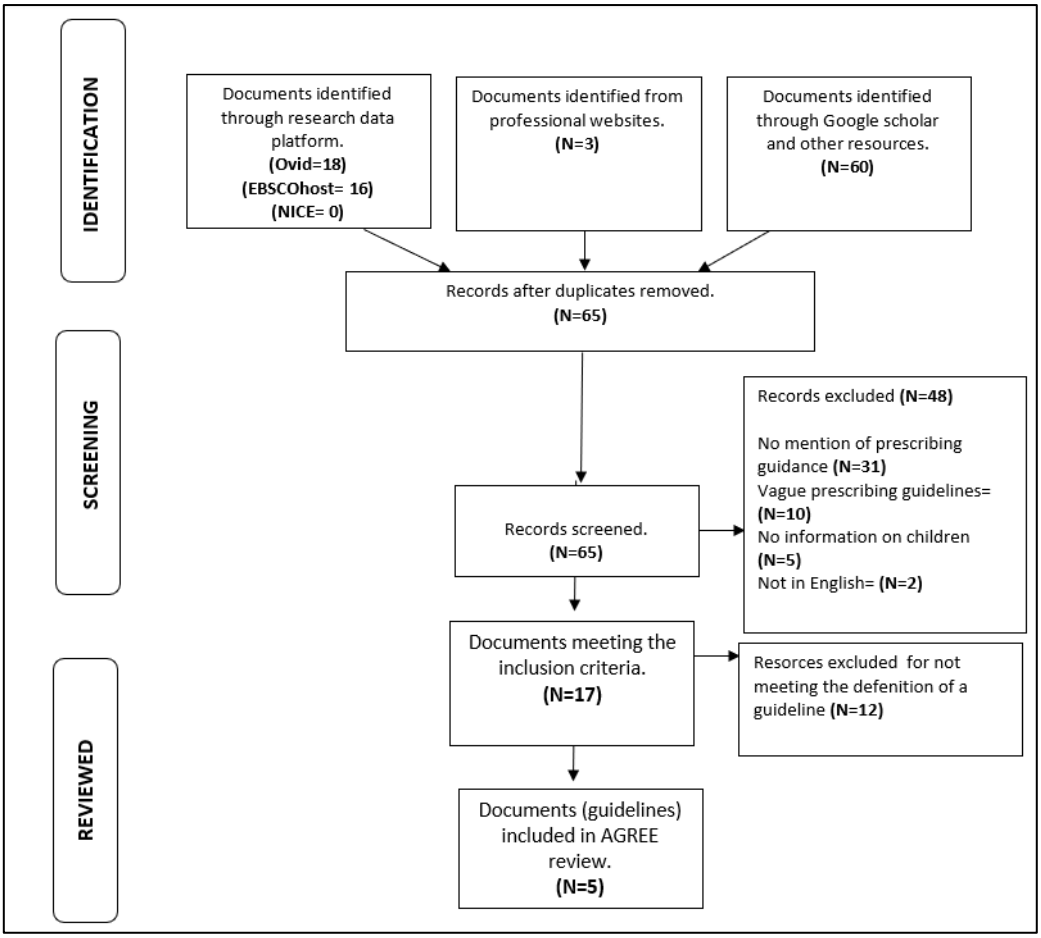
Title	Authors
Guidelines for the Management of Strabismus in Childhood.	The Royal College of Ophthalmologists
All India Ophthalmological Society Guidelines National, Expert-Based Consensus.	All India Ophthalmological Society
Non-cycloplegic refractive screening can identify infants whose visual outcome at 4 years is improved by spectacle correction.	Anker et al., 2004
Infant Hyperopia: Detection, Distribution, Changes and Correlates—Outcomes From the Cambridge Infant Screening Programs.	Atkinson et al., 2007
Evidence-based spectacle prescribing for infants and children.	Bobier, 2007
Diagnosis and treatment of refractive errors in the pediatric population.	Braverman, 2007
Care of the Patient with Hyperopia.	American Optometric Association
The association between refractive cutoffs for spectacle provision and visual improvement among school-aged children in South Africa.	Congdon et al., 2007
Management of Childhood Hyperopia: A Pediatric Optometrist's Perspective.	Cotter, 2007
Amblyopia in astigmatic preschool children.	Dobson et al., 2003
Prescribing Spectacles in Children: A Pediatric Ophthalmologist's Approach.	Donahue, 2007
Cycloplegia and spectacle prescribing in children: attitudes of UK optometrists.	Doyle et al., 2019
Examining children.	Directorate of Optometric Continuing Education and Training
Spectacle prescribing in childhood: a survey of hospital optometrists.	Farbrother, 2008
Eyeglass-prescribing analysis provides pattern in young patients.	Groves, 2015
Prescribing Eyeglass Correction for Astigmatism in Infancy and Early Childhood: A Survey of AAPOS Members.	Harvey et al., 2005
Changes in visual function following optical treatment of astigmatism-related amblyopia.	Harvey et al., 2008
Modifications Made to the Refractive Result when Prescribing Spectacles.	Hrynchak et al., 2012
Infants, Toddlers, and Children.	Marsh-Tootle and Frazier, 2006
Should Glasses Be Prescribed for All Children with Moderate Hyperopia?	Lambert, 2016
Prescribing for Hyperopia in Childhood and Teenage by Academic Optometrists.	Leat et al., 2011
To prescribe or not to prescribe? Guidelines for spectacle prescribing in infants and children.	Leat, 2011
A Survey of Clinical Prescribing Philosophies for Hyperopia.	Lyons et al., 2004
Spectacle prescription in children: Understanding practical approach of Indian ophthalmologists.	Monga and Dave, 2018
Criteria for prescribing optometric interventions: literature review and practitioner survey.	O'Leary et al., 2003
Pediatric Eye Evaluations Preferred Practice Pattern®.	American Academy of Ophthalmology
Survey of German Clinical Prescribing Philosophies for Hyperopia.	Reiter and Madsen, 2007
Spectacles in Children- Do's and Don'ts.	Sharma et al., 2016
How do we tackle a child's spectacle?	Sharma et al., 2018
Spectacles prescribing for young children.	Woodhouse, 2016
Guidelines for Prescribing Optical Correction in Children.	Wutthiphan, 2005
A first attempt to prevent amblyopia and squint by spectacle correction of abnormal refractions from age 1 year.	Ingram et al., 1985
Spectacle prescribing recommendations of AAPOS members.	Miller and Harvey, 1998
In the absence of strabismus what constitutes a visual deficit in children?	Shea and Gaccon, 2006
Harley's Pediatric Ophthalmology.	Nelson and Harley, 1998
Optometry: Science, technique and clinical management.	Rosenfield et al., 2014
The correction of borderline refractive and heterophoric anomalies.	O'Leary, 2009
Care of the Patient with Myopia.	American Optometric Association

Establishing Prescribing Guidelines in School-Based Eye Health Programs in Children Aged 11 to 15 Years-The Conundrum of Cost vs Benefit.	Manh,2019
Spectacle Wear in Children Given Spectacles through a School-Based Program.	Messer et al., 2012
Hyperopia: How Do We Define Abnormal?	Donahue and Baker, 2005
Pediatric ophthalmologist glasses prescribing patterns.	Dawson, 2014
Correcting refractive error in low income countries.	Keay and Friedman, 2011
Prescribing spectacles to children.	Ehrt, 2011
Ocular correction in children.	Apătăchioae et al., 2008
Indication for prescribing spectacles.	Michaels, 1981
Refraction and glass prescription in pediatric age group.	Ashok, 2019
Comparison of prescribing patterns of ophthalmologists and optometrists to published guidelines.	Wanda et al., 2014
Management of refractive errors.	Cochrane et al., 2010
Refraction of children.	Hirsch, 1964
Spectacle prescribing II: practitioner experience is linked to the likelihood of suggesting a partial prescription.	Howell-Duffy et al., 2011
Does correction of hyperopia affect the pattern of children's activities and does this differ from that of emmetropic children?	French et al., 2009
Hyperopia: a meta-analysis of prevalence and review of associated factors among school-aged children.	Castagno et al., 2014
A longitudinal study of a population based sample of astigmatic children.	Abrahamsson et al., 1990
Correcting Indigenous Australians' refractive error and presbyopia.	Anjou et al., 2012
The Correction of Myopia Evaluation Trial (COMET): Design and General Baseline Characteristics.	Hyman et al., 2001
Optical correction of refractive error for preventing and treating eye symptoms in computer users (Protocol).	Li et al., 2012
Spectacle prescribing among 10-year-old children.	Stewart-Brown et al., 1985
School-based Approaches to the Correction of Refractive Error in Children.	Sharma et al., 2012
Ametropia, Preschoolers' Cognitive Abilities, and Effects of Spectacle Correction.	Roch-Levecq et al., 2008
Refractive errors in children: to correct or not to correct?	Marren, 1999
Prescribing cylinders: the problem of distortion.	Guyton, 1977
Associations between Anisometropia, Amblyopia, and Reduced Stereoacuity in a School-Aged Population with a High Prevalence of Astigmatism.	Dobson et al., 2008
The Association between Nonstrabismic Anisometropia, Amblyopia, and Subnormal Binocularity.	Weakley, 2001

The websites of the following professional organisations were also checked for relevant resources; Optometrists Association Australia, Ontario Association of Optometrists and American Optometrist Association, and relevant ophthalmology and orthoptic websites.

Seventeen studies were selected using the inclusion criteria, of which only five met the definition of a guideline and were appraised using the AGREE II tool. Details of the assessment of resources for eligibility, along with the reasons for excluding full-text articles and resources, are shown in the PRISMA diagram in *Figure 4.1* (Moher et al., 2009).

Figure 4.1. *Search results and screening process (Moher et al., 2009).*



AGREE II TOOL RESULTS

The results of appraisal and agreement are shown in *Table 4.4*. Some examples of the reasons for the scores in each domain are given in Appendix 4.6

Table 4.4. *Quality of guidelines (%), based on the six domains of the appraisal tool (AGREE II).*

Clinical Guideline	**AGREE II Domains (%)**						**Quality Of Guideline**	**Agreement**
	Scope and Purpose	**Stakeholder Involvement**	**Rigour of Development**	**Clarity of Presentation**	**Applicability**	**Editorial Independence**		**ICC**
All India Ophthalmological Society Guidelines.	53	39	8	78	6	38	Low	0.91
Guidelines for Prescribing Optical Correction in Children.	28	11	4	33	2	0	Low	0.54
Pediatric Eye Evaluations Preferred Practice Pattern.	89	64	70	94	19	92	High	0.96
To prescribe or not to prescribe? Guidelines for spectacle prescribing in infants and children.	86	28	23	64	17	0	Low	0.81
Evidence-based spectacle prescribing for infants and children.	36	19	22	50	6	0	Low	0.69
Median % (Range)	53 (28-89%)	28 (11-64%)	22 (4-70%)	62 (33-94%)	6 (2-19%)	0 (0-92%)		

PILOT DELPHI STUDY

Recruitment started on the 16th June 2020, and data collection was completed by the 9th August 2020. All three participants provided comments and modifications, which led to the formation of the main Delphi study questionnaire (Appendix 4.5).

MAIN DELPHI RESULTS

Round One

The first round began on 2nd October 2020, and the expert panel were given until the 19th October 2020. The main Delphi study consisted of two paediatric ophthalmologists, six optometrists, and two orthoptists. There was a 100% response rate for round one. The demographic information of the expert panel can be found in *Table 4.5*. One hundred and sixty-eight statements were initially presented. After analysing the responses from round one, the statements and corresponding scores were tabulated (*Table 4.6).* The panel came to a consensus on 85 prescribing statements as appropriate and 32 inappropriate. The qualitative data obtained from round one are presented in *Table 4.7*. The 51 statements that did not achieve consensus were carried through to the subsequent round. Cronbach's alpha (α) of 0.97 indicated high reliability. Average ICC of 0.58 with a 95% confidence interval from 0.48 to 0.67 ($F(167,1503) = 2.63$, $p<0.001$) indicated moderate agreement between participants.

Table 4.5. *Demographic characteristics of the expert panel members who participated in the Delphi study*.

Demographic characteristics	**Frequency (n)**	**%**
Profession		
Optometrist	6	60.0
Ophthalmologist	2	20.0
Orthoptist	2	20 .0
Qualifications		
BSc (Hons) / BMedSci (Hons)	7	28.0
PhD	2	8.0
FCOptom	1	4.0
FAAO	1	4.0
FEAOO	1	4.0
FBCLA	1	4.0
DipCLP	1	4.0
DipOrth	2	8.0
MSc Research Methods	1	4.0
Professional Certificate in Paediatric Eyecare	2	8.0
WOPEC MECS	1	4.0
WOPEC Glaucoma	1	4.0
MB chB FRCOphth MA	1	4.0
ILM5 coaching	1	4.0
Higher Certificate in Paediatric Eyecare	1	4.0
MBBS:DO:FRCS(Ophth)	1	4.0
Number of years of experience in paediatric eyecare		
0-15 years	4	40.0
16- 31 years	5	50.0
32- 47 years	1	10.0
Work setting		
Hospital	7	35.0
Community practice (multiple)	2	10.0
Community practice (independent)	3	15.0
Academia	4	20.0
Research	3	15.0
Domiciliary	1	5.0
Experience examining children		
Extensive experience with a child who is < 12 months old	4	40.0
Good experience with a child who is < 12 months old	1	10.0
Some experience with a child who is < 12 months old	1	10.0
Little experience with a child who is < 12 months old	3	30.0
No experience with a child who is < 12 months old	1	10.0
Extensive experience with a child who is 12-24 months old	4	40.0
Good experience with a child who is 12-24 months old	1	10.0
Some experience with a child who is 12-24 months old	4	40.0
Little experience with a child who is 12-24 months old		
No experience with a child who is 12-24 months old	1	10.0
Extensive experience with a child who is 2-4 years of age	4	40.0
Good experience with a child who is 2-4 years	3	30.0
Some experience with a child who is 2-4 years	2	20.0
Little experience with a child who is 2-4 years	1	10.0
No experience with a child who is 2-4 years		
Extensive experience with a child who is 5-7 years	6	60.0
Good experience with a child who is 5-7 years	4	40.0
Some experience with a child who is 5-7 years		
Little experience with a child who is 5-7 years		
No experience with a child who is 5-7 years		
Extensive experience with a child who is 8-11 years	6	60.0
Good experience with a child who is 8-11 years	3	30.0
Some experience with a child who is 8-11 years	1	10.0
Little experience with a child who is 8-11 years		
No experience with a child who is 8-11 years		
Extensive experience with a child who is 12 years of age and over	6	60.0
Good experience with a child who us 12 years of age and over	3	30.0
Some experience with a child who us 12 years of age and over	1	10.0
Little experience with a child who us 12 years of age and over		
No experience with a child who is 12 years of age and over		
Resources used during the clinical decision making		
Education from university (under and postgraduate).	9	14.1
Pre-registration training and experience.	6	9.4
Clinical guidelines.	7	10.9

CET/CPD [f] courses.	5	7.8
Opinions from lead professionals.	10	15.6
Evidence-based literature.	8	12.5
Patient feedback on adaptation	9	14.1
Clinical experience.	10	15.6

[f] *Continuous Education and Training (CET) / Continuing Professional Development (CPD).*

Table 4.6. *Results from round one highlighting the statements that were agreed upon as being appropriate and inappropriate prescribing refractive error correction recommendations (pink= inappropriate with a median score of ≤5 and green= appropriate with a median score of ≥6).*

Age	Prescribing recommendation (DS= Dioptre Sphere, and DC=Dioptre Cylinder)	Prescribing amount	Median score (9=strongly agree)	Inter-quartile range (IQR)
Less than 1 year No concerns	Hyperopia of +6.00DS or more (with no strabismus)	Full	3.5	2.25-5.75
	Astigmatism of -3.00DC or more (not oblique)	Full	3	2-4.75
	Myopia of -5.00DS or more	Modified	5	3-8
	Astigmatism of -3.00DC or more (oblique)	Modified	5	2.25-8
Less than 1 year Vision reduced	Myopia of -5.00DS or more	Full	5	3-7.25
	Hyperopia of +6.00DS or more (with no strabismus)	Full	5	3.25-6.75
	Astigmatism of -3.00DC or more (oblique)	Full	6	5-7
	Myopia of -5.00DS or more	Modified	5	3.25-8
	Hyperopia of +6.00DS or more (with no strabismus)	Modified	5	3.25-7.75
	Astigmatism of -3.00DC or more (oblique)	Modified	5	4.25-7.75
	Astigmatism of -3.00DC or more (not oblique)	Modified	5	4.25-6
Less than 1 year Constant esotropia	Hyperopia of +2.00DS or more	Full	9	9-9
	Hyperopia of +2.00DS or more	Modified	2	1-4.5
Less than 1 year No concerns Minimum difference of refractive error between both eyes that requires prescribing:	Hyperopia of +2.50DS or more	NA	6.5	3.5-8
	Astigmatism of -2.50DC or more (oblique)	NA	5	3.5-6.75
	Astigmatism of -2.50DC or more (not oblique)	NA	5	3.5-5.75
	Astigmatism of -2.50DC of more (oblique)	Full	7	2-8
	Myopia of -4.00DS or more	Modified	7.5	5-9
	Hyperopia of +2.50DS or more	Modified	7	4.25-8.5
	Astigmatism of -2.50DC or more (oblique)	Modified	7	4.25-7.75
Less than 1 year Vision reduced Minimum difference of refractive error between both eyes that requires prescribing:	Myopia of -4.00DS or more	NA	6	5-7.75
	Hyperopia of +2.50DS or more	NA	8	4.25-9
	Astigmatism of -2.50DC or more (oblique)	NA	8.5	4.25-9
	Astigmatism of -2.50DC or more (not oblique)	NA	7.5	3.75-8.75
	Myopia of -4.00DS or more	Full	7	3.75-8.75
	Hyperopia of +2.50DS or more	Full	6	2.25-6.75
	Astigmatism of -2.50DC or more (oblique)	Full	6.5	3.5-8.5
	Astigmatism of -2.50DC or more (not oblique)	Full	6	5-6
	Myopia of -4.00DS or more	Modified	7.5	7-8
	Hyperopia of +2.50DS or more	Modified	8	6.25-8
	Astigmatism of -2.50DC or more (oblique)	Modified	7	6.25-8
	Astigmatism of -2.50DC or more (not oblique)	Modified	7.5	7-8
1-2 years No concerns	Astigmatism of -2.50DC or more (oblique)	Full	5	4-6.75
	Myopia of -4.00DS or more	Modified	7	4.75-9
	Hyperopia of +5.00DS or more (with no strabismus)	Modified	7.5	4.75-9
	Astigmatism of -2.50DC or more (oblique)	Modified	7	7-7.75
	Astigmatism of -2.50DC or more (not oblique)	Modified	7	6-7
1-2 years Vision reduced	Myopia of -2.00DS or more	Full	6.5	5-7.75
	Hyperopia of +5.00DS or more (with no strabismus)	Full	7	5.25-7.75
	Astigmatism of -2.50DC or more (oblique)	Full	6.5	5.25-7
	Astigmatism of -2.50DC or more (not oblique)	Full	6	5-7
	Myopia of -4.00DS or more	Modified	7	2.25-8.75
	Hyperopia of +5.00DS or more (with no strabismus)	Modified	7	4-8.75
	Astigmatism of -2.50DC or more (oblique)	Modified	6.5	6-7.75
	Astigmatism of -2.50DC or more (not oblique)	Modified	6.5	6-7.75
1-2 years Constant esotropia	Hyperopia of +2.00DS or more	Full	9	9-9
	Hyperopia of +2.00DS or more	Modified	2	1-6.25
1-2 years No concerns Minimum difference of refractive error between both eyes that requires prescribing:	Myopia of -3.00DS or more	NA	6.5	3.25-8
	Astigmatism of -2.00DC or more (oblique)	NA	5	4-6
	Myopia of -3.00DS or more	Full	8.5	6.5-9
	Hyperopia of +2.00DS or more	Full	8	6.5-9
	Astigmatism of -2.00DC (oblique)	Full	7	6.25-8.75
	Astigmatism of -2.00DC (not oblique)	Full	7	6.25-8.75

	Hyperopia of +2.00DS or more	Modified	7.5	3-8.75
	Astigmatism of -2.00DC or more (not oblique)	Modified	6.5	2-8.75
1-2 years Vision reduced Minimum difference of refractive error between both eyes that requires prescribing:	Myopia of -3.00DS or more	NA	7	3.5-7
	Hyperopia of +2.00DS or more	NA	7	2.25-7
	Astigmatism of -2.00DC (oblique)	NA	8.5	5.25-9
	Astigmatism of -2.00DC (not oblique)	NA	7	7-8
	Myopia of -3.00DS or more	Full	7	6-8
	Astigmatism of -2.00DC (oblique)	Full	4	3.25-6.5
	Astigmatism of -2.00DC (not oblique)	Full	5	4.25-7
	Hyperopia of +2.00DS or more	Modified	5	3-8
2-3 years No concerns	Myopia of -3.00DS or more	Full	7.5	4.75-9
	Hyperopia of +4.50DS or more (with no strabismus)	Full	7.5	4-8
	Astigmatism of -2.00DC or more (oblique)	Full	7	5.25-8
	Hyperopia of +4.50DS or more (with no strabismus)	Modified	9	6-9
	Astigmatism of -2.00DC or more (oblique)	Modified	8.5	5.5-9
	Astigmatism of -2.00DC or more (not oblique)	Modified	8	7.25-9
2-3 years Vision reduced	Myopia of -3.00DS or more	Full	8	6.25-9
	Hyperopia of +4.50DS or more (with no strabismus)	Full	6.5	3.75-7
	Astigmatism of -2.00DC or more (oblique)	Full	6.5	5.25-7
	Astigmatism of -2.00DC or more (not oblique)	Full	6	5-6.75
	Astigmatism of -2.00DC or more (oblique)	Modified	5	2.25-6.5
	Astigmatism of -2.00DC or more (not oblique)	Modified	5	2.25-6.5
2-3 years Constant esotropia	Hyperopia of +1.50DS or more	Full	9	9-9
	Hyperopia of +1.50DS or more	Modified	2	1-4.5
2-3 years No concerns Minimum difference of refractive error between both eyes that requires prescribing:	Astigmatism of -2.00DC or more (oblique)	NA	5	4.25-7.25
	Myopia of -3.00DS or more	Full	9	3.5-9
	Astigmatism of -2.00DC or more (oblique)	Full	7	3-8.75
	Astigmatism of -2.00DC or more (not oblique)	Modified	8.5	4-9
2-3 years Vision reduced Minimum difference of refractive error between both eyes that requires prescribing:	Myopia of -3.00DS or more	NA	8	4-9
	Hyperopia of +1.50DS or more	NA	7.5	6-9
	Astigmatism of -2.00DC or more (oblique)	NA	6	5.25-7.75
	Astigmatism of -2.00DC or more (not oblique)	NA	9	8-9
	Myopia of -3.00DS or more	Full	8	7-8.75
	Hyperopia of +1.50DS or more	Full	8	8-8.75
	Astigmatism of -2.00DC or more (oblique)	Full	8	7.25-8.75
	Astigmatism of -2.00DC or more (not oblique)	Full	5	4-7.5
	Myopia of -3.00DS or more	Modified	3	2-8.75
3-4 years No concerns	Myopia of -2.50DS or more	Full	8.5	5.5-9
	Astigmatism of -1.50DC or more (oblique)	Full	6	5-7.75
	Myopia of -2.50DS or more	Modified	9	7-9
	Hyperopia of +3.50DS or more (with no strabismus)	Modified	8	5-9
	Astigmatism of -1.50DC or more (oblique)	Modified	8	7.25-8
3-4 years Vision reduced	Myopia of -2.50DS or more	Full	8	7-8
	Hyperopia of +3.50DS or more (with no strabismus)	Full	3	1-6.25
	Astigmatism of -1.50DC or more (oblique)	Full	6.5	1.75-7
	Astigmatism of -1.50DC or more (not oblique)	Full	6	4.25-7
	Astigmatism of -1.50DC or more (oblique)	Modified	3	2-6.25
3-4 years Constant esotropia	Hyperopia of +1.50DS or more	Full	9	8.25-9
	Hyperopia of +1.50DS or more	Modified	2	1.25-8
3-4 years No concerns Minimum difference of refractive error between both eyes that requires prescribing:	Myopia of -2.50DS or more	Full	7.5	3-9
	Astigmatism of -1.50DC or more (oblique)	Full	6.5	3-8.5
	Astigmatism of -1.50DC or more (not oblique)	Full	8	4-9
	Hyperopia of +1.50DS or more	Modified	7.5	4-9
	Astigmatism of -1.50DC or more (oblique)	Modified	9	5.75-9
	Astigmatism of -1.50DC or more (not oblique)	Modified	8	7-9
3-4 years Vision reduced Minimum difference of refractive error between both eyes that requires prescribing:	Myopia of -2.50DS or more	NA	8	6.25-9
	Hyperopia of +1.50Ds or more	NA	9	7.5-9
	Astigmatism of -1.50DC or more (oblique)	NA	8	8-9
	Astigmatism of -1.50DC or more (not oblique)	NA	9	8-9
	Myopia of -2.50DS or more	Full	8.5	8-9
	Hyperopia of +1.50DS or more	Full	5	1.75-7.25
	Astigmatism of -1.50DC or more (oblique)	Full	4	2.25-5
	Astigmatism of -1.50DC or more (not oblique)	Full	4	3-5
	Myopia of -2.50DS or more	Modified	2	1-4.75

Round 1: Qualitative data

Table 4.7. *Summary of qualitative data obtained during round one for different age groups and whether there was a visual concern when prescribing refractive error.*

Age	Visual concern	Sample quotes	Comments
Less than 1 year	No concerns	*"In most cases should vision be at normal range - for a child under 1yrs of age, I would most likely monitor the child regularly between 8-12 weeks and prescribe when needed."*	Statements that achieved consensus was based on them being inappropriate prescribing statements.
		"I do not prescribe glasses in children under one unless the refractive error is very high and visual behaviour is poor. A refractive error of over 5 (more than or equal to -5.00D) can be 6 or 16. If it is very high, I do give a prescription with reduction of two dioptres."	
Less than 1 year	Constant esotropia Hyperopia of +2.00DS or more	*"It all depends on the cover test results. This should be checked before cyclo to determine how much plus eliminates the esotropia. Exceptionally, full plus could change an esotropia to an exotropia."*	An agreement was obtained that the full prescription should be given, and a consensus was also obtained that giving a modified prescription would be inappropriate in this situation.
		"Esotropia –Full plus."	
		"I would always try full plus as first-line management in an esotropic infant. But if the hypermetropia was mild (2-3D) and it made no difference to the control of the deviation, I might allow the parents to discard glasses for a while if they were finding them difficult. Then refract again after 6 months and see how emmetropisation is going, then make another decision."	
		"Prescribing depends on the child's milestones and development and associated comorbidities. In a child developing normally otherwise, I would not prescribe for 3 DS but prescribe a 7DS or more."	
Less than 1 year	Vision reduced	*"I would probably repeat refraction another day before feeling confident to prescribe in this young age group."*	Consensus was obtained on statements that the prescribing recommendations were inappropriate.
		"I would reassess within 6 months and, depending on emmetropisation trajectory, might adjust the prescription. I would generally give full sphere but might under correct cyls a little at first - but in practice, if you are giving a baby glass, why not the full correction? At these high levels of error, emmetropisation is probably not active, and if they cannot be emmetropic, why give a partial correction?"	
Less than 1 year	Minimum difference of refractive error between both eyes that require prescribing	*"I would prescribe full myopic correction whether there is a difference between the eyes or not. I would correct the cyl (adjusted if the sphere is reduced). I may reduce a hyperopia prescription but always correct the difference between the eyes."*	Agreement on the prescribing recommendations was attained.

		"The prescription of glasses depends on how the parents accept the diagnosis and their willingness to try the prescription for the child. In the area where I am, most patients are socially deprived and have multiple children and are not keen to try glasses. I would prescribe if the child is closer to one and was cooperative for the tests and I have a reliable refraction and vision results."	
1-2 years	Constant esotropia	*"Depends on the effect of proposed Rx on the cover test result, and at this age stereoacuity."*	Consensus was obtained that giving the full hyperopic (+2.00DS or more) prescription is appropriate, and a modified prescription would be inappropriate.
		I would give full prescription to help alleviate any accommodation esotropia."	
		"Full plus in esotropia regardless of age."	
1-2 years	Vision reduced	*"I would be less likely to partial prescribe if VA is poor or BV issues."*	An agreement was obtained on prescribing the full or modifying the prescription is appropriate in clinical situations where emmetropisation has not occurred.
		"If the astigmatism was part of a more complex error with myopia/hypermetropia too, I might give the full sphere, but if the astigmatism was emmetropising in relation to earlier refraction, I might continue to under correct the cyl component. Also depends on whether I have seen the child before and whether they show any sign of emmetropisation - if they do, then maybe under correct, if not, why give an under-correction?"	
1-2 years	Reduced vision Minimum difference in refractive error between both eyes that require prescribing	*"But norms at this age have very wide confidence intervals, so often very difficult to be sure VA is reduced on only one visit. Also, as before, astigmatism does not usually occur in isolation, so the decision to prescribe is more nuanced - depends on emmetropisation trajectory, combination of cyl/sphere, VA, parental attitude, and sometimes just gut feeling."*	An agreement was obtained on the level of refractive error that should warrant prescribing; however, prescribing astigmatic correction in full or a hyperopic prescription was deemed inappropriate.
		"If there is anisometropia and vision is reduced in the eye with high refractive error, I prescribe the full difference. I never prescribe the full myopic or hyperopic prescription to both eyes at the first visit for a child between 1 and 2 years of age."	
2-3 years	Vision reduced	*"Would prescribe hyperopia over 3.5D."*	An agreement was obtained that prescribing the full hyperopic and astigmatic prescription is appropriate.
		"Generally, at this age, I would give what they need. If emmetropisation is going to happen or is mainly over, if they still have a refractive error, give the full prescription because if they haven't emmetropised by now, they probably won't."	
		"If vision is reduced in a three year old with no strabismus, I prescribe full for a hyperope and under correct a myope. I do not reduce the prescription by half but reduce it by a dioptre. In my experience this allows the child the adapt to the	

		prescription. I can always increase the prescription to full if vision does not come up."	
2-3 years	Constant esotropia	*"Depends on how much plus and its effect on cover test and stereo."* *"Full plus in the presence of SOT."* *"Always try full plus. With small errors, abandon if they do not achieve control and VA is good."*	An agreement has been obtained that prescribing hyperopia of +1.50DS or more in full is appropriate, and a modified prescription is inappropriate.
2-3 years	Reduced vision Minimum difference in refractive error between both eyes that require prescribing	*"When there is difference between the eyes and vision is reduced, I try to prescribe the full in a 3 year old."* *"Again, it depends if pure cyl or with additional sphere, but if I decide to give glasses, then why not the full correction, because emmetropisation is not really an issue by this age."*	An agreement was gained on the level of refractive error warranting prescribing and prescribing the full refractive error deemed appropriate.
3-4 years	Vision reduced	*"Why give them an under-correction? emmetropisation will have happened (so not an issue), or not (and probably won't), why leave them with blurred VA?"* *"I would reduce the prescription by 0.5 to 1D depending on the level of refractive error and the level of reduction of vision. If vision is reduced a lot, I would prescribe the full."*	An agreement was found regarding prescribing astigmatic prescription in full being appropriate when prescribing refractive correction. However, prescribing the full hyperopic is inappropriate.
3-4 years	Constant esotropia	*"Esotropia – always give full plus."* *"In a child with esotropia, I might consider prescribing a full prescription to see if this would help. I would not give a partial correction."*	An agreement was obtained that a full hyperopic prescription of +1.50DS or more is appropriate and modifying the prescription is inappropriate.
3-4 years	Reduced vision Minimum difference in refractive error between both eyes that require prescribing	*"If the child needs glasses, at this age, I don't see the point of partial corrections."* *"If it is in the eye with the high refractive error, I would give the full prescription. If the anisometropia is very high, I would under correct to avoid image size disparity. Give a maximum difference of up to 4.0 dioptres. If it is anymore, I discuss contact lens."*	An agreement was found regarding the level of refractive error that warrants prescribing. Therefore, consensus on prescribing hyperopia and astigmatism in full was deemed to be appropriate.

Round Two

There was a 100% response rate for round two, which was conducted from 9th November to 19th November 2020. *Table 4.8* shows the prescribing statements and the corresponding scores at the end of round two. The second-round questionnaire consisted of 51 statements, and the participants' responses were highly reliable (α=0.878). The average ICC was 0.672 with a 95% confidence interval from 0.53-0.79 (F (50,450) =3.337, p <0.001). The panel deemed that nine statements were appropriate and 13 inappropriate. The qualitative data obtained from round two are presented in *Table 4.9*. Statements that did not reach consensus were carried through to the following round.

Table 4.8. *Results from round two highlighting the statements that reached consensus as appropriate or inappropriate as recommendations for paediatric refractive prescribing (pink= inappropriate with a median score of ≤5 and green= appropriate with a median score of ≥6).*

Age	Prescribing recommendation (DS= Dioptre Sphere, and DC= Dioptre Cylinder)	Prescribing amount	Median score (9= strongly agree)	Inter-quartile range (IQR)
Less than 1 year No concerns	Myopia of -5.00DS or more	Full	3	3-5
	Astigmatism of -3.00DC or more (oblique)	Full	3	3-4.75
Less than 1 year No concerns Minimum difference of refractive error between both eyes that requires prescribing:	Myopia of -4.00DS or more	NA	4	3-5
	Myopia of -4.00DS or more	Full	6.5	5-7.75
	Hyperopia of +2.50DS or more	Full	7	5.25-7.75
1-2 years No concerns	Astigmatism of -2.50DC or more (not oblique)	Full	4	3.25-5
1-2 years Vision reduced Minimum difference of refractive error between both eyes that requires prescribing:	Hyperopia of +2.00DS or more	Full	8.5	7.25-9
1-2 years No concerns Minimum difference of refractive error between both eyes that requires prescribing:	Astigmatism of -2.00DC or more (oblique)	Modified	6	5-6
2-3 years No concerns Minimum difference of refractive error between both eyes that requires prescribing:	Hyperopia of +1.50DS or more	Full	6	4.25-7
	Astigmatism of -2.00DC or more (not oblique)	Full	6	5-7
2-3 years Vision reduced Minimum difference of refractive error between both eyes that requires prescribing:	Astigmatism of -2.00DC or more (oblique)	Modified	4	3-5.75
	Astigmatism of -2.00DC or more (not oblique)	Modified	4	3-5.75
3-4 years No concerns	Astigmatism of -1.50DC or more (not oblique)	Full	6	5-6
	Astigmatism of -1.50DC or more (not oblique)	Modified	6	4.25-6
3-4 years Vision reduced	Myopia of -2.50DS or more	Modified	2	1.25-3
	Hyperopia of +3.50DS or more (with no strabismus)	Modified	3	2-4
	Astigmatism of -1.50DC or more (not oblique)	Modified	2	2-3
3-4 years No concerns Minimum difference of refractive error between both eyes that requires prescribing:	Myopia of -2.50DS or more	NA	6.5	5.25-7.75
	Myopia of -2.50DS or more	Modified	3	1.25-4.75
3-4 years Vision reduced Minimum difference of refractive error between both eyes that requires prescribing:	Hyperopia of +1.50DS or more	Modified	3	2-4
	Astigmatism of -1.50DC or more (oblique)	Modified	3	2-3.75
	Astigmatism of -1.50DC or more (not oblique)	Modified	3	2-3.75

Round 2: Qualitative data

Table 4.9. *Summary of qualitative data obtained during round two for different age groups and whether there was a visual concern when prescribing refractive error.*

Age	Visual concern	Sample quotes	Comments
Less than 1 year	No concerns	*"If visions are normal and cyls above 2.50DC, would monitor closely."*	An agreement was gained regarding prescribing myopia greater than -5.00DS or oblique astigmatism of-3.00DC or more is inappropriate.
		"In any case where no risk factors have been detected, there are no binocular vision anomalies or ocular pathology present, and the vision is within normal range to an age-matched norm, I would not prescribe a full prescription under the age of 1 years of age. I would, however, prescribe partial prescription taking special consideration for oblique cyls."	
		"I would still not prescribe before the age of one unless the refractive error is very high."	
Less than 1 year	No concern Minimum difference of refractive error between both eyes requires prescribing	*"For the question on hyperopia, again, the answer depends on the cover test results, stereo, etc. For the question on 2DC, the answer depends on how far below norms the vision is. If far below norms, I would be more inclined to prescribe the full cyl. If only marginally below norms, I would partially correct."*	An agreement was achieved regarding prescribing hyperopia of +2.50DS or more or prescribing the astigmatic correction.
		"Full Cyls in reduced visions"	
1-2 years	No concern	*"When vision and binocular vision are normal, I would not be tempted to prescribe."*	The expert panellists agreed that prescribing astigmatism of -2.50DC or more in full is inappropriate.
		"At this age, prescribing specs is warranted however, if the vision is within normal limits in both eyes, then I would be inclined to give a partial correction only - not full."	
1-2 years	Vision reduced Minimum difference of refractive error between both eyes requires prescribing	*"I would always give full correction if the child had not shown signs of emmetropisation - so I would give glasses, but not a partial correction."*	There was agreement found that hyperopia of +2.00DS or more should be prescribed in full.
2-3 years	Vision reduced Minimum difference of refractive error between both eyes requires prescribing	*"As children get older, I would always give full correction - unless there is a clear trend for emmetropisation. If there is not, they probably can't emmetropise - so why give a partial correction?"*	Consensus was found that prescribing a refractive correction by modifying an astigmatic prescription in this situation would be inappropriate.
		"I would be more inclined to prescribe at these ages whether the vision is reduced or not however, again, I would not prescribe in full. I would correct the anisometropia in full but would adjust the myopia/hyperopia as required for age."	
3-4 years	Vision reduced	*"Would not give partial corrections - if they have not emmetropised, they probably can't."*	There was agreement among the panellists that giving the child a modified refractive error at this age would be inappropriate if there is reduced vision.
		"If vision is down in this age, a full correction is what I would give."	
3-4 years	Vision reduced Minimum difference of refractive error between both eyes requires prescribing	*"Would always give full correction in this case."*	An agreement was obtained that modifying a prescription before prescribing a refractive correction in this situation would be inappropriate.
		"I would always correct the full anisometropia and astigmatism but only partially correct the hyperopia or myopia according to age in the case where amblyopia is present."	

Round Three

The final round, which also had a 100% response rate, was conducted from 30th November to 15th December 2020. The questionnaire included 29 statements; the reliability was found to be questionable (α=0.62). The average ICC was 0.51 with a 95% confidence interval from 0.21-0.73 (F (28,252) =2.09, p=0.002). The panel consensus deemed that one statement was appropriate, and 25 statements were inappropriate (*Table 4.10*). Those statements that did not meet consensus criteria were excluded after this final round. The qualitative data gathered during round three are shown in *Table 4.11*.

Table 4.10. *Results from round three highlighting the statements that reached consensus as either appropriate or inappropriate refractive error correction recommendations (pink= inappropriate with a median score of ≤5 and green= appropriate with a median score of ≥6).*

Age	Prescribing recommendation (DS=Dioptre Sphere, and DC=Dioptre Cylinder)	Prescribing amount	Median score (9= strongly agree)	Interquartile range (IQR)
Less than 1 year No concerns	Astigmatism of -3.00DC or more (not oblique)	Full	4.5	4-5
	Hyperopia of +6.00DS or more (with no strabismus)	Modified	5	5-6
	Astigmatism of -3.00DC or more (not oblique)	Modified	6	5-6
1-2 years No concerns	Hyperopia of +5.00DS or more (with no strabismus)	Full	5	3.5-5
1-2 years No concerns Minimum difference of refractive error between both eyes that requires prescribing:	Hyperopia of +2.00DS or more	NA	4.5	4-5
	Astigmatism of -2.00DC or more (not oblique)	NA	5	4.25-5
	Myopia of -3.00DS or more	Modified	4	3.25-4
1-2 years Vision reduced Minimum difference of refractive error between both eyes that requires prescribing:	Myopia of -3.00DS or more	Modified	5	4-5.75
	Astigmatism of -2.00DC or more (oblique)	Modified	5	4.25-5.75
	Astigmatism of -2.00DC or more (not oblique)	Modified	5	5-5.75
2-3 years No concerns	Astigmatism of -2.00DC or more (not oblique)	Full	5	4-6.75
	Myopia of -3.00DS or more	Modified	5	3.25-6
2-3 years Vision reduced	Myopia of -3.00DS or more	Modified	3	2.25-3
	Hyperopia of +4.50DS or more (with no strabismus)	Modified	3.5	3-4.75
2-3 years No concerns Minimum difference of refractive error between both eyes that requires prescribing:	Myopia of -3.00DS or more	NA	5	4.25-6.75
	Hyperopia of +1.50DS or more	NA	5	4.25-5.75
	Astigmatism of -2.00DC or more (oblique)	NA	5	5-5.75
	Myopia of -3.00DS or more	Modified	4.5	2.5-5
	Hyperopia of +1.50DS or more	Modified	5	5-5.75
	Astigmatism of -2.00DC or more (oblique)	Modified	5.5	4.25-6
2-3 years Vision reduced Minimum difference of refractive error between both eyes that requires prescribing:	Hyperopia of +1.50DS or more	Modified	3.5	3-4.75
3-4 years No concerns	Hyperopia of +3.50DS or more (with no strabismus)	Full	5.5	4.25-6
3-4 years No concerns Minimum difference of refractive error between both eyes that requires prescribing:	Hyperopia of +1.50DS or more	NA	5	5-6
	Astigmatism of -1.50DC or more (oblique)	NA	5	5-6
	Astigmatism of -1.50DC or more (not oblique)	NA	5	4.25-5.75
	Hyperopia of +1.50DS or more	Full	5	5-6.5

Round 3: Qualitative data

***Table 4.11**. Summary of qualitative data obtained during round three for different age groups and if there was a visual concern or not when prescribing refractive error.*

Age	Visual concern	Sample quotes	Comments
Less than 1 year	No concern	*"I replied cautiously to the hyperopia question because I would probably give the full correction if I gave anything."*	An agreement was obtained that prescribing a modified prescription for hyperopia of +6.00DS or more is inappropriate.
1-2 year	No concern	*"Hyperopic children do not often accommodate fully over their error, so no reason to undercorrect*	An agreement was obtained that highlighted prescribing hyperopia of +5.00DS or more in full would be appropriate.
1-2 years	Vision reduced Minimum difference of refractive error between both eyes requires prescribing	*"With the last two astigmatism questions, if the reduced vision is not severe, I would typically start with a partial correction, but monitor closely and increase the correction if the VA does not improve."*	An agreement was attained that refractive errors of hyperopia of +2.00Ds or more, astigmatism of -2.00DC or more are inappropriate difference in refractive error between eyes that warrants prescribing. Likewise, if there is a difference of myopia of -3.00DS or more between both eyes, it would be inappropriate to prescribe a modified prescription.
		"Depends on the progress of any emmetropisation. In practice, I would repeat in a few months and, if not emmetropsing, would then give full correction. If they are not emmetropising, why give a partial correction."	
		"I would prescribe the full anisometropia if amblyopia is already present. If there is no amblyopia, I would consider a reduced anisometropic prescription and prescribe for astigmatism and spherical error according to age. If amblyopia can be demonstrated to be absent, a prescription is not necessary."	
2-3 years	Vision reduced	*"Depends on the level of VA reduction."*	The expert panellists agreed that a modified myopic prescription of -3.00DS or more or hyperopia of +4.50DS or more would be inappropriate.
		"If amblyopia is present, I would consider full correction at this age."	
		"I would prescribe, full rather than partial."	
2-3 years	Vision reduced Minimum difference of refractive error between both eyes requires prescribing	*"Generally, do not favour partial corrections. Monitor emmetropisation, and if not emmetropising, give full correction."*	Myopia of -3.00DS or more, hyperopia of +1.50DS or more or astigmatism of -2.00DC or more (oblique) should not be the minimum amount required and is inappropriate. In addition, prescribing a modified myopic or hyperopic prescription in this situation is inappropriate.
		"I disagreed because I would give the full correction if glasses were to be given."	
3-4 years	Vision reduced Minimum difference of refractive error between both eyes requires prescribing	*"A near full correction may be given at this age, as emmetropisation has essentially ended..."*	An agreement has been found that the minimum difference between both eyes that warrants prescribing for hyperopia (+1.50DS) and astigmatism (-1.50DC) is inappropriate. In addition, prescribing a hyperopic refractive error difference of +1.50DS or more in full has been deemed inappropriate.

After the final round, three statements did not achieve consensus, shown in *Table 4.12.*

***Table 4.12**. Prescribing statements that did not obtain consensus after the final round of the Delphi study.*

Age	Prescribing recommendation (DS=Dioptre Sphere, and DC=Dioptre Cylinder)	Prescribing amount	Median (9=strongly agree)	IQR
Less than 1 year No concern	Astigmatism of -2.50DC or more (not oblique)	Full	5.5	4.25-6
Less than 1 year No concern	Astigmatism of -2.50DC or more (not oblique)	Modified	5.5	5-6
1-2 years No concern	Myopia of -4.00DS or more	Full	5.5	4.25-6.75

Some of the comments obtained from the expert panel members are shown below:

Less than 1 year

"I would prescribe partial refractive error when vision is normal. I would give partial cyl correction up to 3 to 4 years by which time emmetropisation is largely completed."

"I would still be waiting till the child is over 12 months before I prescribe. It also depends on how much more is. If the astigmatism is above 3 dioptres, I would prescribe before the age of one. I have noticed that parents struggle when we prescribe the glasses very early. I work in a place where the socioeconomic issues including young mothers with very little support with multiple children. Once the early months of glass wear become a problem, it is permanently a problem. So, unless the refractive error is very high (over 4 dioptres above the expected norm), I rarely prescribe before the age of one."

1-2 years

"For the myope, it depends on the discussions with the parents about their attitude to myopia control and the family history. For the hypermetrope, prescribing the full cyclo plus would cause many children to be over-plussed and either to not use the glasses or to look over the top. In other words, this could be counter-productive."

"I would not prescribe full refractive error where vision is within normal range and where emmetropisation has not completed."

"If vision is normal, I would keep a close watch on the vision rather than prescribe."

A comparison between the professionals and how their responses changed from round one to round two and then from round two to round three is presented in *Tables 4.13 and 4.14*

***Table 4.13.** The response change (yes= change in response, no= no change in response) from round one to round two for each professional group.*

Professional	Age group			
	Less than 1 years	*1-2 years*	*2-3 years*	*3-4 years*
Optometrists	No (z=-0.610, p=0.542)	Yes (z=-2.494, p=0.013)	Yes (z=-2.639, p=0.008)	Yes (z=-2.755, p=0.006)
Orthoptists	No (z=-1.786, p=0.074)	No (z=-1.891, p=0.059)	No (z=-1.749, p=0.08)	No (z=-1.615, p=0.106)
Ophthalmologists	No (t_{19}=0.309, p=0.761)	Yes (z=2.160, p=0.031)	No (z=0.218, p=0.827)	No (z=-1.325, p=0.185)

Table 4.14. *The response change (yes= change in response, no= no change in response) from round two to round three for each professional group.*

Professional	**Age group**			
	Less than 1 years	*1-2 years*	*2-3 years*	*3-4 years*
Optometrists	No (z=-1.622, p=0.105)	Yes (z=-2.013, p=0.044)	Yes (z=-2.471, p= 0.013)	No (z=-0.112, p=0.911)
Orthoptists	Yes (t_9=-2.449, p=0.037)	No (z=-0.577, p=0.564)	No (t_{21}=-1.164, p=0.257)	No (z=-0.577, p=0.564)
Ophthalmologists	No (z=1.890, p=0.059)	No (z=1.848, p=0.065)	No (z= 0.106, p=0.916)	No (z=-1.134, p=0.257)

Tables 4.15, 4.16, 4.17, 4.18 below highlight the different refractive error correction statements that have been agreed upon as appropriate to prescribe with the strength of agreement (median score) addressed with each prescribing recommendation.

Table 4.15*. Outcome table for infants less than one year of age showcasing prescribing recommendations that are appropriate to consider when prescribing refractive correction (one= strongly disagree, nine= strongly agree).*

Age and scenario	**Prescribing recommendation (DS=Dioptre Sphere, and DC=Dioptre Cylinder)**	**Prescribing amount**	**Median score**
Less than 1 year Vision Reduced	Astigmatism of -3.00DC or more (oblique)	Full	6
Less than 1 year No visual concerns	Astigmatism of -3.00DC or more (not oblique)	Modified	6
Less than 1 year Constant esotropia	Hyperopia of +2.00DS or more	Full	9
Less than 1 year No visual concerns Minimum difference of refractive error between both eyes that requires prescribing:	Hyperopia of +2.50DS or more	NA	6.5
	Hyperopia of +2.50DS or more	Full	7
	Hyperopia of +2.50DS or more	Modified	7
	Myopia of -4.00DS or more	Full	6.5
	Myopia of -4.00DS or more	Modified	7.5
	Astigmatism of -2.50DC or more (oblique)	Full	7
	Astigmatism of -2.50DC or more (oblique)	Modified	7
Less than 1 year Vision reduced Minimum difference of refractive error between both eyes that requires prescribing:	Hyperopia of +2.50DS or more	NA	8
	Hyperopia of +2.50DS or more	Full	6
	Hyperopia of +2.50DS or more	Modified	8
	Myopia of -4.00DS or more	NA	6
	Myopia of -4.00DS or more	Full	7
	Myopia of -4.00DS or more	Modified	7.5
	Astigmatism of -2.50DC or more (oblique)	NA	8.5
	Astigmatism of -2.50DC or more (not oblique)	NA	7.5
	Astigmatism of -2.50DC or more (oblique)	Full	6.5
	Astigmatism of -2.50DC or more (not oblique)	Full	6
	Astigmatism of -2.50DC or more (oblique)	Modified	7
	Astigmatism of -2.50DC or more (not oblique)	Modified	7.5

Table 4.16. *Outcome table for infants between one-two years of age showcasing prescribing recommendations that are appropriate to consider when prescribing refractive correction (one= strongly disagree, nine= strongly agree).*

Age and scenario	**Prescribing recommendation (DS=Dioptre Sphere, and DC=Dioptre Cylinder)**	**Prescribing amount**	**Median score**
1-2 years No visual concerns	Hyperopia of +5.00DS or more (with no strabismus)	Modified	7.5
	Myopia of -4.00DS or more	Modified	7
	Astigmatism of -2.50DC or more (oblique)	Modified	7
	Astigmatism of -2.50DC or more (not oblique)	Modified	7
1-2 years Vision reduced	Hyperopia of +5.00DS or more (with no strabismus)	Full	7
	Hyperopia of +5.00DS or more (with no strabismus)	Modified	7
	Myopia of -2.00DS or more	Full	6.5
	Myopia of -4.00DS or more	Modified	7
	Astigmatism of -2.50DC or more (oblique)	Full	6.5
	Astigmatism of -2.50DC or more (not oblique)	Full	6
	Astigmatism of -2.50DC or more (oblique)	Modified	6.5
	Astigmatism of -2.50DC or more (not oblique)	Modified	6.5
1-2 years Constant esotropia	Hyperopia of +2.00DS or more	Full	9
1-2 years No visual concerns Minimum difference of refractive error between both eyes that requires prescribing:	Hyperopia of +2.00DS or more	Full	8
	Hyperopia of +2.00DS or more	Modified	7.5
	Myopia of -3.00DS or more	NA	6.5
	Myopia of -3.00DS or more	Full	8.5
	Astigmatism of -2.00DC (oblique)	Full	7
	Astigmatism of -2.00DC (not oblique)	Full	7
	Astigmatism of -2.00DC or more (oblique)	Modified	6
	Astigmatism of -2.00DC or more (not oblique)	Modified	6.5
1-2 years Vision reduced. Minimum difference of refractive error between both eyes that requires prescribing:	Hyperopia of +2.00DS or more	Full	8.5
	Hyperopia of +2.00DS or more	NA	7
	Myopia of -3.00DS or more	NA	7
	Myopia of -3.00DS or more	Full	7
	Astigmatism of -2.00DC (oblique)	NA	8.5
	Astigmatism of -2.00DC (not oblique)	NA	7

Table 4.17. *Outcome table of young children between two and three years of age showcasing prescribing recommendations that are appropriate to consider when prescribing refractive correction (one= strongly disagree, nine= strongly agree).*

Age and scenario	**Prescribing recommendation (DS=Dioptre Sphere, and DC=Dioptre Cylinder)**	**Prescribing amount**	**Median score**
2-3 years No visual concerns	Hyperopia of +4.50DS or more (with no strabismus)	Full	7.5
	Hyperopia of +4.50DS or more (with no strabismus)	Modified	9
	Myopia of -3.00DS or more	Full	7.5
	Astigmatism of -2.00DC or more (oblique)	Full	7
	Astigmatism of -2.00DC or more (oblique)	Modified	8.5
	Astigmatism of -2.00DC or more (not oblique)	Modified	8
2-3 years Vision reduced	Hyperopia of +4.50DS or more (with no strabismus)	Full	6.5
	Myopia of -3.00DS or more	Full	8
	Astigmatism of -2.00DC or more (oblique)	Full	6.5
	Astigmatism of -2.00DC or more (not oblique)	Full	6
2-3 years Constant esotropia	Hyperopia of +1.50DS or more	Full	9
2-3 years No visual concerns Minimum difference of refractive error between both eyes that requires prescribing:	Hyperopia of +1.50DS or more	Full	6
	Myopia of -3.00DS or more	Full	9
	Astigmatism of -2.00DC or more (not oblique)	Full	6
	Astigmatism of -2.00DC or more (oblique)	Full	7
	Astigmatism of -2.00DC or more (not oblique)	Modified	8.5
2-3 years Vision reduced Minimum difference of refractive error between both eyes that requires prescribing:	Hyperopia of +1.50DS or more	NA	7.5
	Hyperopia of +1.50DS or more	Full	8
	Myopia of -3.00DS or more	NA	8
	Myopia of -3.00DS or more	Full	8
	Astigmatism of -2.00DC or more (oblique)	NA	6
	Astigmatism of -2.00DC or more (not oblique)	NA	9
	Astigmatism of -2.00DC or more (oblique)	Full	8

Table 4.18. *Outcome table for young children between three to four years of age showcasing prescribing recommendations that are appropriate to consider when prescribing refractive correction (one= strongly disagree, nine= strongly agree).*

Age and scenario	**Prescribing recommendation (DS=Dioptre Sphere, and DC=Dioptre Cylinder)**	**Prescribing amount**	**Median score**
3-4 years No visual concerns	Hyperopia of +3.50DS or more (with no strabismus)	Modified	8
	Myopia of -2.50DS or more	Full	8.5
	Myopia of -2.50DS or more	Modified	9
	Astigmatism of -1.50DC or more (oblique)	Full	6
	Astigmatism of -1.50DC or more (not oblique)	Full	6
	Astigmatism of -1.50DC or more (not oblique)	Modified	6
	Astigmatism of -1.50DC or more (oblique)	Modified	8
3-4 years Vision reduced	Myopia of -2.50DS or more	Full	8
	Astigmatism of -1.50DC or more (oblique)	Full	6.5
	Astigmatism of -1.50DC or more (not oblique)	Full	6
3-4 years Constant esotropia	Hyperopia of +1.50DS or more	Full	9
3-4 years No visual concerns Minimum difference of refractive error between both eyes that requires prescribing:	Hyperopia of +1.50DS or more	Modified	7.5
	Myopia of -2.50DS or more	NA	6.5
	Myopia of -2.50DS or more	Full	7.5
	Astigmatism of -1.50DC or more (oblique)	Full	6.5
	Astigmatism of -1.50DC or more (not oblique)	Full	8
	Astigmatism of -1.50DC or more (oblique)	Modified	9
	Astigmatism of -1.50DC or more (not oblique)	Modified	8
3-4 years Vision reduced Minimum difference of refractive error between both eyes that requires prescribing:	Hyperopia of +1.50DS or more	NA	9
	Myopia of -2.50DS or more	NA	8
	Myopia of -2.50DS or more	Full	8.5
	Astigmatism of -1.50DC or more (oblique)	NA	8
	Astigmatism of -1.50DC or more (not oblique)	NA	9

DISCUSSION

Prescribing refractive error correction in children is conducted by an optometrist and by some ophthalmologists however, previous research shows discrepancies in prescribing practices within and between these professions (Farbrother, 2008; He et al., 2004). Clinical guidelines can provide evidence-based recommendations for practitioners to use when managing patients. The use of guidelines also potentially allows for consistency within the professions. This study aimed to appraise the available paediatric spectacle prescribing guidelines and obtain consensus among professionals regarding their recommendations. The Delphi technique has highlighted agreement on certain levels of myopia, hyperopia and astigmatism that should be considered to be prescribed to children less than 1 years, 1-2 years, 2-3 years, and 3-4 years. These findings can be used in clinical practice when examining and managing young children.

A total of five clinical guidelines met the inclusion criteria. However, only one (the Pediatric Eye Evaluations Preferred Practice Pattern) was found to be of high quality, achieving a high score in five of the six AGREE II domains. The median percentage score calculated for four of the six domains was below 30% from the eligible guidelines. The lowest scoring domains were 'Stakeholder Involvement', 'Rigour of Development', 'Applicability', and 'Editorial Independence'. A score of below 30% in these domains is of concern, reflecting problems in the guideline development process. The appraisal process found no patients' engagement in forming the selected clinical practice guidelines. The areas identified are important as practitioners need to have confidence in the clinical guidelines. Overall, the development of the existing clinical guidelines was poor.

This study's findings and prescribing refractive error recommendations can be adapted for practitioners working in primary or secondary eyecare settings. In addition, the results could enable training and development for all paediatric eyecare professionals by helping practitioners decide when to prescribe refractive error correction and, therefore, allow consistency. This study highlights a gap and a need for high-quality guidelines to be developed to assist in prescribing refractive error correction in children. However, developing high-quality guidelines requires time, expertise, and resources.

Of the 168 prescribing refractive correction recommendation statements used in the Delphi study, 95 statements were deemed appropriate prescribing recommendations to consider when prescribing refractive correction, and 70 statements were classified as inappropriate. This exercise shows the extent to which current paediatric spectacle prescribing guideline recommendations are considered appropriate by paediatric eye care providers. Variations in prescribing patterns between practitioners (Farbrother, 2008; He et al., 2004) may be due to differences in training programmes and the practitioners' experiences. However, current guidelines do not suggest additional information (e.g., vision, cover test results, family ocular history) as prescribing refractive error in children can be a case-by-case decision. For example, when managing myopic children, a modified or full correction may be prescribed depending on the degree of myopia and the child's family ocular history, parents' attitude towards spectacles and myopia control, and the practitioners' preference and prior experience. Current evidence suggests that under correcting myopia can lead to further progression (Yazdani et al., 2021). Members of the expert panel deemed that prescribing very high myopic prescriptions in children less than 1 years of age should be modified by "2 dioptres". This undercorrection is supported by literature that suggests emmetropisation does occur for myopes (Leat, 2011; Ehrlich et al., 1995; Gwiazda et al., 1993). Improvements in guidelines could help reduce variations in clinical decisions and provide consistency amongst professionals when prescribing refractive error correction. The present qualitative and quantitative findings suggest that the current resources available to help practitioners make evidence-based decisions when managing refractive errors in children require further work and improvement.

This study has highlighted that the Delphi technique is suitable for obtaining autonomous expert opinions. Although the prescribing statements used during the Delphi study were extracted from an existing guideline, the expert panellists had the opportunity to add further comments to where they would make refinements. An advantage was that the expert panel consisted of a multi-disciplinary team with a wide range of experience in paediatric eyecare. However, it is acknowledged that the purposive and convenience sampling strategies used to select the expert panellists may have led to hidden bias. Therefore, to produce validated guidance, further consultation would be needed with the relevant stakeholders (e.g., College of Optometrists and the Royal College of Ophthalmologists) in the future to develop a cross-disciplinary guideline.

STRENGTHS AND LIMITATIONS

One of the strengths of the current study was the comprehensive search for eligible clinical practice guidelines. In addition, the critical appraisal stage was conducted independently by two researchers using a well-known appraisal tool (AGREE II) which has been established and validated for the use of evaluating guidelines (The AGREE Collaboration, 2003).

It has been acknowledged that the sampling methods employed to select and form the expert panel may have led to hidden bias. However, efforts to minimise bias were made by ensuring the expert panel consisted of a multidisciplinary team, and all members had extensive experience in paediatric eyecare.

The use of only two researchers during the critical appraisal phase of the study could also be a limitation. However, the initial selection of statements were based on a critical appraisal technique using a robust tool highlighting which guidelines are of high quality. Furthermore, during the Delphi study, the expert panel members had the opportunity to refine the statements by highlighting which recommendations they deemed clinically appropriate.

The online approach for the Delphi technique could perhaps be regarded as a potential limitation. However, online Delphi studies have been identified as successful (Greenhalgh et al., 2011). Furthermore, due to the pandemic (COVID-19) limiting face-to-face interaction, this approach was most suitable. It has been reported that there is no evidence on the reliability of the Delphi method (Hasson et al., 2000). However, due to the lack of information available to ensure methodological rigour, Hasson et al. (2000) recommend that the Lincoln and Guba (1985) evaluation criteria should be applied to the Delphi study. Therefore, by assessing the findings with this qualitative criterion, the findings are credible due to the participants' type, and anonymity allowed participants to be as open as possible. The findings are applicable to all healthcare settings the professional may be in (primary/ secondary) where the management of a child's refractive error is required. The researcher's neutrality and statistical analysis of each round show's signs of reliability as the findings were shaped purely by the participant's confirmability.

CONCLUSION

The results suggest that the current manner in which existing guidelines have been developed for refractive correction in paediatric eyecare is not robust. The application of the AGREE II instrument successfully demonstrated the variability in the quality of the guidelines. The 23- items used to evaluate the quality of guidelines can be used to help improve the methodology and development of guidelines in the future. Despite the fact that guidelines often present conflicting recommendations that can result in a varied approach to clinical care, the AGREE II quality appraisal highlighted several key areas that require improvement, particularly the domains 'Stakeholder Involvement', 'Rigour of Development', 'Applicability', and 'Editorial Independence'. The quality assessment of the guidelines shows significant variability. The Delphi technique has further emphasised the gap and need for developing a prescribing refractive correction guideline. This study demonstrates that the Delphi technique is a suitable method for gaining autonomous expert opinions. The approach has led to highlighting prescribing refractive correction statements from a high-quality guideline that are clinically acceptable. An evidence-based guideline approach will allow coordination amongst the training and development of practitioners involved in paediatric eyecare.

5. AN EXPLORATION OF COMMUNITY EYECARE FOR CHILDREN: IDENTIFYING BARRIERS AND ENABLERS USING A GROUNDED THEORY APPROACH

BACKGROUND

Children's access to paediatric primary eyecare across England has been found to depend on their age (*See Chapter One and the findings for Study One see Chapter Two*). Over a decade later, there is still limited accessibility for young children (*Study One- see Chapter Two*), even with continuous education resources to help optometrists feel more confident and competent in examining young children.

The barriers and enablers that impact the accessibility of primary and secondary eyecare for individuals at risk of developing avoidable sight loss due to diabetic retinopathy in the UK have been touched upon (Hayden, 2012). The main barriers to accessing primary care services included limited community awareness of eye health, symptom-led presentation for an eye examination, and the cost and retail elements associated with primary care (Hayden, 2012). Findings from study one (*see Chapter Two*) touch upon existing barriers, restricting eye examination to young children.

The National Screening Committee (2019) recommends that children in the UK aged between four and five years undergo vision screening which is an orthoptic led service (*See Chapter One and Two*). Vision screening is delivered inconsistently within the UK (*See Chapter One*), resulting in a failure to detect and treat vision disorders (Cassetti et al., 2019). Identifying conditions such as amblyopia, strabismus, and uncorrected refractive error allows treatment to be initiated during the period in which the visual system is sensitive (*see Chapter One*), improving the prognosis (de Zoete, 2007). In addition, there is evidence to suggest that once a child has failed their vision screening appointment, the attendance rates for the follow-up eye examination vary significantly, ranging between 27%-95% attendance (Griffiths et al., 2018). The lack of follow-up is thought to be influenced by factors such as lack of awareness of the importance of eye health, conflicting family needs, socio-cultural background, or economic conditions (Touch and Berg, 2016; Shickle and Farragher, 2014; Gower et al., 2013; Patel et al., 2006). Addressing the challenges within children's eyecare is of great importance due to the potential impact of a visual anomaly on a child's development (*See Chapter One and Two*). Therefore, identify any potential barriers that a clinician may experience which could impact the accessibility of eyecare to young children is important.

Literature has reported that the barriers clinicians face when examining children's eyes are due to a child's ability to communicate and their short attention span, the time-consuming nature of the task, a lack of training or insurance for clinicians, parents' lack of understanding and knowledge in eye health, and parents' concerns with false-positive referrals (Cassetti et al., 2019; Kemper and Clark, 2006). However, developing trust and effective communication is essential in children's eyecare as this can have implications on subsequent visits and compliance with any management required (Cassetti et al., 2019). When performing an eye examination, children are frequently unable to express how well they can see or carry out an accurate subjective refraction. Children may become bored and or tired, demanding additional clinical effort to gain the same information (Cassetti et al., 2019). In younger patients' examinations are regularly incomplete. As a direct results multiple visits are required to obtain a reliable diagnosis, rendering each eye test inefficient in terms of both examination duration and overheads (Cassetti et al., 2019). Further barriers to children's eyecare include the use of diagnostic drops (Cassetti et al., 2019) however, it has been found that professionals can be confident in instilling

cycloplegic drops and are not discouraged by the length of the procedure or the possible side effects of the drops (Doyle et al., 2019). Cycloplegic drops are expensive in terms of both their direct and indirect costs from the additional examination time required to ensure that the children are sufficiently dilated (*See Chapter Three*). Finally, drops are potentially problematic as they are an invasive and sometimes traumatic procedure (*See Chapter Three*).

In 2015, the UK College of Optometrists launched their 'Eyes on our Future' campaign to help raise awareness about children's eyes and their visual development amongst parents and carers, so they are able to detect the signs and symptoms that are vision-related and understand the importance of regular sight tests (College of Optometrists, 2015). Research has already shown that demographics such as ethnicity, parental income, parental education, and confidence with speaking English have the potential to limit children's access to eyecare (Donaldson et al., 2018). Furthermore, this survey revealed that out of the 65% of responses from parents who came from an area with a vision screening programme in place, only 15% of parents were aware of its existence. This work suggests that whilst we are starting to understand some of the parents and guardians' barriers to eyecare in the UK, researchers have not explored the barriers amongst optometrists who work in primary eyecare settings (Cassetti et al., 2019; Little and Saunders, 2015; Solebo et al., 2015; Toufeeq and Oram, 2014; Bruce and Outhwaite, 2013).

Optometrists are the main primary eyecare providers. They work within the community by assessing the health and refractive states of the patient's eyes and referring them to the hospital eye service if required (*See Chapter One*). Therefore, understanding an optometrist's perspective can help explain how and why access to eyecare for young children is not as easily accessible and how it can be facilitated.

AIM

This study aimed to understand the barriers and corresponding enablers when examining young children within a primary care setting from the perspectives of qualified practising optometrists in the UK.

METHODS

FOCUS GROUP

A focus group discussion (FGD) is a "research technique that collects data through group interaction on a topic determined by the researcher" (Morgan, 1996). Focus groups are thought to be a flexible and cost-effective way of exploring attitudes, experiences, and responses (Sofaer, 2002). A FGD can be used independently or in combination with other research methods, including collecting quantitative data (Morgan, 1996).

Some potential limitations can arise from a FGD. A dominant person may control the discussion while the remaining group members remain silent, making it challenging to infer whether a specific viewpoint is an individual or group opinion. On the other hand, an individual's behaviour can also influence group dynamics. Depending on the sample size, it can be difficult to generalize the findings depending on how many participants provided the relevant information (Litoselliti, 2003). It has been suggested that focus groups do not have a pre-determined sample size and are carried out until data saturation is reached (Francis et al., 2010), which is when no new additional information is gained during data collection (Glaser and Strauss, 1967) (discussed further in section: data saturation). Due to the limitations of using focus groups to collect data, the modified nominal group technique (discussed later) was adapted, and a facilitator was present to help facilitate the discussion. Details regarding the importance of a facilitator will be elaborated on further in this chapter.

FOCUS GROUP SETTING

The focus group was conducted in a quiet environment where the participants felt comfortable and had no external disturbances. The discussion was held in the participants' privacy, allowing for a confidential discussion.

The focus group took place on Microsoft Teams Version 1.3 (Microsoft Corporation, 2017). According to Microsoft, "Teams is built on the Office 365 hyper-scale, enterprise-grade cloud, delivering the advanced security and compliance capabilities our customers expect" (Microsoft, 2020a). Microsoft Teams provides privacy and security controls that control who can participate in the focus group and access the focus group information and data (Microsoft, 2020b). This platform was used in conjunction with a Dictaphone to allow audio recording only after gaining consent from the participants. Each focus group was conducted at a pre-arranged date and time slot (details to follow), convenient to all participants and the facilitator. All participants were informed when the audio recording began. The recording was only accessible to the principal researcher. The recordings were stored in a password-protected locked folder.

ONLINE /VIRTUAL FOCUS GROUPS

Virtual methods have been developed and piloted to allow online focus group discussions to be an appropriate alternative to the traditional model of face-to-face focus groups (Woodyatt et al., 2016; DuBois et al., 2015). In addition, online focus group discussions allow the inclusion of diverse participants from widespread geographical locations (Reisner et al., 2018). Another advantage of an online focus groups is that the participants are not concerned with travel or related costs. In addition, the researcher does not need to find a physical space to hold a confidential meeting (Reid and Reid, 2005).

One of the disadvantages of this method is the limited access to nonverbal cues, possibly leading to a misunderstanding or missed body language (Denscombe 2017; Mann and Stewart, 2000). This was overcome by using video conferencing. However, participants were allowed to turn their video cameras off if they wished to, so any limitation in gaining additional information was noted. It has also been highlighted that the lack of physical presence may limit the control over the interaction during the discussion resulting in possible diversion from the research topic (Underhill and Olmsted, 2003). This problem was addressed by adopting a modified version of the nominal group technique to ensure the facilitator-maintained control. Comparisons have been made between focus groups which were conducted in the traditional face-to-face manner to those conducted online and the quality and quantity of the data obtained is broadly comparable (Underhill and Olmsted, 2003; Schneider et al., 2002; Campbell et al., 2001).

NOMINAL GROUP TECHNIQUE

The nominal group technique is a qualitative data collection method that enables a group to generate and prioritise many issues using a structure that gives everyone an equal voice (Van de Ven and Delbecq, 1972). It has been used in varying health contexts to generate ideas and allow groups to reach a consensus on barriers and facilitators to health practices (Suttle et al., 2015; Dreer et al., 2013; Nicklas et al., 2013). A brief description of the steps and how they were implemented are enclosed in *Table 5.1.*

Table 5.1. *Steps undertaken during the focus group using the nominal group technique.*

Nominal Group Technique Steps	Descriptions
Introduction	The facilitator (SJW) started the focus group discussion with an introduction and recapped the aim of the discussion. Then, there was an icebreaker during which all participants introduced themselves. The researcher (SW) was available at the time of the focus group if the participants needed to contact someone for any technical queries.
Silent generation of ideas in writing	The facilitator asked the participants to think of possible difficulties when examining young children in practice; each participant was given approximately two to five minutes to write down or think of difficulties independently in the context of their work setting. The facilitator ensured that all participants were engaged in the tasks. When everyone seemed ready, a request was made to the participants to stop writing so that the discussion could commence.
Round-Robin listing	The challenges reported by the optometrists were via discussion. The facilitator went around and asked each participant to ensure they had contributed and mentioned problems/challenges/barriers they experienced.
Discussion of ideas	The facilitator guided the discussion on the factors that had been identified to ensure that the identified barriers were clarified and to allow further elaboration on these. This opportunity allowed participants to explain their opinion. Moreover, this discussion stage helped new factors emerge that were not identified during the round-robin stage. However, the facilitator did have prompt questions categorised into themes based on relevant published findings (Cassetti et al., 2019; Kemper and Clark, 2006) and the researcher's professional experience working in a community setting.
Ranking barriers in order of importance	After the discussion, the facilitator then advised the participants to prioritise all the barriers discussed in order of importance. The participants then each stated their top two or three barriers.
Discussion of the vote	In a modified nominal group technique, the participants were asked to list possible enablers for the barriers identified in the earlier stage of the discussion. Once the responses had been obtained and discussed, the facilitator ensured everyone had taken part.
Discussion	The facilitator then led another discussion in which the participants could clarify and elaborate on their suggested enablers.
Conclusion of Nominal Group Meeting	The discussion regarding the barriers and possible enablers ended once the participants had no more points to discuss or share. The facilitator asked the participants if they would like to add any more factors that were not identified previously in the discussion.

CONSOLIDATE CRITERIA FOR REPORTING QUALITATIVE RESEARCH (COREQ)

The Consolidated Criteria for Reporting Qualitative Research (COREQ) was also followed to help report important elements from the study (Tong et al., 2007). The COREQ checklist was developed to help conduct and report qualitative studies (Tong et al., 2007). Research has shown that checklists have improved the quality of reporting studies (Delaney et al.,2005; Moher et al., 2001). The COREQ checklist consists of 32 items (Tong et al., 2007). The COREQ criteria were considered in the study design (*Table 5.2*).

Table 5.2. *The Consolidated Criteria for Reporting Qualitative Research (COREQ): a 32-item checklist (Tong et al., 2007).*

Domain	Topic	Details
Domain 1 **Research team and reflexivity**	Personal characteristics	1. *Interview/facilitator* - Which author/s conducted the interview or focus group? 2. *Credentials*- What were the researcher's credentials (e.g., PhD, MD)? 3. *Occupation*- What was their occupation at the time of the study? 4. *Gender*- Was the researcher male or female? 5. *Experience and training*- What experience or training did the researcher have?
	Relationship with participants	6. *The relationship established*- Was a relationship established before study commencement? 7. *Participant's knowledge of the interviewer*- What did the participants know about the researcher? e.g., personal goals, reasons for doing the research. 8. *Interviewer characteristics*- What characteristics were reported about the interviewer/facilitator? e.g., Bias, assumptions, reasons, and interests in the research topic.
Domain 2 **Study design**	Theoretical framework	9. *Methodological orientation and theory*- What methodological orientation was stated to underpin the study? e.g., grounded theory, discourse analysis, ethnography, phenomenology, content analysis.
	Participant selection	10. *Sampling* – How were the participants selected? e.g., purposive, convenience, consecutive, snowball. 11. *Method of approach*- How were participants approached? e.g., face-to-face, telephone, mail, email. 12. *Sample size*- How many participants were in the study? 13. *Non- participation*- How many people refused to participate or dropped out? Reasons?
	Setting	14. *The setting of data collection*- Where was the data collected? e.g., home, clinic, workplace. 15. *Presence of non-participants*- Was anyone else present besides the participants and researchers? 16. *Description of the sample*- What are the essential characteristics of the sample? e.g., demographic data, date.
	Data collection	17. *Interview guide*- Were questions, prompts, guides provided by the authors? Was it piloted? 18. *Repeat interviews*- Were repeat interviews carried out? If yes, how many? 19. *Audio/visual recording* – Did the research use audio or visual recording to collect the data? 20. *Field notes*- Were field notes made during or after the interview or focus group? 21. *Duration* – What was the duration of the interviews or focus group? 22. *Data saturation* – Was data saturation discussed? 23. *Transcripts returned*- Were transcripts returned to participants for comment or correction?
Domain 3 **Analysis and findings**	Data analysis	24. *The number of data coders*- How many data coders coded the data? 25. *Description of the coding tree*- Did the authors describe the coding tree? 26. *Derivation of themes*- Were themes identified in advance or derived from the data? 27. *Software*- What software, if applicable, was used to manage the data? 28. *Participant checking* - Did participants provide feedback on the findings?
	Reporting	29. *Quotation present*- Were participant quotations presented to illustrate the themes/findings? Was each quotation identified? e.g., participant number. 30. *Data and findings consistent*- Was there consistency between the data presented and the findings? 31. *Clarity of major themes*- Were the most frequent themes presented in the findings? 32. *Clarity of minor themes*- Is there a description of the least frequent themes?

ETHICAL APPROVAL

The optometry proportionate review committee at City, University of London (Appendix 5.0) granted ethical approval for this study. All procedures in this study were in accordance with City, University of London ethical standards and conformed to the tenets of the Declaration of Helsinki. Written informed consent was obtained from all participants included in this study.

DURATION

The duration of each focus group meeting is a maximum of 90 minutes. Data collection occurred from November 2020 to January 2021.

PILOT STUDY

The discussion was audio-recorded during the pilot study to allow a trial run of coding information after transcription. One of the pilot study analysis purposes was to provide the researchers with a coding exercise and code independently. In addition, the pilot study allowed the online platform to be trailed and tested. This is important to validate the accessibility, stability, and privacy of the software. The pilot study allowed feedback

from the participants regarding the timing and the context of the discussion. This informed the main study's data collection process, and feedback obtained was used for the sub sequential focus groups.

PARTICIPANTS

The focus groups consisted of registered and practising optometrists in England working in a community (multiple or independent) setting. The choice of exploring the perspective of optometrists in a community setting rather than exploring primary and secondary eyecare is based on research that demonstrates that there is limited accessibility for children among community optometric practices (Swystun and Davey, 2020; Doyle et al., 2019; Shah et al., 2007). This study required participants to be a minimum age of 21 years, with the intent of ensuring all participants who are qualified have an opportunity of participating with varying degrees of experience. This increased the odds in those who could volunteer, resulting in information-rich groups. Those identified participants were verified against the General Optical Council (GOC) register to ensure they met the inclusion criteria (registered and practicing optometrists in a community setting) before obtaining consent and confirming participation.

SAMPLING

Focus group data are not generalisable beyond the groups involved (Harrell and Bradley, 2009). Therefore, to allow some form of generalisability, it is important to have a structured sampling method to allow a widespread of participants to be representation (Harrell, 1999). Purposive sampling was applied to ensure that all participants met the inclusion criteria (described above) and that each focus group had a good mixture of experiences (employment and paediatric eyecare). Data collection and sampling continued until data saturation (discussed in section: data saturation) was reached. Additional sampling methods such as snowballing, where existing participants spread the word to future participants, and emailing the Local Optical Committee (LOC) to advertise the study via email were used. This multi-collection approach avoided a common limitation of the sampling methods, such as introducing selection bias. As the focus groups were conducted, purposive sampling helped fill potential limitations in the selected sample by acting on the feedback obtained from the discussion by ensuring practitioners with various experiences were included.

It has been recommended that between 6-12 participants constitute a focus group (Lasch et al., 2010), however there are no set rules. Despite there are no rules on the number of participants per focus group, as a small sample is likely to limit the dynamics of the discussion, while a large sample may prevent full engagement by all individuals (Harrell and Bradley, 2009). The sample size for the pilot study consisted of five participants (initially, six had been recruited, and five attended the discussion as there was a last-minute drop out). These participants did not take part in the main study. Allowing a sample of six to eight participants would counterbalance any last-minute attrition and ensure the behaviour and interaction of individuals during the focus groups and data collection process is unaffected.

For the main study, participants who expressed interest were sent an invitation letter, participant information leaflet, and consent form. Contact details of the researcher were enclosed in both the participant information sheet and invitation letter. The potential participants were contacted three days after sending the invitation email to ensure they had received the information and to address any queries that may have arisen. The invitation letter stated that if, after one week, no response had been received, the researcher will note that this as the participant has decided not to participate in the study. If no response had been received after one week, another participant was invited. Consenting participants were asked to send a signed copy of the consent form to the researcher by email. Those participants who consented to participate in the study were sent a demographic questionnaire to complete before the focus group commenced. The demographic questionnaire gathered participants' age, work setting, and further qualifications (Appendix 5.2). Each participant was also sent a calendar poll to find a date and time that was convenient for all. Once the focus group was arranged, details and a link to join the online focus group were sent to each participant along with the guidance document (Appendix 5.1) (information on and the structure of the discussion). A reminder email was sent a week before the scheduled date of the focus group to optimise attendance.

FACILITATOR

During a focus group, the role of a facilitator is of great importance in facilitating the discussion (Litosseliti, 2003; Morgan, 1996). The facilitator guides the group discussion but has no participation (Krueger, 1998). Instead, the role of the facilitator is to moderate, to ensure the relevant research question is being addressed and that the participants are in a comfortable environment and to pay attention to the participants' responses, body language, and to encourage all participants to take part in the discussion (Krueger and Casey, 2015; Litosseliti, 2003; Krueger, 1998). The facilitator was a person with the appropriate credentials and experience they have vast experience in facilitating focus groups and can lead and communicate group tasks. The facilitator has experience in qualitative research and conducting focus group discussions and group activities. This was important as during the focus group, there can be situations whereby the facilitator may need to mitigate the influence of certain participants who may be heavily influencing the group discussion (Stewart and Shamdasani, 2014; Morgan and Krueger, 1998). When obtaining consent, the principal researcher informed the participants of the aim of the research and who will be facilitating the discussion. The same person facilitated all focus groups (Mirbaha et al., 2015).

TOPIC GUIDE

The topic guide was based on findings of previous studies on the accessibility of eyecare for young children, the researchers' professional experience, and the feedback gained from the pilot study (Appendix 5.3). Questions and scenarios were developed to encourage brainstorming and help facilitate the reporting of barriers. The research team reviewed the topic guide to ensure the questions and scenarios were appropriate and credible. The pilot study was also used to test run the topic guide and make changes accordingly.

DATA COLLECTION

All discussions within the focus groups were audio-recoded (with permission and consent) and transcribed fully, using a naturalistic approach. Every utterance was transcribed in as much detail as possible. In addition to audio-recording, data were also collected via email from one participant who emailed the researcher the next day regarding a barrier that came to mind the following day and was copied into the transcript. The researcher (SW) conducted the transcription with the help of Microsoft Speech Services, which was verified to ensure every utterance had been transcribed. If the facilitator identified any non-verbal cues related to the issues being discussed, they were noted. For instance, when consensus on a particular barrier or enabler has been reached amongst participants, or whether there may be a disagreement. Once the researcher checked the accuracy of the transcript, the data were imported into NVivo 12 (QSR-International., 2018) for data management and analysis. NVivo software can allow various forms of data to be managed, including text, audio, video, pictures, and internet resources. This software allows the annotation of large amounts of data in an organised fashion and allows memos to be added where needed, the latter involving notes to preserve ideas about the data (Charmaz, 2006). This software can be used to manage coded transcripts so that the conceptual relationships across different focus groups could be identified and keywords could be counted. This allows systematic, efficient coding and complex analyses (Appendix 5.4). Transcripts were entered into NVivo Version 12 software (https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/support-services/nvivo-downloads) for data storage and management.

DATA SATURATION

To determine whether data saturation had been met, the principles for deciding saturation in qualitative studies outlined in Francis et al., 2010 were followed. Data saturation was checked as each focus group was completed. Notes were made, and after each focus group, any vital topic and the frequency of the topic was documented (Brod et al., 2009). A second coder (supervisor: CS) was also part of the research team and coded the information independently, establishing consensus (Brod et al., 2009). Sampling and recruitment continued until data saturation had been reached and no new theme was generated from the data (Fusch and Ness, 2015).

It is recommended that there should be a minimum of three focus groups (Atkins et al., 2017). Francis et al. (2010) suggests that when establishing data saturation, one should consider the size of the initial sample that will be analysed (a priori) and establish a stopping criterion which is how many more rounds are required to be conducted without any new themes or ideas emerging. Based on current literature (Francis et al., 2010), the stopping criterion was tested after each successive focus group until there were three successive focus groups where no additional information was developing.

DATA ANALYSIS

A grounded theory approach was used. It has been reported to be suitable when exploring areas of interest that have not been previously investigated, need to be explored in greater depth or from a different perspective (Strauss and Corbin, 1998). The approach aims to discover theory from data systematically obtained from qualitative research (Glaser and Strauss, 1967), so the theory is grounded in the data collected. Therefore, a theoretical explanation of the topic of interest being explored can be obtained from the data. The grounded theory consists of a chosen research area and a developed research question. The research question is used to collect data which leads to an inductive mode of investigation as the analysis is driven by the data, which will then become deductive near the end of the research when comparisons are made to existing knowledge.

The symbolic interactionism approach of the grounded theory was adopted (Corbin and Strauss, 2008). Therefore, the analysis assumes that the experience of optometrists examining children in community settings is a combination of examining a young child, previous experience, background, beliefs, culture, and values. This combination means optometrists attach to their experience and, therefore, how they react to it. Whilst the openness and reduced risk of bias found in the classic approach introduced by Glaser is attractive, this symbolic interactionism approach was chosen due to the principal's researcher's background. This approach is logical and systematic and was thought to be most appropriate. Furthermore, the symbolic interactionism approach enabled the researcher to hold more credibility and encourage optometrists and the profession to adopt the findings. This is essential as this research study aims to identify key issues and help initiate a drive for service change. Therefore, the findings need to be in a format valued by the target audience. It is, therefore, exploratory, descriptive, and ultimately theory generating, not theory verifying.

The method of participants reviewing transcripts has a relatively small impact on the accuracy of the transcript (Hagens et al., 2009). Participants reviewing transcripts and ensuring confidentiality was maintained was considered. Therefore, the transcripts were not sent back to the participants for verification or additional comments. The transcripts were analysed using thematic analysis to identify, analyse, and report themes and patterns within the data (Braun and Clarke, 2006). The steps for the analysis of the data were as follows (Braun and Clarke,2020, 2006):

Phase I: Data familiarisation and writing familiarisation notes.

During this phase, the data were transcribed, read only by the primary researcher, and re-read so the researcher could be immersed in the data, and there was active reading of the verbatim transcript. The facilitator was not provided with the transcript. During this process, the researcher noted potential initial codes. The data were transcribed, and the accuracy was rechecked against the recording.

Phase II: Systematic data coding.

Coding the data and recording data under relevant codes by analysing each sentence at a time. This allowed the entire transcript to be given equal attention as the coding process began. Two researchers coded each set of focus group transcripts independently, with the consensus reached by discussion.

Phase III: Generating initial themes from coded and collated data.

Collating codes into developing themes. Coding is a way of analysing and managing data where labels are assigned to varying amounts of text, highlighting what is of interest in the data. A theme groups codes into common patterns centred around a specific concept (Braun and Clark, 2006).

Phase IV: Developing and reviewing themes.

Ensuring that all the data in each theme were consistent and coherent with the classified theme. In addition, individual themes were checked to make sure they were based in accordance with the data set. If there were any disagreements between the coders, a third party (another researcher from the research team) would have been consulted however this did not need to occur.

Phase V: Refining, defining, and naming themes.

For each theme, a detailed analysis was undertaken to ensure its relation to the research question. This allowed themes to be identified as barriers or enablers to examining young children and ensured all themes were relevant to the research question.

Phase VI: Writing and reporting.

The data were analysed and interpreted. The themes that were identified as a barrier and or enabler relating to the research question and literature. A good balance of narratives is illustrated to support the interruption and findings from the data sets. Quotations were used anonymously and with consent to contextualise concepts identified in the data analysis. A link was made between the quotations and the findings. The major themes (most common with a high frequency of appearing in the data set) were presented and explained as well as the minor themes. After analysis, all participants received feedback regarding the study findings (Appendix 5.5). A word cloud was used during reporting to allow visual representation of the findings.

All stages of data analysis were supported by memoing. Memos were used to analyse the researcher's approach, views, and experience during coding to help explore codes and categories as they develop. Memoing was vital as it provided a written record of the decision making, ideas emerging, and areas that may need further exploration throughout. This process also provides a way of collating fragments of data back together to produce an emerging theory. During data analysis and memoing, as the researcher immersed themselves in the data, information regarding factors found in agreement, disagreement, and factors that optometrists emphasised were documented. Agreements and disagreements in the data sets were extracted via the memoing notes produced by the researcher.

RESULTS

PILOT FOCUS GROUP STUDY

The pilot study was 78 minutes in duration. From the feedback obtained from the pilot, study changes were made. Such as whereby naming two to three of their top barriers rather than reporting three, as participants found this challenging during the pilot study.

MAIN FOCUS GROUP STUDY

Five focus groups were conducted, consisting of 30 optometrists who worked in community settings and had varied experience and qualifications. Six of the optometrists were directors, and one participant taught at university level and worked in a community setting. *Table 5.3* shows the demographic details of the participants.

Table 5.3. *Demographic details of the optometrists who participated in the main focus group study*.

Demographic characteristics	Frequency (n)	%
Age (years)		
20-24	1	3.33
25-34	11	36.67
35-44	5	16.67
45-54	5	16.67
55-65	6	20
over 65	2	6.67
Additional qualifications		
Professional Certificate Paediatric Eye Care	2	6.06
Professional Higher Certificate Paediatric Eye Care	0	0
MSc	2	6.06
PhD	0	0
Other:	16	48.48
DipTp (IP)	4	
DipGlauc	2	
Dip CLP	2	
Prof Cert Glauc	7	
Prof Cert Low Vision	1	
Prof Cert Med Ret	5	
None	13	39.39
Main practice setting[i]		
Small Multiple (up to 10 practices)	3	10
Large Multiple	13	43.33
Independent	14	46.67
HES	0	0
Experience in working in a paediatric clinic in a hospital		
Yes	9	30
No	21	70
Contact with young children as patients		
Daily	9	30
Every 1-2 weeks	8	26.67
Monthly	12	40
Yearly	0	0
No contact	1	3.33
Geographical location of participants		
Essex	6	20
Lymington	1	3.33
Birmingham	1	3.33
London	4	13.33
Perivale	1	3.33
Hemel Hempstead	3	10
Hereford	1	3.33
Lincoln	1	3.33
Grantham	1	3.33
Axbridge	1	3.33
Towcester	1	3.33
Buckinghamshire	1	3.33
Congleton	1	3.33
Sheffield	1	3.33
Plymouth	1	3.33
Chichester	1	3.33
Portsmouth	1	3.33
Gosport	1	3.33
Watford	1	3.33
Reading	1	3.33
Experience examining		
A child who is < 12 months old		
Extensive experience (e.g., seen a child of this age at least once a day)	2	6.67
Good experience (e.g., seen a child of this age at least once a week)	1	3.33
Some experience (e.g., seen a child of this age at least once a month)	1	3.33
Little experience (e.g., seen a child of this age at least once a few times during the year)	15	50
No experience (e.g., have not seen a child of this age)	11	36.67
A child who is 12-24 months old		
Extensive experience (e.g., seen a child of this age at least once a day)	1	3.33
Good experience (e.g., seen a child of this age at least once a week)	2	6.67
Some experience (e.g., seen a child of this age at least once a month)	5	16.67

Little experience (e.g., seen a child of this age at least once a few times during the year)	13	43.33
No experience (e.g., have not seen a child of this age)	9	30
A child who is 2-4 years of age		
Extensive experience (e.g., seen a child of this age at least once a day)	4	13.33
Good experience (e.g., seen a child of this age at least once a week)	7	23.33
Some experience (e.g., seen a child of this age at least once a month)	11	36.67
Little experience (e.g., seen a child of this age at least once a few times during the year)	7	23.33
No experience (e.g., have not seen a child of this age)	1	3.33
A child who is 5 years of age and older		
Extensive experience (e.g., seen a child of this age at least once a day)	19	63.33
Good experience (e.g., seen a child of this age at least once a week)	10	33.33
Some experience (e.g., seen a child of this age at least once a month)	1	3.33
Little experience (e.g., seen a child of this age at least once a few times during the year)	0	0
No experience (e.g., have not seen a child of this age)	0	0

ǂ *Practice setting where a significant (>50%) time of the optometrists' working week is spent.*

Based on the focus group transcripts, a total of 1819 quotes were coded in 27 themes. Quotes that represented limitations to examining young children were classified as barriers and factors facilitating eye examination for young children as enablers.

A total of 15 barriers were reported relating to examining young children (younger than five years of age) in a community setting. The top five most common barriers found from the perspective of community optometrists are *'Behaviour', 'Professional skills', 'Funding', 'Timing'*, and *'Gap in services'*. Details of the major (most common) and minor (least common) barriers are presented in *Table 5.4,* and further details explaining each theme is to follow.

Table 5.4. *Barriers reported by community optometrists regarding eye examinations for young children (younger than five years of age). Ranked in order of highest frequency to lowest.*

Barriers	Frequency of theme in transcripts
Behaviour	90
Professional skills	88
Funding	76
Timing	45
Gap in services	42
Awareness	34
Equipment	27
Education and training	21
HES involvement	12
Communication	11
Professional body and structure	10
Child characteristics	8
Inequality	8
Environment	5
Covid-19	2

A total of 12 enablers were reported relating to examining young children (younger than five years of age) in a community setting. The top five most common enablers expressed by community optometrists were '*Accommodating', 'Improvement in training', 'Improving behaviour', 'Improving communication'* and '*New schemes'*. Details of the major and minor enablers are presented in *Table 5.5,* and further details explaining each theme is to follow.

***Table 5.5**. Enablers reported by community optometrists regarding eye examinations for young children (younger than five years of age). Ranked in order of highest frequency to lowest.*

Enabler	Frequency of theme in transcripts
Accommodating	70
Improvement in training	60
Improving behaviour	37
Improving communication	32
New schemes	19
Educating	18
Raise awareness	16
Enabling skills	16
Balancing commercial and health aspects	12
Changes in professional bodies	11
Improvement in resources	7
Improve funding	8

BARRIERS

From this study, numerous themes were identified that contribute as a barrier to examining young children in a community setting from the perspective of optometrists. A few of the optometrists' quotes are listed below for each theme.

Theme: Behaviour

Some optometrists indicated that they do not value taking the time to examine children and believe children should be referred elsewhere. Also, it has been reported that rules have been established regarding an age limit as to when a practice is willing to start examining young children.

Sample quotes:

> *"But sometimes it is just one too many. I've seen it in too many practices that they turn around and say to them, let's just refer them straight. Why are you seeing them? You're wasting my time, really…."*

> *"It was kind of a company policy, they kind of put out there, we wouldn't be able to see anyone under the age of four in that specific area."*

Theme: Professional skill

Concerns from optometrists point out that there is a lack of certain eye examination tests, which makes examining young children challenging as optometrists lose a level of prominence of specific skills.

Sample quotes:

> *"If I have been qualified for 20 years and have only used my retinoscope for 10 years, I probably won't be doing it* [if I've been practising for many years and haven't needed to perform retinoscopy the chances of me conducting retinoscopy on a child is small]*, and that is what a lot of the people in my practice are like. They don't have the confidence to test that young as they have not done it for 20 years."*

"… majority of optometrists actually are not cyclo refracting children, and it's really difficult to actually get an accurate prescription on a child so young, ... It is just not accurate. In my opinion."

"There are opticians, and there are shopticians. … some practices, whether they be multiples or independents, the number of cases I've seen with glasses where they shouldn't have been prescribed it in the first place. And that gives everybody a bad reputation that's something else."

"… it's crazy, … he said the quality of referrals that he was getting from the community was pitiable… an eight-year-old can't get a VA, no ret result, no cover test, no ophthalmology, and the same with younger children..."

Theme: Funding

Participants reported that the General Ophthalmic Services (GOS) eye examination fee does not adequately cover the time and cost involved in examining a young child who may need cycloplegic refraction or an early recall.

Sample quotes:

"One GOS fee…double the amount of chair time or triple amount of chair time if you take the cyclo time into effect..."

"While free eye exams are offered, the NHS can't pay us more for a sight test because it is clear that we are comparing ourselves to giving free sight test, so the NHS is saying if you are able to give free eye tests, why should we put up our NHS sight test fee …."

Theme: Timing

Optometrists expressed that in community settings, multiple practices, in particular, tend to give a shorter appointment period for young children, creating extra pressure on the optometrist, and that an additional appointment for cycloplegic refraction was discouraged.

Sample quotes:

"Some multiples that I've worked for…… haven't actually given the same amount of time … for example, 25 minutes for an adult and when it comes to a child …. 20 or sometimes 15 minutes."

"And it has happened to me in the past …. it's actually happened to other colleagues as well, where they say, you haven't seen enough patients to reach your target, or you have a lot of dilations or cyclos …, it's still said to you, as part of your review … having double appointments for children."

Theme: Gap in services

Optometrists identified a need for themselves, General Medical Practitioners (GMP), and health visitors to work more collaboratively. It has been identified that optometrist should work closely with these groups to ensure

that GMPs and health visitors are aware they can suggest to parents of young children to attend a community optometric practice for an eye examination. Despite vision screening programmes for school children, it does not replace a comprehensive eye examination.

Sample quotes:

> *"…it is not just optometrists in store that need to make this change. It is also everyone else. So, therefore, trying to get 3 different people, i.e., GP, healthcare, NHS, and the opticians, to kind of agree on something I think that is the biggest issue overall …."*

> *"I've seen a patient at five years old, for example, who slipped through the net of school screening but has amblyopia. And it's such a shame because we could do more if we see them sooner…."*

Theme: Awareness

Some comments suggest a lack of knowledge amongst parents regarding the importance of children's eyecare. It has also been indicated that optometrists feel the public do not perceive optometry as a healthcare profession.

Sample quotes:

> "*…I think a big issue is that not every parent is aware that they can come to the opticians if there is a visual issue, I think this is where there's not enough communication between the doctor, the optometrist..."*

> *"Optometry is seen as retail, and that's where the biggest problem lies……."*

Theme: Equipment

The optometrists expressed a lack of age-appropriate testing equipment available to use and examine young children, limiting their ability to conduct tests on very young children.

Sample quotes:

> *"…but also, don't think we have the equipment, not just for stereopsis. But for VA as well. If a child is not at the age to be able to communicate in terms of speaking, to do preferential looking or any other motions of VA, you just don't have that equipment."*

> *"…I mean, in my drawer, I literally just have an Ishihara and the stereo fly test, I don't really have much else. So that's definitely a limitation for me."*

Theme: Education and training

Optometrists indicated that the manner paediatric optometry is taught at university level and addressed during pre-registration year [training scheme that must be completed successfully to obtain a qualified optometrist's status] has led to them feeling they haven't been exposed to enough and subsequently do not feel confident examining young children.

Sample quotes:

> *"...I personally don't feel we had enough training at university or even during pre-reg, to see a lot of children who are under the age of five."*

> *"Oh, I agree you're taught by people who have not done it. For people lecturing…talk about it theoretically, they'll tell you all about visual development, but not how to welcome a child into the room and make them smile and play with them. So that's one barrier, the university."*

Theme: HES involvement

An optometrist expressed that a young child should first be seen within the hospital eye service to establish a baseline reading and ensure a comprehensive examination is undertaken. However, this was disputed as filtering all children into the hospital eye service will impact the time available for the hospital to treat those who have a visual condition needing treatment.

Sample quotes:

> *"If you decide to just refer a child to the hospital eye service, you already know how busy their schedules are. Children do not get seen for months and months on end, and soon as their appointments are due, they…get postponed again and again."*

> *"As a first appointment, I would probably vouch for the hospital more than the community only because you know that when the child is seen at the hospital, they will always be given that extra time to do their vision properly, and they will always do cycloplegic refraction."*

Theme: Communication

It was noted that communication between non-optical staff such as receptionists and parents of young children may be problematic and could result in young children not having their eyes examined.

Sample quotes:

> *"Well, at least you did see them twice. For most people. It is from the reception, they're referred into the hospital..."*

> *"I think it is so important because it is one of those things when one child is turned away because they are too young word gets around the school that children cannot be seen at that age. So, it deters other people getting their eye examinations…."*

Theme: Professional body and structure

Optometrists highlighted that the optical professional body guidance for primary eyecare services within the community settings has resulted in practitioners declining to offer services without initially attempting to examine the young child.

Sample quotes:

> *"…the way we get around that is the practitioner would say that there the GOC said if it is not in your sort of zone where you are comfortable with making a decision you should refer on to someone who is so, there would be no way to say to a practitioner that they must see someone if they weren't comfortable and confident..."*

> *"there is a lot of push for sales and reducing testing times and getting more money into the tills and you know getting more people trained up to be optometrists and reducing costs and … increasing student numbers. But there is no push for the things that really matter."*

Theme: Child characteristics

A few practitioners pointed out that a child's cognitive ability plays a role in whether eyecare services in the community are made accessible.

Sample quotes:

> *"…and the reason that they gave …they can't read the letters."*

Theme: Inequality

The participants reported that a young child might be offered different services in an independent practice within the community compared to a multiple practice.

Sample quotes:

> *"Actually, there seems to be a big difference between what happens in the private sector and what happens in the multiple sector."*

> *"I think we just got the hospital at the moment. Maybe some community or maybe some private optometrists* [optometrist working in an independent practice]*. So optical practices, but I don't think we have like a designated place where people can just go for paediatric eye tests other than the hospital."*

Theme: Environment

The optometrists felt that many optometric practices are not geared towards examining children. The testing room layout reportedly created a need for improvisation and adjustments to allow examination for young children.

Sample quotes:

> *"… sometimes you can't even get the child to see the letters on the chart without putting them on a booster seat or on the parents' lap. So, I think it's just the way that high streets are designed, where they're not really child friendly for really young children…it's just the equipment and how the room is set up."*

> *"… parents themselves do not see the practice in terms of being very child friendly. They are not going to essentially engage with the practitioner… say I am a parent of a 4-year-old, and can I bring them along with me to get my own eyes examined, but all I am seeing is glasses on sale for me or all of this equipment…."*

Theme: COVID-19

The Coronavirus disease has impacted eyecare services for young children. For example, school closure has resulted in many children missing out on vision screening services. In these cases, ocular conditions may be missed until later in life. Moreover, the professional guidance for eye examinations during the pandemic has limited availability of eyecare services. As a result, some optometrists feel that offering urgent care to young children may not be a high priority compared to other ocular conditions present in the rest of the population.

Sample quotes:

> *"… Last year, they may have been missed because of COVID, their school screening… so they're going to be six or seven, when they're picked up if they then catch up on the backlog that's two years in seeing worse, if that child had been told to go and see an optician independent of school screening before they went to school that would had been picked…."*

> *"We went college red guidance it was emergency care only …no child really needs an emergency refraction you could argue and now that we are in amber phase how much do we prioritise…."*

ENABLERS

In general, the optometrists expressed many positive solutions that can enable primary eyecare services to be more readily accessible for young children under the age of five years. Some of the optometrists' quotes are highlighted in italics below for each theme.

Theme: Accommodation

Practices have been shown to be very accommodating when it comes to examining young children. Some optometrists work in places that accommodate children of all ages and have adapted the layout of their practice and examination room to make children feel more comfortable.

Sample quotes:

"… we never turn them away. We never say they're too young, …would see anybody whether they were a three-week-old baby up to almost… whatever age really we never turned anyone away."

"So, if you can make access to eyecare a nice, friendly, happy event, and then that's definitely a positive for both and the families, as well as the child…."

Theme: Improvement in training

Optometrists reported that the paediatric eyecare teaching and supervision at undergraduate and pre-registration level leaves many optometrists lacking sufficient exposure and therefore lacking the confidence to examine young children. This results in a vicious circle resulting in less experience, impacting confidence, and reducing the number of optometrists willing to examine young children. It was suggested that education and training should be reviewed and improved to tackle possible issues to make optometrists feel more competent with as much experience as possible.

Sample quotes:

"I think if we can get them seeing more kids … maybe in a course or something so the newly qualified will feel comfortable seeing kids."

"I think it would be a fantastic idea if there was an ongoing CPD where you do have to see a certain number of children that are below the age of five…."

Theme: Improving behaviour

Suggestions were made to change the way optometrists feel about their occupation and practice to improve the accessibility of eyecare for young children among community practices.

Sample quotes:

"But sometimes, I think there ... does need to be some sort of … effort from optoms to try to make sure they see these patients."

"You got to have a bit of pride in what you do. If you are somebody who can help, it feels wrong to not."

Theme: Improving communication

The optometrists noted a need to improve their communication skills and start inter-referring patients more amongst other optometrists when appropriate. This will help increase the accessibility of eyecare for young children and parents being directed to an appropriate place rather than being declined the services.

Sample quotes:

"But then the reception should be referring people on to someone who is…. [able to examine children's eyes rather than turning parents away and saying we do to examine children]."

"…at the end of the day, we want to help the patient. And then if we could assign them to someone who can give them the help they need, and then why not? So maybe we do need to have better inter-relationships with colleagues in the area."

Theme: New Schemes

New ideas were proposed in which awareness and the uptake of young children's eye examinations could be improved in community settings. There have been national campaigns regarding children's eyecare and raising awareness; however, there are still gaps and a lack of awareness amongst the public. For example, providing more information in the Red Book given to parents after the birth of their child or schools by providing a health checklist to be followed in the child's preschool years could improve awareness and uptake of children being examined. Suggestions have also been made regarding the GOS system being modified to allow children to be seen under a separate system that caters for the time and resources required to examine young children.

Sample quotes:

"… we were saying the parents don't know as well…each child when they are born, they are given a red book system saying they need to get their immunisations they need to get this check done…would it not be a good idea maybe we had that process with when a child first attends preschool, they are given at 3 years old or 4 years old when they first attend their nursery. They are given this checklist of things that the parent needs to have done, and they need to present to the school..."

"…we take those children that are under 5 years old or under 7 years old out of the GOS and put them into a special kind of service where they only get seen by specialist paediatric optometrists. Who can do all these tests and spend the time with them alongside an orthoptist in a practice…Where they take care of all of that and push them back out to primary practice once they hit 6 or 7."

Theme: Educating

In addition to education and training, optometrists proposed modifying their teaching material to help improve the learning and experience of optometrists and non-optical staff within community practice. Emphasis was made regarding education for practice managers about the importance of children's eyecare. The data indicated a lack of understanding from non-optical staff and practice managers on the importance of examining young children with more concern placed on the commercial targets of the practice. Potentially by changing behaviour could help improve the accessibility of eyecare for young children.

Sample quotes:

"It also comes down to management they need to be educated. If you're not seeing them or don't have the time or if it's not viable commercially, it becomes a bit of a vicious circle as well."

"Yeah, I think education is really important the parents and the schools as well I think our professional bodies could step up a huge amount and easily say before every child starts school, they need height, weight, ears and, eyes …."

Theme: Raise awareness

Previous research and the current data indicate that many practices decline to examine young children or report that they will not examine children below a certain age, which results in incorrect information spreading amongst parents and the public that young children are unable to have their eyes examined. By raising awareness that there is no minimum age at which a child can have their eyes examined, access to primary eyecare services for young children may be improved.

Sample quotes:

> *"Yeah, so I mean yeah, the awareness needs to spread that there is not a minimum age to come in for a sight test…."*

> *"… I would like to see is that the eyes are thought of in the same ways, as teeth, you know, parents will themselves go and see the dentist on a regular basis, and they take their kids to the dentist on a regular basis, because that's what you do…."*

Theme: Enabling skills

Some optometrists indicated that there is no need for a vast array of equipment when examining young children. At times, all that is needed is some imagination and thinking creatively with how specific skills and tests can be adapted to allow an eye examination to be performed.

Sample quotes:

> *"… you don't need a lot of equipment to test children. It's actually you need less than you do for an adult because you're not looking for glaucoma you do not need to do their visual fields you can make your own you know matching charts, whatever charts are on the wall you can even write the letters on a card and get them to point and you point…just needs a little bit of an imagination, so I think I don't really accept that as a barrier as a lack for equipment. You need a ret, you need a ret, you need to be good... Every optometrist should have a ret and should know how to use it."*

> *"And again, you can only get that by someone saying like get off the chair come this can be done think outside the box… once you're qualified, you've still got a long way to learn…."*

Theme: Balance commercial and health aspects

Optometrists reported commercial pressure within a community setting. Young children do not generate much income, and those practices that give their optometrists specific targets can deter the optometrists from examining children. It has been suggested that practices need to balance the two aspects together, so optometrists do not feel they have to decline examining a child, and the health aspect of the eye examination is also valued.

Sample quote:

> *"…I actually don't agree. I completely understand that it is very much retail-driven, but in the same way, for example, for dentists, I know it is slightly different as it is a service, but do you still pay for products... I think optometry can work alongside retail because of the fact that, for example, majority of people you are recommending glasses … then actually, they are more likely to buy the product from the store because of the fact there is a trusted opinion."*

Theme: Change in professional bodies

Participants reported a need for further guidance from professional bodies so that optometrists know what they need to do and how to conduct themselves if an eye examination for a child younger than five years is requested. This will help practices that do not see children under five years direct them through a specific pathway to have appropriate care.

Sample quotes:

> *"… if …we had some guidelines if the GOC did say you know if someone comes in asking for an appointment for a child under 5, they should get one and not simply say wait until they go to school."*

> *"… I also think with what we have, I think we need to sort of focus more on quality versus quantity, although that is very contradicting in terms of the community practice."*

Theme: Improving funding

The participating optometrists felt that GOS fees for an eye examination are inadequate due to the time and effort spent examining young children. Adjusting the fee of a GOS eye examination for children will allow optometrists, practice owners and managers to value the time needed to examine young children and help invest in age-appropriate tests to allow the optometrist to feel more confident in examining young children. The findings from this study suggest there can be a positive impact on children eyecare if there are improvements in funding.

Sample quote:

> *"… I think a contractual change in what you can do under the general ophthalmic services would lead to an increase in finance, and that would solve your equipment problem…."*

> *"… I think it's something we need to get remunerated properly."*

Theme: Improvement in resources

At times, it was reported that young children have been deterred due to practices not being equipped with the correct equipment to examine young children. This can be rectified by ensuring optometrists have age-appropriate tests to perform an eye examination on a young child. In addition, an audit system was recommended to ensure the necessary equipment is in practice.

Sample quotes:

> *"What is the general feeling about a kind of audit of the actual equipment that ought to be part of a practice?"*

> *"But I think you raise a good point, I think questions should be asked to the practice owners as well, look, I cannot see anybody without these tests."*

> *"I haven't. But I think the current practice I'm working in I don't think there would be any issue with me asking. Probably, if I could maybe financially justify it, then I think it would be ok."*

> *"We need to invest in the equipment and though all the optometrists that work with us whether they're locums or residents. Yeah, I think we should see them in the community. Great thing if we did."*

From the data collected, a word cloud was created combining comments from all focus group meetings. *Figure 5.1* shows the summarised response for optometrists in a word cloud.

Figure 5.1. *Word cloud of optometrists in England working in a community setting and examining young children.*

Agreement amongst optometrists was found among the following barriers: commercial aspect in practices, resources, time, and confidence in examining young children. The lack of experience optometrists have in examining and managing young children was stressed and could be one of the root causes of optometrists or practices declining to offer services to young children. However, there was a disagreement between the educational experience and exposure. The number of universities providing, and teaching optometry could result in there not being a clear-cut standardisation in how things are taught, and the level of exposure received by all optometrists (*"Yeah, I think I've had perhaps a different experience to other people. Because when I went to ***** University, which was longer than I'd like to admit to it, necessarily, but we used to do Wednesday afternoon and Saturday mornings, children's clinics. Erm specifically, you know, that was it was like R*****, we had referrals come in, from the local community, from the local hospitals. And, and it was a case of like, this is how you examine children, and these are children who you are going to examine").* The concept of the behaviour was a frequent factor that appeared however there was disagreement between professionals as to whether certain practitioners' behaviour was influenced by money and financial rewards. As community practices include multiples and independents, optometrists are confined to commercial pressures resulting in a negative mentality of being only concerned about money and getting enough money for their time. In contrast, this may not be as apparent in all practices across England, so the behaviour barrier cannot be generalised amongst all professionals.

Despite the barriers reported above, the participants demonstrated a clear understanding of the importance of children's eyecare. Below are extracts from the transcripts illustrating this point.

> *"I have had a child who had papilledema she was taken to hospital and had a brain tumour and the next day had it removed. So, you know, and that would have not been picked up at visual screening at school."*

"I have had children that have come in and have had terrible reading at those ages and cannot read and haven't been able to read and turn out to be a plus 6 and plus 7 and all of a sudden they have shot up in their class and they are reaching towards some of the smartest children in their class. Then you think to yourself hold on, this could have been easily sorted out a few years ago, but now they are 6 or 7 erm even some of them were reaching 10 because no one thought to look at them and probably get that sorted out."

*"But it is important for me personally I got my first pair of glasses when I was 5 my mum always said I was really happy afterwards and I agree with what A*** said you give them glasses they come back a year later, and the parents say they are doing so much better. It is an amazing thing, an amazing thing to be able to do."*

During the focus groups field notes (description of body language) were not taken as most participants felt comfortable with their video camera off, and video interruptions caused by internet connection problems disrupted any video interpretation

DISCUSSION

This qualitative study is the first to explore the perspective of a community practising optometrists in primary care when examining young children. This study identified several barriers and enablers for young children's eyecare services among community settings. Reasons for selectivity in primary eyecare services for young children is multifactorial. The top five themes identified as a barrier include '*Behaviour*', '*Professional skills'*, '*Funding*', '*Timing*' and, '*Gap in services'*. The top five themes associated with enabling eyecare for young children are '*Accommodating*', '*Improvement in training'*, *'Improving behaviour'*, '*Improving communication*' and '*New schemes'*.

A major concern reported by the optometrists who took part in this study was the behaviour of both the optometrists and staff members (practice managers) who work in community settings which indicated to be a barrier. There are situations reported where optometrists may be willing to see a young child for an eye examination. However, diary constraints and practice managers concerned about meeting financial targets result in managers turning young children away or not providing optometrists with adequate time to conduct an assessment.

The outbreak of the COVID-19 pandemic resulted in the College of Optometrists issuing guidance indicating that community optometrists should only remain open to deliver essential or emergency eyecare (College of Optometrists,2021g). During the pandemic, technology that helped facilitate remote delivery, and optometrists embraced the change in how examinations were conducted however, concerns did arise regarding working safely and obtaining support from professional bodies (Nagra et al., 2021). In addition, further explorations of paediatric eyecare indicated a reduction in clinical activity, within the paediatric ophthalmology department and the capacity being severely limited (Wood et al., 2021). Therefore, due to the pandemic restricting clinical activity in ophthalmology services and resulting in a backlog, it is even more paramount that community optometrists and practices make eyecare services for young children readily and easily available. Moreover, during this investigation, children have been confined at home during the COVID-19 outbreak, resulting in a change in lifestyle and more time doing near work. This change has been shown to impact children between five and seven years, indicating myopia is more prevalent (Andreu-Vázquez et al., 2021). Due to the changes in children's visual demands, it is vital that the accessibility of eyecare improves for young children.

Previous research suggests that there is a lot of misconceptions amongst parents regarding young children's eyecare (Donaldson et al., 2018). Donaldson et al. (2018) found that some parents do not know how to access an eye examination for their child, and there are parents who are apprehensive about taking their child for an eye examination encase they need spectacles. In England, most primary eyecare services are conducted by optometrists (*see Chapter One)*. While concerns are reported, the data from this study indicates that parents

still require further education on the importance on eyecare and when and where they can get their child's eyes examined. This highlights the prominence of creating awareness towards young children's eyecare and how it can be accessed among parents, schools, and non-optical staff members. Emphasis needs to be put on building awareness on a national level. Parents of young children, non-optical, and optical staff who work in community optometric settings all need to be informed that young children can get their eyes examined at their local community opticians. If for whatever reason the community optometric cannot accommodate the child, they need to make it clear that children can be seen but they should then recommend the parent another practice that would be best suited to examining their child. This can help resolve the issue of mixed messages regarding where and when children can get their eyes examined.

The present findings also indicate that optometrists in community setting should all have the correct tests and facilities to examine all children under five years of age. In addition, the education and training structure should be reviewed to allow a larger number of fiver year old's to be examined by undergraduates during their degree. This would help with allow future clinicals feel more confident due to the level of exposure they have had during their education at university. Undergraduate training could be improved by increasing the number of paediatric clinics that are scheduled for students during their studies. By increasing the number and variety of young children that students examine/shadow, this could help improve on their skills and confidence. In addition, by stimulating potential scenarios that are commonly come across in community practices should be discussed so that students are aware of how to go about examining children without feeling they lack exposure. Additional qualifications (*see Chapter One*) and support for those who feel that their skills need further development (mentoring schemes or postgraduate qualifications) need to be highlighted more broadly to ensure all clinicians are aware that further training and support is available. Moreover, another factor that was highlighted as a barrier was the level of funding obtained to conduct an eye examination on a young child. By providing sufficient support in terms of funding and examination duration to ensure that clinicians can carry out an accurate a safe examination could help services for young children be more readily accessible. Some practices have gained additional funding through their local optical bodies for supplementary services. This channel provides practices with additional funding for each child they examine, allowing cycloplegic refraction and the relevant testing equipment to be invested in. Those practices that have not been fortunate enough to obtain this additional funding are in a dilemma of examining young children which takes longer than examining an adult but with the same GOS fee. Those practices also do not have those additional funds to invest in age related testing equipment to examine young children with. The minimum set of skills and equipment that is required include retinoscopy to conduct refraction objectively, printed card with the optotypes relevant to whatever test chart is in practice so that a simpler way of matching what the child sees and any age if funding is limited, and an appropriate stereoacuity test.

One of the key findings from this study is that *behaviour*, *communication*, *funding*, *professional bodies*, *skills*, and *equipment* can act as both a barrier and an enabler for the accessibility of primary eyecare services for young children. An exploration to barriers and facilitators to eyecare delivered by optometrists has been explored which has identified *'time constraints, 'resources and equipment', 'lack of awareness', 'skill proficiency' and 'negative attitudes and beliefs'* are barriers to delivering primary eyecare (Toomey et al., 2021). Recent findings have also indicated that '*time*', '*resources and equipment*', '*education*', '*skill proficiency*', and *'understanding the relevancy of eyecare'* are facilitators to delivery primary eyecare (Toomey et al., 2021). Recently published findings are in line with this study highlighting certain aspects of primary eyecare are impacted by similar factors and contribute to hindering the delivery to young children and the rest of the population. The delivery of paediatric primary eyecare is multifactorial and requires further work to help develop change. Behaviour, communication, funding, professional bodies, skills, and equipment can all be modified in an ideal world. This can be done by educating both non-optical and optical members in community setting the importance of children's eye care and how they should advice parents regarding any enquiry they may have regarding their child's eyes. Modification made to how NHS funded eye examination are formulated and supplementary services are established can help practices be renumerated for the time needed to examined young children and the equipment needed. Professional bodies should promote children eye examinations more and should facilitate optometrists being able to inter-refer amongst one another when examining young children if certain optometrists does not feel competent enough to examine the child.

STRENGTHS AND LIMITATIONS

The optometrists included in this research were selected from various community settings with a broad range of experience and qualifications represented. The participants included locum and resident optometrists and directors who are optometrists, which allowed a varied perspective on this topic from the profession. The focus group process fortunately went well. There was an anticipation in potential challenges in getting participants to be interested in engaging in the research until data saturation had been met. However, there was a positive response from professionals wanting to participate and engage in the discussions.

An inductive and deductive approach was used to code the data. This allowed the identification of new themes in the data rather than confinement to a framework of themes. All the coded data were further analysed using a positivism approach by forming relationships between the knowledge obtained and the reality. Another strength of this research was using a neutral facilitator with the skills and experience to conduct a focus group. The facilitator was neutral as they were only there to moderate the focus group discussion, and do not have a background in the research questions therefore had no personal interest in this field. Moreover, they did not sway the discussion in either way rather mutually accept everyone's point as the discussion went on. Thus, there was no chance for their own opinions regarding this topic influencing data collection. Consequently, this was an advantage as the researcher's reflexivity with possible preconceived ideas about community eyecare and accessibility did not affect the data collection and the views produced. Moreover, the focus group discussions were conducted virtually at the premises of the participant's environment at a time that suited them, which may have influenced the engagement as they were in a comfortable environment, therefore, open to giving their open and honest view on the topic.

There are several limitations to this study. First, barriers and enablers can act at the level of both the provider (optometrist), non-optical staff in between, the recipient, and the child's parent. This research study focused primarily on the providers perspective and, to a lesser extent, to capture the perspective of those members in between the chain and the receivers. Second, the focus group discussions were conducted with practising optometrists in a community setting. However, in the discussion, practice managers with a non-optical background, parents and professional bodies came up frequently. Therefore, to get a broader view on this topic, the perspective from these groups needs to be explored in the future. Thus, the reported barriers and enablers from this study are relevant to community optometrists. In addition, most participants preferred to keep their video cameras off or had to turn them off due to connection issues with the online platform, which resulted in additional information obtained from the participant's body language facial expression not being ascertained.

CONCLUSION

This study has identified many barriers and enablers to community eyecare services for young children in England. Themes such as 'Behaviour', 'Professional skills', and 'Funding' were identified as having high importance, and therefore they are key mediators of accessibility problems for young children in primary eyecare. Several barriers identified from this research were modifiable. However, significant effectors are required to address the accessibility of eyecare services for young children. A draft evidence-based implementation plan could be developed and implemented based on the identified themes. Our findings highlight that the grounded theory approach helped prove a comprehensive and data-driven process to identify critical issues and solutions for community eyecare services for young children.

6. OVERVIEW OF THE MAIN FINDINGS AND FUTURE WORK

SUMMARY AND CONCLUSION

This research aimed to investigate the role of optometrists and the provision of paediatric eyecare in primary care settings in England. The research has established the current accessibility of primary eyecare services and the possible barriers to accessing eye examinations for young children. The barriers experienced by optometrists in community optometric practices were identified by gaining their perspectives, investigating cycloplegic refraction in young children, and assessing the quality of guidance available to help practitioners prescribe refractive error correction in children. The findings from this research highlight that multiple factors affect the provision of primary eyecare for young children including obstacles experienced in community settings and the lack of clear guidance on refracting and correcting refractive errors in children.

The findings from the present studies add to existing evidence indicating that poor communication, a lack of appropriate equipment and other factors related to the child's young age are potential barriers to accessing eyecare. These findings should be used to address how optometrists examine (use of different clinical techniques) and manage young children, and address both professionals and the public regarding the importance of children's eyecare. Furthermore, this research indicates a change in approach is required to address the existing barriers that have resulted in eyecare services being restricted for young children. The results suggest that parents of young children are unable to access eyecare services in their local community, potentially resulting in many young children with undiagnosed visual problems that could subsequently affect their education and social development. Based on the results of the present study and evidence available relating to the accessibility of eyecare, it may be beneficial for practitioners and practice owners who hold a GOS contract to be reminded of the terms of their agreement. On the other hand, accessibility to eyecare for autistic children was facilitated by factors such as adaptability and flexibility in appointment times.

The potential reasons as to why community optometric practices are selective to the age, they are willing to offer an eye examination to a young child was explored. Cycloplegic refraction was explored to determine if this variable hinders optometrists from examining children. The agreement between non-cycloplegic and cycloplegic refraction was investigated to help find guidance in situations where cycloplegic refraction could be forgone (*see Chapter Three*). The systematic review and meta-analysis concluded that a considerable amount of research has been conducted on non-cycloplegic and cycloplegic refraction in children. The findings from the second study (*see Chapter Three*) recommend that care should be taken when refracting young children, and as a baseline measurement, all children should undergo cycloplegic refraction. The results show that the Plusoptix autorefractors are helpful in young children when screening for refractive error, particularly in children with low to moderate levels of hypermetropia. However, practitioners should be cautious because the type and level of refractive error will influence the method of refraction.

Upon completion of an eye examination, an optometrist must decide whether the refractive error they have found requires monitoring or prescribing to help improve the child's vision. The penultimate study (*See Chapter Four*) was conducted to identify clinical guidelines on prescribing refractive error in children and establish whether the quality of guidance currently available contributed to how optometrist manage young children. A lack of accessible guidance on refractive error management could be a barrier to practices declining to see children. Study three (*see Chapter Four*) highlighted significant scope for improving the current guidelines for prescribing refractive error in children by applying the modified Delphi technique to identify specific gaps within existing guidelines. The results indicate a lack of guidance for professionals prescribing refractive error

correction in children, which could explain the discrepancies amongst professionals when prescribing refractive error correction in a child. The Delphi study highlighted that the prescribing refractive error recommendations suggested by one high quality guideline can be disputed, and some are found to be inappropriate prescribing recommendations. The findings suggest that further work (training and development of guidelines) is required to help professionals prescribe refractive errors in young children.

The initial study (*see Chapter Two*) provided a snapshot of the accessibility of eyecare for young children across England and the barriers perceived by optometric practices. The latter was investigated by obtaining the perspectives of qualified optometrists working in community settings using focus groups (*see Chapter Five*). The findings of the final study highlight various barriers to examining young children in a community setting. This research has also demonstrated a need to increase the awareness amongst parents (optometrists have reported that some parents are unaware that they can bring young children to a community practice for an eye examination). Further work is required to help improve the behaviour of optical and non-optical staff (e.g., being more flexible in accommodating young children despite financial pressures they may be under), and the training needs for undergraduate optometrists and practising optometrists (e.g., more practical exposure to examining young children to help develop clinical skills during undergraduate training). Moreover, funding (GOS sight test fees) needs to be also addressed.

UPDATE TO SYSTEMATIC REVIEW AND META-ANALYSIS

The systematic review and meta-analysis were conducted on 8th September 2020. To ensure all new work since the last search have been identified, the search was replicated on 17th September 2021. In addition, citation alerts were used to ensure that the more recently published studies were included.

IDEAS FOR FUTURE WORK

This research raises many interesting questions and has highlighted the need for additional work in this area. Despite the previously reported findings of a telephone survey by Shah et al. 2007 and possible subsequent introduction of binocular vision and paediatric resources a gap still exists in the provision of children's eyecare. Assessing the accessibility of eyecare for young children within community settings and the barriers perceived by optometrists demonstrates a need for Continuing Professional Development (CPD) resources on paediatric eyecare. These resources should be disseminated to all practising optometrists with the ultimate aim of increasing the proportion of optometrists who provide eyecare for young children in a community setting. Based on the findings of the current study, it is clear that the accessibility to eyecare for young children in England has not changed notably since it was last explored over 10 years ago. It would therefore be in the profession's interest to introduce specific paediatric competencies that all practitioners must attain during their CPD cycles. The focus group participants indicating that mandatory paediatric experience during each CPD cycle would help improve the practitioner's confidence due to the continuous need for exposure.

Moreover, paediatric eyecare services could be improved by investigating the agreement between non-cycloplegic and cycloplegic refraction for different patient ages, levels and types of refractive error. This will help ascertain whether a specific type or degree of refractive error at a certain age can be measured without cycloplegic refraction. This should be explored in children were there are no symptoms, family history of a ocular anomaly or risk of a binocular anomaly being present. This will help develop practice and hospital policies on paediatric refraction and in turn, reduce time and cost.

From the findings presented in study three (*see Chapter Four)* further research is required to help format and build evidence-based guidelines with high methodological quality for professionals to use when prescribing refractive error correction in children. These guidelines should be jointly agreed upon by the Royal College of Ophthalmologists and the College of Optometrists to ensure continuity across professions. Therein, professionals could use these agreed outcomes together with their clinical discretion when managing children. Moreover, another Delphi study could be undertaken incorporating the qualitative information gained from study three before formatting a resources to be used in practice. In addition, adding information regarding

prescribing refractive error during myopia control would be beneficial and would aid those practitioner involved in myopia control.

Further research is recommended to validate the barriers and enablers developed from this research. This can be done by exploring the perspective of non-optical staff members involved in eyecare services in community settings. Recommendations can be put into place using the findings of this study to help improve the training structure, behaviour and communication skills for practitioners. This can be done by modifying the undergraduate and postgraduate approaches to teaching paediatric eyecare and changing CPD requirements. This will allow the initiation of programmes to help implement changes amongst professionals and those involved in children's eyecare and, thereby improving community eyecare services for children.

From the findings presented from study four *(see Chapter Five*) the theme 'behaviour' came up most frequently as a barrier (e.g., some optometrists do not value taking time out to examine children). The behaviour of various members of staff who work within a community setting could be developed to help improve accessibility of eyecare services for young children. Behaviour change interventions are intended to achieve positive outcomes but can be challenging to implement. Therefore, it is recommended that implementation strategies have a theoretical basis. With a significant number of behaviour change theories (Michie et al., 2014) available, it is important to select a theory appropriate for the behavioural problem. The Behaviour Change Wheel (BCW) framework provides programme planners with a comprehensive, coherent, and universal toolkit to guide the choice of an appropriate intervention (Michie et al., 2011). There are four steps to developing a theory-informed intervention (French et al., 2012): identifying the specific behaviour and the target group and, secondly, using the Theoretical Domain Framework (TDF) to identify the barriers and enablers that need to be addressed. Based on these two factors, the third step is to identify the intervention components that are feasible and relevant and the last step measures behaviour change. This approach is essential and helpful in implementing a plan which involves optometrists, optical managers, other members and stakeholders in the profession. The Behaviour Change Wheel could be used to address the confidence optometrists have when examining paediatric patients. The action plan would consist of ensuring all optometrists are motivated and happy to embrace the change that is aimed to be achieved. Additional mentoring facilities and resources should be made available to help track the changes and progress in confidence in examining young children. This should be reviewed periodically and then evaluated at the end by exploring what the accessibility is like for young children in community setting. If the evaluation results are different to the findings enclosed in chapter 2 where a telephone study was conducted would highlight the fact that behaviour is changing.

SUPPORTING PUBLICATIONS

Peer-reviewed manuscripts

Title: How accessible is primary eyecare for children in England?

Authors: Wilson, S.; Ctori, I.; Suttle, C.; Conway, M.; Shah, R.

Journal: Ophthalmic and Physiological Optics

Accepted: 28th June 2021

CONFERENCE PRESENTATIONS

European Academy of Optometry and Optic- EAOO 2020- Helsinki- Oral presentation (Unable to present due to COVID-19 conference moved to 2021)

Pre-recorded presentation 24th April 2021.

Title: Are children part of the community served by community optometrists?

Authors: Wilson, S.; Ctori, I.; Suttle, C.; Conway, M.; Shah, R.

British Congress of Optometry and Visual Science -BCOVS 2020 -Virtual-Poster presentation

Title: The accessibility of primary eyecare for young children and children with autism in England.

Authors: Wilson, S.; Ctori, I.; Suttle, C.; Conway, M.; Shah, R.

Joint symposium in Vision Science between LV Prasad Eye Institute and City, University of London- 2021- Oral presentation

Title: The accessibility of primary eyecare for young children and children with autism in England.

Authors: Wilson, S.; Ctori, I.; Suttle, C.; Conway, M.; Shah, R.

8th SHS Annual Doctoral Conference- Oral presentation

Title: Investigation of current guidelines for prescribing spectacles to children using a modified Delphi approach and the AGREE II tool.

Authors: Wilson, S.; Shah, R.; Suttle, C.; Conway, M.; Ctori, I.

Additional contributions made

Cochrane Blog- Blogging for Evidently Cochrane

July 2020

Spectacle correction versus no spectacles for prevention of strabismus in hyperopic children.

Figure 6.1. Cochrane blog for: Spectacle correction versus no spectacles for prevention of strabismus in hyperopic children (https://www.evidentlycochrane.net/long-sighted-children/).

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8. APPENDICES

APPENDIX 2.0: ETHICAL APPROVAL

Dear Salma

Reference: ETH1819-1329

Project title: How accessible is state-funded primary eyecare in England for young children and those with autism?

Start date: 1 Aug 2019

End date: 31 Jan 2021

Your application to Senate Research Ethics Committee was considered on the 17 Jul 2019. The decision is:

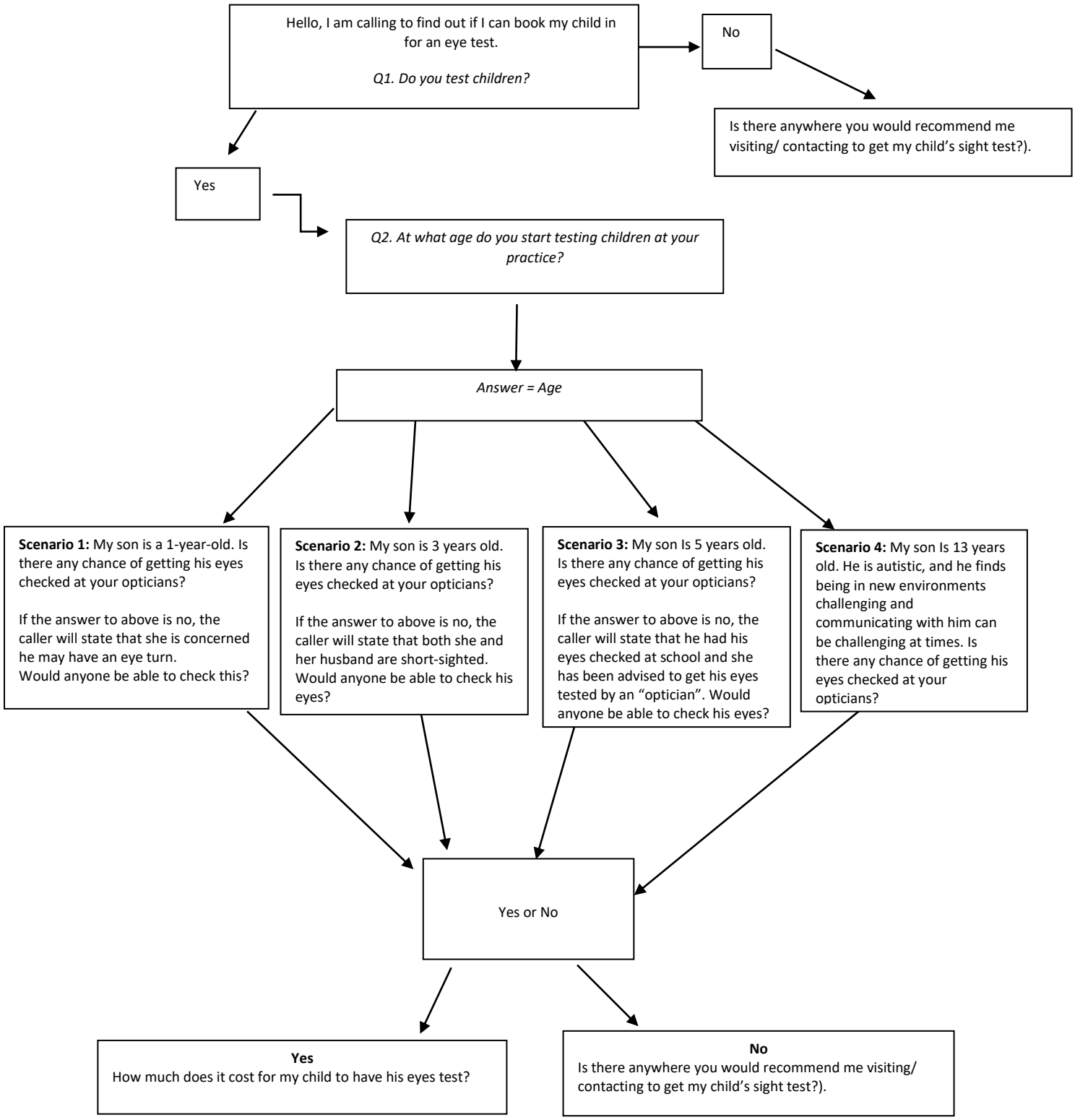
Approved

The Committee's response is based on the protocol described in the application form and supporting documentation.

Kind regards

[redacted]

APPENDIX 2.1: SCRIPTED QUESTIONS USED DURING THE TELEPHONE SURVEY



APPENDIX 3.0: DATA COLLECTION FORM

Date: **Reviewer:** **Study Title:**

First author	
Year of publication	
Country of publication	
Publication type	Journal / Abstract / other (specify)
Source of funding	
Conflicts of interests	
Study aim	

Study Characteristics	**Inclusion Criteria**	**Study** Yes	No	Unclear	**Location in text or source** (page/figure/ table)
Type of study	Randomised Controlled Trial	☐	☐	☐	
	Quasi-randomised Controlled Trial	☐	☐	☐	
	Single gate design	☐	☐	☐	
	Two-gate design	☐	☐	☐	
	Cross-sectional study	☐	☐	☐	
	Other design (specify):	☐	☐	☐	
Participants	Age less than 12 years	☐	☐	☐	
	No ocular and health co-morbidities	☐	☐	☐	
Types of cycloplegic refraction	Retinoscope	☐	☐	☐	
(equipment used)	Type of autorefractor	☐	☐	☐	
Type of non-cycloplegic refraction	Retinoscope	☐	☐	☐	
	Type of autorefractor	☐	☐	☐	
Refractive error measures	Spherical	☐	☐	☐	
	Cylindrical	☐	☐	☐	

	Astigmatic	☐ ☐ ☐	

Include ☐ Exclude ☐

Reason for exclusion:

PLEASE PROCEED TO THE BELOW TABLE IF THE STUDY WILL BE INCLUDED IN THE REVIEW

Included study	**Study**	**Location in text or source** (page/figure/ table)
Trial inclusion criteria		
Trial exclusion criteria		
Participants	Age: median……. Mean…… range…… Sex: Ethnicity: Other characteristics:	
Recruitment procedure		
Setting		
Unit of allocation		
Definition of refractive error		
Cycloplegic trial (include duration)		
Non-cycloplegic trial (include duration)		
Duration of follow-up		
Duration to allow cycloplegia to take effect		
Number of participants in the analysis		
Ethical approval needed/obtained for the study	Yes No Unclear ☐ ☐ ☐	

Informed consent obtained	Yes ☐ No ☐ Unclear ☐	

Results

Comparison:

Outcome:

Person measuring/reporting:

Imputation of missing data:

Experimental: Cycloplegic		**Control: Non-cycloplegic**	
Observed (n)	total (N)	observed (n)	total (N)

	Experiment: Cycloplegic	**Control: Non-cycloplegic**
Total randomised		
excluded*		
Observed		
lost to follow up*		

*Reasons for loss/exclusion

Mean difference in refraction

Mean cycloplegic refraction (SD)=

Mean non-cycloplegic refraction (SD)=

Other

Contact with primary investigators	Clarify methods: Clarify the results:
Notes:	

APPENDIX 4.0: ETHICAL APPROVAL.

Dear Salma

Reference: ETH1920-0714

Project title: Investigation of current guidelines for prescribing spectacles to children using a modified Delphi approach and the AGREE II tool.

Start date: 1 Mar 2020

End date: 28 Feb 2021

I am writing to you to confirm that the research proposal detailed above has been granted formal approval from the Optometry Proportionate Review Committee. The Committee's response is based on the protocol described in the application form and supporting documentation. Approval has been given for the submitted application only and the research must be conducted accordingly. You are now free to start recruitment.

Please ensure that you are familiar with City's Framework for Good Practice in Research and any appropriate Departmental/School guidelines, as well as applicable external relevant policies.

Please note the following:

Project amendments/extension

You will need to submit an amendment or request an extension if you wish to make any of the following changes to your research project:

- Change or add a new category of participants;
- Change or add researchers involved in the project, including PI and supervisor;
- Change to the sponsorship/collaboration;
- Add a new or change a territory for international projects;
- Change the procedures undertaken by participants, including any change relating to the safety or physical or mental integrity of research participants, or to the risk/benefit assessment for the project or collecting additional types of data from research participants;
- Change the design and/or methodology of the study, including changing or adding a new research method and/or research instrument;
- Change project documentation such as protocol, participant information sheets, consent forms, questionnaires, letters of invitation, information sheets for relatives or carers;
- Change to the insurance or indemnity arrangements for the project;
- Change the end date of the project.

Adverse events or untoward incidents

You will need to submit an Adverse Events or Untoward Incidents report in the event of any of the following:

a) Adverse events

b) Breaches of confidentiality

c) Safeguarding issues relating to children or vulnerable adults

d) Incidents that affect the personal safety of a participant or researcher

Issues a) and b) should be reported as soon as possible and no later than five days after the event. Issues c) and d) should be reported immediately. Where appropriate, the researcher should also report adverse events to other relevant institutions, such as the police or social services.

Should you have any further queries relating to this matter, please do not hesitate to contact me. On behalf of the Optometry Proportionate Review Committee, I do hope that the project meets with success.

Kind regards

[redacted]

Optometry Proportionate Review Committee

City, University of London

APPENDIX 4.1: KEYWORDS USED DURING ELECTRONIC DATABASE SEARCHES.

OR (any of the following terms)	**OR (any of the following terms)**	**OR (any of the following terms)**	**OR (any of the following terms)**	**AND (a combination term from the OR columns)**
Refractive error Ametropia Spectacle Prescription Glasses prescription	Guideline's recommendations specification standard, criterion protocol	Prescribing	Child* Infan* Newborn P#ediatric* Minors Preschool	

APPENDIX 4.2: PILOT DELPHI QUESTIONNAIRE.

Investigation of current guidelines for prescribing spectacles to children

Start of Block: Questionnaire Instructions

Instructions You should find there are several statements regarding the refractive errors and prescribing a correction in children. You will note there are several columns besides each statement in the questionnaire. The first column is the research statement being discussed. To the right, the second column shows the possible responses to that research statement. Your response will be recorded as a number from a scale 1-9 which corresponds to the scale below.

1- Strongly disagree. 2- Mostly disagree. 3- Somewhat disagree. 4- Slightly disagree. 5- Neither disagree nor agree. 6- Slightly agree. 7- Somewhat agree. 8- Mostly agree. 9- Strongly agree. Please read each statement and select ONE box in the second column based on what you deem clinically appropriate. There is also an additional notes section whereby you can justify your decision and explain your opinion based on experience and current knowledge etc, should you wish to do so. You may also use this section to provide feedback on the wording and structure of the questionnaire to make it more coherent and effective for the main study.

Page Break

End of Block: Questionnaire Instructions

Start of Block: Less than 1 year of age.

Q1a. You examine a child **less than 1 year of age**. After a comprehensive eye examination, no risk factors have been detected, there are no binocular vision anomalies or ocular pathology present. Following a cycloplegic refraction, I would prescribe the **full** refractive finding when there is an isometropic refractive error of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Myopia of ≥ -5.00DS	○	○	○	○	○	○	○	○	○
Hyperopia of ≥+6.00DS (with no strabismus)	○	○	○	○	○	○	○	○	○
Astigmatism of ≥-3.00DC	○	○	○	○	○	○	○	○	○

Q1b. Following a cycloplegic refraction, I would prescribe a **partial** refractive finding when there is an isometropic refractive error of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Myopia of ≥ -5.00DS	○	○	○	○	○	○	○	○	○
Hyperopia of ≥+6.00DS (with no strabismus)	○	○	○	○	○	○	○	○	○
Astigmatism of ≥-3.00DC	○	○	○	○	○	○	○	○	○

Notes: Please use this space to state what your decision would be in practice based on your experience and knowledge if different to the above recommendations. Any feedback on the wording and structure of the questionnaire may be made here too.

_____

_____

Q1c. Consider the same child above presenting with a constant esotropia during the examination with no other visual anomalies.
Following a cycloplegic refraction, I would prescribe the **fu**ll refractive finding when there is an isometropic refractive error of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Hyperopia of ≥+2.00DS	○	○	○	○	○	○	○	○	○

Q1d. Following a cycloplegic refraction, I would prescribe a **partial** refractive finding when there is an isometropic refractive error of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Hyperopia of ≥+2.00DS	○	○	○	○	○	○	○	○	○

Notes: Please use this space to state what your decision would be in practice based on your experience and knowledge if different to the above recommendations. Any feedback on the wording and structure of the questionnaire may be made here too.

_____

_____

Q2a. You examine a child **less than 1 year of age**. After a comprehensive eye examination, no binocular vision anomalies, no ocular pathology, or risk factors have been detected. Following a cycloplegic refraction, the **minimum difference in refractive error between both eyes** that prompts refractive correction is:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
≥-4.00DS of Myopia	○	○	○	○	○	○	○	○	○
≥+2.50DS of Hyperopia	○	○	○	○	○	○	○	○	○
≥-2.50DC of Astigmatism	○	○	○	○	○	○	○	○	○

Q2b. Following a cycloplegic refraction, I would prescribe the **full** refractive finding when there is a refractive error difference between both eyes of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
≥-4.00DS of Myopia	○	○	○	○	○	○	○	○	○
≥+2.50DS of Hyperopia	○	○	○	○	○	○	○	○	○
≥-2.50DC of Astigmatism	○	○	○	○	○	○	○	○	○

Q2c. Following a cycloplegic refraction, I would prescribe a **partial** refractive finding when there is a refractive error difference between both eyes of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
≥-4.00DS of Myopia	○	○	○	○	○	○	○	○	○
≥+2.50DS of Hyperopia	○	○	○	○	○	○	○	○	○
≥-2.50DC of Astigmatism	○	○	○	○	○	○	○	○	○

Notes: Please use this space to state what your decision would be in practice based on your experience and knowledge if different to the above recommendations. Any feedback on the wording and structure of the questionnaire may be made here too.

_____

_____

End of Block: Less than 1 year of age

Start of Block: 1-2 years of age.

Q1a. You examine a child between **1-2 years** of age. After a comprehensive eye examination, no risk factors have been detected, there are no binocular vision anomalies or ocular pathology present. Following a cycloplegic refraction, I would prescribe the **full** refractive finding when there is an **isometropic** refractive error of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Myopia of ≥ -4.00DS	○	○	○	○	○	○	○	○	○
Hyperopia of ≥+5.00DS (with no strabismus)	○	○	○	○	○	○	○	○	○
Astigmatism of ≥-2.50DC	○	○	○	○	○	○	○	○	○

Q1b. Following a cycloplegic refraction, I would prescribe a **partial** refractive finding when there is an **isometropic** refractive error of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Myopia of ≥ -4.00DS	○	○	○	○	○	○	○	○	○
Hyperopia of ≥+5.00DS (with no strabismus)	○	○	○	○	○	○	○	○	○
Astigmatism of ≥-2.50DC	○	○	○	○	○	○	○	○	○

Please use this space to state what your decision would be in practice based on your experience and knowledge if different to the above recommendations. Any feedback on the wording and structure of the questionnaire may be made here too.

_____

_____

Q1c. Consider the same child above presenting with a constant **esotropia** during the examination with no other visual anomalies.

Following a cycloplegic refraction, I would prescribe the **full** refractive finding when there is an **isometropic** refractive error of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Hyperopia of ≥+2.00DS	○	○	○	○	○	○	○	○	○

Q1d. Following a cycloplegic refraction, I would prescribe a **partial** refractive finding when there is an **isometropic** refractive error of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Hyperopia of ≥+2.00DS	○	○	○	○	○	○	○	○	○

Notes: *Please use this space to state what your decision would be in practice based on your experience and knowledge if different to the above recommendations. Any feedback on the wording and structure of the questionnaire may be made here too.*

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Q2a. You examine a child between **1-2 years** of age. After a comprehensive eye examination, no risk factors have been detected, there are no binocular vision anomalies or ocular pathology present. Following a cycloplegic refraction, the minimum difference in refractive error between both eyes that prompts refractive correction is:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
≥- 3.00DS of Myopia	○	○	○	○	○	○	○	○	○
≥+2.00DS of Hyperopia	○	○	○	○	○	○	○	○	○
≥-2.00DC of Astigmatism	○	○	○	○	○	○	○	○	○

Q2b. Following a cycloplegic refraction, I would prescribe the **full** refractive finding when there is a refractive error difference between both eyes of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
≥- 3.00DS of Myopia	○	○	○	○	○	○	○	○	○
≥+2.00DS of Hyperopia	○	○	○	○	○	○	○	○	○
≥-2.00DC of Astigmatism	○	○	○	○	○	○	○	○	○

Q2c. Following a cycloplegic refraction, I would prescribe a **partial** refractive finding when there is a refractive error difference between both eyes of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
≥ -3.00DS of Myopia	○	○	○	○	○	○	○	○	○
≥+2.00DS of Hyperopia	○	○	○	○	○	○	○	○	○
≥-2.00DC of Astigmatism	○	○	○	○	○	○	○	○	○

Notes: *Please use this space to state what your decision would be in practice based on your experience and knowledge if different to the above recommendations. Any feedback on the wording and structure of the questionnaire may be made here too.*

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End of Block: 1-2 years of age

Start of Block: 2-3 years of age.

Q1a. You examine a child between **2-3 years** of age. After a comprehensive eye examination, no risk factors have been detected, there are no binocular vision anomalies or ocular pathology present. Following a cycloplegic refraction, I would prescribe the **full** refractive finding when there is an **isometropic** refractive error of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Myopia of -≥ 3.00DS	○	○	○	○	○	○	○	○	○
Hyperopia of ≥+4.50DS (with no strabismus)	○	○	○	○	○	○	○	○	○
Astigmatism of ≥-2.00DC	○	○	○	○	○	○	○	○	○

Q1b. Following a cycloplegic refraction, I would prescribe a **partial** refractive finding when there is an **isometropic** refractive error of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Myopia of ≥ -3.00DS	○	○	○	○	○	○	○	○	○
Hyperopia of ≥+4.50DS (with no strabismus)	○	○	○	○	○	○	○	○	○
Astigmatism of ≥-2.00DC	○	○	○	○	○	○	○	○	○

Notes: *Please use this space to state what your decision would be in practice based on your experience and knowledge if different to the above recommendations. Any feedback on the wording and structure of the questionnaire may be made here too.*

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Q1c. Consider the same child above presenting with a constant **esotropia** during the examination with no other visual anomalies.

Following a cycloplegic refraction, I would prescribe the **full** refractive finding when there is an **isometropic** refractive error of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Hyperopia of ≥+1.50DS	○	○	○	○	○	○	○	○	○

Q1d. Following a cycloplegic refraction, I would prescribe a **partial** refractive finding when there is an **isometropic** refractive error of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Hyperopia of ≥+1.50DS	○	○	○	○	○	○	○	○	○

Notes: *Please use this space to state what your decision would be in practice based on your experience and knowledge if different to the above recommendations. Any feedback on the wording and structure of the questionnaire may be made here too.*

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Q2a. You examine a child between **2-3 years** of age. After a comprehensive eye examination, no risk factors have been detected, there are no binocular vision anomalies or ocular pathology present. Following a cycloplegic refraction, the **minimum difference in refractive error between both eyes** that prompts refractive correction is:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
≥ -3.00DS of Myopia	○	○	○	○	○	○	○	○	○
≥+1.50DS of Hyperopia	○	○	○	○	○	○	○	○	○
≥-2.00DC of Astigmatism	○	○	○	○	○	○	○	○	○

Q2b. Following a cycloplegic refraction, I would prescribe the **full** refractive finding when there is a refractive error difference between both eyes of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
≥ -3.00DS of Myopia	○	○	○	○	○	○	○	○	○
≥+1.50DS of Hyperopia	○	○	○	○	○	○	○	○	○
≥-2.00DC of Astigmatism	○	○	○	○	○	○	○	○	○

Q2c. Following a cycloplegic refraction, I would prescribe a **partial** refractive finding when there is a refractive error difference between both eyes of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
≥ -3.00DS of Myopia	○	○	○	○	○	○	○	○	○
≥+1.50DS of Hyperopia	○	○	○	○	○	○	○	○	○
≥-2.00DC of Astigmatism	○	○	○	○	○	○	○	○	○

Notes: *Please use this space to state what your decision would be in practice based on your experience and knowledge if different to the above recommendations. Any feedback on the wording and structure of the questionnaire may be made here too.*

_____

_____

End of Block: 2-3 years of age

Start of Block: 3-4 years of age.

Q1a. You examine a child between **3-4 years** of age. After a comprehensive eye examination, no risk factors have been detected, there are no binocular vision anomalies or ocular pathology present. Following a cycloplegic refraction, I would prescribe the **full** refractive finding when there is an **isometropic** refractive error of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Myopia of -≥ 2.50DS	○	○	○	○	○	○	○	○	○
Hyperopia of ≥+3.50DS (with no strabismus)	○	○	○	○	○	○	○	○	○
Astigmatism of ≥-1.50DC	○	○	○	○	○	○	○	○	○

Q1b. Following a cycloplegic refraction, I would prescribe a **partial** refractive finding when there is an **isometropic** refractive error of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Myopia of - ≥ 2.50DS	○	○	○	○	○	○	○	○	○
Hyperopia of ≥+3.50DS (with no strabismus)	○	○	○	○	○	○	○	○	○
Astigmatism of ≥-1.50DC	○	○	○	○	○	○	○	○	○

Notes: *Please use this space to state what your decision would be in practice based on your experience and knowledge if different to the above recommendations. Any feedback on the wording and structure of the questionnaire may be made here too.*

_____

_____

Q1c. Consider the same child above presenting with a constant **esotropia** during the examination with no other visual anomalies.

Following a cycloplegic refraction, I would prescribe the **full** refractive finding when there is an **isometropic** refractive error of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Hyperopia of ≥+1.50DS	○	○	○	○	○	○	○	○	○

Q1d. Following a cycloplegic refraction, I would prescribe a **partial** refractive finding when there is an **isometropic** refractive error of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Hyperopia of ≥+1.50DS	○	○	○	○	○	○	○	○	○

Notes: *Please use this space to state what your decision would be in practice based on your experience and knowledge if different to the above recommendations. Any feedback on the wording and structure of the questionnaire may be made here too.*

_____

_____

Q2a. You examine a child between **3-4 years of age.** After a comprehensive eye examination, no risk factors have been detected, there are no binocular vision anomalies or ocular pathology present. Following a cycloplegic refraction, the **minimum difference in refractive error between both eyes** that prompts refractive correction is:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
≥ -2.50DS of Myopia	○	○	○	○	○	○	○	○	○
≥+1.50DS of Hyperopia	○	○	○	○	○	○	○	○	○
≥-1.50DC of Astigmatism	○	○	○	○	○	○	○	○	○

Q2b. Following a cycloplegic refraction, I would prescribe the **full** refractive finding when there is a refractive error difference between both eyes of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
≥ -2.50DS Myopia	○	○	○	○	○	○	○	○	○
≥+1.50DS of Hyperopia	○	○	○	○	○	○	○	○	○
≥-1.50DC of Astigmatism	○	○	○	○	○	○	○	○	○

Q2c. Following a cycloplegic refraction, I would prescribe a **partial** refractive finding when there is a refractive error difference between both eyes of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
≥ -2.50DS of Myopia	○	○	○	○	○	○	○	○	○
≥+1.50DS of Hyperopia	○	○	○	○	○	○	○	○	○
≥-1.50DC of Astigmatism	○	○	○	○	○	○	○	○	○

Notes: *Please use this space to state what your decision would be in practice based on your experience and knowledge if different to the above recommendations. Any feedback on the wording and structure of the questionnaire may be made here too.*

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APPENDIX 4.3: INVITATION LETTER.

City, University of London
Northampton Square
London
EC1V 0HB
T +44(0)20 7040 5972

Monday 21st September 2020

Dear Participant,

RE: Investigation of current guidelines for prescribing spectacles to children using a modified Delphi approach and the AGREE II tool.

We would like to invite you to take part in a research study that is being conducted at City, University of London. It is up to you whether you would like to take part or not.

What is the purpose of the study?
Within the ophthalmic profession (optometry/ophthalmology/orthoptics), there are numerous pieces of literature on whether or not to prescribe spectacles to children. Although there is some research in the area of paediatric prescribing, there currently are no national guidelines within the UK, nor have the guidelines been appraised to date. There is a need for a better understanding of what age and what level of ametropia requires clinical intervention. The aim of this research is to evaluate current evidence and come to an agreement with age-specific refractive errors that need to be corrected. This research will, therefore, ensure there is a more focused and coherent approach to guide future practitioners when refracting and managing children.

To participate?
This research study has an inclusion criterion which we think you may meet. The inclusion criteria for this research study are;
Registered qualified, practising ophthalmic professional in the UK including:
Ophthalmologist – subspecialty paediatrics (working in private or NHS setting)
Optometrist - working in primary (multiple and independent) or secondary (hospital) setting.
Orthoptist- qualified and working with children either in a private or NHS setting.

What will happen if I take part?

This research study will be using the Delphi technique, which will consist of 3 questionnaires aiming to achieve consensus. With your permission, only the questionnaire will be posted or emailed over to you. After the receipt of the consent form, you will be sent the instructions alongside the first questionnaire. The amount of time taken to complete each questionnaire will vary with each participant and can range from 15-30 minutes. There is no right or wrong answer. The aim is to obtain an expert opinion. We believe you will find this process interesting, and the findings can be analysed once the study has been concluded.

What to do next.
Your participation in this study is completely voluntary, and if you do not wish to participate, it will not affect you. All information provided will be kept confidential and anonymised. If you do meet the inclusion criteria mentioned above and if you would like to take part, please contact the principal researcher on email at: [redacted] If, after two weeks, if there is no response, the researcher will understand this as you have decided not to participate in the study.

Thank you for your time and any contribution you make to this study.

Kind regards,

Salma Ahmad BSc (Hons) MCOptom MSc DipTp (IP)
Optometrist

APPENDIX 4.4: PARTICIPANT INFORMATION SHEET.

Participant Information

Title of the study: Investigation of current guidelines for prescribing spectacles to children using a modified Delphi approach and the AGREE II tool.

REC reference number: ETH1920-0714

Date: 22/01/2020

Version: 2.0

Name of researcher: Salma Ahmad

We would like to invite you to take part in a research study. Before you decide whether you would like to take part it is important that you understand why the research is being done and what it would involve for you. Please take the time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. You will be given a copy of this information sheet to keep for your records.

What is the purpose of the study?

Within the ophthalmic profession (optometry/ophthalmology/orthoptics), there is numerous literatures on whether or not to prescribe spectacles to children. Although there is some research in the area of paediatric prescribing, there currently are no national guidelines within the UK, nor have the guidelines been appraised to date. There is a need for a better understanding of what age and what level of ametropia requires clinical intervention. The aim of this research is to evaluate current evidence and come to an agreement with age-specific refractive errors that need to be corrected. This research will, therefore, ensure there is a more focused and coherent approach to guide future practitioners when refracting and managing children.

Why have I been invited to take part?

We would like to invite ten volunteers to take part in this study.

The inclusion criteria for this research study are;

Registered qualified, practising ophthalmic professional in the UK including:

Ophthalmologist – subspecialty paediatrics (working in private or NHS setting)

Optometrist - working in primary (multiple and independent) or secondary (hospital) setting.

Orthoptist- qualified and working with children either in a private or NHS setting.

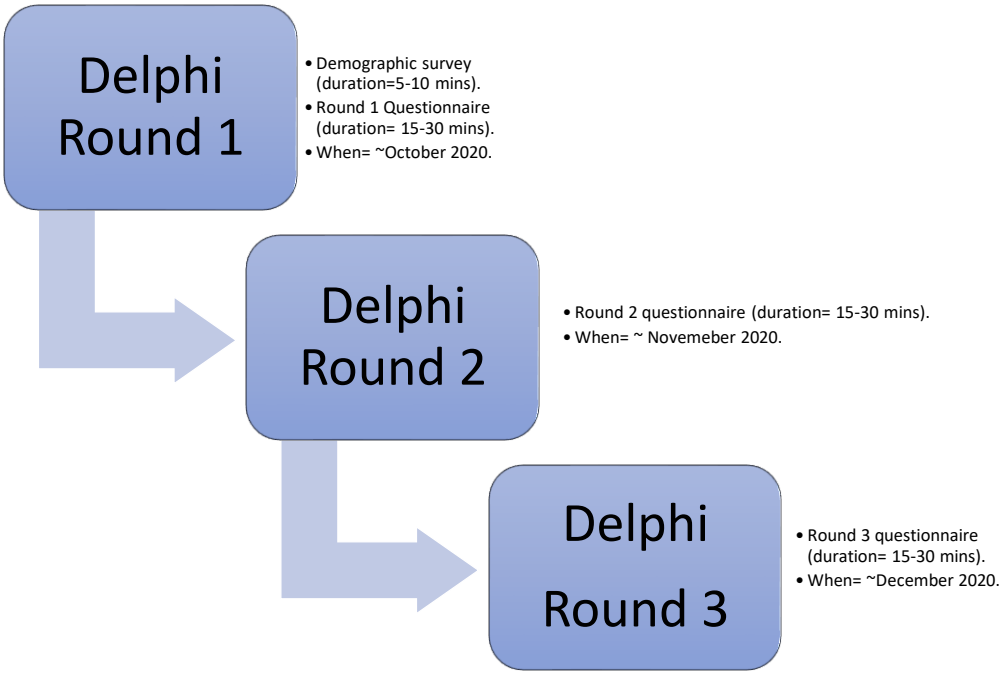
If you are unsure whether you qualify for participation, we would be able to discuss this with you.

Do I have to take part?

It is up to you to decide whether to take part. If you do decide to take part, you will be asked to sign a consent form. If you decide to take part, you are still free to withdraw at any time and without giving a reason. You will not be penalised or disadvantaged in any manner if you choose to withdraw yourself from the study.

What will happen if I take part?

This research study will be using the Delphi technique, which will consist of 3 questionnaires aiming to achieve agreement regarding prescribing refractive error correction in children. With your permission, only the consent form will be posted or emailed over to you. Upon receipt of the consent form, we will send you the instructions and the questionnaire. The amount of time taken to complete the questionnaire will vary with each participant and can range from 15-30 minutes. There is no right or wrong answer, the aim is to obtain an expert opinion. We believe you will find this process interesting, and the findings can be made available once the analysis of the study has been concluded.



What should I do if I want to take part?

Your participation in this study is completely voluntary, and if you do not wish to participate, it will not affect you. All information provided will be kept confidential and anonymised. If you do meet the

inclusion criteria mentioned above and if you would like to take part, please contact Salma Ahmad on email at: [redacted]

What are the possible disadvantages and risks of taking part?

There are no risks involved by taking part in this study and or any possible disadvantages.

What are the possible benefits of taking part?

Whilst the knowledge gained from this study may be of no immediate benefit to you, the results will provide a better understanding of what level of refractive error should be prescribed to children of different ages with knowledge on which guidelines are of high quality.

Expenses and Payments

Not applicable.

How is the project being funded?

Not applicable.

Data privacy statement

City, University of London is the sponsor and the data controller of this study based in the United Kingdom. This means that we are responsible for looking after your information and using it properly. The legal basis under which your data will be processed is City, University of London public task.

Your right to access, change or move your information are limited, as we need to manage your information in a specific way for the research to be reliable and accurate. To safeguard your rights, we will use the minimum personal-identifiable information possible (for further information, please see https://ico.org.uk/for-organisations/guide-to-data-protection/guide-to-the-general-data-protection-regulation-gdpr/lawful-basis-for-processing/public-task/).

City, University of London will use your name and contact details to contact you about the research study, as necessary. If you wish to receive the results of the study, your contact details will also be kept for this purpose. The only person at City, University of London who will have access to your identifiable information will be the researcher. City, University of London will keep identifiable information about you from this study for 10 years after the study has finished.

You can find out more about how City, University of London handles data by visiting https://www.city.ac.uk/about/governance/legal. If you are concerned about how, we have processed your personal data, you can contact the Information Commissioner's Office (IOC) https://ico.org.uk/.

Will my taking part in the study be kept confidential?

Your identity will be recorded against the findings but will not be stored on any computer. This information will be kept in a locked filing cabinet in the Optometry and Visual Science Division, City,

University of London. Only the investigators will have access to this information. All data will be anonymised. The results obtained will be analysed and probably published, but your identity will never be unveiled.

What will happen to the results?

You will be given a written summary of any significant results during the questionnaire procedures. Please note that although these procedures may give you useful information about consensus, they are not the finalised results until the end of the procedure. At the end of the study, we aim to publish the findings in an internationally peer-reviewed journal.

Who has reviewed the study?

This study has been approved by City, University of London Division of Optometry and Visual Science Research Ethics Committee.

What if there is a problem?

If you have any problems, concerns, or questions about this study, you should ask to speak to a member of the research team. If you remain unhappy and wish to complain formally, you can do this through City, University of London's complaints procedure. To complain about the study, you need to phone 020 7040 3040. You can then ask to speak to the Secretary to Senate Research Ethics Committee and inform them that the name of the project is [Investigation of current guidelines for prescribing spectacles to children using a modified Delphi approach and the AGREE II tool].

You can also write to the Secretary at:

[redacted]
Research Integrity Manager

City, University of London, Northampton Square
London, EC1V 0HB

Email: [redacted]

Further information and contact details

In case you have any further queries regarding this study, please feel free to contact Salma Ahmad by email at: [redacted]

Thank you for taking the time to read this information sheet.

APPENDIX 4.5: MAIN DELPHI QUESTIONNAIRE.

Round one

Start of Block: Questionnaire Instructions

Instructions You should find there are several statements regarding the refractive errors and prescribing a correction in children. You will note there are several columns besides each statement in the questionnaire. The first column is the research statement being discussed. To the right, the second column shows the possible responses to that research statement. Your response will be recorded as a number from a scale 1-9 which corresponds to the scale below.

1- Strongly disagree. 2- Mostly disagree. 3- Somewhat disagree. 4- Slightly disagree. 5- Neither disagree nor agree. 6- Slightly agree. 7- Somewhat agree. 8- Mostly agree. 9- Strongly agree. Please read each statement and select ONE circle in the second column based on what you deem to be clinically appropriate. There is also an additional notes section whereby you can justify your decision and explain your opinion based on experience and current knowledge etc, should you wish to do so.

Page Break

End of Block: Questionnaire Instructions

Start of Block: Expert Panellist Demographics

What setting do you work in (tick all that apply)?

- ☐ Hospital
- ☐ Community practice (multiple)
- ☐ Community practice (independent)
- ☐ Academia
- ☐ Research
- ☐ Health centres
- ☐ Domiciliary
- ☐ Other (specify) _____

Please list your qualifications.

_____

_____

_____

_____

_____

Please list how many years of experience you have within paediatric eyecare since qualifying.

_____

Please indicate the profession you work in (tick all that apply)

- [ ] Optometry
- [ ] Ophthalmology
- [ ] Orthoptics

How much experience have you had examining children of the following age groups?
A child who is < 12 months old.

- ○ Extensive experience (e.g., seen a child of this age at least once a day).
- ○ Good experience (e.g., seen a child of this age at least once a week).
- ○ Some experience (e.g., seen a child of this age at least once a month).
- ○ Little experience (e.g., seen a child of this age at least a few times during the year).
- ○ No experience (e.g., have not seen a child of this age).

A child who is 12-24 months old.

- ○ Extensive experience (e.g., seen a child of this age at least once a day).
- ○ Good experience (e.g., seen a child of this age at least once a week).
- ○ Some experience (e.g., seen a child of this age at least once a month).
- ○ Little experience (e.g., seen a child of this age at least a few times during the year).
- ○ No experience (e.g., have not seen a child of this age).

A child who is 2-4 years of age.

- ○ Extensive experience (e.g., seen a child of this age at least once a day).
- ○ Good experience (e.g., seen a child of this age at least once a week).
- ○ Some experience (e.g., seen a child of this age at least once a month).
- ○ Little experience (e.g., seen a child of this age at least a few times during the year).
- ○ No experience (e.g., have not seen a child of this age).

A child who is 5-7 years of age.

- ○ Extensive experience (e.g., seen a child of this age at least once a day).
- ○ Good experience (e.g., seen a child of this age at least once a week).
- ○ Some experience (e.g., seen a child of this age at least once a month).
- ○ Little experience (e.g., seen a child of this age at least a few times during the year).
- ○ No experience (e.g., have not seen a child of this age).

A child who is 8-11 years of age.

- ○ Extensive experience (e.g., seen a child of this age at least once a day).
- ○ Good experience (e.g., seen a child of this age at least once a week).
- ○ Some experience (e.g., seen a child of this age at least once a month).
- ○ Little experience (e.g., seen a child of this age at least a few times during the year).
- ○ No experience (e.g., have not seen a child of this age).

A child who is 12 years of age and over.

- ○ Extensive experience (e.g., seen a child of this age at least once a day).
- ○ Good experience (e.g., seen a child of this age at least once a week).
- ○ Some experience (e.g., seen a child of this age at least once a month).
- ○ Little experience (e.g., seen a child of this age at least a few times during the year).
- ○ No experience (e.g., have not seen a child of this age).

When prescribing optical correction in children, what sources influence your clinical decision making? (tick all that apply)

- ☐ Education from university.
- ☐ Pre-registration training and experience.
- ☐ Clinical guidelines.
- ☐ CET/CPD courses.
- ☐ Opinions from lead professionals.
- ☐ Evidence-based literature.
- ☐ Patient feedback on adaptation (clinical experience from patients' ability in adjusting to different amounts of refractive correction once prescribed).
- ☐ Clinical experience.
- ☐ Textbooks.

End of Block: Expert Panelist Demographics

Start of Block: Less than 1 year of age.

You examine a child **less than 1 year** of age. After a comprehensive eye examination, no risk factors have been detected, there are no binocular vision anomalies or ocular pathology present. The **vision measurements are within the normal range**.

Following a cycloplegic refraction, I would prescribe the **full** refractive finding when there is an isometropic refractive error of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Myopia of -5.00DS or more	○	○	○	○	○	○	○	○	○
Hyperopia of +6.00DS or more (with no strabismus)	○	○	○	○	○	○	○	○	○
Astigmatism of -3.00DC or more (oblique)	○	○	○	○	○	○	○	○	○
Astigmatism of -3.00DC or more (not oblique)	○	○	○	○	○	○	○	○	○

Following a cycloplegic refraction, I would prescribe a **modified** refractive finding when **vision measurements are within normal range,** and there is an isometropic refractive error of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Myopia of -5.00DS or more	○	○	○	○	○	○	○	○	○
Hyperopia of +6.00DS or more (with no strabismus)	○	○	○	○	○	○	○	○	○
Astigmatism of -3.00DC or more (oblique)	○	○	○	○	○	○	○	○	○
Astigmatism of -3.00DC or more (not oblique)	○	○	○	○	○	○	○	○	○

Notes: Please use this space to state what your decision would be in practice based on your experience and knowledge if different to the above recommendations.

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Consider the **less than 1-year old** child above presenting with a constant esotropia during the examination with no other visual anomalies.

Following a cycloplegic refraction, I would prescribe the **full** refractive finding when there is an isometropic refractive error of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Hyperopia of +2.00DS or more	○	○	○	○	○	○	○	○	○

Following a cycloplegic refraction, I would prescribe a **modified** refractive finding in the child less than 1- year with a constant **esotropia** when there is an isometropic refractive error of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Hyperopia of +2.00DS or more	○	○	○	○	○	○	○	○	○

Notes: Please use this space to state what your decision would be in practice based on your experience and knowledge if different to the above recommendations.

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You examine a child **less than 1 year of age**. After a comprehensive eye examination, no binocular vision anomalies, no ocular pathology, or risk factors have been detected. **The vision measurements are within the normal range.**

Following a cycloplegic refraction, **the minimum difference in refractive error** between both eyes that prompts refractive correction is:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Myopia of -4.00DS or more	○	○	○	○	○	○	○	○	○
Hyperopia of +2.50DS or more	○	○	○	○	○	○	○	○	○
Astigmatism of -2.50DC or more (oblique)	○	○	○	○	○	○	○	○	○
Astigmatism of -2.50DC or more (not oblique)	○	○	○	○	○	○	○	○	○

Following a cycloplegic refraction, I would prescribe the **full** refractive finding when **vision measurements are within normal range,** and there is a **refractive error difference** between both eyes of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Myopia of -4.00DS or more	○	○	○	○	○	○	○	○	○
Hyperopia of +2.50DS or more	○	○	○	○	○	○	○	○	○
Astigmatism of -2.50DC or more (oblique)	○	○	○	○	○	○	○	○	○
Astigmatism of -2.50DC or more (not oblique)	○	○	○	○	○	○	○	○	○

Following a cycloplegic refraction, I would prescribe a **modified** refractive finding when **vision measurements are within normal range,** and there is a **refractive error difference** between both eyes of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Myopia of -4.00DS or more	○	○	○	○	○	○	○	○	○
Hyperopia of +2.50DS or more	○	○	○	○	○	○	○	○	○
Astigmatism of -2.50DC or more (oblique)	○	○	○	○	○	○	○	○	○
Astigmatism of -2.50DC or more (not oblique)	○	○	○	○	○	○	○	○	○

Notes: Please use this space to state what your decision would be in practice based on your experience and knowledge if different to the above recommendations.

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End of Block: Less than 1 year of age

Start of Block: 1-2 years of age.

You examine a child between **1-2 years** of age. After a comprehensive eye examination, no risk factors have been detected, there are no binocular vision anomalies or ocular pathology present. **The vision measurements are within the normal range.**

Following a cycloplegic refraction, I would prescribe the **full** refractive finding when there is an **isometropic** refractive error of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Myopia of -4.00DS or more	○	○	○	○	○	○	○	○	○
Hyperopia of +5.00DS or more (with no strabismus)	○	○	○	○	○	○	○	○	○
Astigmatism of -2.50DC or more (oblique)	○	○	○	○	○	○	○	○	○
Astigmatism of -2.50DC or more (not oblique)	○	○	○	○	○	○	○	○	○

Following a cycloplegic refraction, I would prescribe a **modified** refractive finding when **vision measurements are within normal range,** and there is an **isometropic** refractive error of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Myopia of -4.00DS or more	○	○	○	○	○	○	○	○	○
Hyperopia of +5.00DS or more (with no strabismus)	○	○	○	○	○	○	○	○	○
Astigmatism of -2.50DC or more (oblique)	○	○	○	○	○	○	○	○	○
Astigmatism of -2.50DC or more (not oblique)	○	○	○	○	○	○	○	○	○

Please use this space to state what your decision would be in practice based on your experience and knowledge if different to the above recommendations.

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Consider the **1-2 year old** child above presenting with a constant **esotropia** during the examination with no other visual anomalies.

Following a cycloplegic refraction, I would prescribe the **full** refractive finding when there is an **isometropic** refractive error of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Hyperopia of +2.00DS or more	○	○	○	○	○	○	○	○	○

Following a cycloplegic refraction, I would prescribe a **modified** refractive finding in the 1-2 year old with a constant **esotropia** when there is an **isometropic** refractive error of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Hyperopia of +2.00DS or more	○	○	○	○	○	○	○	○	○

Notes: *Please use this space to state what your decision would be in practice based on your experience and knowledge if different to the above recommendations.*

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You examine a child between **1-2 years** of age. After a comprehensive eye examination, no risk factors have been detected, there are no binocular vision anomalies or ocular pathology present. T**he vision measurements are within the normal range.**

Following a cycloplegic refraction, the **minimum difference in refractive error** between both eyes that prompts refractive correction is:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Myopia of -3.00DS or more	○	○	○	○	○	○	○	○	○
Hyperopia of +2.00DS or more	○	○	○	○	○	○	○	○	○
Astigmatism of -2.00DC or more (oblique)	○	○	○	○	○	○	○	○	○
Astigmatism of -2.00DC or more (not oblique)	○	○	○	○	○	○	○	○	○

Following a cycloplegic refraction, I would prescribe the **full** refractive finding when **vision measurements are within normal range,** and there is a **refractive error difference** between both eyes of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Myopia of -3.00DS or more	○	○	○	○	○	○	○	○	○
Hyperopia of +2.00DS or more	○	○	○	○	○	○	○	○	○
Astigmatism of -2.00DC or more (oblique)	○	○	○	○	○	○	○	○	○
Astigmatism of -2.00DC (not oblique)	○	○	○	○	○	○	○	○	○

Following a cycloplegic refraction, I would prescribe a **modified** refractive finding when **vision measurements are within normal range,** and there is a **refractive error difference** between both eyes of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Myopia of -3.00DS or more	○	○	○	○	○	○	○	○	○
Hyperopia of +2.00DS or more	○	○	○	○	○	○	○	○	○
Astigmatism of -2.00DC or more (oblique)	○	○	○	○	○	○	○	○	○
Astigmatism of -2.00DC or more (not oblique)	○	○	○	○	○	○	○	○	○

Notes: *Please use this space to state what your decision would be in practice based on your experience and knowledge if different to the above recommendations.*

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End of Block: 1-2 years of age

Start of Block: 2-3 years of age.

You examine a child between **2-3 years** of age. After a comprehensive eye examination, no risk factors have been detected, there are no binocular vision anomalies or ocular pathology present. The **vision measurements are within the normal range.**

Following a cycloplegic refraction, I would prescribe the **full** refractive finding when there is an **isometropic** refractive error of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Myopia of -3.00DS or more	○	○	○	○	○	○	○	○	○
Hyperopia of +4.50DS or more (with no strabismus)	○	○	○	○	○	○	○	○	○
Astigmatism of -2.00DC or more (oblique)	○	○	○	○	○	○	○	○	○
Astigmatism of -2.00DC or more (not oblique)	○	○	○	○	○	○	○	○	○

Following a cycloplegic refraction, I would prescribe a **modified** refractive finding when **vision measurements are within normal range,** and there is an **isometropic** refractive error of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Myopia of -3.00DS or more	○	○	○	○	○	○	○	○	○
Hyperopia of +4.50DS or more (with no strabismus)	○	○	○	○	○	○	○	○	○
Astigmatism of -2.00DC or more (oblique)	○	○	○	○	○	○	○	○	○
Astigmatism of -2.00DC or more (not oblique)	○	○	○	○	○	○	○	○	○

Notes: *Please use this space to state what your decision would be in practice based on your experience and knowledge if different to the above recommendations.*

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Consider the **2-3 year old** child above presenting with a constant **esotropia** during the examination with no other visual anomalies.

Following a cycloplegic refraction, I would prescribe the **full** refractive finding when there is an **isometropic** refractive error of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Hyperopia of +1.50DS or more	○	○	○	○	○	○	○	○	○

Following a cycloplegic refraction, I would prescribe a **modified** refractive finding in the 2-3 year old with a constant **esotropia** when there is an **isometropic** refractive error of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Hyperopia of +1.50DS or more	○	○	○	○	○	○	○	○	○

Notes: *Please use this space to state what your decision would be in practice based on your experience and knowledge if different to the above recommendations.*

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You examine a child between **2-3 years** of age. After a comprehensive eye examination, no risk factors have been detected, there are no binocular vision anomalies or ocular pathology present. The **vision measurements are within the normal range.**

Following a cycloplegic refraction, the **minimum difference in refractive error** between both eyes that prompts refractive correction is:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Myopia of -3.00DS or more	○	○	○	○	○	○	○	○	○
Hyperopia of +1.50DS or more	○	○	○	○	○	○	○	○	○
Astigmatism of -2.00DC or more (oblique)	○	○	○	○	○	○	○	○	○
Astigmatism of -2.00DC or more (not oblique)	○	○	○	○	○	○	○	○	○

Following a cycloplegic refraction, I would prescribe the **full** refractive finding when **vision measurements are within normal range,** and there is a **refractive error difference** between both eyes of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Myopia of -3.00DS or more	○	○	○	○	○	○	○	○	○
Hyperopia of +1.50DS or more	○	○	○	○	○	○	○	○	○
Astigmatism of -2.00DC or more (oblique)	○	○	○	○	○	○	○	○	○
Astigmatism of -2.00DC or more (not oblique)	○	○	○	○	○	○	○	○	○

Following a cycloplegic refraction, I would prescribe a **modified** refractive finding when **vision measurements are reduced compared to the age-matched norm**, and there is a **refractive error difference** between both eyes of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Myopia of -3.00DS or more	○	○	○	○	○	○	○	○	○
Hyperopia of +1.50DS or more	○	○	○	○	○	○	○	○	○
Astigmatism of -2.00DC or more (oblique)	○	○	○	○	○	○	○	○	○
Astigmatism of -2.00DC or more (not oblique)	○	○	○	○	○	○	○	○	○

Notes: *Please use this space to state what your decision would be in practice based on your experience and knowledge if different to the above recommendations.*

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End of Block: 2-3 years of age

Start of Block: 3-4 years of age.

You examine a child between **3-4 years** of age. After a comprehensive eye examination, no risk factors have been detected, there are no binocular vision anomalies or ocular pathology present. The **vision measurements are within the normal range.**

Following a cycloplegic refraction, I would prescribe the **full** refractive finding when there is an **isometropic** refractive error of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Myopia of -2.50DS or more	○	○	○	○	○	○	○	○	○
Hyperopia of +3.50DS or more (with no strabismus)	○	○	○	○	○	○	○	○	○
Astigmatism of -1.50DC or more (oblique)	○	○	○	○	○	○	○	○	○
Astigmatism of -1.50DC or more (not oblique)	○	○	○	○	○	○	○	○	○

Following a cycloplegic refraction, I would prescribe a **modified** refractive finding when **vision measurements are within normal range,** and there is an **isometropic** refractive error of:

	(1)	(2)	(3)	(4)	5 (5)	(6)	(7)	(8)	(9)
Myopia of -2.50DS or more	○	○	○	○	○	○	○	○	○
Hyperopia of +3.50DS or more (with no strabismus)	○	○	○	○	○	○	○	○	○
Astigmatism of -1.50DC or more (oblique)	○	○	○	○	○	○	○	○	○
Astigmatism of -1.50DC or more (not oblique)	○	○	○	○	○	○	○	○	○

Notes: *Please use this space to state what your decision would be in practice based on your experience and knowledge if different to the above recommendations.*

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Consider the **3-4 year old** child above presenting with a constant **esotropia** during the examination with no other visual anomalies.

Following a cycloplegic refraction, I would prescribe the **full** refractive finding when there is an **isometropic** refractive error of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Hyperopia of +1.50DS or more	○	○	○	○	○	○	○	○	○

Following a cycloplegic refraction, I would prescribe a **modified** refractive finding in the 3-4 year old with a constant **esotropia** when there is an **isometropic** refractive error of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Hyperopia of +1.50DS or more	○	○	○	○	○	○	○	○	○

Notes: *Please use this space to state what your decision would be in practice based on your experience and knowledge if different to the above recommendations.*

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You examine a child between **3-4 years of age.** After a comprehensive eye examination, no risk factors have been detected, there are no binocular vision anomalies or ocular pathology present. The **vision measurements are within the normal range.**

Following a cycloplegic refraction, the **minimum difference in refractive error** between both eyes that prompts refractive correction is:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Myopia of -2.50DS or more	○	○	○	○	○	○	○	○	○
Hyperopia of +1.50DS or more	○	○	○	○	○	○	○	○	○
Astigmatism of -1.50DC or more (oblique)	○	○	○	○	○	○	○	○	○
Astigmatism of -1.50DC or more (not oblique)	○	○	○	○	○	○	○	○	○

Following a cycloplegic refraction, I would prescribe the **full** refractive finding when **vision measurements are within normal range,** and there is a **refractive error difference** between both eyes of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Myopia of -2.50DS or more	○	○	○	○	○	○	○	○	○
Hyperopia of +1.50DS or more	○	○	○	○	○	○	○	○	○
Astigmatism of -1.50DC or more (oblique)	○	○	○	○	○	○	○	○	○
Astigmatism of -1.50DC or more (not oblique)	○	○	○	○	○	○	○	○	○

Following a cycloplegic refraction, I would prescribe a **modified** refractive finding when **vision measurements are within normal range,** and there is a **refractive error difference** between both eyes of:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Myopia of -2.50DS or more	○	○	○	○	○	○	○	○	○
Hyperopia of +1.50DS or more	○	○	○	○	○	○	○	○	○
Astigmatism of -1.50DC or more (oblique)	○	○	○	○	○	○	○	○	○
Astigmatism of -1.50DC or more (not oblique)	○	○	○	○	○	○	○	○	○

Notes: *Please use this space to state what your decision would be in practice based on your experience and knowledge if different to the above recommendations.*

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End of Block: 3-4 years of age

APPENDIX 4.6: EXAMPLES OF WHY THE ELIGIBLE GUIDELINES SCORED HIGH OR LOW.

Clinical Guideline: All India Ophthalmological Society Guidelines

Examples of positive findings:

- The guideline specified who the guideline has been developed for.
- The recommendations were easily identifiable within the guidelines.
- The views of the funding body did not influence the content of the guideline.
- The guideline indicated that individuals with relevant professional backgrounds were involved in developing the guideline

Examples of negative findings:

- The objective of the guideline and the target population were not clearly defined.
- Information regarding the professionals involved in developing the guideline was not given in detail.
- Patients' views were not considered in forming the guideline.
- No systematic method was used to search for evidence regarding prescribing recommendations during the guideline development.
- Details regarding the procedure for updating the guideline was minimal.
- No supporting data was found within the guideline that looked upon the strengths and limitations of the evidence.
- Detail regarding how the recommendations were formulated and the benefits of formulating the recommendations were not given.
- The potential resources implication and the auditing criteria for the guideline were not considered.
- During the development of the guideline, possible competing interests from members were not disclosed.

Clinical Guideline: Guidelines for Prescribing Optical Correction in Children

Examples of positive findings:

- The prescribing recommendations were under a heading, making them easy to identify.

Examples of negative findings:

- The guideline's objective and health question were briefly described.
- There was a lack of description regarding the intended population to which this guideline would be applied.
- The development of the guideline did not include a group of individuals from relevant professional groups, and the patient's views and preferences were not sought after.
- The recommended users for the guideline were not clearly defined.
- A systematic method was not used to search for evidence, and no criteria were established for selecting the evidence.
- The strengths and limitations of the evidence obtained and the methodology of formulating the recommendations were not described.

- The guideline has not been externally reviewed by experts prior to the publication, nor has a procedure for updating the guideline been provided.
- No declaration was made about funding bodies views influencing the guideline's content or whether there were any conflicts of interest.
- There were no monitoring or auditing criteria.

Clinical Guideline: Pediatric Eye Evaluation Practice Pattern

Examples of positive findings:

- The guideline was clear, and the objectives and health questions were addressed.
- The target population for this guideline was described explicitly with specific age categories.
- A systematic method was used to search for evidence, and the criteria for searching were described.
- Strengths and limitations of the evidence being used were described, and the method used to formulate the recommendations is enclosed in the guideline.
- The guideline was externally reviewed prior to publication, and a procedure for updating the guideline was enclosed.
- It was clearly stated that the views of a funding body did not influence the guideline content, nor were there any conflicts of interest.
- Prescribing refractive error corrections were specific, with different options for managing refractive error and easily identifiable.

Examples of negative findings:

- There was limited information on individuals involved in the development of the guideline.
- The views of the target population were not sought after, and whom the guideline was intended to be used by was not clearly defined.

Clinical Guideline: To prescribe or not to prescribe? Guidelines for spectacle prescribing in infants and children

Examples of positive findings:

- The guideline was descriptive regarding their target audience.
- The benefits and risks have been touched upon when formulating the recommendations, and evidence has been used in support.
- The recommendations were clear, specific, and easily identifiable.

Examples of negative findings:

- There was no information on any professionals included in the formation of the guideline.
- The views of the target population were not included.
- No systematic method was used to search for the evidence. In addition, the criteria for selecting the evidence were not clearly described.

- The strengths and limitations of the evidence used were not disclosed, and the methodological approach for formulating recommendations was not given.
- The implications of applying the recommendations and the auditing and monitoring criteria for the guidelines were not considered.
- There was no information on whether a funding body influenced the formulation of recommendations.

Clinical Guideline: Evidence-based spectacles prescribing for infants and children

Examples of positive findings:

- The population is initially broadly described as paediatrics and then goes into age-specific later in the report.

Examples of negative findings:

- The overall objective is vaguely described by the health question covered by the guideline.
- No clear systematic method was apparent when evidence was searched and selected.
- The strengths and limitations of the evidence are vaguely described, and the methods for formulating recommendations are vague.
- Prior to publication, the guideline was not externally reviewed, and there is no procedure for updating the guideline.
- The guideline did not address monitoring or auditing criteria.
- No information is declared whether the funding body influenced the content produced or whether there were any conflicting interests during the guideline development.

APPENDIX 4.7: THANK YOU LETTER FOR PILOT STUDY PARTICIPANTS.

City, University of London
Northampton Square
London
EC1V 0HB
T +44(0)20 7040 5972

Wednesday 20th August 2020

Dear << Participant's name>>,

RE: Investigation of current guidelines for prescribing spectacles to children using a modified Delphi approach and the AGREE II tool.

Thank you again for your willingness to participate in this pilot study on prescribing spectacle guidelines to children. I have very much appreciated you taking out the time, and your thoughts about the questionnaire have been extremely informative and useful.

Based on the comments obtained from the questionnaire, I have attached a description of both what the recommendations were and how I have developed the questionnaire subsequently.

Please feel free to respond with any necessary additions.

Comments and planned amendments:

The values for ametropia (myopia and hypermetropia) will remain the same as they have been extracted from guidelines after critical appraisal. However, we do appreciate the fact that some practitioners may not prescribe myopia so readily in under 1 year of age.

The recommendation regarding having multiple options for each type of refractive error with various dioptric values has been taken into consideration. It is a particularly good point; however, since the aim of the study is to gain consensus on "high-quality" guidelines, the dioptric values will remain the same as stated in the guidelines.

The comment regarding prescribing anisometropia in under 1 year of age cannot be made without accurate visual acuity measurements indicating reduced vision has been taken on board. Changes will be made to all questions to ensure there is more information on what the child's level of vision is and whether it is reduced and how accurate the measurement is.

The statement regarding oblique astigmatism being of more concern when prescribing has been taken on board. Alternations shall be made to the question by adding oblique and non-oblique astigmatism to the dioptric value.

I have greatly valued your participation in this research study and your willingness to share your experience and comments. If you have any concerns, please contact me. Again, thank you very much for your time and effort that made this research study possible.

With warm regards,

Salma Wilson BSc (Hons) MCOptom MSc DipTp (IP)

Optometrist

APPENDIX 5.0: ETHICAL APPROVAL

Dear Salma

Reference: ETH1920-1860

Project title: An exploration of community eyecare for children: identifying barriers and enablers using a grounded theory approach.

Start date: 10 Sep 2020

End date: 30 Sep 2021

I am writing to you to confirm that the research proposal detailed above has been granted formal approval from the Optometry Proportionate Review Committee. The Committee's response is based on the protocol described in the application form and supporting documentation. Approval has been given for the submitted application only and the research must be conducted accordingly. You are now free to start recruitment.

Please ensure that you are familiar with City's Framework for Good Practice in Research and any appropriate Departmental/School guidelines, as well as applicable external relevant policies.

Please note the following:

Project amendments/extension

You will need to submit an amendment or request an extension if you wish to make any of the following changes to your research project:

- Change or add a new category of participants;
- Change or add researchers involved in the project, including PI and supervisor;
- Change to the sponsorship/collaboration;
- Add a new or change a territory for international projects;
- Change the procedures undertaken by participants, including any change relating to the safety or physical or mental integrity of research participants, or to the risk/benefit assessment for the project or collecting additional types of data from research participants;
- Change the design and/or methodology of the study, including changing or adding a new research method and/or research instrument;
- Change project documentation such as protocol, participant information sheets, consent forms, questionnaires, letters of invitation, information sheets for relatives or carers;
- Change to the insurance or indemnity arrangements for the project;
- Change the end date of the project.

Adverse events or untoward incidents

You will need to submit an Adverse Events or Untoward Incidents report in the event of any of the following:

a) Adverse events
b) Breaches of confidentiality
c) Safeguarding issues relating to children or vulnerable adults
d) Incidents that affect the personal safety of a participant or researcher

Issues a) and b) should be reported as soon as possible and no later than five days after the event. Issues c) and d) should be reported immediately. Where appropriate, the researcher should also report adverse events to other relevant institutions, such as the police or social services.

Should you have any further queries relating to this matter, please do not hesitate to contact me. On behalf of the Optometry Proportionate Review Committee, I do hope that the project meets with success.

Kind regards

[redacted]
Optometry Proportionate Review Committee

APPENDIX 5.1: PARTICIPANT'S GUIDANCE SHEET

Brief structure of the focus group discussion

An exploration of community eyecare for children: identifying barriers and enablers using a grounded theory approach.

Duration: 90 minutes

Phase I

Introduction

Ground rules

An audio recording will start with consent

Phase II

Discuss your perspective of the difficulties in examining young children (< 5 years of age) in a community setting.

Examples:

- Skills
- Resources

(Please be aware this is by no means an exhaustive list, and your opinions and experiences will be explored, and you are free to express whatever factors deem appropriate and relevant to you.)

Phase III

Discuss what could be the potential solutions to points raised in the discussion earlier (phase II).

Examples:

- Training
- The decision process in practices (practice rules, etc.).

(Please be aware this is by no means an exhaustive list, and your opinions and experiences will be explored, and you are free to express whatever factors deem appropriate and relevant to you.)

Phase IV

Wrap session and chance to express other points that you may feel are important and were not mentioned.

APPENDIX 5.2: DEMOGRAPHIC QUESTIONNAIRE

What age are you?

- ☐ 20-24
- ☐ 25-34
- ☐ 35-44
- ☐ 45-54
- ☐ 55-65
- ☐ Over 65

Do you have any additional qualifications (please tick all that apply)?

- ☐ Professional Certificate Paediatric Eye Care.
- ☐ Professional Higher Certificate Paediatric Eye Care.
- ☐ MSc
- ☐ PhD
- ☐ Other (specify) _____

In what practice setting do you spend a significant (>50%) of your working week?

- ☐ Small Multiple (up to 10 practices)
- ☐ Large Multiple
- ☐ Independent
- ☐ HES

Do you have experience working in a paediatric clinic in a hospital?

- ☐ Yes
- ☐ No

Do you have contact with young children (aged less than 5 years) as patients;

- ☐ Daily
- ☐ Every 1-2 weeks
- ☐ Monthly
- ☐ Yearly
- ☐ No contact

How much experience have you had examining children with typical development (a child who has been meeting their milestones with no binocular vision anomaly or ocular pathology) of the following age groups?

A child who is < 12 months old.

- ☐ Extensive experience (e.g., seen a child of this age at least once a day).
- ☐ Good experience (e.g., seen a child of this age at least once a week).
- ☐ Some experience (e.g., seen a child of this age at least once a month).
- ☐ Little experience (e.g., seen a child of this age at least a few times during the year).
- ☐ No experience (e.g., have not seen a child of this age).

A child who is 12-24 months old.

- ☐ Extensive experience (e.g., seen a child of this age at least once a day).
- ☐ Good experience (e.g., seen a child of this age at least once a week).
- ☐ Some experience (e.g., seen a child of this age at least once a month).
- ☐ Little experience (e.g., seen a child of this age at least a few times during the year).
- ☐ No experience (e.g., have not seen a child of this age).

A child who is 2-4 years of age.

- ☐ Extensive experience (e.g., seen a child of this age at least once a day).
- ☐ Good experience (e.g., seen a child of this age at least once a week).
- ☐ Some experience (e.g., seen a child of this age at least once a month).
- ☐ Little experience (e.g., seen a child of this age at least a few times during the year).
- ☐ No experience (e.g., have not seen a child of this age).

A child who is 5 years of age and older.

- ☐ Extensive experience (e.g., seen a child of this age at least once a day).
- ☐ Good experience (e.g., seen a child of this age at least once a week).
- ☐ Some experience (e.g., seen a child of this age at least once a month).
- ☐ Little experience (e.g., seen a child of this age at least a few times during the year).
- ☐ No experience (e.g., have not seen a child of this age).

APPENDIX 5.3: TOPIC GUIDE

Welcome Duration= 5 minutes	Hello everyone. Thank you very much for making time to talk to me today. I am…… (facilitator gives a brief introduction) Have you all had a chance to read through the patient information leaflet and guidance sheet for today's focus group that was sent out to you? Your input as a clinician is instrumental. This focus group aims to explore your views on examining young children's eyes and your perception of the potential barriers to examining young children in primary eyecare and the enablers to achieve appropriate eyecare services for young children. Young children will be referred to as children under the age of 5 years. This discussion should last for approximately 90 minutes and will be audio-recorded. We will be using the chat function on MS Teams which can be found at the top of your screen pictured as a message icon. This function will be used to brainstorm your ideas and indicate your agreement or disagreement with a statement by using the like or dislike function on each message. You know that anything you say will be kept entirely confidential, and you will not be identified in any form or way. We can stop at any time and understand that you are happy for the discussion to be recorded?
Ground rules Duration= 5minutes	"Before we begin, I would like to review some of the ground rules for the discussion, which are as follows; " All participants must listen to each other and not interrupt or talk over one another. All participants must respect each other's opinions and comments made. Participants may ask questions but remember the facilitator is not here to share their opinion or indulge in the discussion. Participants should not make derogatory remarks about the case scenarios, or the environment participants work in. Participants should criticise constructively if there is a disagreement with an opinion. It is fine to have a difference in opinion. However, please do respect each other's opinions. Participants should not ask personal questions. All participants should contribute. No participant should dominate the discussion. Everything should remain confidential and should not be discussed outside the group. GET VERBAL CONSENT TO START RECORDING. TURN ON THE RECORDER.
Introduction Duration= 5 minutes	Icebreaker "I would like you all to one by one take turns and introduce yourself to each other. Please tell us your first name only and the type of community setting you work in." (e.g., Multiple or an independent)
Discussion Duration= 65 minutes	I know that we could potentially spend the entire time discussing the issues that arise when examining young children in practice. Today we are here to learn from your experiences. ***Silent generation of ideas (8 minutes)*** Bring up Padlet with a link for participants to share their thoughts from your experience on a slide, and all participants can view the slide.

	Participants will write down as many barriers they perceive when examining a young child in their work/practice setting. *After the first 2-3 minutes of participants brainstorming, use the probes below to see if there could be any other barriers present.* Are there different concerns or difficulties when it comes to examining children of a specific age, such as: *(go through each age one by one allow the participants to state the difficulties with each age).* **Examining a child who is:** • **Less than 12 months old.** • **12-24 months old.** • **2-4 years old.** Ensure that all participants are engaging in the tasks, and when everyone seems to be ready, a request will be made to the participants to stop writing so a discussion can commence. ***<u>Round-robin listing (2 minutes)</u>*** The facilitator reads out the barriers/challenges that have been posted on Padlet. ***<u>Discussion (25 minutes)</u>*** Go round the focus group allowing everyone to clarify and elaborate on why the barriers are expected. **Probes to help stimulate discussion:** <u>Knowledge</u> What comes to mind with the word "training" and "knowledge" playing a role in the current accessibility and delivery of eyecare for young children by optometrists. In your view, where should young children get their eyes examined? Are you aware of any guidelines/ recommendations regarding offering young children an eye test when it has been requested? Are there any limitations on how paediatrics is covered in your education and pre-registration year? Do you have any postgraduate experience or qualifications relevant to paediatrics? <u>Resources / environmental context</u> What resources might help you provide appropriate eyecare services to young children? - Are the resources already readily available to you? Are there any aspects of your work environment that prevents you from examining young children's eyes? If you decide to examine the young child, are there any factors preventing you from completing the eye test? Are there times or situations in the past when you have had problems and not been able to manage a young child? <u>Skills</u> What skills do you think you might need to complete an eye test on a young child? Are there any skills/ techniques that help you examine young children?

	Did the experience of examining a young child make it more or less likely that you would examine another young child in the future? What encourages you to examine young children? What discourages you from examining young children? <u>Professional role</u> What makes testing young children a challenge or not suitable for primary eyecare? What would you consider your responsibilities to be within the multidisciplinary team? - Is there anything you would consider to be beyond your responsibility as an optometrist? How does undertaking an eye test on a very young child fit in with the other responsibilities of your job? - Is there anyone else who should be involved? <u>Beliefs and capabilities</u> On a scale of 0-10, where 0 is "not at all confident", and 10 is "very confident", how confident are you to examine young children's eyes? What makes it easy/hard? - Can you think of any difficulties that you may experience in examining a young child? Why do some optometrists restrict at what age they see children from? Where do you feel the overall responsibility for primary eyecare for young children lies? Do you think optometrists are appropriate individuals for examining very/young children? What do you think happens when a young child is declined an eye test by their local opticians? <u>Decision process</u> Have you ever declined or delayed seeing a young child for an examination? Do you know why? How are decisions made in your practice about which young children receive the service of an eye test? Are decisions about how you manage young children easy or difficult to make? - In what way? <u>Influences</u> Who would influence your decision about examining a young child's eyes? - Anyone else. - How did this happen? To what extent do the views of your practice or colleague's influence whether you undertake an eye examination on a young child? <u>Emotion</u>

	What kind of feedback is given to the parent/carer/guardian when an eye test for a young child does not occur/declined? Additional probes: Does anyone have an example of that? Has anyone else experienced this? Does anyone have a different experience? ***Ranking (2-5 minutes)*** Ask the participants to post the top three barriers they deem to be the most important factors after the discussion has taken place. The facilitator will read them out after factors have been posted. ***Round-robin listing (5 minutes)*** Ask the participants to list possible enablers for the barrier that have been identified in the earlier stage of the discussion. Then read out the enablers. ***Discussion (20 minutes)*** Allows participants to elaborate and clarify their thoughts on enablers and how things can be improved. Probes to help stimulate brainstorming: Knowledge/Skills Are there any changes or new courses you feel would help with training optometrists in examining young children? How can the limitation in ungraduated and pre-registration training be addressed? Do you know of anything that an optometrist in a primary setting can do to improve the accessibility of eyecare for young children? Going forward, what training would be helpful to you in addressing these issues effectively? In your opinion, what knowledge or resources do you need to help examine young children in a community setting. Resources/environmental context What kind of things do you need to examine young children? - How would you rate these in order of importance? - Who gave you this information? How can the environment be improved? Professional role What things can be implemented in community practices to make it easier and suitable to examine young children? Beliefs and capabilities What do you think would help you to overcome these problems? How important is it to you to change the accessibility of eyecare for young children? - In what circumstances would you think it was less important to make changes? What do you see as the most important goal when examining a young child's eyes? Decision process How can a decision made in your practice be tackled and enable accessibility for young children to be improved?

	<u>Influences</u> How can views of your practice and colleagues be changed to help undertake eye examinations for young children? <u>Emotion</u> What would make you consider examining young children of all ages? If a parent were upset or anxious because of your attempt suggesting going elsewhere for an eye test, how would this influence your decision to proceed further and help implement change?
Final thoughts Duration= 5 minutes	The facilitator will ask the participants if they would like to add any more factors that come to mind which were not identified previously in the discussion "Does anyone have any final thoughts about the barriers and enablers discussed or anything you may feel has been missed out but is relevant?"
Review and wrap up Duration= 5 minutes	"Thank you very much for taking the time and sharing your opinions with us. We hope you enjoyed the discussion today.

APPENDIX 5.4: EXAMPLE OF TRANSCRIPT CODING

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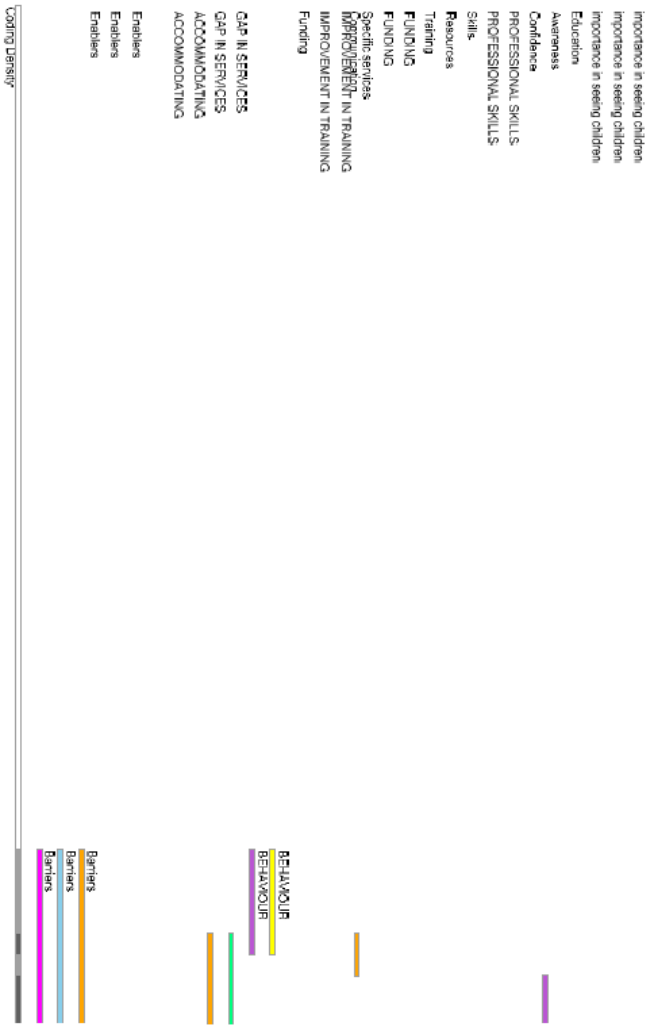


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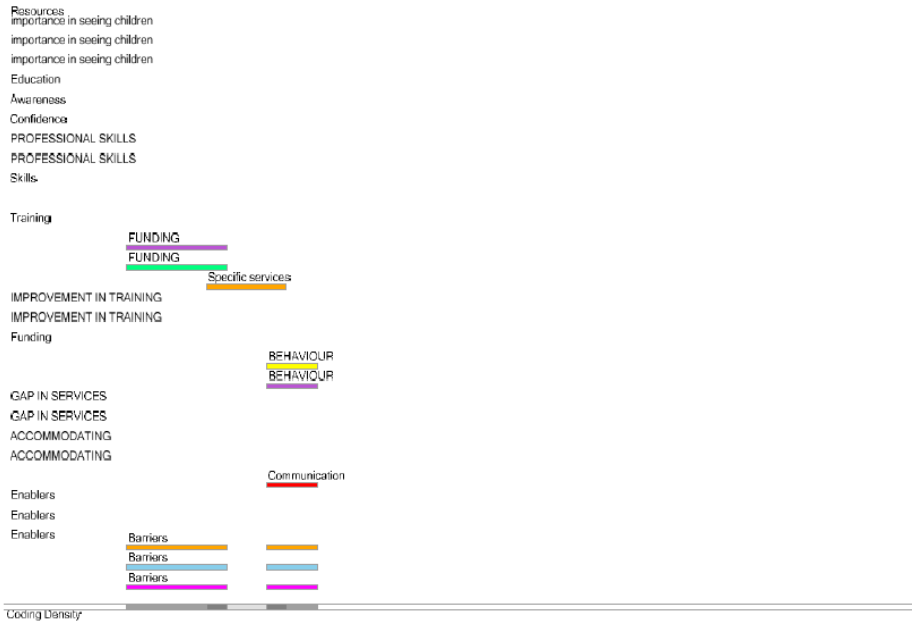
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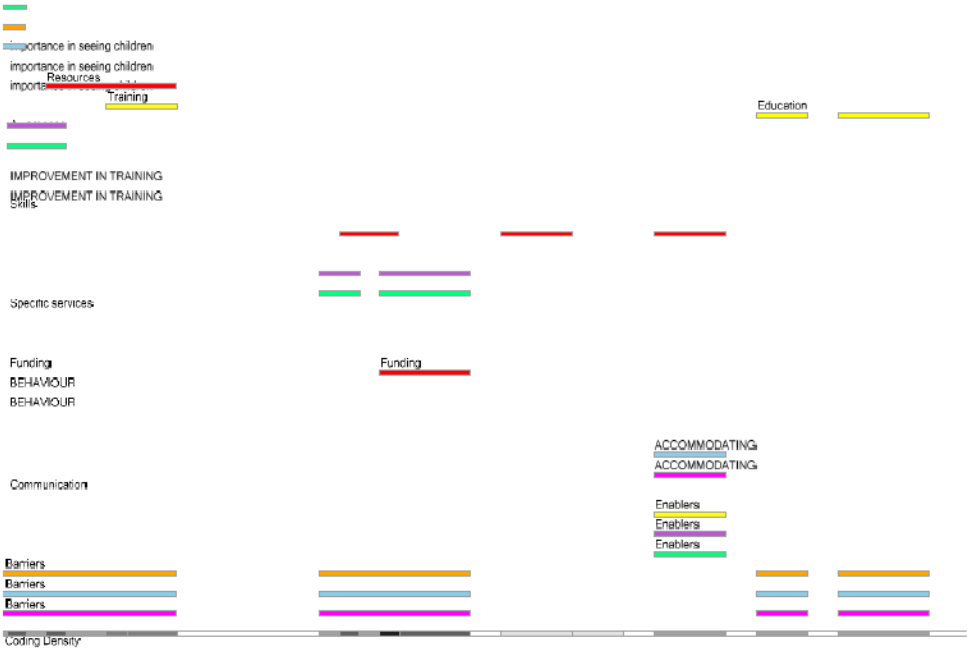
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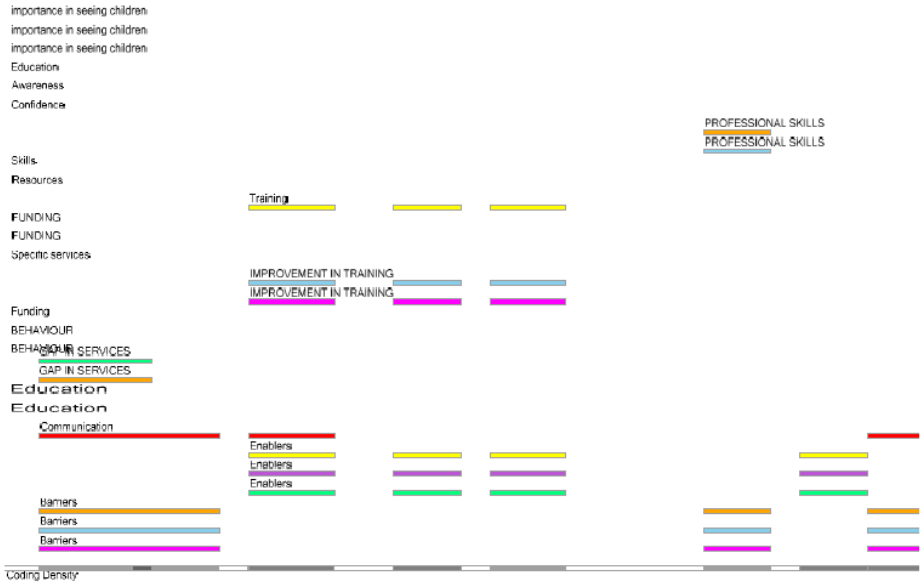
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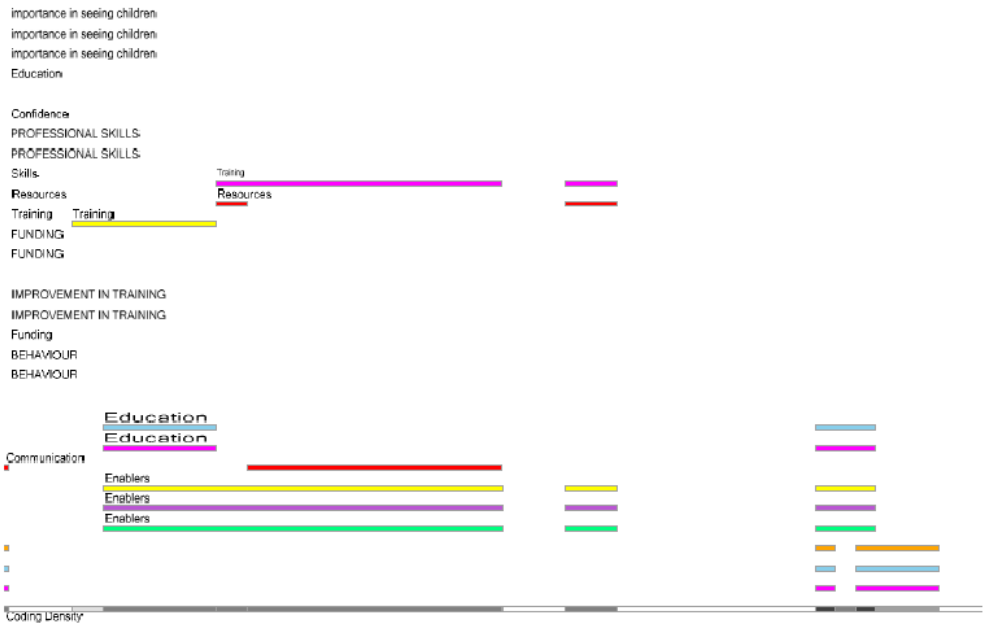
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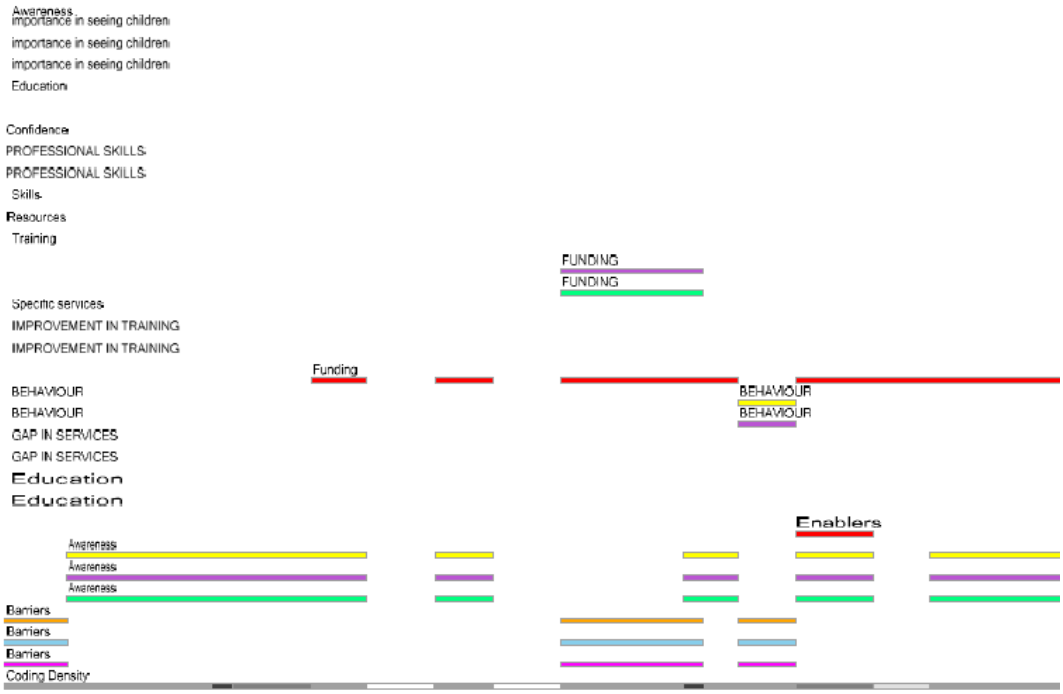
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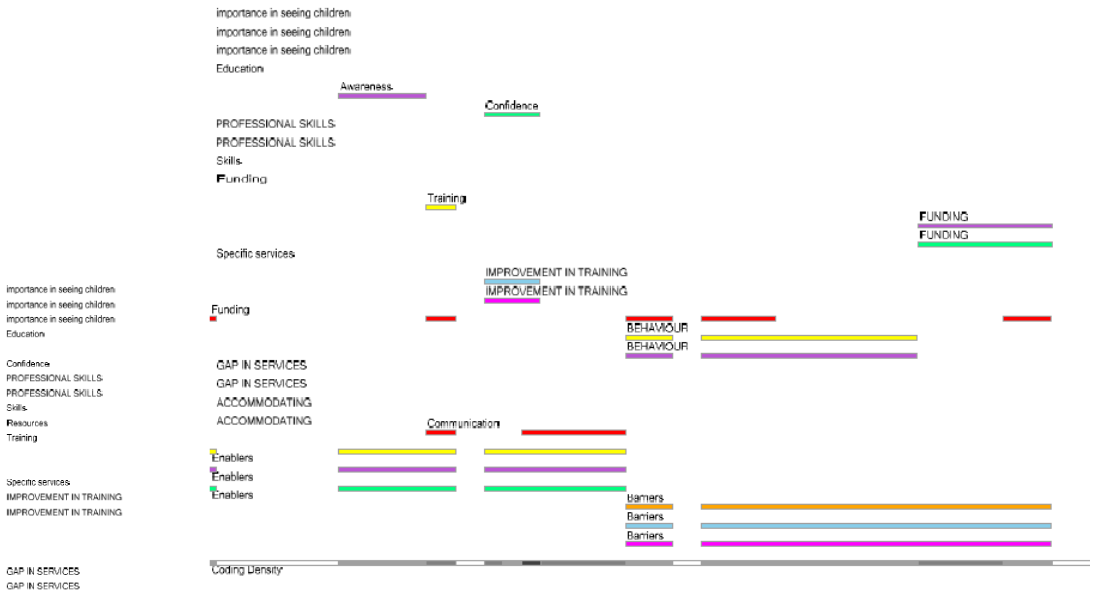

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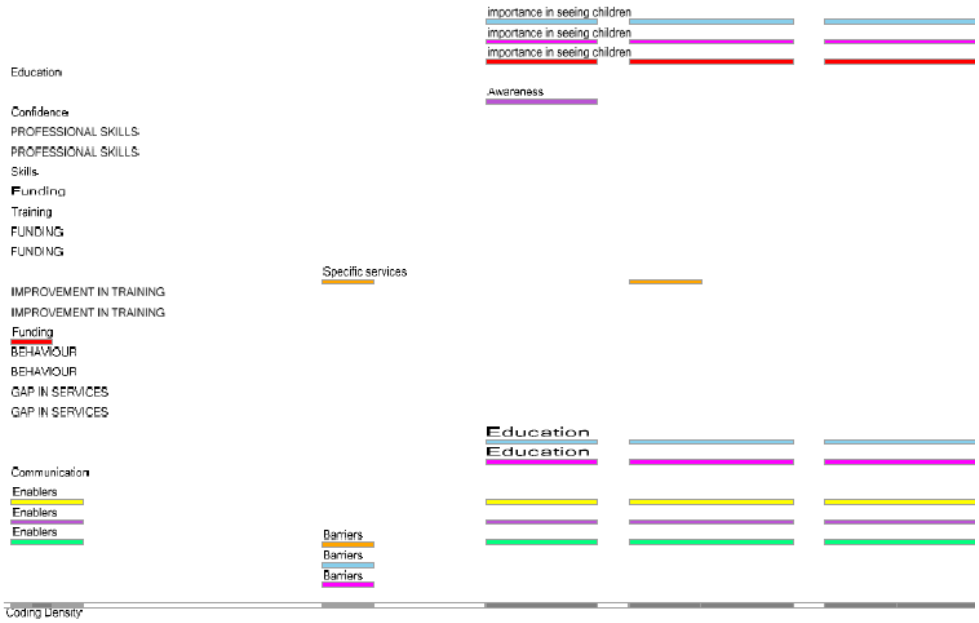
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APPENDIX 5.5: PARTICIPANT FEEDBACK SHEET

An exploration of community eyecare for children: identifying barriers and enablers using a grounded theory approach.

Name: Salma Wilson

Supervisors: Dr Catherine Suttle, Dr Irene Ctori, Dr Rakhee Shah, and Dr Miriam Conway

Literature suggests a gap in the accessibility of primary eyecare for young children (less than five years of age). Good vision from both eyes is essential for a child's visual, educational, and social development. Therefore, they must have the opportunity to get their eyes examined. Although there is some research around examining young children, there currently is no information to date on how optometrists feel when examining young children in community practices.

There is a need for a better understanding. This study aims to identify barriers and corresponding enablers associated with primary eyecare for young children by mapping out the underpinning themes identified by applying the grounded theory approach. This research will, therefore, help improve the current approach to examining young children by future practitioners.

Prior to conducting focus groups, a topic guide was developed based on literature and the research teams professional experience. The topic guide was successfully tested in a pilot study and used for the focus groups of which data was collected. Five focus groups were conducted, with a total of 30 optometrists participating. The focus groups were audio-recorded and transcribed. Transcripts were coded in NVivo 12 and were used to identify themes based on barriers and enablers of children's eyecare in a community setting.

Some of the most common barriers expressed by community optometrists were "Behaviour", "Professional skills", "Funding", "Timing", and "Gap in services". The most common enablers were "Improvement in training", "Improving behaviour", "Improving communication" and, "New schemes".

This study has identified many barriers and enablers to community eyecare services for young children in England. Themes such as "Behaviour", "Professional skills", and "Funding" were identified as having high importance, and therefore they are key mediators of accessibility problems for young children in primary eyecare. Several barriers that were identified from this research were modifiable. However, significant effectors are required to address the accessibility of eyecare services for young children. A draft evidence-based implementation plan could be developed and implemented based on behavioural changes amongst optometrists based on the identified themes. Our findings highlight that the grounded theory approach was useful in providing a comprehensive and data-driven process to identify key issues and solutions for community eyecare services for young children.

We anticipate publication of the study over the next year or so, where full details of this study will be enclosed.