PROFILING THE VISUAL CHARACTERISTICS OF SCHOOL CHILDREN IN ABIA STATE, NIGERIA, TOWARDS THE DEVELOPMENT OF A VISION SCREENING PROTOCOL

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DECLARATION

I, Uchenna Chigozirim Atowa, declare as follows:

1. That the work described in this thesis has not been submitted to UKZN or another tertiary institution for purposes of obtaining an academic qualification, whether by me or any other party.

2. That my contribution to the project was as follows:

- conception of the idea,
- study design and proposal writing,
- data collection and analysis,
- report writing.

3. That the contributions of others to the project were as follows:

a) Dr Rekha Hansraj and Dr Samuel Wajuihian,

- reviews and supervision,
- approval for submission.

4. Signed _______________ Date_________________

CERTIFICATE OF APPROVAL

This is to certify that the research work presented in this thesis, entitled 'Profiling the visual characteristics of school children in Abia State, Nigeria, towards the development of a vision screening protocol' was conducted by UCHENNA CHIGOZRIM ATOWA under our supervision.

That the thesis is submitted to the UKZN in fulfilment of the requirements for the degree of Doctor of Philosophy in Optometry.

1). Supervisor Name: ____________________ Signature: __________

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ABSTRACT

Vision is an important factor for realization of the full learning potential and intellectual performance of a child. While the ability to perform optimally at school depends significantly on the visual status of the individual, the prevalence of common vision conditions in children in Abia State and Nigeria remains largely unknown. The focus of the limited school-based cross-sectional studies on paediatric vision conditions have been mainly to quantify significant refractive errors (RE), whereas the prevalence of strabismus, amblyopia, accommodative anomalies and vergence disorders, most of which have been linked to reduced academic-related performance has not been established. It is imperative that the paucity of data on the prevalence of paediatric vision conditions in Abia State is addressed as this will ensure that common visual anomalies are identified early and treated before functional performance of children is affected. An invaluable approach will be through a coordinated and standardized paediatric vision screening delivery system. However, no standard vision screening guidelines was found for school children in Abia State and Nigeria. The purpose of this study is to characterise the visual anomalies in school children in Abia State and to develop a common and comprehensive paediatric vision screening model based on an evaluation of the current paediatric vision screening programs of individual optometrists.

This was a population based observational, descriptive study, using cross-sectional design to provide quantitative data. The study consisted of two parts. In part one, a total of 550 school children between 10 and 16 years were recruited from 9 schools (public and private) through a systematic random sampling method starting from the three geographic districts to the classrooms. Data were collected by means of a symptom questionnaire and a series of vision assessment instruments including visual acuity (VA), plus lens test, stereopsis, ocular motility, color vision test, non-cycloplegic autorefraction, accommodation, binocular vision and ocular health. Thirteen children were excluded from further participation due to not satisfying the inclusion criteria. A total of 537 (97.6%) children were examined with a mean age of 13.0 ± 2.0 years and median age of 13 years. Participants were divided into two age groups namely group 1 (10 – 12 years) and group 2 (13 – 16 years). The distribution of participants according to age group, gender and school level showed that 41.9% were from age group 1, 52.5% were female and 43.6% were from primary school. The prevalence of vision conditions such as visual impairment, RE, strabismus, colour vision deficiency, cornea opacity, retinal disorder, accommodative and vergence anomalies in school children in Abia State were determined.

The prevalence of presenting, uncorrected and best corrected VA of ≤ 6/12 or worse in the better eye was 3.5%, 4.1% and 0.8%, respectively. Refractive error (78.9%) was the major

cause of presenting visual impairment. Other causes include amblyopia (10.5%), corneal opacity (5.3%) and retinal disorders (5.3%). The prevalence of RE was 10.6%. Among the different REs, low categories of myopia, hyperopia, and astigmatism were the most frequent with corresponding values of 88.9%, 86.4% and 82.4% respectively. None of the children had a high degree hyperopia, myopia or astigmatism. Significant differences between age groups were found in hyperopia and myopia, with the prevalence of hyperopia (p = 0.03) decreasing with age while myopia (p = 0.01) increased with age, and as expected with school level (p = 0.04). There was no significant association between gender and RE. Similarly, no significant difference was found between age group or school level and astigmatism. The prevalence of strabismus, corneal opacity, and retinal disorder was 0.2 % each. A small percentage (0.9%) of children had red-green colour vision deficiency.

Four participants (additional to the baseline data of 13) who have amblyopia were further excluded from the analysis of accommodative and vergence anomalies. For accommodative anomalies the estimates were 3.9% for accommodative insufficiency, 2.8% for accommodative excess and 10.1% for accommodative infacility. There were no association based on age, gender, school level with specific types of accommodative anomalies. For vergence anomalies, the estimates for low suspect, high suspect and definite convergence insufficiencies were 9.6%, 5.8% and 4.1%, respectively. Other prevalence estimates include convergence excess (2.9%), fusional vergence dysfunction (2.6%), basic exophoria (1.7%), basic esophoria (2.8%), divergence insufficiency (0.8%) and divergence excess (0.6%). The prevalence of high suspect ($p < 0.01$) and definite ($p < 0.01$) convergence insufficiency were significantly higher in older children than younger children and as expected therefore with secondary school children than primary school children (p = 0.01). There was no statistically significant association between gender and various vergence anomalies.

In part two of this study, all registered optometrists currently practising in Abia State for at least one year prior to the survey were eligible to participate. A self-administered questionnaire was distributed to the optometrists by hand or email. The questionnaire covered areas such as the optometrist's participation in paediatric vision screening, location of the screenings, the age of children being screened, tests performed and referral criteria, as well as children seen by the optometrists in their practice who were referred from a screening program.

Out of a total of 83 registered optometrists that were contacted for the survey, 64 (77.1%) responded. The majority (87.5%) of the respondents were working in the two cosmopolitan cities of Aba and Umuahia and 71.9% were working in private eye care facilities. Analysis of optometrists' participation in paediatric vision screening showed that only 28 optometrists had participated in one or more vision screening that included children in the last one year before this study and only 10 have provided vision screening services more than four times. Visual acuity and ocular health assessment procedures were the major components of the screening battery of the optometrists. While a child with any disease abnormality was referred for evaluation, the referral criteria for a full examination were inconsistent. The follow-up of those referred for complete examination, could not be established due to lack of uniform guidelines and improper documentation.

The present study has systematically characterised the prevalence of vision conditions in children in Abia State and efforts that have been made at their early detection through vision screening. The findings indicate that while the prevalence of visual impairment in school children in Abia State is low, uncorrected RE is the major cause of reduced vision in those with visual impairment. Given that children within the age group of 10 to 16 years are in stages of rapid growth and intensive education which can complicate RE progression, the high proportion of uncorrected RE in the study sample is a major concern as undetected and untreated RE may progress to sight threatening complications or permanent vision loss.

On the contrary, a significant proportion of the study participants were affected by visual anomalies which do not necessarily affect VA but can negatively impact on school performance. Such visual anomalies include accommodative and vergence anomalies as well as low magnitude of hyperopia and astigmatism. Considering the public health implication, vision screening should be an immediate intervention. However, data on vision screen survey demonstrated that the existing paediatric screening programs in Abia State are irregular, unequal, unstandardized and limited in range with focus mainly on the detection of REs that are detrimental to VA. The implication is that many children with common paediatric eye conditions including those that have been linked to reduced academic achievements are not routinely screened. Overall, it appears that the current screening programs are not meeting the visual needs of the paediatric population suggesting the need for a new strategy that will increase the coverage and effectiveness of paediatric vision screening in Abia State. It is therefore expected that the public-private partnership strategy as proposed in this study will provide greater access to vision screening services across the state as well as help in the early detection of vision anomalies before functional performance of children is affected.

Key words

School children, prevalence of visual anomalies, academic performance, paediatric vision screening, test batteries, visual impairment, refractive error, strabismus, colour vision deficiency, corneal opacity, retinal disorder, accommodative anomalies, vergence anomalies, convergence insufficiency, convergence excess, fusional vergence dysfunction, exophoria, esophoria, accommodative insufficiency, divergence insufficiency, divergence excess, accommodative excess, accommodative infacility, Abia State, Nigeria.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

Realization of the full learning potential of a child depends to a significant extent on the child's visual status, as researchers believe that over 85% of what a child learns in school is through visual presentation.[1,2] Vision is a process which involves the integration and coordination of several functions in the visual system, as well as, other body senses. In a properly developed visual system, the visual cortex of the brain should comfortably integrate clear, focused images from both eyes into a single representation.[3,4] While performing daily visual tasks, children may complain of eye strain, headaches, watery eyes, blurred vision, diplopia and ocular fatigue. These symptoms are mainly because of the inability to sustain single, clear binocular vision because of anomalies in the visual system. The ocular discomforts are particularly worrisome during prolonged near visual tasks such as reading, writing and computer works when the demand on the binocular vision system is very intense.

Numerous studies[1,5,6,7,8,9] conducted in the last decade have elaborated on the relationship between vision anomalies and academic-related performance. In particular, uncorrected hyperopia, accommodative anomalies and vergence disorders can potentially reduce optimum school performance.[6,7,8,9,10]

As a child progresses in school, the demand of near work activities on visual abilities increases significantly. Since 30% to 60% of school activities involve intensive reading, writing and other near work activities,[11,12] it is possible that children with visual problems may lose interest or even avoid engaging in tasks they find uncomfortable to do.[1,13,14,15] Unidentified visual anomalies may also progress to sight threatening complications including amblyopia, cataract, glaucoma, retinal degeneration and myopic macular degeneration, which could lead to permanent visual impairment (VI), with a considerable impact on learning, achievement and quality of life.[16,17,18] In addition, studies[19,20] have reported that covert visual problems that interfere with childrens' abilities to assimilate information may cause them to behave in manners similar to those with behavioural, emotional or attention deficit problems. As a result, these children are often misunderstood and misjudged as having "Attention Deficit Hyperactivity Disorder" (ADHD).

Vision screening of children is an invaluable approach for the detection of potential visual disorders that may have a negative impact on the overall health and wellbeing of a child. Although screening should not be an alternative to a comprehensive examination, it is a means of identifying individuals with or those who are predisposed to having specific vision disorders. Moreover, the detection of ocular disorders during the early critical stage of development can allow for assessment and treatment of vision threatening conditions with better prognosis which is preferable to a comprehensive examination after the condition has deteriorated to obvious visual impairment or blindness.[21,22] Besides, vision screening serves as a medium for promoting eye health among children, parents and the broader community.

1.2 CONTEXT AND PROBLEMS

The recent decline in academic performance of Nigerian school children as demonstrated in public examinations, despite efforts at improving the curriculum and teaching has been a major concern. For instance, between the years 2000 and 2006, on average, only 13.8% and 20.72% of the students who sat for the West African Senior School Certificate Examination (WASSCE) and the National Examination Council Certificate examination (NECO) respectively obtained more than five credits (including Mathematics and English). A worse scenario was reported in 2009, where 98.25% of all those that sat the NECO examination could not obtain five subject passes.[23,24]

Several factors may be responsible for the current decrease in educational achievements of Nigerian school children over the past few years. Determining the prevalence of those factors that have negatively impacted on the childrens' academic abilities should be a major step towards unravelling the causes of this problem. Although, vision anomalies may be one of these factors, the prevalence of common vision disorders in children in Abia State and Nigeria remains largely unknown.[25,26,27,28,29] The limited school-based cross-sectional studies on children have focus mainly on the prevalence of refractive error (RE), while the prevalence of strabismus, amblyopia, accommodative anomalies and vergence disorders, most of which have been associated with reduced academic-related performance, has not been established. Furthermore, there is a need for an effective and sustainable paediatric vision screening program, considering the implication of vision problems on the overall development of a child.

Efficient vision screening services depend on the validity and reliability of the test protocols, the components of screening batteries and the exact age to screening. In addition, applicable referral system comprising the most appropriate referral criteria for vision screening batteries[21] and adequate documentation to ensure that those identified as having visual problems are receiving the recommended complete examination should be in place. However, no standard vision screening protocol or guidelines were found for school children in Nigeria and particularly in Abia State.[27,29,30,31,32] Visual conditions that could have far-reaching implications on the development of a child should be screened for and test batteries should be appropriate for the population being screened.[21] A reliable information on the common visual problems of Nigerian children should be central to the development of a vision screening strategy which will target those visual conditions common in children particularly in Abia State.

1.3 RESEARCH QUESTIONS

1. What is the prevalence of RE, amblyopia, strabismus, accommodative anomalies, vergence disorders and ocular diseases in school children in Abia State?
2. What is the coverage of current vision screening services available to Abia State school children by optometrists?
3. What are the contents of the current vision screening programs available to school children in Abia State provided by optometrists on an individual basis?
4. Are the existing vision screening services offered by optometrists targeting conditions common to school children in Abia State?
5. What are the referral criteria for the existing vision screening programs available to school children in Abia State?

1.4 AIM AND OBLECTIVES

1.4.1 Aim

The purpose of this study was to determine the visual characteristics of school children aged (10 – 16 years) in Abia State and to evaluate the paediatric vision screening programs of individual optometrists, to guide the development of a common vision screening strategy.

1.4.2 Objectives

The objectives of this study, more specifically, were to:

i. develop a visual profile of school children by determining the prevalence of RE, amblyopia, strabismus, accommodative, vergence anomalies and ocular disease using a selected battery of vision tests.

ii. determine the extent to which the vision screening provisions by optometrists are providing access to eyecare to the children of Abia State.

iii. evaluate the contents (test batteries) of vision screening programs currently available to school children in Abia State as offered by individual optometrists.

iv. determine whether the vision screening services offered by individual optometrists target conditions that are more prevalent in school children in Abia State.

v. evaluate the referral criteria for the vision screening programs available to school children in Abia State offered by individual optometrists.

vi. Make recommendations towards the development of a common vision screening strategy for children in Abia State.

1.5 SIGNIFICANCE OF THE STUDY

Prevalence information on visual conditions in children is necessary for planning and implementation of child eye health services. However, the prevalence of visual anomalies in children in Abia State and Nigeria as a whole has not been comprehensively characterized to date. No study has reported on childhood VI, amblyopia, strabismus, accommodative and vergence anomalies in this region. Given that various studies in other countries have documented the adverse impact of visual disorders on educational outcome of school children, it is imperative that the paucity of information in this area is addressed. This will ensure that common visual anomalies peculiar to Abia State school children are identified early on and treated before educational and social progress are affected.

An invaluable approach will be through a coordinated and standardized common strategy that will involve valid and reliable test batteries. Vision screening programs provided to the children by individual optometrists will be evaluated to determine the nature of the programs and referral criteria used. Using the information on the prevalence of visual anomalies in children, it will be determined whether vision screening services provided by individual optometrists are meeting the visual needs of the school children. The outcome of the evaluation will apply towards the development of a common protocol for early detection and effective treatment of those visual anomalies, thereby reducing the adverse effect of the untreated conditions on the general development of children. Furthermore, this study will help in the promotion of eye health to the children, teachers and the wider community particularly in the remodelling of vision screening programs throughout Nigeria.

1.6 TYPE OF STUDY AND METHODS

This was a population-based observational descriptive study, using cross-sectional design to provide quantitative data. The study consisted of two parts. Part one employed the use of probability sampling method in selecting primary and secondary school children in Abia State, who are between the ages of 10 – 16 years. A total of 550 school children were recruited from 9 schools (public and private) through a systematic random sampling method. Part two of the study comprised registered optometrists currently working in Abia State in the past one year prior to the study. A non-probability convenience sampling method was used in recruiting 83 registered optometrists working in private or public health facilities in Abia State. The study methods will be discussed in detail in Chapter Three (Research methods).

1.7 STUDY SCOPE

This study consists of two parts (part one and part two). In part one, the focus was on those visual conditions that are regularly tested for during a paediatric eye examination and have been established by previous studies[1,3,6,7,8,9,19,20] to adversely impact on childrens' academic performances and overall wellbeing. The vision tests that were included also depended on the availability and affordability of optometric instruments. The tests included measures of VA, RE, stereoacuity, accommodative function, binocular function and ocular health assessment.

The inclusion of the specific accommodative and vergence function tests depended on their strength to classify accommodative and vergence anomalies.[33,34] At the same time, the addition of tests that were mainly subjective was minimized, considering the age of the study participants. Thus, for accommodative function, emphasis was more on accommodative response using the monocular estimation retinoscopy and accommodative facility test with ± 2.00 D flipper lens. Whereas efforts were made to measure the accommodative amplitude using Donder's push up to blur method, test for negative and positive relative accommodation were not included. Given the complex nature of the accommodative test children may not accurately report the blur experience.[34]

For part two of the study, the focus was on the appropriateness of the school vision screening programs offered by individual optometrists in Abia State. Using the findings of the first part (visual characteristics of school children), the study assessed whether the existing vision screening services offered by individual optometrists are meeting the visual needs of the school children.

1.8 STUDY OUTCOMES

The study outcomes are the prevalence of visual anomalies and the components and referral criteria for childrens' vision screening programs provided by individual optometrists.

1.9 DEFINITION OF TERMS

Prevalence: This concept describes the total number of people in a given population that is affected by a disease condition at a specific time and is usually expressed as a fraction or as a percentage.

School children: These are children attending primary and secondary schools in Abia state, mostly between the ages of 10 and 16 years.

Vision screening: This is a process of identifying individuals with visual problems or those with the likelihood of developing visual problems using a battery of vision test and a defined referral criterion. It may be administered by ophthalmic and trained non-ophthalmic personnel. Those who did not meet the pass criteria are referred for complete examination and possible treatment.

Refractive error: Describes a visual condition that results from the failure of the eye to focus parallel rays of light from optical infinity exactly on the retina. Refractive error is categorized as hyperopia, myopia and hyperopia.

Accommodative and vergence anomalies: These are the abnormal conditions of the accommodative and vergence system and were classified as accommodative insufficiency, accommodative excess, convergence insufficiency, convergence excess, fusional vergence dysfunction, basic esophoria, basic exophoria, divergence insufficiency and divergence excess. The individual parameters of near point of convergence, heterophoria assessment, AC/A ratio, fusional vergence range, stereoacuity, accommodative amplitude, response and facility as well as the presence of strabismus.

Strabismus: A manifest deviation of ocular alignment as a result of the departure from the parallel nature of a normal gaze of the eye.

Amblyopia: Describes an abnormal vision in at least one eye even with the best compensating lens and with no other ocular and/or neural anomaly.

1.10 THESIS OUTLINE

The thesis is submitted in the manuscript format and is therefore structured in the following ways:

Chapter one (Introduction): In this chapter, the background information, rationale, objectives, significance and scope of the study were presented. The outline of subsequent chapters was also presented. Finally, a summary of chapter was presented.

Chapter two (Literature review): A review of empirical studies on common visual problems in school-age children worldwide and efforts at their early detection through vision screening is presented in this chapter. The chapter consists of an introduction, four review (three published and one unpublished) papers and a summary of the whole chapter.

The review papers are presented as follows:

- 2.2 Visual problems: a review of prevalence studies on visual impairment in school-age children. This paper has been published as:

  Atowa UC, Hansraj R, Wajuihian SO. Visual problems: a review of prevalence studies on visual impairment in school-age children. *International Journal of Ophthalmology*. 2019;12(6):1037-1043. https://doi.org/10.18240/ijo.2019.06.25

- 2.3 Visual problems: a review of prevalence studies on refractive errors in school-age children. This paper has been published as:

  Atowa UC, Hansraj R, Wajuihian SO. Vision problems: A review of prevalence studies on refractive errors in school-age children. *African Vision and Eye Health.* 2019;78(1), a461. https://doi.org/10.4102/ aveh.v78i1.461

- 2.4 Visual problems: a review of prevalence studies on accommodative and vergence anomalies in school-age children.

- 2.5 A review of paediatric vision screening guidelines. This manuscript provides an overview of some important aspects of the history of paediatric vision screening and the available evidence in support of the use of paediatric vision screening to detect vision conditions in children. This paper has been published as:

  Atowa UC, Wajuihian SO, Hansraj R. A review of paediatric vision screening guidelines and protocols. *International Journal of Ophthalmology*. 2019;12(7):1194-1201.

Chapter three (Research Methods): This chapter describes in detail the study design, research setting, study population and the sampling method for the study. In addition, the data collection instruments and a detailed procedure in each step of the data collection process are presented including the statistical methods that were applied in analyzing the findings.

Chapter four, five and six (Reports for part one of the study): These chapters characterised visual anomalies in school children in Abia State, as well as, with their relationship with sample demographics such as age, gender and school level. The results for each of the visual anomalies are presented separately in each chapter and discussed in relation to similar studies. The significance of the study findings for child eye health including the strengths and limitations of the studies are clearly stated.

The presentation is as follows:

- Chapter four - Refractive error and visual impairment among school children in Abia State, Nigeria.

- Chapter five - Accommodative anomalies among school children in Abia State, Nigeria. Chapter five has been published as:

  Atowa UC, Hansraj R, Wajuihian SO. Accommodative anomalies among school children in Abia State, Nigeria. *African Vision Eye Health*. 2019;78(1),a465. https://doi.org/10.4102/ aveh.v78i1.465

- Chapter six - Vergence profiles and prevalence of non-strabismic vergence anomalies among school children in Abia State, Nigeria. Chapter six has been published as:

  Atowa UC, Wajuihian SO, Hansraj R. Vergence profile and prevalence of non-strabismic vergence anomalies among school children in Abia State, Nigeria. *Ophthalmic Epidemiology*. 2019;26(2):121-131. https://doi.org/10.1080/09286586.2018.1532523 [published online first: 10 October 2018]

Chapter seven (Report for part two of the study): The results and discussion on the survey of vision screening programs of individual optometrists in Abia State is presented in this chapter. A recommendation for a new strategy that will improve coverage and ensure uniformity of service provisions is also presented.

Chapter eight (Conclusion): A recap of the major findings including the significance of the study, as well as, limitations and recommendations for further studies are presented.

1.11 SUMMARY

This chapter provided background information on the childhood visual conditions and paediatric vision screening. It also stressed the need to have comprehensive data on vision problems in school children in Abia State, Nigeria which is necessary for the development of a standardized paediatric vision screening protocol. The chapter also outlines the specific objectives that were pursued to achieve the main objective of this study, which is ‘Profiling the visual characteristics of school children in Abia State towards the development of a vision screening protocol'. The significance, as well as, the scope of the study was presented. Finally, the layout of subsequent chapters was also presented.

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CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter provides a review of relevant literature on the visual anomalies in children and paediatric vision screening. The prevalence of visual anomalies such as visual impairment, refractive errors, accommodative and vergence anomalies in school-age children across various countries and regions are presented. The findings of the corresponding studies are discussed in relation to measuring techniques and diagnostic criteria, as well as, study limitations. The contribution of each study to understanding the research problem being studied, as well as, the relationship between the corresponding studies is outlined. The objective is to identify significant gaps in knowledge which will direct additional research in this area. Furthermore, the chapter presents a discussion on some important aspects of the history of paediatric vision screening and available evidence in support of its use to detect vision conditions in children. It also evaluates some of the contentious issues surrounding paediatric vision screening. An overview of child eye health in Nigeria and vision screening models in other countries are also presented. Overall, the review of literature provides a clear framework for the design, goals and research questions of the studies included in this thesis, as well as, direct the development of an evidence-based broad and uniform screening model. This chapter consists of three published and one ready to submit paper.

2.2 VISUAL PROBLEMS: A REVIEW OF PREVALENCE STUDIES ON VISUAL IMPAIRMENT IN SCHOOL-AGE CHILDREN

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ABSTRACT

Childhood visual impairment (VI) can have a significant impact on the educational achievement, career choices and social life of affected individual, and in children, is mainly due to either preventable or treatable causes. Reliable data on the prevalence and causes of VI in children will guide the development of a systematic vision screening program for its early detection and successful treatment of possible causes. The purpose of this literature review is to summarize the available data on prevalence and causes of VI in school-age children from various regions globally. A discussion on the major findings highlighting the definition criteria, classifications and limitations for further studies is also presented.

KEYWORDS: visual impairment; school-age children; vision screening; school performance

INTRODUCTION

Visual impairment (VI) has a considerable impact on the lives of the affected individuals as well as their families and society. Its effect on development and learning is more significant when it is present at birth or shortly afterwards compared to when it is acquired later in life. Loss of vision in children influences their academic opportunities, career choices, and social life, with[1-2] defective near vision influencing their ability to perform a variety of tasks that involve reading. As more than 85% of what a child learns in school is through visual presentation, their ability to perform optimally will be affected[3-4]. Visual field deficits also affect the child's ability to accomplish tasks that require ambulation in challenging environments or the application of peripheral vision[1]. In addition, approximately 90% of visually impaired children are not receiving adequate education due to factors that include discrimination, stigmatisation and lack of access to appropriate schools[5-6].

Reports suggests that in both developed and developing countries, the majority of VI is either preventable or treatable[7-8]. Early detection and effective treatment of underlying causes at the 'sensitive' period of visual development therefore remains an important approach for preventing VI[9-11] Reliable data on the prevalence and causes of VI in children are necessary for developing a systematic vision screening program with valid and reliable test protocols. Such data will help to direct the application of available resources and efforts for early detection to people who are at risk, thereby reducing the high short- and long-term costs to the health system and society. The purpose of this literature review is to document the prevalence and causes of VI in school-age children from various regions globally. A discussion on the major findings highlighting the definition criteria, classifications and limitations for further studies is also presented.

METHOD

The online databases of PubMed, Medline, OVID, Google Scholar, Science Direct and Embase were explored for the keywords, and VI (prevalence and causes) in school children. The search was restricted to primary research published in the English language and in peer-reviewed journals. Only epidemiological studies with stated the measures of prevalence and causes of VI among school-age children between 5-18y of age were included. However, two studies on VI among Nigerian children with participants in the age groups 4–24y [12] and 9–21y [13] were included due to insufficient data on visual anomalies in these age groups in Nigeria.

In this narrative review, a summary of each study that met the outlined criteria is presented first and then evaluated in relation to other studies. Parameters of interests for review included: sample size and sampling method; participant characteristics, including gender and age; prevalence rates and causes of VI; information on diagnostic criteria and measurement techniques. The studies were compared according to geographic regions or ethnicity.

STUDIES ON SCHOOL-AGE CHILDREN

African region

Table 1 shows the various studies that have reported on prevalence and causes of VI in paediatric populations in Africa and elsewhere, while Table 2 presents the major causes of VI for these studies, where available. The exact prevalence and causes of Childhood VI and blindness are difficult to establish due to the infrequent occurrence of relevant pediatric eye conditions and the lack of well-designed epidemiological studies, particularly in developing countries. For instance, in Nigeria, a national survey[14]. on blindness and VI conducted between 2005 and 2007 reported only on the causes of VI in an adult population. In addition, the study was constrained by the sampling method used to identify the paediatric population, which limits the generalization of findings, as the school-age children were invited to participate only if they were living in a family of at least one eligible adult[14-16] In the study, blindness was defined as presenting visual acuity (VA) of 6/120 or worse in the better eye, while VI was defined as presenting VA of less than 6/12 in the better eye. Of the 5371 children who were examined, the prevalence of blindness was 0.6%, with a higher prevalence in females (0.89%) than males (0.33%). The study also reported that the prevalence of mild, moderate and severe VI was much lower than that of blindness[14-16].

Two cross-sectional studies[15,16] were reported in some Nigerian cities, although with an older population than the studies included in this review. The studies were limited by poor diagnostic criteria, with that by Megbelayin and Asana[13] defining VI as presenting VA of 6/9 or less in one or both eyes and reported a prevalence of VI of 6.9%. The definition criteria they adopted has the potential of overestimating the prevalence of VI in the study sample. In the earlier study by Ajaiyeoba *et al*[12], the prevalence of VI was estimated to be 1.5%, but it provided no clearly defined criteria. However, in both studies[12,13], refractive error (RE) was the major cause of VI.

In a large-scale Refractive Error Study in Children (RESC) study in a South African population, Naidoo *et al*[17] reported on the prevalence of uncorrected (1.4%), presenting (1.2%) and best corrected (0.32%) VA of ≤ 6/12 in children 5-15y of age in the Durban area. A geographically defined cluster sampling design and a door-to-door enumeration survey was applied to recruit the participants. RE (63.6%) was the major cause of VI, with only 12 (19.0%) of those affected wearing spectacles during examination. A more recent school-based RESC study was conducted in the Ashanti Region of Ghana[18] on children whose ages ranged from 12-15y. Reliable VA testing was possible in all but one of the 2454 children examined for VI and RE, with 119 children having VI in one or both eyes. Approximately, 3.7%, 3.5%, and 0.4% had uncorrected, presenting and best VA of 6/12 or worse in the better eye respectively, with RE being the major cause of reduced vision.

Asian region

The prevalence of VI and RE in school children 12-15y of age was studied in Ba Ria, Vung Tau Province, Vietnam[19]. The authors examined each subject with a standardized test protocol and found that 87.8% of 2258 children had normal or near normal vision (≥6/9.5) in the better eye. A total of 434 (19.4%) children had uncorrected VA of ≤ 6/12 in both eyes, with 71 (3.2%) being blind, while the prevalence of VI (presenting vision ≤6/12 in the better eye) was 12.2%, including six blind children. However, with best-corrected VA, no children were found to be blind. RE was the major cause of VI in 92.7% of the vision-impaired children, and amblyopia was responsible for 2.2%. A comparatively similar result was obtained by Goh *et al*[20] in multi-ethnic population, including Malay (70.3%), Chinese (16.5%), Indian (8.9%) and others (4.3%) in Malaysia. The prevalence of uncorrected, presenting, and best-corrected VI (VA ≤20/40) in the better eye was 17.1%, 10.1%, and 1.4%, respectively. In eyes with reduced vision, RE was the cause in 87.0%, amblyopia in 2.0%, other causes in 0.6%, and unexplained causes, suspected to be amblyopia, accounted for another 10.4%.

In India, a population-based study involving a random selection and door-to-door enumeration of children aged 5-15y from 22 geographically defined clusters found that RE (81.7%) was a major contributor to the cause of VI in children in New Delhi. The prevalence of uncorrected, presenting, and best corrected VA of 6/12 or worse in the better eye was 6.4%, 4.9%, and 0.81%, respectively[21]. A similar study with children aged 7-15y from rural India found a lower prevalence of uncorrected, presenting and best corrected VA of 6/12 or worse in the better eye, with corresponding values of 2.7%, 2.6%, and 0.78%. RE (61%) was also the major causes of reduced vision in eyes with VI[22]. The difference between these two studies, despite the age ranges differing by only two years, may be related to a higher prevalence of RE, especially myopia, in urban compared to rural areas, due possibly to differing education systems and the children's exposure to near-work activities.

Americas and European region

Salomao *et al*[23] examined 2825 school children aged 11-14y sampled by cluster random technique from 374 schools in three districts of Sao Paulo, Brazil. VA was measured at 4 m using a standardized protocol, with the prevalence of uncorrected, presenting, and best-corrected VA of 6/12 or worse in the better eye being 4.82%, 2.67%, and 0.41%, respectively. RE contributed to76.8% of children with VI in one or both eyes. O'Donoghue *et al*[24] reported on the Northern Ireland Childhood Errors of Refraction study, where VA was measured using a logarithm of the minimum angle of resolution (logMAR) protocol on 392 (6-7y) and 661 children (12-13y). Approximately, 3.6% of presenting VI in the better eye was found in the older (12-13y) children, which was higher than the 1.5% in the younger (6-7y) group. Approximately 25% of the children with RE presented for examination without spectacle correction.

A cross-sectional survey of children aged 5-18y living in a resource-poor community in Peru reported a high prevalence of VI, which may be attributed to its definition criteria. Participants completed a socio-demographic and health risk factor questionnaire and were screened for reduced distance VA, stereopsis, external eye examination and colour vision deficiency, with VI being defined as VA less than 0.2 logMAR (≤6/9). Of the 380 children who were examined, the mean uncorrected VA was found to be 0.07±0.13 logMAR, the findings indicating that 8.9% of the children were visually impaired in both eyes and 26.3% in one eye. Severe VI (<6/60) in both eyes was 0.3% and 0.7% in one eye, with the study recommending the performance of regular vision screening of children in Peru[25].

Oceania region

Taylor *et al*[26] assessed low vision and blindness in 1694 Australian indigenous school-age children aged 5-15y, with a VA measurement of scholars randomly selected from 30 geographic areas. The rate of low vision, defined as best VA of less than 6/12 and equal to 6/60 was 1.5%, and the rate of blindness of best VA of less than 6/60 was 0.2%, with RE accounting for the most of their low vision. Relative risk of vision loss and blindness in the indigenous compared with the wider population children in Australia were found to be 0.2 and 0.6, respectively. In another school-based survey in Sydney, Australia, the prevalence of non-correctable VI (VA < 6/12) was only between 0.03% and 0.08%, which was 45 times lower than that reported in adults.[27] RE was responsible for 69.0% of the VI in the children.

Limitations of Previous Studies

While all studies (Table 1), except for Sauer *et al*[25], included large sample sizes and traditional VA chart measuring technique, some flaws inherent in the study designs may have affected the generalizability of their findings. Some of the studies failed to state the eligibility criteria for participant recruitment[12]. In others, amblyopia was identified as a major cause of VI with no stated definition criterion[13,17,19-20], while others[14,25,27] failed to provide detailed information on the causes of VI in their study samples. In addition, the study by Ajaiyeoba *et al*[12] did not indicate the definition criteria used to identifying participants with VI. In relation to RE, the emphasis in some studies was on VI with RE[14,18,26], thereby undermining the quantification of children at risk of developing VI due to RE and preventing the development of screening and intervention strategies to prevent VI in this cohort.

Table 1 Prevalence of childhood visual impairment across various countries

Study	Country	Age (y)	Sample size (*n*)	VA threshold	Prevalence (%)		
					Uncorrected VA	Presenting VA	Best corrected VA
Abdull *et al*[14]	Nigeria	10–15	5371	< 6/12	Not reported	Not reported	1.2
Ajaiyeoba *et al*[12]	Osun, Nigeria	4–24	1144	Not reported	Not reported	1.5	Not reported
Megbelayin[13]	Calabar, Nigeria	9–21	1175	≤ 6/9	Not reported	6.9	Not reported
Kumah *et al*[18]	Ghana	12–15	2435	≤ 6/12	3.7	3.5	0.4
Naidoo *et al*[17]	South Africa	5–15	4238	≤ 6/12	1.4	1.4	0.32
Taylor *et al*[26]	Australia	5–15	1694	< 6/12	Not reported	Not reported	1.7
Robaei *et al*[27]	Sydney, Australia	6	1740	< 6/12	4.1	Not reported	Not reported
Murthy *et al*[21]	India (urban)	5–15	6447	≤ 6/12	6.4	4.9	0.81
Dandona *et al*[22]	India (rural)	7–15	4074	≤ 6/12	2.7	2.6	0.78
Paudel *et al*[19]	Vietnam	12–15	2238	≤ 6/12	19.4	12.2	Not reported
Goh *et al*[20]	Malaysia	7–15	4634	≤ 6/12	17.1	10.1	1.4
Salomao *et al*[23]	Brazil	11– 14	2441	≤ 6/12	4.8	2.7	0.41
O'Donoghue *et al*[24]	United Kingdom	6–7	392	< 6/12	Not reported	1.5	Not reported
		12–13	661			3.6	
Sauer *et al*[25]	Peru	5–18	380	≤ 6/9	Not reported	8.9	Not reported

VA: Visual acuity.

. Table 2 Causes of childhood visual impairment across various countries

Study	Country	Age (y)	Sample size (n)	Percentage of participants (%)						
				Refractive error	Amblyopia	Corneal opacity	Retinal disorder	Cataract	Other causes	Unexplained Causes
Ajaiyeoba *et al*[12]	Osun, Nigeria	4–24	1144	58.8	5.9	11.8	0	11.8	11.8	–
Megbelayin[13]	Calabar, Nigeria	9–21	1175	61.1	0.3	0.2	0.7	0	0.6	–
Kumah *et al*[18]	Ghana	12–15	2435	71.7	9.9	4.6	5.9	0	1.88	–
Naidoo *et al*[17]	South Africa	5–15	4238	63.6	7.3	3.7	9.9	0	3.1	12.0
Murthy *et al*[21]	India (urban)	5–15	6447	81.7	4.4	–	4.7	–	3.3	5.9
Dandona *et al*[22]	India (rural)	7–15	4074	61.0	12.0	–	–	–	15.0	13.0
Paudel *et al*[19]	Vietnam	12–15	2238	92.7	2.2	0	0.4	0.7	1.5	2.6
Goh *et al*[20]	Malaysia	7–15	4634	87.0	2.0	0	0	0	0.6	10.4
Salomao *et al*[23]	China	11–14	2441	76.8	11.4	0	5.9	0	2.7	7.7
Taylor[26]	Australia	5-15	1694	47.0	19.0	0	0	0	0	34.0
Robaei *et al*[27]	Sydney, Australia	6	1740	69.0	–	–	–	–	–	–

DISCUSSION

Definition of visual impairment

The definition criterion for identifying children with VI is very important. Until recently, the definition of VI was predicated on the second revision of the 10th ICD edition,[28] which followed from a 1972 World Health Organization (WHO) study of blindness and demonstrated that the best corrected VA should be used as the basis for estimating VI.[29] At that stage, RE was not considered a priority and a major cause of VI, and was excluded from reports of the total number of persons with VI. However, data from recent population-based studies indicates that uncorrected RE contributes significantly to the total number of persons with VI.[30] Accordingly, the WHO adopted a new definition of VI in the revised ICD-10 version: 2016, and uses presenting VA and visual loss from uncorrected RE.[31] Under this classification, low vision (moderate and severe impairment) is defined as a presenting VA of less than 6/18, but equal to or better than 6/120, or a visual field loss to less than 20 degrees diameter in the better eye with best possible refractive correction.

In the reviewed studies (Table 1), although VI was mostly defined as a VA of less than or equal to 6/12, a broad range of definition criteria was applied in its diagnosis : from a VA of 6/9 or less to less than 6/12, including Ajaiyeoba, et al.,[12] who did not indicate the definition criterion for VI. The use of a VA of 6/9 by some studies will overestimate the prevalence of VI and weigh heavily on the cost of intervention services for affected individuals, and cause considerable psychological effect on the affected children and their families. When compared to other studies on African children, Megbelayin,[13] who defined VI as a VA of 6/9 or less, reported a higher prevalence of VI than other studies[14,17,18] that utilized a VA of 6/12 or worse.

The trend was also observed in the studies conducted in the Americas, where the study in Peru[25] that applied a VA threshold of 6/9 or less reported a higher prevalence of VI than another study in Brazil.[23] Studies have reported that the mean VA acuity in young children was 6/7.5,[32] and that an acuity of 6/12 or less would have a harmful effect on their vision[33] and potentially reduce their functional performance. Considering that school-age children are in an active growth stage and intensive education, When compared with the WHO definition of VI, the VA of 6/12 or less used by the RESC studies provides a better indicator to accurately estimate the magnitude of VI due to RE and a proper assessment of the demand for eye care services,[34] including those with mild VI. Its use will also ensure timely detection and treatment of the underlying factors of mild VI before they progress to permanent.

Classification of visual impairment

The categories of VI adopted by the majority of the studies reviewed suggest that a person with a presenting VA of worse than 6/60 should be regarded as blind. However, a substantial number of children who are classified as blind still have usable vision and can sustain activities of daily living independently.[35] Reports indicate that in developing countries, such as in Africa, approximately 20% of children categorized as blind were found to have significant residual vision.[36,37] The implications for rehabilitation and education is that children with low vision may be educated using techniques that are appropriate for those who are totally blind, despite their having some useful vision that can support other activities of daily living if they can be taught how to use it appropriately.[38,39] For instance, approximately 66% and 1.45% of children who were initially classified as blind but reading with the aid of Braille were found to have low and normal vison, respectively, after best refraction.[40] In view of the importance of functional vision, the WHO in 1992 added another perspective to the definition of VI that covers both distance and near vision.[35] The definition states that: *a person with low vision is one who has impairment of visual functioning even after treatment and/or refractive correction, and has a vision in the better eye of less than 10 degree from the point of fixation (or 20 degrees across), but who uses or is potentially able to use vision for planning or execution of a task*. This functional definition ensures that people who have low vision, but with a VA of less than 6/120, are included in low vision programs and are eligible for appropriate services.

Regional variations in the prevalence and causes of visual impairment

The prevalence and causes of VI varied across the different regions[1] (Table 2). A lower prevalence of VI was reported for African children compared to other regions, especially Southeast Asian countries. This may be explained by the lack of robust epidemiological studies in developing countries such as Africa. The higher prevalence of VI in Southeast Asian countries compared to other regions may be related to the reported high prevalence and severity of myopia in these populations. Myopigenic factors including; i) genetic predisposition, such as ethnicity and a family history of high myopia; ii) intensive near work activities due to competitive education and schooling systems are common among Southeast Asian children,[41] with myopic eyes being at risk of developing functional visual impairment at a relatively young age.[42] In addition, the causes of VI varied widely among studies, which may be attributed to differences in socio-economic developments as well as the availability of efficient and broad screening strategies. These factors can all influence the prevalence and causes of VI in different regions.

Causes of visual impairment in school-age children

Uncorrected RE is a leading cause of VI and the second leading cause of treatable blindness among people of all age groups.[43] This is evident in the reviewed studies (Table 2), where 47–92.7% of the reduced vision in school-age children was caused by uncorrected RE, and 0.3–19.0% were caused by amblyopia. The risk factors for amblyopia include strabismus, anisometropia and congenital cataract or the less prevelant media opacification. Unlike VI associated with amblyopia, simple RE (RE not associated with amblyopia) is correctable with the use of appropriate spectacles and is thought to not affect normal visual development. According to the WHO, there would be over 19 million children less than 15 years of age with VI worldwide, with 12.8 million being due to uncorrected RE. Consequently, Vision 2020 initiative: The Right to Sight, identified the correction of RE as one of its major objectives. The initiative advocates vision screening in schools with the provision of affordable spectacles.[44] Similarly, amblyopia can also be effectively treated with early detection and correction of the underlying amblyogenic risk factor.

However, the available evidence indicates that amblyopia is treatable, even in the teenage years.[45,46] Other studies show that improvements in binocularity and VA in the amblyopic eye can also be realized in adulthood.[47,48] Available treatments for amblyopia include patching or atropine therapy of the affected eye; surgery for strabismus and cataracts; and refractive error correction with spectacles or contact lenses. Overall, treatable causes were responsible for majority of the VI in the study populations (Table 2).

CONCLUSION

The present review has highlighted the prevalence and causes of VI in various countries as well as some methodological concerns regarding the reported studies. Diagnostic criteria for VI varied across the studies, and in some cases, the adopted definition criteria can overestimate the prevalence of VI. As the variation in diagnostic criteria can make comparing the results very difficult, it is important to develop a standard and uniform diagnostic criterion that is appropriate for detecting children at risk of developing a VI. Nonetheless, regional variations in the prevalence of VI were significant, and may be attributed to differences in socio-economic development, race, cultural factors, as well as the availability of interventions, and implies that the prevalence data in one population cannot necessarily be extrapolated to another. The review also demonstrated that treatable causes were responsible for the most of the VI in the study populations, and highlights the need for adequate strategies that will promote vision screening in school children and the wider community, with the goal of timely detection and treatment of common visual problems.

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2.3 VISUAL PROBLEMS: A REVIEW OF PREVALENCE STUDIES ON REFRACTIVE ERRORS IN SCHOOL-AGE CHILDREN

Atowa UC, Hansraj R, Wajuihian SO. Vision problems: A review of prevalence studies on refractive errors in school-age children. *African Vision and Eye Health.* 2019;78(1), a461. https://doi.org/10.4102/ aveh.v78i1.461

ABSTRACT

Background: Refractive errors are common eye disorders and are leading causes of visual impairment in the general population. Children with uncorrected refractive error may experience reduced visual acuity, transient blurring, headache and persistent ocular discomforts particularly for close work which can impair reading efficiency and school performance.

Aim: This article documents the prevalence of refractive errors in school-age children of different ethnic origins. The goal is to identify possible variation in measuring techniques and diagnostic criteria, as well as limitations of studies, to provide a clear direction for future studies.

Methods: The review was undertaken through a detailed evaluation of peer-reviewed publications of primary research on this topic. The keywords for the search included 'refractive error', 'hyperopia', 'myopia', and 'astigmatism' and 'school children'. Only epidemiological studies with participants between 5 and 18 years of age were included.

Results: Although several population and school-based studies have been conducted in various racial groups and populations, their findings were diverse owing to inconsistencies in the methods applied in identifying children in need of refraction, measurement techniques and diagnostic criteria for refractive errors. There are also some limitations associated with the sampling design and characteristics, which may have influenced the outcome measures.

Conclusion: Despite the problems inherent in the studies, the review indicates that refractive error in school-age children is a public health concern in those populations and warrants additional research that will provide reliable data for proper planning of intervention strategies.

Keywords: hyperopia; myopia; astigmatism; school-age children; school performance.

INTRODUCTION

Refractive errors (RE) including myopia, hyperopia and astigmatism are common eye disorders and are leading causes of visual impairment and treatable blindness in the general population.[1] Myopia is characterised by axial length elongation and positive image position relative to the retina and is often associated with structural changes of the retina and choroid. Myopia causes a reduction in visual acuity (VA) that cannot be overcome by accommodation.[2,3] In addition, highly myopic eyes, that is, of −6 dioptres (D) or more, may develop sight-threatening complications, leading to visual impairment at a young age.[4] Hyperopia, by contrast, is a condition in which the eye is shorter.[4] Although distance VA may be unaffected, especially in mild hyperopia, it can create visual disturbances which can affect optimum functional performance of school children.[4,5] Hyperopia is also a predisposing factor to convergent strabismus, esophoria, amblyopia and angle closure glaucoma in young children.[6] Astigmatism is a condition that causes a certain degree of blurred vision at all distances including other near vision-related symptoms.[7,8] If uncorrected during early development, astigmatism induces a form of visual deprivation that can result in meridional amblyopia[7,8] and possibly permanent visual impairment.[8]

This article presents a review of the prevalence of REs in school-age children, along with their association with age and gender. A discussion about variation in measuring techniques and diagnostic criteria, as well as limitations of studies, is provided to direct future studies. Considering the implications of uncorrected RE to academic achievement and overall well-being, this review could provide useful information for policymakers and can help in planning, provision and evaluation of child eye health services.

METHOD

A literature search was conducted on the online databases of PubMed, Medline, OVID, Google Scholar, ScienceDirect and Embase from November 2016 to November 2017 using the following keywords: refractive error, hyperopia, myopia, astigmatism and school children. The review was restricted to primary research published in English and in peer-reviewed journals. Only epidemiological studies with stated measures of prevalence of corresponding RE among school-age children between 5 and 18 years of age were included.

In this narrative review, findings from studies that met the outlined criteria were reviewed. Variables of interests for review included the following: sample size and sampling method, participant characteristics including gender and age, prevalence rates of corresponding RE, information on diagnostic criteria and measurement techniques. A summary of each study was first presented and evaluated in relation to findings from other studies. Eligible studies on myopia, hyperopia and astigmatism were compared according to geographic regions or ethnicity.[9]

PREVIOUS STUDIES IN SCHOOL-AGE CHILDREN

Prevalence of hyperopia

African population

Table 1 shows the prevalence of hyperopia from selected countries in various geographic regions. Lower prevalence of hyperopia in African populations was reported by studies that included only significant RE in their prevalence estimation. In Nigeria, Atowa et al.[10] reported 0.9% hyperopia in 1197 school children aged 8–15 years, with only 29.1% of the children with RE wearing spectacles during examination. Hyperopia was defined as a spherical equivalent refraction (SER) of 2 D or more in one or both eyes, if none of the eyes were myopic. All the study participants underwent cycloplegic refraction. Similarly, Mehari and Yimer reported 0.3% hyperopia (SER $\geq$ 2 D) in 4238 school children between the ages of 7 and 18 years in Ethiopia.[11] Non-cycloplegic retinoscopic refractions were performed on all participants, and VA thresholds of 6/9 or worse in the better eyes were applied to identify those in need of refractive correction. Two studies on African populations included hyperopia of 0.50 D in their prevalence estimation and reported a prevalence of hyperopia of 5.0% in Ghana[12] and South Africa[13] each in high school children. It is important to note that the inclusion of low categories of REs is of clinical significance because such refractive anomalies can possibly impair reading efficiency and school performance.[13]

Asian population

As with studies on African populations, prevalence studies on children from other geographic locations also reported varied results. Although the studies in Asia utilised a logMAR protocol, common definition of SER 2 D or more, large sample sizes, differences in age group of the study participants and study locations (rural or urban) may have influenced the reported prevalence of hyperopia in the various studies reviewed. In rural China,[14] the prevalence was 1.2% in children aged between 13 and 17 years, while in urban China[15] the prevalence was 5.8% in participants between 5 and 15 years. Likewise, in rural India,[16] the prevalence of hyperopia in children aged between 7 and 15 years was 0.4% and in urban India[17] it was 7.7%

in children aged 5–15 years. The prevalence of hyperopia in a suburban area of Malaysia[18] was 1.6% in participants aged between 7 and 15 years, whereas in high school children aged between 12 and 15 years in Vietnam,[19] the prevalence was 0.4%. A study in Saudi Arabia[20] reported a prevalence of 0.9% hyperopia in primary school children aged 6–13 years in Al-Qassim region. The authors considered only children with a VA of ≤ 6/12 as needing RE assessment. Norouzirad et al. reported a prevalence of 12.9% in school children between the ages of 6 and 15 years in Iran, with all children refracted irrespective of VA.[21] The evaluation of the refractive status of all children is important because this enables the detection of children with significant hyperopia even when VA is unaffected but the development of convergent strabismus and amblyopia because of excessive use of accommodation to maintain normal (6/6) VA may be possible.[22]

Caucasian population

For studies conducted on caucasian populations, diagnostic criteria and age ranges of the study samples affected the reported prevalence of hyperopia (Table 1). Two studies in the United States that adopted a common definition of hyperopia of 1.25 D or more in both meridians reported a prevalence of 12.8%[23] and 8.6%,[24] respectively. Differences between the findings can at least be accounted for by the different age ranges of the study populations. The study by Kleinstein et al.[23] had a larger age range (5–17 years) compared with the study by Zadnik et al.[24] (6–14 years). In Europe, the Northern Ireland Childhood Errors of Refraction study examined 1053 white children (392 aged 6–7 years old and 661 aged 12–13 years old) and reported that the prevalence of hyperopia (SER ≥ 2 D) was 20.6% and 14.7%, respectively.[25] An earlier study in Poland[26] had found a prevalence of hyperopia (SER 1 D) of 38.0% in 5721 school children between the ages of 6 and 18 years. The differences in findings by the studies on the European population may be attributed to the differences in definition criteria for hyperopia, population age group and sample size. Similarly, two studies in Australian children with different age ranges reported different prevalence estimates for hyperopia. The study by Ip et al.[27] conducted with children between the ages of 11 and 14 years reported a prevalence of 5.0%, whereas Fotedar et al.[28] reported a 3.5% prevalence of hyperopia in 12-year-old children.

Table 1: Prevalence of hyperopia among school-age children in selected countries from various geographic regions

Study	Country	Ethnicity	Age (years)	Sample size	Definition criteria	Measurement technique	Prevalence (%)
Atowa, et al.[10]	Nigeria	African	8-15	1197	SER ≥ 2.00	Cycloplegic autorefraction	0.9
Ovenseri-Ogbomo and Assien[12]	Ghana	African	11-18	595	SPH ≥ 0.75	Noncycloplegic retinoscopy	5.0
Mehari and Yimer[11]	Ethiopia	African	7-18	4238	SER ≥ 2.00	Noncycloplegic retinoscopy	0.3
Wajuihian and Hansraj[13]	South Africa	African	13-18	1586	SER ≥ 0.50	Noncycloplegic autorefraction/ Subjective refraction	5.0
Aldebasi[20]	Saudi Arabia	Middle East	6-13	5176	SER ≥ 2.00	Cycloplegic autorefraction	0.9
Norouzirad, et al.[21]	Iran	Middle East	6-15	1130	SER ≥ 2.00	Noncycloplegic retinoscopy	12.9
He, et al.[14]	Rural China	Asian/East	13-17	2454	SER ≥ 2.00	Cycloplegic autorefraction	1.2
He, et al.[15]	Urban China	Asian/East	5-15	4347	SER ≥ 2.00	Cycloplegic autorefraction	
Paudel, et al.[19]	Vietnam	Asian/South East	12-15	2238	SER ≥ 2.00	Cycloplegic autorefraction	0.4
Goh, et al.[18]	Malaysia	Asian/South East	7-18	4634	SER ≥ 2.00	Cycloplegic autorefraction	1.6
Dandona, et al.[16]	Rural India	Asian/South	7-15	3976	SER ≥ 2.00	Cycloplegic autorefraction	0.4
Murthy, et al.[17]	Urban India	Asian/South	5-15	6447	SER ≥ 2.00	Cycloplegic autorefraction	7.7
Zadnik, et al.[24]	USA	Caucasian	6-14	2583	SER ≥ 1.25	Cycloplegic autorefraction	8.6
Kleinstein, et al.[23]	USA	Caucasian	5-17	2523	SER ≥ 1.25	Cycloplegic autorefraction	12.6
O'Donoghue, et al.[25]	United Kingdom	Caucasian	6-7	392	SER ≥ 2.00	Cycloplegic autorefraction	20.6
			12-13	661			14.7
Czepita, et al.[26]	Poland	Caucasian	6-18	5724	SER ≥ 2.00	Cycloplegic retinoscopy	4.0
Ip, et al.[27]	Australia	Caucasian	11-14	2352	SER ≥ 2.00	Cycloplegic autorefraction	5.0
Fotedar, et al.[28]	Australia	Caucasian	12	2233	SER ≥ 2.00	Cycloplegic autorefraction	5.0

Prevalence of myopia

African population

Except for two studies in the United States,[23,24] myopia was defined as –0.50 D or worse in all the studies reviewed (Table 2). However, measuring techniques and participants' ages in addition to geographic variations appear to have an influence on the reported prevalence of myopia, with a significantly higher prevalence in Asian children compared with other ethnic backgrounds. For studies on African populations, Mehari and Yimer[11] and Wajuihian and Hansraj[13] included older children and reported a higher prevalence of myopia (6.0% and 7.1%, respectively) compared with the reported 2.7% by Atowa et al.[10] with younger children. Although the prevalence of myopia increases with age because of more involvement and longer duration of near-work activities during high school years,[10,13,19,20] the non-cycloplegic refraction technique applied by the two studies[11,13] tends to overestimate myopia in children.[19] However, Ovenseri-Ogbomo and Assien[12] reported a prevalence of 2.6% in children aged between 11 and 18 years. The low prevalence despite older children and the performance of non-cycloplegic retinoscopic refraction may be related to the use of least myopic corneal meridian in quantifying myopia.

Asian population

Variations in the prevalence of myopia in Asian children have also been widely reported, with considerable differences existing between various countries and study locations. Overall, the studies reviewed showed that myopia is more prevalent in East Asian and South-East Asian countries than in other parts of the world. For instance, studies by He et al. using cycloplegic autorefraction found that 35.1% and 42.4% of school-age children in rural[14] and urban[15] China, respectively, were myopic. These values are higher when compared with the estimates reported for South-East Asian population, such as 20.7% in Malaysia[18] and 20.4% in Vietnam.[19] In contrast, studies on the South Asian population reported a much lower prevalence of myopia than other Asian regions. In rural India,[16] myopia prevalence was 4.1% and in urban India[17] it was 7.4%. Two studies in the Middle East reported a prevalence of 6.5% (Saudi Arabia)[20] and 14.1% (Iran)[21] in children in the age range of 6–15 years.

Caucasian population

As with studies on African and Asian populations, the prevalence of myopia in caucasian children was also influenced by the definition criteria and participants' ages (Table 3). A comparatively similar finding was reported by two studies[18,24] in the United States that defined myopia as −0.75 D or worse in participants of similar age group. However, studies in Europe, which defined myopia as SER ≤ −0.50 D, reported varied results, possibly because of dissimilar age ranges of the study participants. O'Donoghue et al.[25] found that 2.3% of children who are between 6 and 7 years old are myopic compared with 17.7% of 12 to 13-year-olds. Czepita et al.[26] reported a myopia prevalence of 13.0% in children between 6 and 18 years in Poland, which was 1.9% in 6-year-olds and 31.9% in 18-year-olds. In Australia, Fotedar et al.[28] found a myopia prevalence of 9.8% in 12-year-old students.

Table 2: Prevalence of myopia among school-age children in selected countries from various geographic regions

Study	Country	Ethnicity	Age (years)	Sample size (N)	Definition criteria	Measurement technique	Prevalence (%)
Atowa, et al. (2017)[10]	Nigeria	African	8-15	1197	SER ≤ −0.50	Cycloplegic autorefraction	2.7
Ovenseri-Ogbomo and Assien[12]	Ghana	African	11-18	595	SPH ≤ −0.50	Noncycloplegic retinoscopy	2.6
Mehari and Yimer[11]	Ethiopia	African	7-18	4238	SER ≤ −0.50	Noncycloplegic retinoscopy	6.0
Wajuihian and Hansraj[13]	South Africa	African	13-18	1586	SER ≤ −0.50	Noncycloplegic autorefraction	7.1
Aldebasi[20]	Saudi Arabia	Middle East	6-13	5176	SER ≤ −0.50	Cycloplegic autorefraction	6.5
Norouzirad, et al.[21]	Iran	Middle East	6-15	1130	SER ≤ −0.50	Noncycloplegic retinoscopy	14.9
He, et al.[14]	Rural China	Asian/East	13-17	2454	SER ≤ −0.50	Cycloplegic autorefraction	42.4
He, et al.[15]	Urban China	Asian/East	5-15	4347	SER ≤ −0.50	Cycloplegic autorefraction	35.1
Paudel, et al.[19]	Vietnam	Asian/South East	12-15	2238	SER ≤ −0.50	Cycloplegic autorefraction	20.4
Goh, et al.[18]	Malaysia	Asian/South East	7-18	4634	SER ≤ −0.50	Cycloplegic autorefraction	20.7
Dandona, et al[16]	Rural India	Asian/South	7-15	3976	SER ≤ −0.50	Cycloplegic autorefraction	4.1
Murthy, et al.[17]	Urban India	Asian/South	5-15	6447	SER ≤ −0.50	Cycloplegic autorefraction	7.4
Zadnik, et al.[24]	USA	Caucasian	6-14	2583	SER ≤ −0.75	Cycloplegic autorefraction	10.1
Kleinstein, et al.[23]	USA	Caucasian	5-17	2523	SER ≤ −0.75	Cycloplegic autorefraction	9.2
O'Donoghue, et al.[25]	United Kingdom	Caucasian	6-7	392	SER ≤ −0.50	Cycloplegic autorefraction	2.3
			12-13	661			17.1
Czepita, et al.[26]	Poland	Caucasian	6-18	5724	SER ≤ −0.50	Cycloplegic retinoscopy	13.1
Fotedar, et al.[28]	Australia	Caucasian	12	2233	SER ≤ −0.50	Cycloplegic autorefraction	9.8

Prevalence of astigmatism

African population

Previous studies exploring the prevalence of astigmatism in school-age children have also shown marked variations in prevalence levels (Table 3). Although most of the studies[10,11,12,13] on African children defined astigmatism as cylindrical error of at least −0.75 D, different measuring techniques (retinoscopy or autorefraction) were applied in the detection of astigmatism. For studies that performed autorefraction technique, Atowa et al.[10] who applied cycloplegia reported a higher estimate compared with Wajuihian and Hansraj[13] who utilised non-cycloplegic refraction method, which was followed by subjective refraction. Similarly, two studies that utilised non-cycloplegic retinoscopic technique reported varied results. Ovenseri-Ogbomo and Assien[12] with a smaller sample size and older children reported a higher prevalence value compared with Mehari and Yimer[11] with a larger sample size and younger children.

Asian and Caucasian populations

The studies on Asian populations were consistent in the definition of astigmatism and the use of cycloplegic objective measurement methods. In most of the studies, both objective (retinoscopy and autorefraction) methods were applied and the results showed that autorefraction technique yielded higher values compared with the retinoscopic technique (Table 3). In using cycloplegic retinoscopic technique, the prevalence of astigmatism ranged between 3.8% and 33.6%, while with cycloplegic autorefraction technique the estimates ranged between 9.7% and 42.7%. Overall, a higher prevalence of astigmatism was reported for East Asian children compared with other regions of Asia as well as other continents (Table 3).

For studies on caucasian children, the prevalence of astigmatism was also influenced by the definition criteria and measurement methods (Table 3). Two studies[23,29] that applied cycloplegic autorefraction method and defined astigmatism as cylindrical error of at least −1.00 D reported comparatively similar findings, whereas a study in Poland[26] which defined astigmatism error of at least −0.50 D determined by cycloplegic refraction reported a prevalence of 4.0% in children aged between 6 and 18 years.

Table 3: Prevalence of astigmatism among school-age children in selected countries from various geographic regions

Study	Country	Ethnicity	Age (years)	Sample size (N)	Definition criteria	Measurement technique	Prevalence (%)
Atowa, et al.[10]	Nigeria	African	8-15	1197	≥ −0.75	Cycloplegic autorefraction	4.4
Ovenseri-Ogbomo and Assien[12]	Ghana	African	11-18	595	≥ −0.75	Noncycloplegic retinoscopy	6.5
Mehari & Yimer[11]	Ethiopia	African	7-18	4238	≥ −0.75	Noncycloplegic retinoscopy	2.0
Wajuihian and Hansraj[13]	South Africa	African	13-18	1586	≥ −0.75	Noncycloplegic autorefraction	3.0
Aldebasi[20]	Saudi Arabia	Middle East	6-13	5176	≥ −0.75	Cycloplegic autorefraction	11.2
He, et al.[14]	Rural China	Asian/East	13-17	2454	≥ −0.75	Cycloplegic autorefraction	25.3
He, et al.[15]	Urban China	Asian/East	5-15	4347	≥ −0.75	Cycloplegic retinoscopy	33.6
						Cycloplegic autorefraction	42.7
Paudel, et al.[19]	Vietnam	Asian/South East	12-15	2238	≥ −0.75	Cycloplegic autorefraction	20.4
Goh, et al.[18]	Malaysia	Asian/South East	7-18	4634	≥ −0.75	Cycloplegic retinoscopy	15.7
						Cycloplegic autorefraction	21.3
Dandona, et al.[16]	Rural India	Asian/South	7-15	3976	≥ −0.75	Cycloplegic retinoscopy	3.8
						Cycloplegic autorefraction	9.7
Murthy, et al.[17]	Urban India	Asian/South	5-15	6447	≥ −0.75	Cycloplegic retinoscopy	7.0
						Cycloplegic autorefraction	14.6
Kleinstein, et al.[23]	USA	Caucasian	5-17	2523	≥−1.00	Cycloplegic autorefraction	28.4
Czepita, et al.[26]	Poland	Caucasian	6-18	5724	≥ −0.50	Cycloplegic retinoscopy	4.0
Robaei, et al.[29]	Australia	Caucasian	12	2353	≥ −1.00	Cycloplegic autorefraction	21.8

Age and refractive errors

Most of the studies showed that the prevalence of hyperopia decreases significantly with age.[14,15,18,20,21,24,25,26] In using the same RE definition and logMAR protocol to assess children aged 5–15 years, Murthy et al.[17] and He et al.[15] revealed that early significant hyperopia decreases rapidly from age 5 years to an insignificant level by the age of 15 years, with a noticeable myopic shift taking place around age 12. This agrees with the views of Saunders et al.[30] and Borish[31] that infants are usually born with some amount of hyperopia which tends towards emmetropia and possibly myopia as they grow older.

Regarding myopia, several studies reviewed were consistent in reporting a significant age increase in the prevalence of myopia.[15,16,17,18,19,20,21,24,25,26] Atowa et al.[10] reported that 12 to 15-year-old children had a 1.2 times higher risk of developing myopia than those aged 8–11 years. Near-work activities, such as reading, writing, computer use and playing video games, have been indicated in the significant increase in the prevalence of myopia as well as increased risk for developing myopia.[32] The prevalence of astigmatism has been found to vary with age. Some studies[28,33] associated astigmatism with older age children, while others[14,15,18,26] associated astigmatism with younger age children.

Gender and refractive errors

It has been suggested that, on average, women have shorter axial length when compared with men.[27,34,35] As such, women are more likely to be hyperopic when compared with men. These findings are consistent with the observations of studies in China,[14,15] India[17] and Malaysia[18] that found more hyperopia in women than in men. In Australia,[27] the significant increase in hyperopia prevalence with women compared with men were only found in younger children (6 years old) and not in older children (12 years old). In contrast, a study in Saudi Arabia[20] found that the prevalence of hyperopia was higher in boys than in girls. For the study participants, physiological maturation occurred faster in girls than in boys.[20] Several studies[10,11,13] on African children found no difference between gender and myopia risk, whereas studies in Asia[14,15,17,18,20] revealed that the prevalence of myopia was significantly higher in female subjects than in male subjects. Some studies have also found astigmatism to be significantly higher in boys than in girls.[20,21] He et al.[15] and Dandona et al.[16] reported contrary results.

Limitations of previous studies

There are some limitations associated with the studies reviewed, which may have influenced the interpretation of their findings and conclusions. All studies except Atowa et al.[10] and Wajuihian and Hansraj[13] failed to indicate how sample sizes were derived. The use of small sample sizes,[21,24] limited age range of participants[25,28,29] and non-use of cycloplegia or the plus lens test to screen for latent hyperopia[11] may have affected the results of some studies. Although the study by Ovenseri-Ogbomo and Assien[12] applied a random sampling approach at classroom level, the use of convenience sampling technique in selecting the participating schools may limit the generalisation of findings of the study.

DISCUSION

This literature review has highlighted the prevalence of RE in school-age children in various countries. However, inconsistent methods were applied across studies in identifying children in need of refraction. Although a VA threshold of 6/9 or less can reliably detect myopia in school-age children, there is no reliable VA threshold for clinically significant hyperopia and astigmatism. High amounts of hyperopia (> 5 D) and astigmatism (> 1.5 D) have been reported in children who were able to read 6/6 (20/20) on the VA chart.[20,21] Reports indicate that uncorrected hyperopia, which is less likely to cause a reduction in VA, is a risk factor for strabismus, amblyopia and angle closure glaucoma.[4,5,22] Therefore, to determine the actual prevalence of RE in a study sample, refraction should be performed on all children irrespective of VA.

There is no consensus on the most appropriate method for the measurement of RE. Some studies reported myopia and hyperopia in terms of the spherical component, while others reported them based on the SER (sphere + ½ cylindrical components). Although an objective method (retinoscopy or autorefraction) was the preferred measuring technique, the use of cycloplegia was not a constant factor. Instead some studies utilised the plus lens test to screen for latent hyperopia because cycloplegia was contraindicated as accommodative tests were also included in their evaluations or for concerns of ethical issues.[11,12,13] For the studies that adopted the plus lens technique, analysis was based on the subjective findings, while that of the cycloplegic refraction technique was based on cycloplegic findings. In addition, most studies identified an individual as having RE after binocular examination, but others use the eyes separately as unit samples or examine only one of the eyes (usually the right eye) relying on evidence of good correlation between ametropia in both eyes. To facilitate comparison of findings among studies, a better approach will be to develop a standardised method of measuring RE in children.

A wide variety of criteria were applied in the diagnosis of individuals with different types of RE, with many studies focusing mainly on RE that significantly affects VA (Tables 1–3).[10,11,12,13,14,15,16,17,19,20,21,23,24,25,26,27,28,29] Overall, myopia was defined as –0.50 D or –0.75 D or more; hyperopia definition ranged between 0.50 D and 2 D and astigmatism varying from –0.50 D to –1 D. Given the progressive nature of myopia during the teenage years,[10] all myopic eyes are at risk for complications.[4] Likewise, visual discomfort is more common in children with low degrees of hyperopia and astigmatism because of excessive use of accommodation to maintain normal vision.[5,6] For high school children who are engaged in intensive reading and longer duration of near-work activities, it will be difficult to comfortably sustain normal vision for long periods of time, especially at close distances where reading takes place. As a result, the child may lose interest in reading and other near-vision-related academic tasks which may affect his or her school performance. It is, therefore, important to include low categories of RE in prevalence estimations as this will provide comprehensive data for proper planning and implementation of intervention strategies.

The studies[14,15,18,20,21,24,25,26] consistently reported a significant age-related decrease in hyperopia prevalence and a significant age increase in prevalence of myopia. Hyperopia in infants usually decreases to emmetropia as they grow, with myopia starting to develop around age 6 years when school begins.[29,31] However, myopia becomes significant during high school and teenage years when there is rapid growth and heavier load of near work.[10,19,20] Regarding gender and different types of REs, variations in trends were observed for men and women by some studies, which may be partly related to gender representativeness in these studies. Differences in growth spurts and maturation rate between genders may also explain the gender differences in the prevalence of REs. Peak height velocity is associated with earlier axial length peak and spherical equivalent velocity[20,36] and some studies noted that peak height velocity was commonly earlier in women.[14,15,17,20] In these studies, physiological maturation occurred faster in female participants than in male participants; therefore, a higher prevalence of myopia was found in women and a higher prevalence of hyperopia was found in men as women would have already undergone emmetropisation with men lagging slightly behind. Cultural distinctiveness and lifestyle characteristics, such as number of hours spent on near work and outdoor activities, between men and women have also been shown to affect gender pathogenesis of RE in each geographic area.[10,20] It has been suggested that hyperopic SER is more common in children who dedicated less time to near activities and more time to outdoor activities.[37]

The disparity in the RE prevalence by regions and study locations can be explained by ethnicity and geographical factors. Hyperopia prevalence was low in African and East Asian populations compared with Caucasians. Similarly, myopia and astigmatism were higher in East and South-East Asian populations compared with other regions. Reports indicate that South-East Asian children are genetically predisposed to having myopia because of the influence of ethnicity, family history of myopia and schooling system.[10,19,38] About ocular components, axial length in both African and Asian children is longer than in caucasian children.[38] In addition, reports show that populations with high myopia prevalence rates, like in China, generally have a low hyperopia prevalence.[13,14,15,31] The higher prevalence of hyperopia and low prevalence of myopia in rural populations may be because of their involvement in more outdoor activities. Competitive education may also be a contributory factor to the higher prevalence of myopia reported for East Asian and South-East Asian children. The implications are that, even within the same country, RE estimates in one population cannot necessarily be extrapolated to another population.

CONCLUSION

This article indicates that the prevalence of RE in school-age children is a public health concern in the various study locations. The methodological differences, such as inappropriate study designs, variations in defining and quantifying the RE and improper measuring techniques, complicate the comparison of the corresponding findings. The article highlights the gaps in knowledge in this area of study, including the non-inclusion of low categories of RE, non-inclusion of all children for refraction within some studies, non-application of cycloplegia or the plus lens test, limited age range, small sample size and inappropriate sampling methods. The review of the literature also reveals regional variations in the prevalence of RE, which may be related to differences in socio-economic development, race, cultural factors as well as availability of interventions. Considering the implication of visual anomalies for academic achievement, as well as overall well-being, this review could provide useful information for policymakers and can help in planning, provision and evaluation of child health services. Future research should include near vision anomalies which are capable of affecting school performance even when VA is not affected. This would assist in developing broad interventions and management strategies targeting these conditions in school-age populations.

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2.4 VISION PROBLEMS: A REVIEW OF PREVALENCE STUDIES ON ACCOMMODATIVE AND VERGENCE ANOMALIES IN SCHOOL-AGE CHILDREN

ABSTRACT

Accommodative and vergence dysfunction can create visual discomforts especially during excessive near task which could possibly affect efficient reading and learning. Therefore, the aim of this review is to document the prevalence and distribution of accommodative and vergence anomalies in school-age children across the world. The review involved a comprehensive evaluation of peer-reviewed publications of primary research on this area. Although several clinic and school-based studies have been conducted in various racial groups and populations, their findings differ due to distinct exclusionary criteria, measurement techniques and diagnostic methods. Overall, there are lack of inclusive data on the prevalence and distribution of accommodative and vergence anomalies on children. Discussion on the major findings highlighting the variations in measuring techniques and diagnostic criteria, as well as, limitations of studies are presented to provide clear direction for future studies.

Key words: accommodative anomalies, vergence anomalies, prevalence, distribution, school children

INTRODUCTION

A significant proportion of a child's classroom activities involve shifting focus from one distance to another which requires simultaneous adjustment of both the alignment and focus of the eyes to accomplish a single, clear and comfortable visual outcome.[1,2] The accommodative and vergence response are cross-coupled and any imbalances between the sensory-motor integrative functions could result in accommodative vergence anomalies with associated visual discomfort, such as headaches, diplopia, blurred vision and loss of attention, especially during excessive near work activities.[3,4] Available evidence indicate that when compared with children without accommodative and non-strabismic vergence disorders those with accommodative and non-strabismic vergence disorders are more susceptible to visual symptoms resulting from excessive use of the eyes.[5,6,7,8] These symptoms become more apparent during the school years, when there is greater demand on the binocular system.[9]

The current paper is part of the literature review on visual anomalies in school-age children and efforts that have been made at their early detection. In part one and two, studies on visual impairment and refractive error, respectively were reviewed. In this part three, accommodative and non-strabismic vergence anomalies have been reviewed. Overall, the review is expected to identify important gaps in knowledge and direct additional research in this field of study. The review is also expected to contribute towards the development of a common vision screening strategy, for early detection and treatment of these visual disorders.

METHOD

The electronic databases of PubMed, Medline, OVID, Google Scholar, Science Direct and Embase were explored from November 2016 to November 2017 using the following keywords: accommodative insufficiency, accommodative excess, accommodative infacility as well as convergence insufficiency, convergence excess, divergence insufficiency, divergences excess, fusional vergence dysfunction, basic esophoria, basic exophoria and school children. Our search was restricted to primary research published in peer-reviewed English language journals. Only epidemiological studies with stated measures of prevalence of corresponding visual anomalies in children within the age of 5 and 18 years were included. Due to insufficient data on accommodative and vergence anomalies on African populations, three studies on African populations with participants in the age groups 13 – 19 years[10,11] were included. Additionally, a study[12] on a clinic sample in a Puerto Rican population with participants aged between 5 and 20 years were also included.

In the present review, data was extracted and compared between the studies that met the eligibility criteria using the narrative synthesis approach. The following key data was extracted and collated from all the eligible papers: sample size and sampling method; participant demographics such as gender and age, prevalence estimates of corresponding visual anomaly; information on diagnostic criteria, and measurement techniques. The relationship of each study to the others, as well as, the limitations of the studies was identified. The included studies are grouped according to study setting (clinic or school) and compared according to the number of diagnostic criteria for the corresponding anomalies. Findings of the studies on accommodative anomalies are summarised first, followed by that of non-strabismic vergence anomalies.

ACCOMMODATIVE ANOMALIES

Accommodative anomaly is a focusing syndrome characterized by difficulty changing focus from one distance to another, reduced gain or amplitude and reduced sustainability of accommodation with associated symptoms.[1] Although the symptoms associated with accommodative anomalies may overlap each other, some may be specific to a syndrome.[8] The specific accommodative disorders that are included in the current review are accommodative insufficiency (AI), accommodative excess (AE) and accommodative infacility (AIF).

Accommodative insufficiency

Accommodative insufficiency is a disorder of the sensory motor of the visual system that is characterized by an inability to focus or sustain focus at near. In an individual, it is marked by a low amplitude of accommodation (AA) based on the age expected norm and is not due to sclerosis of the crystalline lens.[13,14] The diagnostic clinical signs include low AA, high values of accommodative lag determined by monocular estimation method (MEM) with retinoscopy and poor monocular accommodative facility (MAF) using minus 2 D lenses.[1]

Studies on school-based populations

Two school-based studies on accommodative and convergence insufficiency in the United States of America (USA) reported a significant difference in the prevalence of AI. The study by Marran et al.[13] included 299 participants with a mean age of 11.5 years and reported an estimate of AI of 8.0%. The estimate is lower than the 17% reported earlier by Borsting, et al.[15] in 392 participants whose ages were from 8 and 15 years. This is interesting considering that both studies utilized the push up to blur technique (PUBT) and adopted the single criteria of AA of 2 D or more, lower than Hofstetter's age formula for minimum AA. Thus, a possible explanation for the differences in findings between both studies[13,15] might be owing to the subjective measurement methods. However, the two studies[13,15] excluded children with uncorrected visual acuity (VA) and refractive error (RE) and their AI estimate is lower compared to the 32.4% prevalence reported by another study in USA[16] that used the same measuring technique and diagnostic criteria. The difference was that Davis, et al.[16] included all children (n = 484), with those having RE wearing their spectacle during testing. The prevalence of AI is also influenced by the characteristics of the study sample (symptomatic or non-symptomatic), as the symptomatic children have greater probability of having visual anomalies.[17] This is reflected by the relatively high prevalence of AI of 24.2% reported by Abdi and Rydberg[18] in 120 symptomatic school children which was twice the estimate reported by Abdi, et al.[19] (11.1%) on a general population of school children. Both studies were conducted in Sweden using similar techniques and diagnostic criteria and with children of similar age groups.

Two South African studies[20,21] using a similar PUBT reported varying prevalence estimates for poor AA. Although the studies did not categorically define AI, the poor AA was determined using one clinical sign of only 2 D below Hofstetter's age formula for minimum AA, as such may imply a single-sign classification of AI.[6] The study by Metsing and Ferreira[20] was on 80 participants within the age range of 8 and 13 years and 10% of the participants was found to have poor monocular AA. Moodley[21] reported a poor monocular and binocular AA of 24% and 26%, respectively from a retrospective study on 264 children within the age range of 6 and 13 years. Given that the two studies applied a similar technique and that the age range of the participants differed by only two years, the possible cause of the difference between both studies may be due to subjectivity of responses, smaller sample size[20] and retrospective study design.[21] A more recent study from South Africa[11] that applied the PUBT reported a lower prevalence of AI of 4.6% for single sign definition than other South African studies that also applied single sign criteria and similar technique.[20,21] The study by Wajuihian and Hansraj[11] had a considerably larger sample size (n = 1211) and older participants (13-19 years) than the other study samples,[20,21] which may be responsible for the difference in the reported estimate, as older children may provide better subjective response for AI and the large sample size will yield a higher statistical power to determine a precise prevalence estimate.[22] In addition, the definition criteria for the other two studies[20,21] was not clearly stated.

In using multiple sign criteria (minimum of two clinical signs), Wajuihian and Hansraj[11] reported the prevalence of AI of 4.5% which is comparatively similar to 4.6% found for single sign criteria. This may imply that almost all the participants with reduced AA in their sample may also have a deficiency in at least one other clinical measures of AI. The estimate for their multiple sign criteria[11] was lower than the value for AI of another study[8] on an African population. The two studies[8,11] on African population involved a random selection of high school children. However, the sample sizes used were 1201 [11] and 627.[8] Similarly, in South Korea, Jang and Park[23] reported a prevalence of AI of 5.3% (minimum of three clinical signs) in a random selection of 589 participants. In using the same criteria and with participants of comparable age range, Shin, et al.[24] that included only symptomatic participants reported a higher prevalence of 18.3%. The reason for the differences between the two South Korean studies may be related to symptomatic children being more prone to having AI compared to the unselected population of children.[17]

Studies on clinic-based samples

Previous clinic-base studies were also conducted using the PUBT. As with the school-based studies, the sample characteristics also influenced the findings of these studies. In an assessment of the visual function of children (6 – 14 years) with near work related problem in Austria, Dusek, et al.[25] examined 328 participants with no reading and writing difficulty which served as their control group. Among the group, accommodation was assessed successfully in 308 subjects with 0.6% of the children having AI classified as reduced AA of at least 2 D, lower than Hofstetter's age formula for minimum AA. In another clinic-based cohort study of patients from 6 month old to 18-year-olds in Pennsylvania, USA, including 1650 school-aged children, 0.8% of the preschool children were diagnosed with AI, whereas 2.3% of school-age children had AI, indicating an increase in AI with age and school level.[26] Similarly, Dwyer and

Wick[27] examined 144 patients aged (7 – 18 years) from an optometry clinic in Australia and found a prevalence of AI of 0.7%. Recently, Paniccia and Ayala[12] evaluated health records of 593 randomly selected patients within the age range of 5 and 20 years in Puerto Rico. The prevalence of AI defined with a minimum of three clinical signs was 39%. Although, AI was diagnosed with a minimum of 3 clinical signs compared to other clinic-based studies with one clinical signs[25,26,27] a higher prevalence of AI was reported by the study,[12] which may be explained in terms of the already established relationship of decrease in AA and with age.[26] However, a clinic-based study which did not categorically diagnose AI but applied the single criteria of AA of at least 2 D lower than Hofstetter's age formula for minimum AA to define subnormal AA, reported that 36% of their subjects had poor AA. Data was analysed using health records of 60 patients aged from 6 to 10 years;[28] accordingly, the limited sample size may have influenced the findings of the study.

Table 1: Prevalence of accommodative insufficiency among school-age children

Author/year	**Country**	**Study setting**	**Age (years)**	**Sample size**	**Prevalence (%)**
Marran, et al.[13]	USA	School	11.5 (mean)	299	8.0
Borsting, et al.[15])	USA	School	8-15	392	17
Davis, et al.[16]	USA	School	11.7±1.81	484	32.4
Abdi and Rydberg[18]	Sweden	School	6-16	120	24.2
Abdi, et al.[19]	Sweden	School	6-16	216	11.1
Metsing and Ferreira[20]	South Africa	School	8-13	112	10
Moodley[21]	South Africa	School	6-13	264	24
Wajuihian and Hansraj[11]	South Africa	School	13-19	1201	4.5
Darko-Takyi, et al.[8]	Ghana	School	12-17	627	7.7
Jang and Park[23]	South Korea	School	8-13	589	5.3
Shin, et al.[24]	South Korea	School	9-13	114	18.3
Dusek, et al.[25]	Austria	Clinic	6-14	308	0.6
Scheiman, et al.[26]	USA	Clinic	6-18	1650	2.3
Dwyer and Wick[27]	Australia	Clinic	7-18	144	0.7
Paniccia and Ayala[12]	Puerto Rica	Clinic	5-20	593	39
Benzoni and Rosenfield[28]	USA	Clinic	5-10	60	36

Accommodative excess

Accommodative excess is a visual condition that interferes with the ability of an individual to perform visual tasks that requires relaxation of accommodation.[1] In such circumstances, the individual's accommodative response is higher compared to the accommodative stimulus.[29] Accommodative excess causes esophoria or esotropia, decreases visual strength and affects binocularity. This is of great concern in school children because of its ability to reduce visual efficiency, as well as, delay the capacity to interchange focus between different working distances. . It is commonly associated with symptoms of near tasks and binocular inefficiency as the individual strives to maintain clear single and comfortable vision.[30] In certain instances, AE has been referred to as spasms of accommodation, spasms of the ciliary muscle, hyper-accommodation,, pseudo-myopia and spasms of the near reflex.[1] The diagnosis of AE requires a thorough analysis of AA, monocular accommodative facility (MAF) and binocular accommodative facility (BAF) using 2 D lenses. It also includes the analysis of the negative relative accommodation, positive relative accommodation, MEM retinoscopy and the fused cross-cylinder test.[1,29]

Most of the studies that reported on AI also reported on the prevalence of AE; therefore, their methodological characteristics have been previously outlined. As indicated in Table 2, the highest estimate for AE (5.1%) was reported in a clinic-based study in Puerto Rico.[12] Among the two school-based studies on a South Korean population that utilized similar criteria, the prevalence of AE of 3.7% as observed by Shin, et al.[24] that included only symptomatic participants was higher compared to the 1.2% found by Jang and Park[23] that applied a random selection of children. However, for the school-based studies[8,11] in Africa that applied a random selection of participants, the prevalence of AE was higher in the study in South Africa[11] compared to the study in Ghana.[8] The possible cause of the discrepancy in the findings between these two studies may be that Darko-Takyi, et al.[8] analysed for only symptomatic AE, while Wajuihian and Hansraj[11] included both symptomatic and asymptomatic children.

Table 2: Prevalence of accommodative excess among school-age children

Author/year	**Country**	**Study setting**	**Age (years)**	**Sample size**	**Prevalence (%)**
Wajuihian and Hansraj[11]	South Africa	School	13-19	1211	2.8
Darko-Takyi, et al[8]	Ghana	School	12-17	627	1.4
Jang and Park[23]	South Korea	School	8-13	589	1.2
Shin, et al.[24]	South Korea	School	9-13	114	3.7
Scheiman, et al.[26]	USA	Clinic	6-18	1650	1.2
Paniccia and Ayala[12]	Puerto Rica	Clinic	5-20	593	5.1

Accommodative infacility

In AIF it is challenging for a person to accurately transfer focus from one distance to another within a short period of time.[1,31] The evidence relating to the prevalence of AIF in the studies reviewed are limited to nine studies. Overall, the age group of the study participants, sample sizes diagnostic criteria and participant characteristics influenced the prevalence of AIF. Shin, et al.[24] estimated a prevalence of AIF of 13.4% in symptomatic children within the age range of 9 and 13 years in South Korea. The prevalence in another study in South Korea[23] with a representative sample of school children from age 8 and 13 years was 2.5%. In Ghana,[8] the prevalence of AIF was 3.8% in junior high school (12-17 years) students who reported at least two severe symptoms of accommodative anomalies. In South Africa,[11] the prevalence of AIF was 12.9% in older (13 – 19 years) high school students; AIF with being more common among participants in the younger grade-level than those in the higher-grade level. In using a single definition criterion of poor accommodative facility, the authors[11] also found that 31.2% of the participants failed binocular accommodative facility. Their finding of poor accommodative facility was comparable to the 30.0% prevalence reported by another study[21] on a South African population that also reported poor binocular accommodative facility. However, in another South African[20] study poor accommodative facility was found to be 12.3% without clear diagnostic criteria. Two clinic-based studies reported a prevalence of AIF of 5%[27] and 7 %.[12]

Table 3: Prevalence of accommodative infacility among school-age children

Author/year	**Country**	**Study setting**	**Age (years)**	**Sample size**	**Prevalence (%)**
Metsing and Ferreira[20]	South Africa	School	8-13	112	12.3
Moodley[21]	South Africa	School	6-13	264	30
Wajuihian and Hansraj[11]	South Africa	School	13-19	1211	12.9
Darko-Takyi, et al.[8]	Ghana	School	12-17	627	3.8
Jang and Park[23]	South Korea	School	8-13	589	2.5
Shin, et al.[24]	South Korea	School	9-13	114	13.4
Scheiman, et al.[26]	USA	Clinic	6-18	1650	2.3
Dwyer and Wick[27]	Australia	Clinic	7-18	144	5
Paniccia and Ayala[12]	Puerto Rica	Clinic	5-20	593	7

VERGENCE ANOMALIES

Vergence anomalies are disorders of binocular vision that is characterized by the inability of the vergence mechanism to establish or maintain comfortable bifoveal fixation.[1,6] In vergence eye movement, the two eyes rotate concurrently in the opposite direction to focus the objects of regard on corresponding retinal points, by changing the direction of gaze. However, a single binocular image is achieved when the images from corresponding retinal points of both eyes are cortically integrated into a single representation. Vergence eye movements can be in the same (convergence) or opposite (divergence) direction and it is elicited by changes in both disparity and blur-driven accommodation.[1,4,6] The vergence anomalies that are considered in the current review include convergence insufficiency (CI), convergence excess (CE), fusional vergence dysfunction (FVD), basic esophoria (BS), basic exophoria (BX) divergence insufficiency (DI) and divergence excess (DE).

Convergence insufficiency

Convergence insufficiency is a vision problem in which an individual is incapable of initiating or maintaining convergence for a prolonged time without utilizing excessive effort, particularly during close work. Available evidence show that CI is the most widely reported and most prevalent form of vergence anomaly in both adult and paediatric populations.[1,6.10,17] It is often associated with symptoms of diplopia and headaches when reading. However, CI presents as a syndrome that is identified with more than one clinical signs and symptoms.[6] The examination includes the determination of near point of convergence (NPC), Monocular estimation retinoscopy and measurement of fusional vergence amplitude. Presence of any RE, eye muscle dysfunction, or weaknesses is also evaluated.[32-37]

Diverse criteria and cut-off thresholds as evidenced in several clinic and school-based studies are applied in the classification of CI. With single criteria, most studies identified participants with CI using single sign of receded NPC or exophoria at near. The studies that defined CI using multiple criteria followed the recommendation by the Convergence Insufficiency Reading Study (CIRS) group[35-37] which includes:

- exophoria at near
- exophoria at near that is ≥ 4 prism dioptre (pd) greater in magnitude than the distance phoria
- insufficient positive fusional vergence (PFV): fails Sheard's criteria or poor PFV at near ≤ 12 pd base-out (BO) blur or ≤ 15 pd BO break, and/or
- receded NPC ≥ 7.5 cm break or ≥ 10.5 cm recovery.

A summary of studies on the prevalence of CI on school-age children in various countries is presented in Table 4.

School-based studies

Of the reviewed school-based studies, four adopted the single sign criterion of receded NPC in identifying children with CI. However, the cut-off thresholds for NPC break were diverse among the studies. Three studies in Canada[38] and Sweden[18,19] that applied a NPC cut-off point of 10 cm for break reported prevalences of CI of 9%,[38] 18%[18] and 6%.[19]. The two studies in Sweden[18,19] were conducted on children of a similar age group (6-16 years). Therefore, the significantly higher prevalence of CI reported by the earlier study[18] may be because the participants consisted of symptomatic children referred by their school nurses. In Australia, Macfarlene, et al.[39] applied similar methodology but with NPC cut-off point ≥ 6 cm break and reported a prevalence of 6.5% in participants aged from 6 to 11 years. Similarly, Junghans, et al.[40] while investigating the incidence of vision problems among Australian children from varying racial backgrounds found that the prevalence of CI was comparatively similar for both NPC cut-off points ≥ 7.5 cm break (11%) and ≥ 10 cm break (11.2%). The estimates by

Junghans, et al.[40] was higher compared to the study by Macfarlene, et al.[39] which applied a lower NPC cut off point of 6 cm or more.

For studies that defined CI by two or more criteria, exophoria at near than at distance was a constant criterion. Using two clinical signs of receded NPC and higher magnitude of exophoria at near than at distance, Letourneau and Ducic[41] reported a prevalence of CI of 2.3% in Canada with children between the age range of 5 and 13 years. The push up to break point (PUBP) with a non-accommodative target was the measuring technique for NPC, while heterophoria was measured with the cover test and prism bar. Four other studies[13,15,16,37] were conducted on school children in the USA using comparable methods and definition criteria. Diagnostic criteria for high suspect/definite CI included a higher magnitude of exophoria at near than at distance, insufficient positive fusional vergence (PFV), receded NPC. The reports show that the estimate for CI was 13.0% with participants 9 to 13 years-old in Rouse, et al.,[37] it was 17.3% with participants 8 to 15 years in Borsting, et al.[15] and in Marran et al.[13] it was 18.0% in children with a mean age of 11.5 years. More recently, Davis, et al.[16] assessed CI using the same criteria in 3rd to 8th-grade students of Native American origin and reported a clinical CI of 31.4%. The four studies in the USA assessed NPC utilizing letter targets, however, children with poor VA and RE were excluded from participating in the earlier studies,[13,15,39] whereas in the more recent study,[16] all children participated with those having RE wearing their correction during testing which may partly explain the comparatively higher prevalence of CI in the study. Secondly, since the other three studies[13,15,37] were conducted in a cosmopolitan city (California) possibly with participants from different racial backgrounds, ethnicity (native Americans[16] versus mixed ethnicity[13,15,37]) may also be a factor. Other studies in different geographical areas that used similar criteria as those in the USA reported varying results. Wajuihian and Hansraj[10] assessed CI in a random selection of students in South Africa and found high suspect/definite CI in 10.3%. Near point of convergence was measured with a PBUP technique on a single line target. Although children with RE were included, there was no information on the number of children with RE who wore their correction during testing. In South Korea, Jang and Park[23] also reported a 10.3% of CI in primary school children within the age range of 8 and 13 years. Children with RE were included only if they revealed symptoms of refractive errors. In Nigeria, Ovenseri-Ogbomo and Ovigwe[6] reported a prevalence of CI of 3.8% without indicating the visual and refractive status of participants and in addition the measuring techniques for the CI parameters were not stated.

Socio-economic factors and study location may influence the occurrence of CI in children. This is reflected by the findings of studies that compared the prevalence of CI from different socio-economic settings and locations. By applying the CIRS recommended criteria, Hussaindeen, et al.[42] compared the prevalence of CI between rural and urban children in India and reported a CI of 17.6% in rural and 16.5% in urban areas. Overall, the prevalence of CI was higher in older (13-17 years) than younger (7-12 years) children. In contrast, Hopkins, et al.[43] compared the prevalence of CI between two groups of Australian children and found that 10.3% of indigenous children had CI which is twice the estimate for the non-indigenous children. According to the authors, the findings highlight the implication of CI on academic performance, considering the variation in the reading achievements between the groups.[43]

In other school-based studies[16,24,44] that utilized multiple sign criteria, CI analysis were performed using data from only symptomatic participants. Children with reduced binocular vision parameters that do not present with any symptom related to binocular vision as determined using the Convergence Insufficiency Symptom Score (CISS)[16,44] and the College of Optometrists in Vision Development Quality of Life (COVD-QOL)[24] questionnaires were considered as having normal binocular vision. This methodology has the possibility of affecting the prevalence of CI in those study samples. In Ghana,[44] 627 (symptomatic and asymptomatic) children were randomly selected but only 220 participants who reported at least two severe symptoms underwent comprehensive binocular vision assessments. The prevalence of CI determined using the sample size of 627 was 8.6%. In students ($n = 484$; mean age as 11.67 ± 1.81 years) in USA, Davis, et al.[16] found that the frequency of symptomatic and asymptomatic CI as 6.2% and 3.1%, respectively. Students were considered as having symptomatic CI, if they had a CISS score ≥ 16, in addition to having exophoria greater at near than at distance, receded NPC value and inadequate near PFV. The findings of Shin, et al.[24] showed that 82 of the 114 (71.9%) of symptomatic participants had non-strabismic binocular disorder; of the 82, 23 (28.0%) had CI. Children with scores ≥ 20 in the COVD-QOL questionnaire were considered as being symptomatic.

Clinic based studies

The clinic-based studies reviewed applied single[26] and multiple sign[12,26,36] criteria in the identification of patients with CI. In Austria,[25] the data of 328 patients between 6–14 years were reviewed for the prevalence of visual anomalies, It was found that 5.2% of the patients had CI. The PUBP technique with a penlight target was applied in the measurement of NPC. In another clinic-based cohort study of patients 6 months to 18-years old, including 1650 school-aged children, 5.3% of CI was found among the school-aged children and 1.6% for preschool children, suggesting that CI increases with age.[26] The increase of CI with age as shown in the study[26] may be related to heavier loads of near work associated with an increase in level of education.[1,10,45] The more recent study[12] evaluated a randomly selected health records of 593 patients (5 – 20 years) in a Puerto Rican population and found CI (12.6%) to be one of the commonest binocular disorder among the study sample. A minimum of five clinical signs was applied in the diagnosis of CI, however, the measuring technique for CI parameters was not stated. The highest prevalence of 17% CI (high suspect and definite) among the reviewed studies in a clinical setting was by Rouse, et al.[36] in the USA. The study was a retrospective analysis of randomly selected clinical data of 415 patients (8-12 years). The prevalence of low suspect criteria was found to be 33%.

Table 4: Prevalence of convergence insufficiency among school-age children

Author/year	**Country**	**Setting**	**Sample size**	**Age (years)**	**Prevalence (%)**
Letourneau, et al.[38]	Canada	School	735	7-14	9
Abdi and Rydberg[18]	Sweden	School	120	6-16	18
Abdi, et al.[19]	Sweden	School	216	6-16	6
Macfarlene, et al.[39]	Australia	School	877	6-11	6.5
Ovenseri-Ogbomo and Ovigwe[5]	Nigeria	School	212	15-28	3.8
Letourneau and Ducic[41]	Canada	School	2084	5-13	2.3
Rouse, et al.[37]	USA	School	453	9-13	LCI=8.4; HCI=8.8; DCI=4.2
Borsting, et al.[15]	USA	School	392	8-15	HCI & DCI=17.3
Marran, et al.[13]	USA	School	299	11.5	HCI & DCI=18.3
Wajuihian and Hansraj[10]	South Africa	School	1201	13-19	LCI=11.8; HCI=6; DCI=4.3
Davis, et al.[16]	USA	School	484	11.7±1.8	31.4
Jang and Park[23]	South Korea	School	589	8-13	10.3
Hussaindeen, et al.[42]	India (rural)	School	358	7-17	17.6
	India (Urban)		562		16.5
Hopkins, et al.[43]	Australia*	School	181	5 & 13	10.3
	Australia**		414		5.2
Darko-Takyi, et al.[44]	Ghana	School	627	12-17	8.6
Shin, et al.[24]	South Korea	School	114	9-13	28
Scheiman, et al.[26]	USA	Clinic	1650	6-18	5.3
Dusek, et al.[25]	Austria	Clinic	328	6-14	5.2
Paniccia and Ayala[12]	Puerto Rico	Clinic	593	5-20	12.6
Rouse, et al.[36]	USA	Clinic	415	8-12	LCI=33; HCI=12; DCI=6

LCI – low suspect CI; HCI – high suspect CI; DCI – definite CI, * Indigenous, ** non-indigenous

Convergence excess

In CE there is the possibility for an individual to excessively converge their eyes at near.[1,32] The examination may include a cycloplegic refraction, determination of AC/A ratio and MEM retinoscopy. Also included are the determination of phoria and near fusional vergence amplitude.[1,10,24] Previous studies on vergence anomalies that reported on CI also reported on the prevalence of other vergence anomalies such as CE, DI, DE, BES, BEX. Thus, methodological differences which may have influenced the interpretation and generalization of their findings have already being highlighted. The prevalence estimates for CE are summarized in Table 5.

In school-based studies, Borsting, et al.[15] reported a lower prevalence of 0.8% compared to another school-based study[13] in USA that reported a prevalence of 5%. The difference may be related to the subjective nature of the measuring technique for clinical parameters of CE. In South Africa,[10] a prevalence of CE of 5.6% were observed in high school students. The CE estimate was significantly higher in younger (13-16 years) than older (17-19 years) participants and was attributed to a higher frequency of esophoria in the younger age group.[10] In a sample of junior high school students in Ghana, Darko-Takyi, et al.[44] reported a prevalence of 1.8% for symptomatic CE. Another school-based study[23] reported a prevalence of CE of 1.9% in unselected primary school children in rural South Korea. Whereas, an earlier study also in South Korea[24] that comprised a selected number of school children with accommodative and vergence symptoms reported a prevalence of 2.4%. Similarly, Ovenseri-Ogbomo and Ovigwe[6] reported a prevalence of CE of 2.8% in self-selected university students in Nigeria. Hussaindeen, et al.[42] compared CE between children in rural and urban areas of India and found that CE was more prevalent among children schooling in urban (1.4%) than rural (0.8%) areas. For clinic-based studies that reported on the prevalence of CE, the highest prevalence of CE (9.1%) was reported in Puerto Rico.[12] This is followed by 8.2% reported in Austria.[25] In the evaluation of the clinical records of school children from two university optometry clinics, Scheiman, et al.[26] reported a prevalence of 7.1%, which was significantly higher with increasing age and in black than in white children.

Table 5: Prevalence of convergence excess among school-age children

Author/year	Country	Setting	Sample size	Age (years)	Prevalence (%)
Ovenseri-Ogbomo and Ovigwe[5]	Nigeria	School	212	15-28	2.8
Borsting, et al.[15]	USA	School	392	8-15	0.8
Marran, et al.[13]	USA	School	299	11.5	5
Wajuihian and Hansraj[10]	South Africa	School	1201	13-19	5.6
Jang and Park[23]	South Korea	School	589	8-13	1.9
Hussaindeen, et al.[42]	India (rural)	School	358	7-17	0.8
	India (Urban)		562		1.4
Darko-Takyi, et al.[44]	Ghana	School	627	12-17	1.8
Shin, et al.[24]	South Korea	School	114	9-13	2.4
Scheiman, et al.[26]	USA	Clinic	1650	6-18	7.1
Dusek, et al.[25]	Austria	Clinic	328	6-14	8.2
Paniccia and Ayala[12]	Puerto Rico	Clinic	593	5-20	9.1

Basic esophoria, basic exophoria and fusional vergence dysfunction

The existing literature on BS, BX and FVD in school-age children is sparse and their prevalences are less compared to CI and CE.[1,10,32] Basic esophoria is a binocular condition where the eyes have the tendency to turn more inward than necessary when an individual is viewing an object at near or at distance which may cause the individual to experience eyestrain, headaches, blurred vision, hazy motion of print, and loss of concentration while reading. Clinical signs of BS include normal AC/A ratio, equal esophoria at distance and near, and normal NPC. In BX, the eyes may turn more outward than expected when a person is looking at a target at either near or distance with associated symptoms like that of BS. Clinical signs of BX include normal AC/A ratio, equal exophoria at distance and near, and decreased NPC.[1,32] Of the three studies that reported on the prevalence of BS, the highest estimate (5.1%) was reported by a clinic-based study[12] whereas three school-based studies reported a prevalence of 1.9%,[5] 1.4%[44] and 2.4%.[43] In contrast, the prevalence of BX of 3.7% reported by a school-based study[24] in South Korea is comparatively similar to 3.5% reported by Paniccia and Ayala[12] in a clinic-based sample. The study by Shin, et al.[24] was conducted using only symptomatic participants which is characteristically similar to participants in clinic-based studies. Other school-based studies reported BX of 1.0%,[42] 1.4%[44] and 2.4%.[5]

Fusional vergence dysfunction is the failure of the eyes to efficiently utilize or maintain binocular vision due to deficiencies in the fusional vergence dynamics. Individuals with FVD (vergence insufficiency) often have normal phorias and AC/A ratios but reduced fusional vergence amplitudes. Symptoms of FVD include blurred vision, eyestrain, excessive tearing headaches, loss of attention and comprehension.[1,32] In 1201 students in South Africa, whose age ranged between 13 and 19 years, a prevalence of FVD of 3.3% was found.[10] The estimate for clinic-based study in USA[26] with participants from 6 to 18 years was 0.4%. Hussaindeen, et al.[44] found a prevalence of FVD of 0.8% and 1.3% in rural and urban India respectively with children aged from 7 and 17 years. The prevalence of FVD was 0.8% among high school students in Ghana.[44] In an evaluation of patients' clinical data in Puerto Rico, Paniccia and Ayala[12] reported a prevalence of 4.7% in patient aged from 5 and 20 years.

Divergence insufficiency and divergence excess

Divergence insufficiency describes a clinically acquired anomaly of ocular horizontal version, characterized by full appearing ocular ductions and comitant esotropia at distance.[46] It can also be referred to as an uncommon form of strabismus with esotropia and diplopia only at distance and single binocular vision at near. Divergence insufficiency has often been considered as a consequence of a neurological disorder of the central nervous system.[47] Divergence excess refers to a binocular condition in which the exodeviation tendency is greater at distance than at near. In DE, binocular fixation is not always present when viewing under normal conditions. In such situation, the foveal line of sight of one eye deviates outwards and fails to intersect the object of fixation.[48]

The literature search showed that DI and DE are the least studied vergence dysfunction in children. Among the vergence anomalies DI and DE seems to be the least prevalent, with DI reported to occur more in adult populations.[42] Ovenseri-Ogbomo & Ovigwe[5] reported a prevalence of DI of 0.9% in a sample of university students in Nigeria. In rural India, the prevalence of DI was 0.3% in school children aged 7 to 17 years. A higher prevalence of DI of 2.7%[12] compared to the two school-based studies[5,42] was reported by a clinic-based study in Puerto Rico. Similarly, the prevalence of DE in school-based studies was 0.9%,[5] 0.4%[42] and 0.8%.[44] while a clinic-based study reported a prevalence of DE of 1.3%.[12]

DISCUSSION

Sample characteristics

The present review has highlighted the prevalence of accommodative and vergence anomalies in school-age children across various studies. Although, these studies provided useful information on the prevalence estimates in various racial groups, sample characteristics and diagnostic criteria of each study precludes comparison of corresponding findings. Regarding, population characteristics, our search did not reveal any epidemiological study on the general paediatric population. Studies were conducted using school populations or clinical samples.

Considering that accommodative and vergence functions are mostly activated during near vision, school settings affords the opportunity of testing children in conditions comparable to their learning environment. School setting will also allow for random sampling and school children can be considered as being closely related to the general paediatric population. Therefore, the findings of school-based studies have the advantage of being extrapolated to the general population. To the contrary, clinical samples provide biased data as participants have been preselected because patients who visit an optometry clinic are more prone to having visual anomalies than those randomly selected from the general population.[17] Therefore, clinics samples have the tendency of overestimating the prevalence of visual anomalies and cannot be relied on in planning and implementation of intervention programs.

Sample selection and sample size are other important characteristics that influence the interpretation of study findings, which could result in differences in prevalence estimates between studies. Although, studies conducted in school settings have the merit of randomization, so many studies reviewed applied convenience sampling methods, perhaps because of ease of recruiting participants[49] However, the convenience sampling method is prone to biased data, thus cannot be extrapolated to the target population. In relation to sample size, most studies[13,15,18,19,20,21,25,27,28] were carried out on limited sample sizes that are not representative of the targeted populations. Furthermore, the selection of only symptomatic school children by Shin, et al.[24] may overestimate the prevalence of visual anomalies in their study population as the children with symptoms have a greater probability of having visual anomalies. Among the reviewed studies, four[13,15,24,37] did not include participants with uncorrected visual acuity and RE, thereby reducing the likelihood of their study samples to provide a valid data. In some studies,[10,11] children with RE were included but information on number of children with RE who wore their correction for testing was not provided. In most of the studies, information on the inclusion criteria with respect to visual and refractive status of participants were not indicated.[5,8,12,20,21,25,44] It is important to consider the management of RE when evaluating the prevalence of accommodative and vergence anomalies, as it is one of the primary aetiological factors for the development of accommodative and vergence anomalies.[16,29]

It has been suggested that AA reduces with age and that excessive near vision task increases the likelihood of having accommodative and vergence anomalies.[32,45] However, sampling error, sample size and limited age range may have affected the findings of some studies. Although, studies that reported an association between prevalence of specific accommodative and vergence anomalies and age were few, those[26,42] that found an increase in AI and CI with age had larger age ranges which comprised both primary and secondary school children. The few studies that reported on gender and specific accommodative vergence anomalies found no significant variation in the prevalence of specific vergence anomalies between male and female participants. Overall, there are limited data on the influence of age, gender, ethnicity, study location, and socio-economic status on accommodative and vergence anomalies.[6]

Diagnostic techniques

A range of criteria was used in diagnosing accommodative and vergence anomalies, especially AI and CI. Similarly, different techniques were applied in measuring the accommodative and vergence parameters and their outcome measures were determined using different cut-off thresholds. For AI, the basis of diagnosis for both single and multiple criteria were low AA below the age expected norm determined mostly by Hofstetter's age formula for minimum AA. The studies consistently utilized the PUBT for AA measurement. The basic diagnostic criteria for CI, was the use of receded NPC or exophoria at near. The cut-off threshold for receded NPC (break) ranged from 6 to 10 cm, whereas, that of near exophoria ranged between 2 and 6 prism dioptres. It is important to point out that accommodative and vergence disorders are mostly diagnosed as a syndrome of clinical signs. Thus, the use of single criterion definition by some studies may limit their interpretation and conclusion. In addition, single diagnostic criteria may not provide adequate information to warrant a definitive diagnosis. Nonetheless, for symptomatic patients whose evaluation indicate that other binocular vision parameters are normal, one clinical sign may provide a clear diagnosis of accommodative and vergence anomalies.[6]

CONCLUSION

The present review highlights the gaps in knowledge on visual anomalies in school-age children especially the lack of sufficient data on accommodative and vergence anomalies in some countries. The review also reveals a large variation in the prevalence of accommodative and vergence anomalies. These variations may not be entirely attributed to methodological characteristics and may warrant additional research on the role of socio-economic factors, gender, age, race and ethnicity. However, to improve comparability of findings, measurements and diagnostic criteria for accommodative and vergence disorders need to be standardized. It is also important to have adequate and representative samples of children that is proportional to the age groups of the study populations with low percentage loss to follow-up.[22] Reports suggest that accommodative and vergence anomalies begin during the later years of primary education and become intense during high school level.[1,7,45] More studies with larger age range consisting of primary and secondary school children and adequate samples are necessary to obtain more accurate prevalence estimates. Furthermore, a deeper understanding of the association between sample demographics and accommodative and vergence anomalies will help to identify the population at risk of developing these anomalies that can affect social and educational development.[47] Considering that traditional vision screening protocols may not adequately identify near vision anomalies, timely detection may warrant the development of a broad screening strategy. In addition, eyecare practitioners may consider it mandatory to evaluate every school child for near vision anomalies, particularly those that present with near vision related symptoms.

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2.5 A REVIEW OF PAEDIATRIC VISION SCREENING PROTOCOLS AND GUIDELINES

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ABSTRACT

Vision screening plays an important role in the early detection of children who have or probably are predisposed to having specific visual problems. The validity and reliability of the screening batteries in relation to the age group to be screened, and the person administering the test as well as the referral and follow-up criteria contribute to the overall outcome of the vision screening. Despite the long history of vision screening and significant improvement in the development of screening protocols, no agreement exists concerning the age at which children should be screened, the exact test batteries that should be included and who should conduct the screening. This review highlights some important aspects of the history of paediatric vision screening and available evidence in support of their use to detect visual conditions in children. It also examines some of the barriers against the development of paediatric vision screening models especially in low and medium income countries.

KEYWORDS: vision screening; children; visual problems; screening batteries

INTRODUCTION

The primary goal of pediatric vision screening is to detect children with unsuspected remediable visual conditions, to implement early treatment and reduce the impact that any untreated condition may have on their educational and social progress[1-2]. Starting with the first approved vision screening program in Connecticut[3] in 1899 that utilized the traditional visual acuity (VA; Snellen) chart, screening programs and test batteries have evolved over the years. Despite the significant improvements, the value of paediatric vision screening programs and the ideal protocol to be adopted has continued to dominate scientific and health policy discussions. While it is generally accepted that the detection of vision anomalies in children depends on the availability of valid and reliable test batteries, no agreement exists concerning the age at which children should be screened, the exact test batteries that should be included and who should conduct the screening. This review highlights some important aspects of the history of paediatric vision screening and available evidence in support of their use to detect visual conditions in children. It also evaluates some of the more contentious issues against the development of paediatric vision screening guidelines.

THE NEED FOR VISION SCREENING

According to the recommendations of the World Health Organisation, effective screening programs should include tests to detect conditions that are common and can present serious health problems. Such conditions can easily be detected through cheap and reliable screening tests that are available. It should also be economically amenable to treatment[4].

Significant refractive error (RE) is a leading cause of visual impairment in childhood and its detection is the main target of vision screening programs[5]. A series of Refractive Error Study in Children (RESC) surveys, conducted in several countries on children of comparable age group and by utilizing common diagnostic criteria and measurement methods observed that uncorrected RE was responsible for about 56-94% of cases of reduced vision in children[6]. The studies suggest that the vision of those children would have been effectively treated with early detection and spectacle correction. There are over 19 million children less than 15 years of age with visual impairment worldwide with 12.8 million of them due to uncorrected RE[6].

Amblyopia is also a common cause of vision loss in children. It is mostly cause by strabismus, RE and congenital cataract[7-8]. Testing for amblyopia is one of the focus areas of many screening programs because of its prevalence, its effect on children and society, and the effectiveness of amblyopia treatment. It is estimated that 2-4% of people in developed nations are affected by amblyopia depending on the population and study[9-10]. Individuals with amblyopia are more likely to have bilateral vision impairment compared to non-amblyopic persons which exacts a significant burden on the individual and society[11-12]. Amblyopia can be easily treated by cost effective means including optical correction of any significant RE, patching of the non-amblyopic eye, or use of atropine in the non-amblyopic eye[8,13]. Available studies indicate that amblyopia can be treated later in life but is most effectively treated, and can only be prevented, in early childhood[7,8,13].

The condition of strabismus or misalignment of the eyes is related to amblyopia and therefore, there may also be a “critical period” after which permanent vision loss may occur without early intervention. For instance, to avoid confusion of receiving two disparate retinal images, the brain can ignore or suppress the image from one eye which could remotely lead to amblyopia. Once the visual system in the brain is fully developed, however, such adaptations are not possible[7]. Colour vision deficiency (CVD) is rarely included in screening protocols considering that congenital CVD are untreatable and not always considered as a disease. However, some people argue that CVD testing should be included as part of screening batteries as CVD can affect the development of a child. As such early identification will help to counsel the affected child of possible career choices thereby reducing the psychological effect this may have in the future[14]. Screening for accommodative and binocular dysfunction is preferable, as there is some evidence in support of an association with impaired school performance. Other conditions targeted in paediatric vision screening programs include ocular pathology such as trachoma, vitamin A deficiency, cataract, glaucoma and retinoblastoma[5].

HISTORICAL DEVELOPMENT OF VISION SCREENING PROTOCOLS

Traditional Methods

The first state approved school vision screening program that included only a Snellen chart was established in Connecticut in 1899. However, this achievement was marred by poor test results owing to the under-standardization of the testing conditions. In 1934, a series of slides that were used in the assessment of VA, fusion and stereopsis was developed[3]. The development marked an important point in the history of vision screening, as it became the first commercially available stereoscope, after incorporating it into the Keystone Ophthalmic Telebinocular Vision Testing instruments. Similarly, the tests results were considered unacceptable by the American Medical Association in 1939 due to its high failure rates of 85%[3].

The idea of incorporating ocular examination into screening programs, as well as ensuring a wider coverage through rapid and precise methods led to the development of the Massachusetts Vision Test in 1938, which included tests for VA using the Snellen chart, hyperopia using +1.00 D lenses, and heterophoria using the Maddox rod. Teachers were entrusted with the responsibility of identifying children in need of vision correction and promptly referring them to the ophthalmologist. The screening maintained good correlation with ophthalmologists producing agreements of 86% of those who passed and 93% of those who failed. The main challenge for this screening test was the inability to develop consistent and reliable passing criteria[15].

Contemporary Methods

Using the concept of the Massachusetts Vision Test, optical companies started producing commercially available vision screening instruments that included the Massachusetts School Vision Screening Test, the modified Keystone Telebinocular, the modified Bausch and Lomb School Ortho-Rater, and the Titmus Optical School Vision Tester in 1955. Although these instruments provided a cost-effective and rapid testing approach, the issue of who should administer the test, how often it should be performed, and the referral and follow-up criteria were still controversial[3].

The first comprehensive and systematically validated children’s vision screening tool known as the Modified Clinical Technique (MCT) was developed from a three-year study period in the Orinda School District in California, USA. Starting from 1954, parents, teachers, nurses and optometrists utilized a combination of assessment procedures to re-examine a single cohort of primary school children seven or eight times in every subsequent year of the study. The Orinda study identified reduced VA, RE, binocular vision dysfunction (strabismus) and ocular pathology as specific problems that should be prioritised for screening by either optometrists or ophthalmologists[16-17]. Interestingly, the test protocol can be completed in about 5 to 6min per child[14]. The remarkably high sensitivity (98%), specificity (99%) and good predictive value (positive predictive value of 0.90 and negative predictive value of 0.99) of the Orinda Study and its MCT has gained wide acceptance as it is considered as the "gold standard" vision screening procedure for school-aged children[14,18].

However, tests for non-strabismic binocular dysfunction were not part of the MCT and ophthalmic-trained personnel (ophthalmologists and optometrists) are required to perform RE assessment with a retinoscope and to screen for ocular disorders[19]. With the exception of distance and near cover test, no other functional and performance-oriented testing was included in the MCT battery[19]. In addition, the high sensitivity and specificity reported for the Orinda MCT has not been replicated in subsequent studies that applied the MCT battery[14,18]. This may be due to the lack of a definitive pass/fail criterion for the MCT in the Orinda study. A child is considered to have passed or failed the test based on the decision of two independent optometrists after reviewing the results of the series of tests. In case of any disagreement between the optometrists, four additional vision care experts are consulted[14]. Given that the MCT cannot be administered by non-ophthalmic trained vision screeners including the non-replication of its sensitivity and specificity values, the status of a "gold standard" vision screening protocol has been questionable[18].

A modified version of the Orinda MCT (Portsea MCT) was introduced in vision screening programs between 1980 and 1983 as part of a larger public health initiative at Portsea in Victoria, Australia[14]. In the Portsea MCT fusional vergence ranges, accommodative facility, ocular motility, stereopsis and colour vision tests were added to the Orinda battery to provide a comprehensive assessment of visual parameters associated with reduced school performance[20]. However, the added test protocols did not increase the time efficiency of the Portsea MCT when compared to the Orinda MCT[20-21]. Similarly, when compared to other screening programs that utilized the Orinda MCT the referral rate from the Portsea study of 17.7% and 10.4% was classified as unsatisfactory and borderline, respectively[16-17,22].

In 1985 a screening battery that uses a functional vision screening approach to detect learning related vision problems was developed by the New York State Optometric Association (NYSOA)[23]. The test battery included distance and near VA, as well as screening tests for hyperopia, convergence, fusion (with the Keystone Telebinocular), stereopsis, saccadic skills, visual motor integration, and colour vision and was designed to be administered by parent volunteers trained by an optometrist. A validation study for the screening protocol observed a sensitivity of

72% and specificity of 65% when compared to professional eye examination, and that the Snellen test missed 75% of the visual problems that were detected in the full examinations. Concerns about the practical applicability of this screening protocol apparently contributed to its lack of acceptance by schools. The test battery is long and involves both optometrists and trained parent volunteers, as school nurses cannot alone administer the screening and schools may not be able to provide enough of their own personnel for the screening[14,23].

Computerized Methods

The development of computerised screening protocols helped to tackle some of the issues which has been a major drawback for screening programs. For instance, a computer software known as Visual Efficiency Rating (VERA) was developed to address some of the concerns of NYOSA test batteries, so that school nurses could screen for binocular, accommodative, and ocular motor disorders in addition to hyperopia and VA. The protocol involves a 2-level testing approach in which children must pass VA, hyperopia, and stereopsis screening tests before the performance of a visual skills battery. The visual skills screened are vergence facility, accommodative facility and saccadic tracking. VERA screening batteries were designed to increase specificity and can be completed in about 12 to 15min per a child. A study was conducted by Gallaway and Mitchell[24] to validate the VERA visual skill test. Initially, the sensitivity of VERA in detecting visual skills problems was 45%, and the specificity was 83%. The sensitivity increased to 64% and specificity to 100% in professional eye examination data in 28 subjects when the symptom survey (Convergence Insufficiency Symptom Survey), reading level and a classroom behaviour survey (completed by the teacher) were included. The analysis was not limited to visual skills data but also comprised of acuity and refractive data. It was noted that VERA was an acceptable alternative to other protocols for screening visual skills and could be efficiently administered by a school nurse.

Although several vision screening protocols that can detect broad range of paediatric vision problems have been developed, there sensitivity/specificity, time efficiency and level of expertise required for their administration differs[14,16,23]. For instance, MCT which takes only about 5 to 6min per child requires some qualified ophthalmic personnel to administer, whereas the NYOSA test batteries which can be administer by a train non-ophthalmic personnel takes about 12 to 15min to complete per child[23]. Therefore, in developing optimum screening guideline, it is important to strike a balance between sensitivity/specificity and time efficiency[14].

VISION SCREENING MODEL IN SELECETED COUNTRIES AND REGIONS

Vision screening programs are in existence in most developed countries across the world[8,14,25-27]. However, the debate on the fundamental components and nature of the screening programs has not been resolved. Even within a country, there has not been any agreement about when children should be screened, which conditions should be targeted, which protocols should be used, and which screening personnel are best equipped to provide services. In addition, traditional VA test protocol has continued to be the fundamental of test batteries for these screening programs, despite significant improvement in the screening protocols. The implication is that the screening programs that mainly assess distance VA are likely to miss other basic visual skills necessary for optimum school performance[14]. A summary of screening programs from selected countries are presented in Table 1.

Table 1 Summary of paediatric vision screening guidelines from selected countries

Country	Age screened	Screening test	Screening personnel
British Columbia, Canada[8]	3y	Amblyopia, Strabimus (Eye check HOTV), Randot preschool stereo test, Sure sight vision screener; reduced VA	Public health staff
Manitoba, Canada[25]	Kindergarten to grade 1	Stereoacuity, vertical or lateral heterophoria, reduced VA	School health nurse
	Grade 3 and above	vertical or lateral heterophoria, reduced VA, plus lens test (+2.25 D)	School health nurse
Kansas, USA[26]	Birth to 6mo	Eyelid reflex, fixation, tracking, pupil response, corneal reflex test	School health nurse, volunteers
	6-18mo	Tracking pupil response, corneal reflex test, cover test, NPC, Teller card acuity	School health nurse, volunteers
	18 months-3y	Fixating, tracking pupil response, corneal reflex test, cover test, NPC, Teller card acuity, fusion (Worth-4-dot), stereopsis, HOTV	School health nurse, volunteers
	3-5y	Fixating, tracking pupil response, corneal reflex test, cover test, NPC, Teller card acuity, fusion (Worth-4-dot), stereopsis, HOTV, colour vision test	School health nurse, volunteers
	5-8y	Fixating, tracking pupil response, corneal reflex test, cover test, NPC, Teller card acuity, fusion (Worth-4-dot), stereopsis, distance VA, colour vision test, plus lens test, near VA	School health nurse
	8-12y	Pupil response cover test, NPC, stereopsis, distance VA, colour vision, plus lens, near VA	School health nurse
Alaska, USA[27]	Distance VA: Preschool, Kindergarten, grade 1 to 12	Sloan, LEA or HOTV, occlude	
	Binocular vision: Preschool, Kindergarten, grade 1	Stereofly or butterfly test, Random dot 'E' Cover test or Hirschberg, paddle ocluder and fixation target	
	Photoscreen: Preschool or kindergarten, special needs population	Valid photoscreen instrument	
Queensland, Australia[14]	0-18mo	Visual behaviour, Hirschberg test (6-18mo)	Well child visit, health nurse
	2.5-3.5y	Hirschberg test, vision, near cover test	School entry screening; child health nurse
	4-5y	Hirschberg test, vision, near cover test, distance and near cover test, Vision: LEA/HOTV/STYCAR	Child health nurse
	6-12y	Vision-Snellen chart	Referred by parents; child health nurse
United Kingdom[1]	Pre-Kindergarten, Kindergarten	logMar Crowded test	Orthoptics
Spain[28]	4-5y	LEA charts, ocular alignment test, ocular motility test, Random dot stereo test	Qualified healthcare professional

VA: Visual acuity; LEA and HOTV: VA chart for children; STYCAR: Screening test for young children and retardates; NPC: Near point of convergence.

Non-governmental organisations working in eye health have also recommended screening guidelines to be adopted by specific countries in their regions of operation. In Eastern Mediterranean region[29] and India[30], the recommended guidelines for school vision screening prioritised the detection and correction of significant RE to reduce the prevalence of preventable blindness and low vision due to uncorrected RE in the region. However, the guidelines fail to specify the age of children to be screen, the screening tools to use and who should administer the screen.

Recently a standard guideline for comprehensive school eye health programs in low and medium income countries was developed by International Agency for Prevention of Blindness (IAPB)[5]. The guideline was a revised version of an earlier document develop by a coalition of non-governmental organisations working in the field of eye health. The guideline was designed to provide direction in planning and implementation of efficient and sustainable school eye health programs through step by step approach that will be implemented base on the availability of resources and the nature of existing child eye health service in any given system. The guideline recommends that health care professionals and trained non-health professionals such as school teachers should be involved in the provision of school health programs and that schools should be visited every 1-2y[5]. Although common childhood eye conditions including eye infections, lid infections and allergies were recommended to be screened, the focus of the screening strategy is on visual conditions that can cause reduced VA and loss of vision in children (Recommendation of the IAPB for school eye health program)[5]. Visual problems such as accommodative and vergence disorders which can reduce functional performance and overall quality of life of a child are not among the conditions to be screened.

VISION SCREENING PROGRAMS AND CHILD EYE HEALTH IN NIGERIA

Early detection and treatment of potential visual impairment and blinding diseases is a key factor in the actualization of children rights, particularly the right to the highest attainable health and ensuring their protection against preventable diseases[31]. While the expanded program on immunization against measles and vitamin A supplementation have impacted positively on child eye health, the realization of efficient and a sustainable child eye health program in Nigeria has not been achieved.

Eye care services in Nigeria are delivered in public and private hospitals, however, reports indicate that eyecare services are mainly provided by private health institutions[32-33]. A situational review of paediatric eye care in Nigeria report that there were only 400 ophthalmologists in Nigeria (including those in training) with only 12 of them specializing in paediatric ophthalmology[32]. Similarly, a situational analysis of optometry in Africa, indicates that there are approximately 4000 optometrists in Nigeria[34]. The reviews[32,34] also emphasized on the uneven distribution of eye health facilities and eyecare practitioners. Among the ophthalmologists in Nigeria, 95-99%[32] were practising in urban areas and state capitals and according IAPB[34] 60% of optometrists in Africa are working in their various country capitals with only 40% practising mainly in urban areas of the constituent states or provinces.

Although, eye health is included as one of the components of primary health care (PHC) in Nigeria, eyecare services are only provided in few PHC centres across the country. In some states secondary eye care services are non-existent and where it is provided, it is grossly under-resourced and limited by inadequate human resource capacity, equipment and referral opportunities to tertiary level services. The few tertiary centres are not adequately prepared to support the child eye health in Nigeria. The two most active and equipped tertiary paediatric centres are privately owned and are in the north central and south west geopolitical zones. In addition, only a few states have functioning blindness prevention programs and school eye health is not a priority of all the three tiers of government in Nigeria[32-33]. Thus, the provision of eyecare services including school eye health programs is mainly by private eyecare facilities. Vision screenings delivered in school settings, as well as religious centres by local eye care practitioners, are often driven by commercial interest and availability of time of the individuals involved. There is no strategic coordination between eyecare practitioners and no screening guidelines on how and when children should be screened, the screening batteries that should be included and the appropriate referral criteria. Furthermore, some prevailing eye disorders including accommodation and vergence anomalies, low amount of hyperopia and astigmatism are not necessarily included by individual eyecare practitioners. Altogether, the screening programs administered by private individuals in Nigerian are unmethodical and irregular.

MAJOR CHALLENGES TO THE DEVELOPMENT OF A VISION SCREENING MODEL

Evidence for Childhood Vision Screening

One of the major challenges facing vision screening programs of school children is the lack of direct evidence demonstrating the effectiveness of childhood vision screening in reducing the prevalence of ocular disorders or in improving visual outcomes. For instance, a Cochrane review of literature from 1966 to 2004 on screening for correctable VA impairment in school-aged children and adolescents concluded that there were no available robust trials that can be used in evaluating the advantages of school vision screening. The harmful effect of reduced VA on schooling needs to be quantified. The authors suggest that in assessing the impact of a screening program, consideration will be given to the geographical and the socio-economic environment in which it is administered[35]. This however does not imply that there is no benefit derived from screening programs, rather the impact has not been systematically tested in randomized controlled trial[36]. In contrast, a convincing series of indirect evidence supports the early detection of sight threatening visual condition[36-37]. In addition, the American Academy of Ophthalmology and the American Academy of Paediatrics recommend visual assessment from birth and at all routine health visits[38].

Components of Vision Screening Protocol

Even though computerized methods of vision screening are now available, the VA chart has continued to be one of the basic tools of a vision screening protocol especially in the developing countries where the acquisition of computerized instruments is not always easy. While children with uncorrected myopia can easily be detected through measures of unaided distance VA, it is not always same for those with near vision anomalies such as hyperopia, astigmatism, accommodative and binocular vision dysfunction[39-40]. A validation study[40] for VA protocol and RE detection recorded a high sensitivity and specificity for myopia detection in 12-year-old children but was not effective in detecting hyperopia or astigmatism. Children with good accommodative ability were still able to read a 6/6 (20/20) letters on the VA chart, despite having high amount of hyperopia and astigmatism. However, with increasing age and excessive near work activities, these children may experience some visual discomforts[38-39]. In another study involving high school children with poor reading ability in California, only 17% had reduced VA of less than 20/40 or worse in at least one eye, whereas 80% had deficiency in at least one of the clinical measures of accommodative and vergence functions including, near fusional amplitude, accommodative facility and near point of convergence[41]. Likewise, a significant increase in the prevalence of binocular vision problems was found among public school children in New York City[42]. The implication of these findings is that with traditional VA measurement which is mostly used in school vision screening programs, many children with impaired reading ability would be missed. Consequently, Bodach *et al*[42] had reiterated the importance of periodic screening and rescreening for hyperopia and binocular vision anomalies in addition to distance visual acuities.

Provision of Vision Screening

Vision screening conducted by adequately trained health professionals is vital for the detection of vision problems in children[5,43]. An assessment of screening programs in Sweden[44] and Vietnam[45] revealed that adequately trained non-ophthalmic personnel can competently screen 4-year-old children, while children who fail screening tests should be referred to an ophthalmologist[44]. A study on the SureSight vision screener found an inverse relationship between the experience of the screeners and the referral rate. In this case, the referral rate decreased as the volunteers gained more experience. At the beginning, the average referral rates for the screeners were 10.6% which overtime decreased markedly to 7%[46]. Although, the study did not assess the sensitivity, specificity, or positive predictive values of the screeners, it revealed that vision screenings are mostly subjective, and the accuracy of screening results will depend greatly on the experience of the screener. Overall, these studies revealed that the sensitivity of the test administered by different people varied depending on the protocol adopted and the age of the children being screened. However, adequate training is necessary to achieve a reliable result.

The Vision in Preschoolers (VIP) study compared the performance of vision screening tests in 3- to 5-year old by trained nurses and lay screeners, using the results of examination administered by an ophthalmologist or optometrist as the gold standard. The screening tests performed included SureSight, Retinomax, crowded linear LEA Symbols, single LEA Symbols (administered by lay screeners only) and stereo smile II test[47]. Except for linear LEA symbols which were significantly higher, the sensitivities of all other tests were not statistically significant, even though the sensitivities were marginally higher when administered by nurse screeners than lay screeners. In contrast, lay screeners achieved a considerably higher sensitivity with the Single LEA Symbols VA test than did nurses or lay screeners using the Linear LEA Symbols VA test. These findings indicate that similar results can be achieved by adequately trained nurses and lay screeners in preschool vision screening[47].

The Age to Administer Vision Screening

There is no consensus on the ideal age at which screening should be administered in children. In Australia, vision screening is mostly conducted at school entry which for most children is about 5 to 6 years of age. This guarantees a wider coverage and early detection of amblyopia, as children are readily available[11,39]. Sjöstrand and Abrahamsson[48] recommend vision screening for amblyopia at 5 years of age because at that age children can be properly screened with a linear acuity chart and adequately treated, with less psychosocial burden for the child and the family. Besides, treatment at this age can result in a better visual outcome as children are still in the critical period of visual development[11,39]. According to Hartmann *et al*[46] the chance of achieving a better test result is higher in older children, as screening in younger children is more difficult. Due to the subjective nature of most screening protocols, screening younger children may be difficult and lengthy especially for the inexperienced screener.

Preschool vision screening has also received some support, as it allows for timely detection and treatment of amblyopia before schooling begins[49-50]. Screening for amblyogenic factors in school-aged children is also warranted because amblyopia can be effectively treated into the teenage years and beyond[51]. While there may be some disadvantage in delaying the detection of amblyopia until school entry, the reliability of the screening is higher and the costs significantly less. It is more difficult for a preschool age group to follow test procedures and instructions. Thus, there is more likelihood of having a higher false positive rate from preschool vision screening than for that performed at school entry[43]. However, some others have recommended the performance of vision screening at regular intervals. For example, the American Academy of Ophthalmology and the American Academy of Paediatrics recommend eye health screening from birth and at all routine health visits[40]. The guidelines on school eye health recently developed by IAPB recommend that schools be visited at least once in every two years to screen new intake and to rescreen those given spectacle the previous year[5]. Similarly, Bodach *et al*[42] have stressed the relevance of periodic screening and rescreening for various ocular defects.

CONCLUSION

Vision screening of children is a valuable approach for the detection of potential visual disorders that may impact negatively on the overall development of a child. The specific test batteries, the age group to be screen, and the personnel administering the test all contribute to the overall outcome of the vision screening. While the VA chart is a traditional screening tool, it may not be effective in the detection of some visual disorders like, hyperopia, astigmatism and anomalies of binocular function. Since children of different age groups present with varying degrees of visual problems, it may be necessary to use age appropriate test batteries to assess vision in the different age group of children. There seems to be no agreement as to who should be administering the children's vision screening programs and the age at which it should be administered. Perhaps, a collaborative effort of eye care professionals, nurses and lay screeners (while keeping the cost very low) may be ideal. This will require the development of test protocols for each of the group of screeners base on their expertise and knowledge. As indicated in the reports, eye care professionals are better equipped to provide complex screening procedures. Overall, the studies reviewed emphasized on adequate training of the vision screener as being essential in achieving a reliable screening result. In addition, screening of all children at school entry age may offer a wider coverage, as the children can reliably cooperate with vision screening tests and are readily accessible. Subsequent periodic screening as recommended by the American Academy of Ophthalmology and the American Academy of Paediatrics will be essential. The lack of randomized controlled data has not helped the evaluation of the effectiveness of vision screening. However, no studies have observed any risk associated with screening: the tests can detect the defects they are meant to detect, and there are effective treatments for these vision defects.

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2.6 SUMMARY

The literature review highlights the prevalence of a range of eye disorders in children in various populations. However, measurement methods, definition of key terms and exclusion criteria varied across studies. Furthermore, there is lack of data on the prevalence of visual conditions in Nigerian children. Although, uncorrected hyperopia, amblyopia, accommodative anomalies and vergence disorders can possibly affect optimum school performance, no study in Abia State was found to have reported on the prevalence of visual impairment, amblyopia, strabismus, accommodative and vergence disorders in school-age children. Reliable data on childhood vision conditions are necessary for developing adequate intervention and management strategies.

Timely detection of visual anomalies in children will ensure that these problems are treated before they impact negatively on the childrens' academic performances or possibly degenerate to permanent visual impairment with associated socio-economic consequences. A coordinated and common screening strategy that has valid and appropriate age-related test batteries should be central to achieving this objective. Current paediatric screening services offered by individual optometrists are often driven by commercial interest and availability of time of the individual involved, resulting in unmethodical and inconsistent service provision in the community. Therefore, understanding the visual profiles of school children in Abia State will help to ascertain the extent of the disparity between preponderance of visual anomalies and service provision by optometrists. This data will help in the development of an evidence-based strategy for early detection of those conditions.

In order to address these problems, this study has been designed to consist of two parts. The first part included the establishment of the prevalence estimate for the measures of visual acuity, refractive error, accommodation, binocular vision and ocular health assessment. These anomalies have been reported by previous studies to have obvious negative consequences on children academic performances and overall development. The focus of part two of the study was on the suitability (coverage, components and referral criteria) of the individual optometrists' paediatric vision screening program to identify these conditions. The findings from both part one and two would be directed towards developing a common and coordinated strategy that will aim at meeting the visual needs of school children in Abia state. The study design and methods including data collection processes are outlined in the next chapter.

CHAPTER THREE

DETAILED RESEARCH METHODS

3.1 INTRODUCTION

This chapter discusses the study design and methods applied in recruiting participants. In addition, a details procedure of step of the data collection processes using a questionnaire and a series of vision assessment protocols are presented. The reliability of the instruments, as well as the validity of the study, data analysis and ethical considerations are also presented in the chapter.

3.2 STUDY DESIGN

This was a cross-sectional, observational, descriptive study, designed to provide quantitative data on visual anomalies in school children in Abia State. Cross-sectional design has important application in population-based surveys and disease epidemiology. For instance, it allows the observation of a number of participants with varied characteristics and demographic variables at a single point in time.[1] Other advantages include:

- Affordability of the study method.
- Good controls over the measurement process.
- Key data points are mostly complete.
- Better precision in the sampling process.
- Data is easier to analyse and to draw conclusions.
- Access to multiple outcomes and exposures.
- Provides information for a descriptive analysis.
- Provides a framework for additional research opportunities.

This design was selected because of its numerous advantages and suitability in providing prevalence information of visual disorders which is a very crucial step in the development of visual profile of school children and strategy for timely identification and treatment of those visual problems. Apart from the advantage of not losing participants to follow-up, the fact that the method of data collection was relatively cost effective and practical given the timelines involved in a doctoral research study made it an approach of choice.

3.3 STUDY AREA

The study was conducted in Abia State, Southeast of Nigeria. Abia State was created in 1991 from the former Imo State with its capital in Umuahia. The State consists of 17 local government areas (LGA) (Figure 1) that stretches across 5 834 square kilometres with a total population of 2.8 million people according to the 2006 national census.[2] The population was projected to grow at three per cent per annum, given an estimated population of about 3 584 959 by 2017. Abia State is bounded on the north and northeast by the States of Anambra, Enugu, and Ebonyi; on the east and southeast by Cross River State and Akwa Ibom State and on the south by Rivers State. Abia State is primarily inhabited by Igbo ethnic group with their main occupations including farming, trade and civil service.[4]

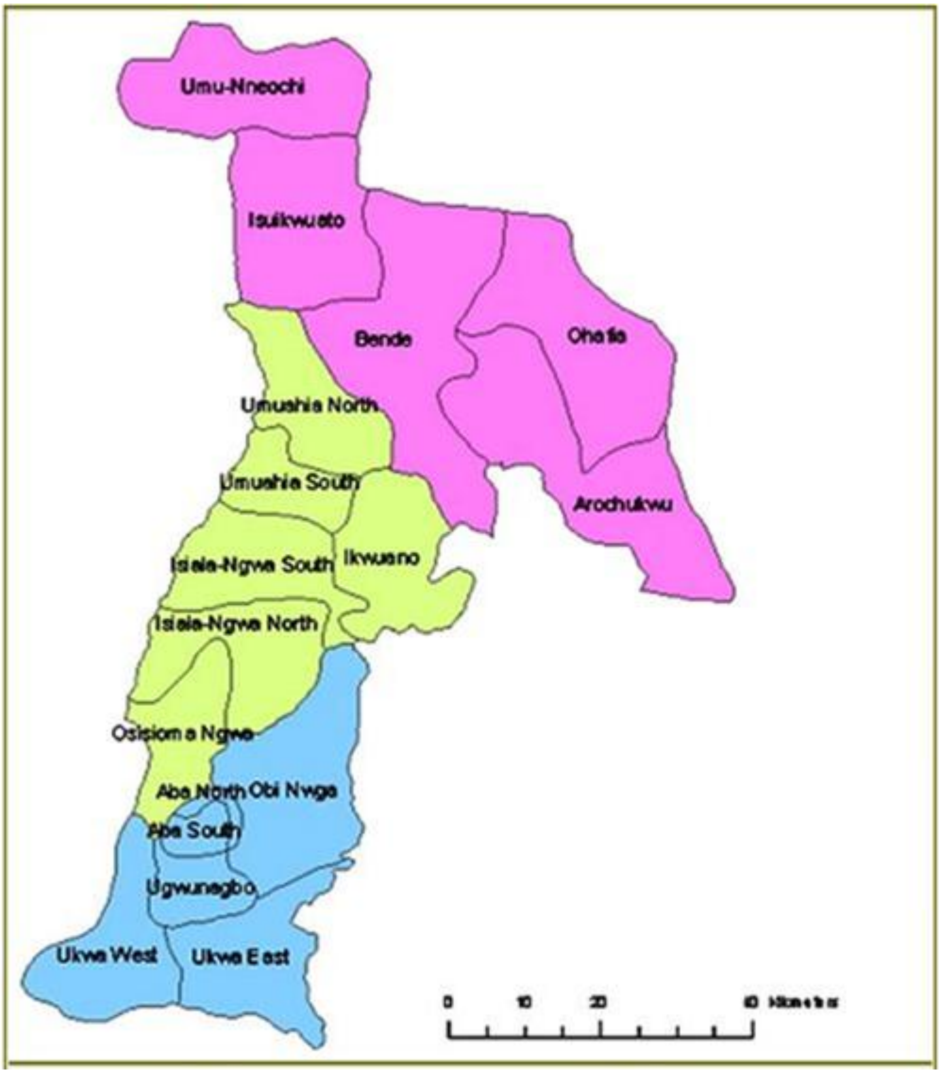

Figure 1: Map of Abia State showing the three senatorial districts and 17 local government areas[4]

Primary and secondary education is served by public and private institutions, and all schools follow the same 9-3-4 national system of education and curriculum. The 9-3-4 system of education implies, nine years of compulsory universal basic education (UBE), three years of secondary education and a minimum of four years of university education. The UBE comprises six years of primary and three years of junior secondary education and children enter primary school at age six. The public primary and secondary schools are separately managed by the State Primary Education Board (SPEB) and Secondary Education Management Board (SEMB), respectively. Private schools are self-governed under the supervision of the State Ministry of Education to ensure that minimum standards as outlined in the national curriculum are adhered to.[5,6,7] The State government is responsible for the provision of secondary health care services, while the provision of primary health care (PHC) falls within the jurisdiction of the LGAs. However, the State Ministry of Health plays a supervisory role over LGAs in the implementation of PHC programs and guidelines. The public health facilities include a state owned Abia State University Teaching Hospital in Aba and a Federal Medical Centre in Umuahia (both serve as tertiary centres), 18 secondary health facilities and 501 PHC centres across the State. The private health facilities make up to 66.3% of the total number of health facilities in the State.[2] With less than 2% of the public health institutions having an eye care units, eye health are delivered mainly by private health institutions. These private eye facilities are situated in the cosmopolitan cities and are managed as a commercial entity. Eye care personnel include ophthalmologists, optometrists, ophthalmic nurses and dispensing opticians.

3.4 STUDY POPULATION

The study population for part one of the study consisted of school children in Abia State, who are between the ages of 10 and 16 years. Participation was open to both private and public schools, and all schools have similar academic programs and activities. There are about 856 public primary schools and 212 public secondary schools in Abia State. The age group at the schools is preferred because they belong to the group ‘read to learn’. This group of students read for longer periods of time and the print size of the letters are usually small, such that they require more visual effort in focusing and comprehending what they read.[8] Overtime, this may trigger many symptoms, especially when associated with visual anomalies. In addition, the study participants comprised of primary and secondary school children and therefore, represent the learning experience of children in these two levels of education, as well as, provide adequate age range to assess the association between age and visual anomalies.

For the part two of the study, the participants were registered optometrists working in Abia State. They included those working in both public and/or private health facilities in the last one year before the study.

3.5 SAMPLING

3.5.1 Sample selection and sample size

A probability sampling method was applied in selecting participants through a multi-stage random sampling approach. Using the senatorial districts, Abia State was demarcated into three geographic areas. One LGA was randomly selected in each of the three districts from where the participating schools were selected. Private and public (primary and secondary) schools were included in the sampling frame. The private schools have both primary and secondary sections. Each of the schools listed in each of the three selected LGA was assigned a cluster number. A public primary, secondary and private school were randomly selected from each of the cluster areas. The next stage was the random selection of classes from grades 5 to 11 from where participants aged between 10 and 16 years were randomly selected. Grades 5 to 6 included those in primary schools, while Grades 7 to 11 were those in secondary schools. At the class level, children were recruited using a systematic sampling approach, where every second child starting from the first child in a class register was included until the desired cluster sample size was reached. In cases of inadequate number of children, the next selected class were used to attain the required sample size.

The sample size was estimated using the prevalence formula;[9]

$$N = (Z)2\,\frac{(1.0 - p)(p)}{(b)2}$$

where N is the minimum sample size, p is the anticipated prevalence (Table 1), b is desired error bound considered as 5% and Z = 1.96 for a 95% confidence interval (CI). The minimum sample size required for the various visual anomalies are presented in Table 1. However, 550 children were recruited to compensate for the design effect (1.5%) and 10% contingency factor as well as increase the statistical power of the sample size to adequately estimate the prevalence of the various visual anomalies.

Table 1: Estimation of minimum sample size for some visual anomalies

Visual anomalies	Expected prevalence (p)	Minimum sample size
Visual impairment and Refractive error	8.0% (Atowa, et al., 2017)[5]	113
Accommodative and Vergence	12.7% (Ovenseri-Ogbomo & Ovigwe, 2015)[13]	170

In the part two of the study, a non-probability convenience sampling method was used in selecting study participants from Abia State. The total number of registered optometrists in the State was obtained from the secretariat of the Nigerian Optometrist Association (NOA) Abia State chapter and all registered optometrist who have been practising in the state in the last one year were eligible to participate in the study. The optometrists were contacted either by email, telephone or visitation at the bimonthly general meeting.

3.5.2 Inclusion and exclusion criteria

The inclusion and exclusion criteria are outlined in Table 2.

Table 2: Inclusion and exclusion criteria

Inclusion	Exclusion
Part one of the study	
• All primary and secondary school students aged 10 – 16 years.	• Any known history of systemic disease that may affect vision.
• Both genders	• Any systemic or ocular medication that may affect vision
• Attending school in Abia state	
Part two of the study	
• Optometrists registered with the Nigeria Optometric Association	
• Working in a public, private eye clinic or hospital	
• Minimum of one year working in Abia State as a registered optometrist	

3.6 DATA COLLECTION INSTRUMENTS

3.6.1 Questionnaire

Data were collected using two sets of different questionnaires and a series of vision assessment protocols. Firstly, a case history questionnaire adapted from Wajuihian & Hansraj[12,14] and Hopkins, et al.[15] (Appendix A) were used for the part one of the study to collect data on the ocular/health history of the children. Through case history taking, participants who did not satisfy the eligibility criteria were excluded from further participation. The second questionnaire was distributed to registered optometrists in Abia State. This consisted of questions on the extent of their involvement in paediatric vision screening in Abia State, tests performed, age of children being screened and their referral criteria. The questionnaire also covers areas such as the number of children seen by the optometrists in their clinic or hospital practice who were referred from a screening program. The questionnaires were distributed by hand and by email. The questionnaire was modelled from Hopkins, et al.[15] but was slightly modified to fulfil the objectives of this study (Appendix C).

3.6.2 Vision assessment protocols.

The measurement of vision parameters was performed using validated optometric instruments in three repeated measures. The procedures were conducted in examination stations set-up in each participating school. Testing distance and room illumination were standardized using a tape measure and light meter (Extech SDL400) respectively. The digital instruments had already been calibrated. All procedures and techniques performed in the study followed the standard optometric examination as described in the literature and had been used by previous studies.[12,15,16,17,18,19,20,21,22]

3.7 PILOT STUDY

3.7.1 Pilot study part one

Fifty participants aged between 10 and 16 years were randomly recruited at primary and secondary schools from one of the cluster areas (but not included in the main study), for a pilot field exercise to validate the data collection procedure and instruments, as well as, to familiarise with the data collection instruments for part one of the study. Twenty-three of the participants were male and 20 were from primary school. Through the pilot exercise, some questions which were not very clear to the children were identified. Those questions were modified to give a better understanding to the respondents before the survey. Initially, only clinical measures of accommodative facility (monocular and binocular) using ±2.00 D lens were evaluated. However, the analysis of the results obtained from the pilot study showed that more clinical parameters of accommodative function are required to adequately classify accommodative and vergence anomalies. Therefore, test procedures such as monocular and binocular accommodative facility using only +2.00 D lens and −2.00 D lens were added. The findings from the pilot study (part one) are presented in Tables 3 to 8. A flow chart process (Figure 2) for the data collection process was also developed after the pilot exercise.

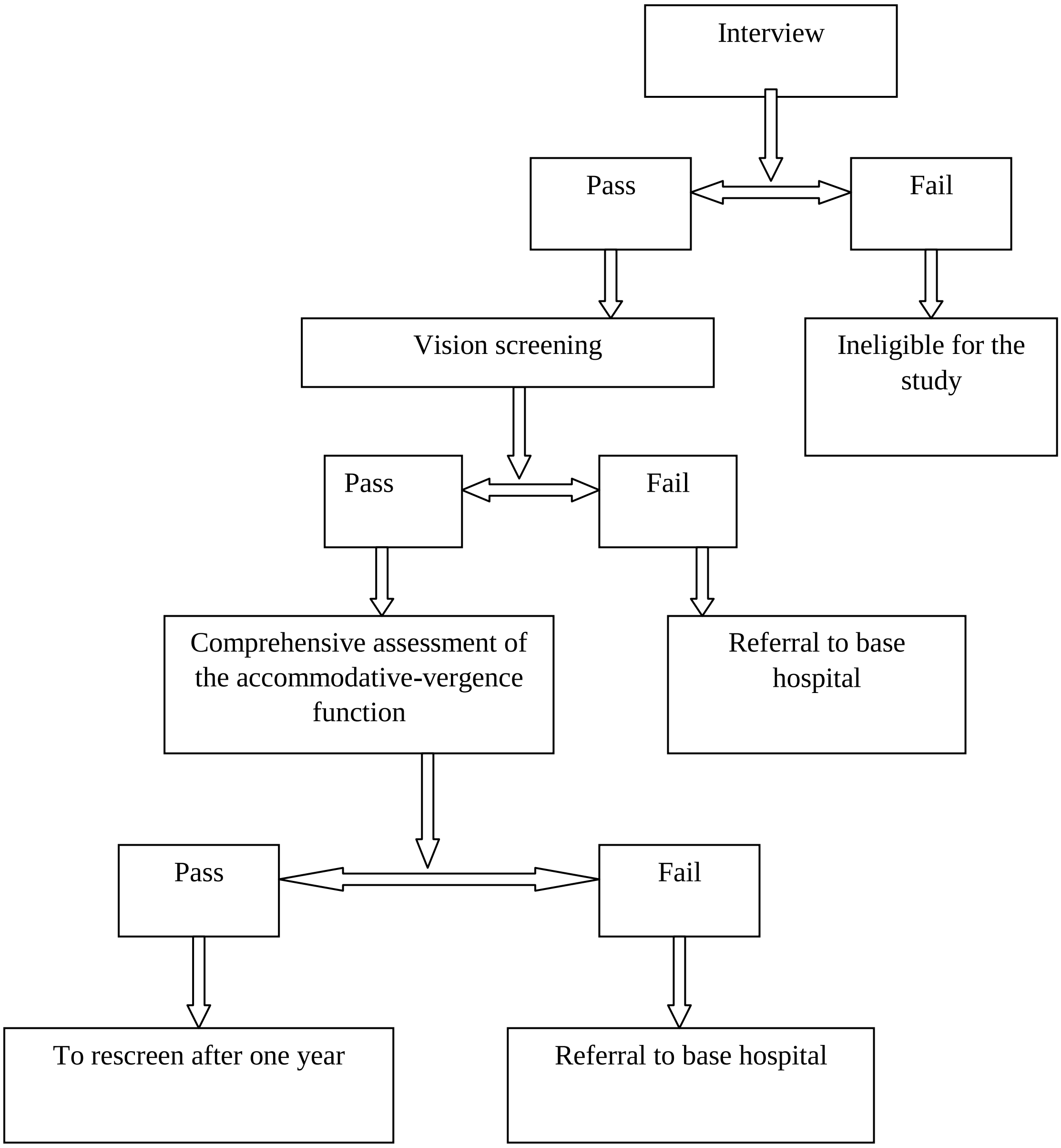

Figure 2: Flow chart depicting the data collection process

3.7.1.1 Analysis of the case history questionnaire

A summary of the analysis of the case history questionnaire is presented in Table 3. The result showed that all the children (N = 50) assessed reported at least one visual symptom,

Table 3: Responses to case history questionnaire (pilot study)

	Questionnaire items	**Number**	**Percentage (%)**
Ocular history	Children that had received previous eye examination	13	26
	Children that have been prescribed spectacles before	1	2
	Children with previous medical/surgical treatment to their eyes?	0	0
	Children with a positive family history of eye disease/conditions	11	22
Medical history	Percentage of children with general health problems	3	6
	Children with hearing/ear problems	1	2
	Children with concerns about their eyes or how they see	0	0
Near visual tasks performed outside school hours	Children that spend at least one hour per day reading	50	100
	Children that spend at least one hour per day on the computer	30	60
Symptoms	Children that reported at least one visual symptom	50	100

3.7.1.2 Analysis of the clinical measures of refractive, accommodative and vergence parameters

A summary of the analysis of refractive, accommodative and vergence parameters are presented in Table 4; not all the children that were evaluated completed all the tests.

Table 4: Descriptive statistics for clinical measures of refractive, accommodative and vergence measures (pilot study)

Variables	n	Mean ± SD	Min	Max
Presenting distance visual acuity (logMAR)				
• Right eye	50	−0.02 ± 0.08	0.30	−0.01
• Left eye	50	−0.02 ± 0.08	0.30	−0.01
Refraction				
• Sphere RE (D)	50	0.10 ± 0.18	-1.00	0.50
• Sphere LE (D)	50	0.11 ± 0.19	-1.00	0.75
• Cylinder RE (D)	50	-0.08 ± 0.12	0.00	-0.75
• Cylinder LE (D)	50	-0.07 ± 0.11	0.00	-0.75
Best corrected distance visual acuity (logMAR)				
• Right eye	50	−0.04 ± 0.05	−0.10	0.00
• Left eye	50	−0.05 ± 0.05	−0.10	0.00
Best corrected binocular near visual acuity (logMAR)	50	-0.05 ± 0.05	0.00	-0.10
Visual acuity with +1.50 D (logMAR)				
• Right eye	50	0.58 ± 0.06	0.50	0.60
• Left eye	50	0.49 ± 0.09	0.40	0.60
Random dot stereoacuity (seconds of arc)	50	34.00 ± 15.12	10.00	60.00
Amplitude of accommodation (D)				
• Monocular (right eye)	46	14.87 ± 3.61	5.00	20.00
• Binocular	46	14.96 ± 3.72	5.30	20.00
Accommodative response (D)	50	0.53 ± 0.29	0.25	1.50
Near point of convergence (cm)				
• Break	46	5.92 ± 2.82	4.00	14.00
• Recovery	46	8.95 ± 3.02	6.00	18.00
Vergence facility (cycles/minute)	42	8.99 ± 3.85	16.30	3.00
Accommodative facility with ± 2D lens (cycles/minute)				
• Monocular	45	9.64 ± 2.95	2.00	16.00
• Binocular	45	9.46 ± 3.04	2.00	16.30
Horizontal Phoria				
• Distance	46	0.14 ± 1.51	−5.00	4.00
• Near	46	1.68 ± 2.99	−7.00	8.00
AC/A ratio	46	5.87 ± 2.22	2.00	8.00
Distance positive fusional vergence				
• Break	46	14.60 ± 4.88	25.00	4.00
• Recovery	46	10.24 ± 4.65	20.00	2.00
Distance negative fusional vergence				
• Break	46	13.46 ± 4.66	25.00	2.00
• Recovery	46	9.14 ± 4.43	18.00	1.00
Near positive fusional vergence				
• Break	46	19.16 ± 5.95	30.00	6.00
• Recovery	46	13.58 ± 5.11	25.00	4.00
Near positive fusional vergence				
• Break	46	15.60 ± 4.60	30.00	4.00
• Recovery	46	11,22 ± 4.32	25.00	2.00

3.7.1.3 Analysis of the visual acuities of the pilot study participants

The distribution of the visual acuity of the participants show that 98.0% has normal or near normal (VA of 6/9.5 or better) in at least one eye (Table 5)

Table 5: Distribution of visual acuity (pilot study)

	Visual acuity		
Visual acuity categories	**Uncorrected**	**Presenting**	**Best corrected**
6/9.5 or better in at least one eye	49 (98.0%)	49 (98.0%)	50 (100%)
6/12 to greater than 6/120 in the worse eye	1 (2.0%)	1 (2.0%)	0 (0%)
6/120 or poorer in the worse eye	0 (0%)	0 (0%)	0 (0%)

3.7.1.4 Analysis of refractive error

Among the participants in the pilot study, only four had RE with hyperopia being the most common of the different types of RE.

Table 6: Diagnostic criteria and prevalence of refractive errors (pilot study)

Visual anomalies	**Criteria**	**n**	**Prevalence %**
Refractive errors			
• Hyperopia	+ 0.50 dioptre (D) or more	2	4.0
• Myopia	− 0.50 D or less	1	2.0
• Astigmatism	0.75 D cylinder or more	1	2.0
• Anisometropia	Equal or greater than 0.75 sphere or cylinder between both eyes	0	0

3.7.1.5 Analysis of accommodative anomalies

Three children had accommodative anomalies (Table 7) according to the criteria for the specific accommodative anomalies as listed in Table 7.

Table 7: Diagnostic criteria and prevalence of accommodative anomalies (pilot study)

Accommodative anomalies	**Diagnostic criteria**	**n**	**Prevalence %**
Accommodative insufficiency	All clinical signs 1. Reduced amplitude of accommodation (AA) of at least 2.00 dioptre (D) below Hofstetter's calculation for minimum amplitude: 15 – 0.25 × age (years). 2. High monocular estimation method (MEM) > + 0.75 D. 3. Fails monocular accommodative facility (MAF) – 2D < 6 cycles per minute (cpm) 4. Fails binocular accommodative facility (BAF) − 2D < 3 cpm	1	2.0
Accommodative excess	Clinical signs 1 and 2 or 3 1. Low MEM < + 0.25 D 2. Difficulty clearing ± 2.00 D with MAF with a criterion < 6 cpm. 3. Fails BAF test with ± 2.00 D with a criterion < 3 cpm.	0	0
Accommodative infacility	All clinical signs 1. Normal AA 2. Fails MAF using ± 2.00 D lenses, with a criterion of MAF < 11cpm 3. Fails BAF using ± 2.00 D lenses, with a criterion of BAF < 8 cpm	3	6.0

3.7.1.6 Analysis of vergence anomalies

The result shows that the overall prevalence of veregence anomalies (Table 7) according to the criteria for the specific accommodative anomalies as shown in Table 7 was 8.0%.

Table 8: Diagnostic criteria and prevalence of vergence anomalies (pilot study)

Vergence anomalies	Diagnostic criteria	n	Prevalence (%)
Convergence insufficiency	Clinical sign 1 and 2 or more signs 1) Exophoria at near 2) Exophoria at near ≥ 4 prism diopter (pd) and greater than at distance 3) Insufficient fusional vergence at near: i) fails Sheard's criteria or (ii) poor positive fusional vergence (PFV) at near ≤12 pd Base Out (BO) to blur or ≤15 pd BO to break. Poor BO to break was used for PFV criteria 4) Receded Near point of convergence (NPC) ≥7.5 cm break or ≥10.5 cm recovery.	2	4.0
Convergence excess	Clinical sign 1 and minimum of 2 other signs 1) Esophoria at near is greater than measured at distance, (≥ 2 pd) 2) High AC/A > 5/1 3) Reduced binocular accommodative facility (BAF) with ± 2.00 D (< 3 cycles/min) 4) Reduced negative fusional vergence (NFV) at near <8/16/7 for blur/break/recovery (at least 1 of 3) 5) High monocular estimation method (MEM) (≥ +0.75) (may show high lag)	2	4.0

3.7.2 Pilot study part two

The vision screening questionnaire was distributed to 10 registered optometrists across Abia State for a pilot exercise. These optometrists were not included in the actual survey. Among the selected optometrists only two had delivered vision screening services that included children as participants in the last one year prior to the exercise. Questions which were not clear to the respondents during the pilot study were identified and modified for better clarity before the actual survey.

3.8 DATA COLLECTION PROCEDURES

3.8.1 Vision assessment (Part one of the study)

3.8.1.1 Case history

A case history questionnaire[14,15,23] (Appendix A) which included the Convergence Insufficiency Symptom Survey (CISS) were used to gather information on the ocular and general health conditions of the participants such as near task characteristics, visual symptoms and asthenopia. The CISS is a validated and reliable child questionnaire that employs the Likert-type scale to measure frequency and severity of symptoms and to differentiate between symptomatic and asymptomatic CI in children.[14,23]

Likert-type or frequency scales are designed to measure attitudes or opinions using fixed choice response format.[24] The CISSS have 15 items and a five-point response scale regarding the symptoms' participants usually experience when reading or doing other near tasks. The questions were arranged in sequential order and read out audibly with the child directed to look at the five-response choice card while listening attentively. In case of any ambiguity, the questions were repeated without clarification. For each child, an overall CISS score was obtained by aggregating the points for the 15 items which was between a symptom severity of 0 (asymptomatic) to 60 (most symptomatic). The questionnaire was administered to the children by a research assistant independently of the optometrist prior to the vision examination. The research assistant was adequately trained on the administration of the questionnaire before the main survey.

3.8.1.2 Visual acuity

Distance visual acuity (VA) was measured for each eye at three-metre with a retro-illuminated Bailey-Lovie logMAR chart (Precision Vision Villa Park, IL, USA) containing five optotypes per line and near vision was tested at 40cm using a logMAR chart. Bailey-Lovie charts which were used in this study have several merits over Snellen charts. The merits include:[25]

- a logarithmic progression of the size of the optotype from line to line,
- equal legibility of the optotypes ,
- equal number of letters on every line,

- equal spacing between lines
- the optotypes being proportional to the size of the optotype.
- allowing for a more precision in recording of VA for research purposes as compared to Snellen charts.

To measure the distance VA, each child was seated comfortably three meters from the chart and was asked to occlude one eye at a time (right eye was preferred first) using a handheld occluder. Starting from the top line (6/60), the child was asked to read the letters one by one. If at least 4 letters were read correctly, the child was then directed to line 4 (6/30). If one or no optotypes was missed, the testing continued at line 7 (6/15), then line 10 (6/7.5) and finally line 11 (6/6). If the child failed to identify 4 or more optotypes on any of the lines, the line directly above the failed line was tested until successful. If at three meters the child could not recognize the letters on the topmost line, the child was asked to move towards the chart at one meter progressions until the child was able to read the letters as described above. The lowest line that was read successfully was recorded as the VA of the eye being tested. For known spectacle wearers, unaided VA was measured first, followed by aided VA with spectacles. The procedure was repeated for near VA with the child holding the logMAR near vision card at a 40 cm testing distance and at a reading angle.

3.8.1.3 Suppression test

The near Worth-4-Dot (Haag-Streit UK) test was performed at 33 cm with a flashlight composed of four lights (one red light at the top, two green lights at both sides and one white light at the bottom). The flashlight is move close or away from the child to change the angle projection of the target image on the retina. The child was required to wear red-green anaglyphic filters (with one red filter over right and the green one over the left) alongside the spectacle correction if prescribed. The child was asked to indicate the number of lights seen, their colours, location, whether they are properly aligned and whether all the lights show up at one time or flashing on and off. The response of the child was recorded. If the child reports seeing three green dots, right eye is suppressed. If the child sees two red dots, left eye is suppressed. If the child sees all four dots, no eye is suppressed. If the child sees five dots it implies that there is no fusion.

3.8.1.4 Stereopsis

The Randot stereoacuity test was used as it can assess stereoacuity using random dot targets (500 to 250 seconds of arc) and contour targets (400 to 20 seconds of arc).[26] The target distance was at 40 cm and the test chart kept in an upright position from the child with the child wearing polarized filters (over prescription). The child was asked to identify the circle that appears to float or appears different from the others, left, middle or right. The child was asked to identify which area does not have a shape/letter in it (for both top and bottom Randot tests). All children were tested for local and global steroacuity. The last group of circles that were identified correctly was recorded as the level of local stereopsis in seconds of arc. The level of global stereopsis was classified as ‘good’ (250 seconds of arc), ‘reduced’ (500 seconds of arc) or ‘no stereopsis.

3.8.1.5 Refractive error

Considering the effect of cycloplegia on accommodation which was also investigated in this study, as well as, the unwillingness of the school principals to allow for a second day of testing, cycloplegic refraction was not performed. School principals were concerned about the impact of cycloplegia and a second day testing on the participants’ academic activities. Thus, refraction was performed objectively using non-cycloplegic autorefraction (Topcon RM-8000B, Topcon Corporation, Tokyo, Japan) findings as the starting point then subjectively (monocular and binocular) to determine the endpoint which was the maximum plus required to achieve the best comfortable VA. However, the plus lens (+2.00 DS) test were conducted on all subjects to rule out latent hyperopia.

3.8.1.6 Accommodative functions

The accommodative function tests that were performed included amplitude of accommodation (AA), accommodative response (AR) and accommodative facility (AF).

a) Amplitude of accommodation

The AA was measured using the Donder’s push-up to blur (PUTB) method with a RAF rule with 6/9 row of letters as the target. The target was moved slowly towards the child while the child was instructed to keep the letters clear and asked to report when a blur was observed. An average of three readings was recorded as the AA in dioptres.

b) Accommodative response

The AR was assessed using the monocular estimation method (MEM) with dynamic retinoscopy at Harmon’s distance and under room illumination with the child’s highest compensating plus lens for refractive error in place if prescribed. A special near-point card with a central hole was attached to the head of the retinoscope. The target point was a paragraph of approximately 6/9 text on the card. A string was attached to the retinoscope handle on one side and the trial frame on the other side to ensure that testing distance was maintained throughout the procedure. The retinoscopic reflex was evaluated with the streak oriented vertically, while the subject read the text on the card adjacent to the central hole. Trial lenses were used to neutralise the motion. The lowest power lens that neutralised the reflex was recorded for each subject.

c) Accommodative facility

The AF was measured with the target (6/9/N5 letters at 40 cm using the ±2.00 D flipper lens and accommodative target of 6/9 (N5) letters. As the lenses were flipped, the children were required to report each time the print became clear. The number of cycles completed per minute was recorded. One cycle means clearing both the plus and minus lens.

3.8.1.7 Vergence functions

a) Near Point of Convergence (NPC)

The NPC was measured using the Royal Air Force (RAF) rule with a vertical line as the target point. This allowed for direct comparison of results with previous studies. Starting from 40 cm as long as the target was still seen singly, the target was moved gradually towards the child until they reported seen double or a deviation of the eyes was observed by the examiner. Again a sustained break was ensured by the examiner. The break value was measured from the point of sustained break to the bridge of the nose. The target was then gradually moved backward from the break point until the child reported seen the target as single or the examiner observed fusion. The recovery point was measured from the point single vision was restored to the nose bridge. The values were recorded in centimetres.

b) Cover test and phoria measurement

The unilateral cover test was performed first to identify the existence of a tropia. In the absence of a tropia the Howell-Dwyer phoria card was used in the measurement of distance and near phoria. The child was seated three meters from the distance Howell-Dwyer phoria card. With their refractive correction in place if prescribed, the child was directed to the chart and was asked to confirm if they can see the blue and the yellow sides of the chart and the arrow. Six prism dioptre was held in a base down direction in front of the child’s right eye and the child was asked if they could see two arrows. They were then directed to the top arrow and asked if it was pointing down to the blue side or the yellow side, and what number the pointer was closest to. Any odd number (in yellow) indicates esophoria while the even number (in blue) shows exophoria. The procedure was repeated at near, with the near Howell-Dwyer phoria card held at 33 cm from the child. The child wore their best near correction.

c) Accommodative convergence to accommodation (AC/A) ratio

The gradient method was used in measuring AC/A ratio because of its numerous advantages over the calculated method which include having a better control over proximal convergence and the influence of lag of accommodation,[17] thereby giving a more precise value of the AC/A ratio. The test instrument for gradient method included the Howell-Dwyer near phoria card and the +/−2.00 D lenses. Immediately after initial phoria measurement with the subjective best visual acuity (BVA) lenses, another phoria measurement was taken through a − 2.00 D over and above the BVA lenses with the same procedure above. The change in phoria as a result of the change in stimulus to accommodation was determined and recorded as the gradient AC/A ratio.

d) Fusional vergence

Fusional vergence amplitude was measured using step vergences at distance and near with a prism bar. This technique is quicker and appropriate for a non-clinic-based screening of school-aged children[18] and has been found to be valid and reliable.[27] Base in (BI) and BO prisms were used to measure negative fusional vergences (NFV) and positive fusional vergence (PFV). Positive fusional vergence and NFV range was measured first at distance and then at near. To help relax accommodation, NFV procedure was performed first.

For distance testing, the target was a single letter on a line above the child's best corrected distance VA. Using a prism bar, low powered BI prism was introduced and increased gradually in front of the child's best correction. until the child reported blur and then diplopia or the examiner observed the eye moving in that is, losing fixation; prism power was then gradually reduced until the child reported single vision or the examiner observed the eye moved back to take up fixation. The child however, was not expected to have a blur value on BI/NFV at distance unless he/she was over-minused or under-plussed. This procedure was repeated three times and the average recorded. The procedure was repeated for PFV at distance using BO prisms.

Negative fusional vergences was then measured at near with the child directed to a 6/12 letter (N_6) at 40 cm, with their near best correction. As above, BI prisms of increasing power were introduced until blur and then diplopia was reported or the examiner observed a loss of fixation. Following this break point, lesser powered prism was re-introduced until fusion was regained. This was repeated three times and the average recorded as blur/break/recovery points. Positive fusional vergence was finally measured at near with the same procedure mentioned above but using BO prisms.

Usually, the blur point is used (not break point) as it represents the limit of fusional vergence on its own.[15,27] Considering the age of the study participants, it would be more difficult to accurately report the blur experience.[15] Thus, break and recovery points were selected, as they can both be easily determined subjectively.

f) Vergence facility

Vergence facility was performed with the child directed to view a vertical 6/9 target or similar at 40 cm with the child wearing their near correction. Twelve prism dioptre BO and 3 pd BI loose prisms were alternated over one eye. The child was asked to report when the target becomes single and clear. The procedure was repeated continuously for one minute and the number of times the BO and BI prism were alternated before the eye in one minute was recorded as cycles (a movement of the BO and BI prism over one eye) performed. The presence of suppression is indicated when the child reported a lateral movement of the target in either left or right direction or when the examiner observed no movement of the eye.

3.8.1.8 Ocular health

Eyelids, conjunctiva, cornea, iris, and pupil were examined in dim illumination with a trans-illuminator for any abnormalities. The lens, vitreous chamber and fundus were examined with a direct ophthalmoscope. The child was properly on the examination chair and was directed to focus at the largest letter on the VA chart directly opposite at four meters. With the eye open, the media and fundus were assessed for any abnormalities by an optometrist.

3.8.2 Vision screening survey (Part two of the study)

The questionnaire[15] (Appendix D) was the data collection instrument for part two of the study. The questionnaire contained questions on the optometrists' participation on paediatric vision screening in Abia state, test administered and referral criteria. The questionnaire also covered areas such as the number of children who have received complete eye examination in the optometrists' clinics/hospitals who were referred from a screening program and the reason for the referral.

The questions comprised of closed ended questions. Closed format questions are the type of questions where the respondent is restricted to choose from pre-selected options. Closed format question can be completed in a lesser time and is easier to perform preliminary analyses compared to open format. These questions are ideal for the estimation of statistical data and percentages, as the answers set is known. [28]

3.9 CLASSIFICATION OF OUTCOME VARIABLES

3.9.1 Visual anomalies

The presenting VA ranges selected to define visual impairment (Table 9) was based on the classifications used by previous studies[29,30,31] in various countries.

Table 9: Classification of visual impairment

Visual Impairment	Visual Acuity (VA)
Normal/near normal	≥ 6/9.5 in the better eye
Mild	≤ 6/12 – 6/18 in the better eye
Moderate	6/24 – ≤ 6/60 in the better eye
Severe	Less than 6/60

3.9.2 Refractive error

Refractive error was reported as hyperopia, myopia and astigmatism using the results of the subjective refraction. Regarding hyperopia (Table 10), the cut-off for clinically significant hyperopia (2.00 D or more) was classified as moderate rather than mild hyperopia because clinically insignificant hyperopia which may not affect VA but may impair near vision tasks were considered as mild hyperopia.[32,33] The classification for myopia, astigmatism and anisometropia applied in this study were all considered clinically significant. A child was identified as being myopic if there was the presence of myopia in at least one eye; hyperopic if there was hyperopia in at least one eye and no myopia in the other eye and emmetropic if the child had no myopia, hyperopia or astigmatism in any of the eyes.[5,14,32,33] A summary of the definition criteria and classification for different types of RE is shown in Table 10.

Table 10: Classification of Refractive errors

Refractive errors	Definition (D)	Categories
Hyperopia	0.50 or more	Mild (0.50 D – 1.75 D) Moderate (2.00 D – 4.75 D) High (5.00 D and more)
Clinical significant hyperopia	2.00 or more	
Myopia	0.50 D or less	Mild (0.50 D – 3.00 D) Moderate (3.25 D – 6.00 D) High (6.25 D and more)
Emmetropia	−0.49 to +0.49	
Astigmatism	0.75 or more (However, astigmatism was classified using cylinder of at least −0.25 D)	Low (0.25 D – 0.50 D) Mild (0.75 D – 2.00 D) High (2.25 D or more)
Anisometropia	Difference of 0.75 SER or more between two eyes	

3.9.3 Amblyopia

Unilateral amblyopia was defined as a two line, or more, difference in BCVA between the two eyes when the VA was < 6/9 in the worse eye and with amblyogenic factors such as past or current strabismus, anisometropia (≥1.00 D difference in hyperopia, ≥3.00 D difference in myopia, and/or ≥1.50 D difference in astigmatism) and past or current obstruction of the visual axis.[11,34]

Bilateral amblyopia was defined as BCVA in both eyes of less than 6/12 in addition to the presence of amblyogenic factors including hyperopia (5.00 D of more), myopia (6.00 D of more), or astigmatism (2.50 D or more), or a history of eye patching or any obstruction of the visual axis.[11,34]

3.9.4 Accommodative anomalies

The classification of accommodative anomalies as shown in Table 11 was according to the method used by Wajuihian & Hansraj[12] and Shin, et al.[35]

Table 11: Classification of accommodative anomalies

Accommodative anomalies	**Clinical signs**	**Diagnostic criteria**
Accommodative insufficiency	1. Reduced AA of at least 2.00 D below Hofstetter's calculation for minimum amplitude: 15–0.25 × age (years). 2. High MEM > +0.75 D. 3. Fails monocular accommodative facility (MAF) testing with −2.00 D with a criterion < 6 cpm.	A minimum of clinical signs (1 and 2) or (1 and 3), or all clinical signs
Accommodative excess	1. Low MEM < +0.25 D 2. Difficulty clearing +2.00 D with MAF with a criterion < 6 cpm. 3. Fails binocular accommodative facility (BAF) test with +2.00 D with a criterion < 3 cpm.	Clinical signs (1 and 2) or (1 and 3)
Accommodative infacility	1. Normal AA. AA meets Hofstetter's calculation for minimum amplitude: 15 – 0.25 x age (years) 2. Fails MAF using ±2.00 D lenses, with a criterion of < 11cpm, 3. Fails BAF using ±2.00 D lenses, with a criterion of BAF < 8 cpm	All Clinical signs

3.9.5 Vergence anomalies

3.9.5.1 Heterophoria (Distance and near)

The classification of heterophoria is illustrated in Table 12. Exophoria was defined according to the method used by Borsting, et al.[23] while esophoria was defined according to the method used by Bade, et al.[36]

Table 12: Classification of heterophoria

Type of heterophoria	**Diagnostic criteria** (pd)
Orthophoria	Between 2 pd esophoria and 0
Exophoria	
	Mild (1 – 7 prism dioptre [pd])
	Moderate (8 – 13 pd)
	Severe (>13 pd)
Esophoria	
	Eso >2 pd

3.9.5.2 Near point of convergence

For this study, NPC break of greater than 7.5 cm and an NPC recovery point of greater than 10.5 cm were recorded as reduced NPC.[37] This agrees with a study which recommends a cut-off break point range of 6 to 8 cm and recovery of 3 to 4 cm greater than the break for school-age children in a screening context.[38] In addition, Wajuihian & Hansraj[19] found a mean NPC break and recovery point of approximately 7 cm and 10 cm, respectively in a population of black school-age children.

3.9.5.3 AC/A ratio

The range of the AC/A ratio between 5/1 and 3/1 were considered normal values. Values below and above the normal range are considered to indicate accommodative convergence insufficiency and excess, respectively.[39]

3.9.5.4 Other vergence anomalies

The classification of vergence anomalies are shown in Table 13. Convergence insufficiency was classified according to the Convergence Insufficiency Reading Study group.[23,37] Other vergence anomalies were classified using the integrative analysis approach. This approach involves the consideration of many clinical signs as indicators of vergence anomaly.

Table 13: Classification of other vergence anomalies

Vergence anomalies	Clinical signs	Diagnostic criteria
Low suspect convergence insufficiency		Clinical signs 1 and 2
High suspect convergence insufficiency	1.Exophoria at near 2.Exophoria at near ≥4 prism diopter (pd) greater than at distance 3.Insufficient fusional vergence at near: (i) fails Sheard's criteria or (ii) poor positive fusional vergence (PFV) at near ≤12 pd. Base out (BO) to blur or ≤15 pd BO to break. Poor BO to break was used for PFV criteria	Clinical sign 1 and two other clinical signs or clinical sign 1 and 2 plus 3 or 4
Definite convergence insufficiency	4. Receded NPC ≥7.5 cm break or ≥10.5 cm recovery.	All clinical signs. The cut-off points for ''symptomatic'' in the CISS score should be ≥16
Convergence excess	1.Esophoria at near is greater than measured at distance, (≥ 2 pd) 2.High AC/A > 5/1 3.Reduced binocular accommodative facility (BAF) with ± 2.00 D (< 3 cycles/min) 4.Reduced negative fusional vergence (NFV) at near <8/16/7 for blur/break/recovery (at least 1 of 3) 5.High MEM (≥ +0.75) (may show high lag)	Clinical sign 1 and minimum of 2 other signs
Fusional vergence dysfunction	1. Normal phoria 2. Reduced NFV and PFV at near 3. Reduced vergence facility with both base out and base in 4. Fails BAF with ±2 D lens	Clinical sign 1 and 2 other signs
Divergence excess	1.Exophoria greater at distance (distance exophoria ≥1pd more exophoric than near phoria) 2.High AC/A > 5/1 3.Low negative fusional vergence (break) at near (< 7pd)	Clinical sign 1and a minimum of 2 other signs
Divergence insufficiency	1.Esophoria greater at distance (distance esophoria ≥1 more esophoric than near phoria) 2.Low AC/A < 3/1 3.Low negative fusional vergence at distance (< 4 pd) 4.Poor recovery to base in prism at distance (< 2 pd)	Clinical sign 1 and a minimum of 2 other signs
Basic Exophoria	1.Equal exophoria at distance and near (distance exophoria = near exophoria) 2.Normal AC/A (between 3/1 – 5/1 pd) 3.Reduced PFV at near ≤ 12/15/4 (at least 1 of 3) 4.Reduced BAF with ±2.00 D (< 3 cycles/min)	Clinical sign 1 and a minimum of 2 other signs
Basic Esophoria	1.Equal esophoria at distance and near 2.Normal AC/A (3/1 – 5/1) 3.Reduced NFV at near ≤ 8/16/7 (at least 1 of 3) 4.Reduced BAF with ±2.00 D (< 3 cycles/min)	Clinical sign 1 and a minimum of 2 other signs

CISS – Convergence insufficiency symptom score

3.10 DATA MANAGEMENT AND ANALYSIS

Data were entered into a Microsoft excel database and data cleaning and consistency checks were conducted by the principal investigator. Data were then imported into the Statistical Package for Social Sciences (SPSS) version 23 and analysed by the statistician. Descriptive statistics were used to present group means, standard deviation, and prevalence estimates, while tables, pie charts and bar charts were used to present frequencies and distributions of variables. Categorical variables were assessed with Z-test and chi-square tests and continuous variables with *t*-tests. The analysis of variance (ANOVA) was used for the comparison of differences in means among groups. For all statistical tests, a *p*-value of less than or equal to 0.05 indicated a statistically significant difference.

3.11 RELIABILITY AND VALIDITY

3.11.1 Reliability

One of the important requirements of any research protocol is the reliability of the data and findings. Reliability describes the extent to which a particular test, procedure or tool, will produce similar results in different circumstances, assuming nothing else has changed.[39] Lincoln & Guba[40] refers to it as the dependability and consistency of the results based on the data collection process.

In the present study, data were collected in a detailed and systematic approach by means of a validated questionnaire and optometric examination. Questionnaire one (Appendix A) was designed based on the CISS[23] which has been used by several other studies,[12,15,16,17,19,20,21,22] while questionnaire two (Appendix C) was adopted from Hopkins, et al.[15] Optometric instruments were sourced from an optometry practice in Abia State. The digital instruments had already been calibrated. An average of three readings was recorded for each procedure. The testing distance and illumination were standardized in each testing stations in the various schools selected, using a tape measure and light meter, respectively. All the data collection instruments were pilot tested, and problems encountered were addressed before the survey. The vision tests were only conducted by the principal investigator; however, expert reviews on the accuracy, interpretation and analysis of data were performed by peer-reviewers. An audit trail of data was maintained, documenting clearly the flow and processing of the data including data collection decisions.

3.11.2 Validity

Validity can be defined as the extent to which a test measures what it is intended to measure.[39] There are different forms of research validity which include internal and external validity. In internal validity the interest is on the agreement of the study findings with the available data. Also, it is concerned with the extent to which the researcher examines and quantifies what is supposed to be measured. While external validity deals with the generalization and application of the study findings to the wider population and in other settings.[39,41]

This study was designed based on a protocol that had already been used in recent studies[12,15,16,19,20,21,22,35] on this area. The cross-sectional descriptive study design which was employed in the study ensured that participants were not lost to follow-up considering that all vision tests including the administration of the questionnaires were conducted on the same day. In addition, only one examiner performed all the vision assessment procedures with strict adherence to ethical rules and principles that minimized bias.

For part one of the study, a minimum sample size was determined using the prevalence estimate formula and allowance was made for drop outs. The sample size was further increased which resulted in an increase in the statistical power to accurately determine to prevalence of visual anomalies in the study sample. A stratified multistage and random sampling was used in the recruitment of participants. The sampling was stratified according to type of school and level of education. In selecting the schools, consideration was given to the socioeconomic characteristics of the State. The study also included students from both primary and secondary schools which represents the learning experience and characteristics of these two levels of educations. The Eligibility criteria ensured that children or participants using or on systemic and/or ocular medications which may affect near vision were excluded. Altogether, these measures increased the likelihood of having a valid representative, such that the findings can be generalized to the wider population.

3.12 ETHICAL CONSIDERATION

a. Ethical clearance (BE/619/16) was obtained from the Biomedical Research and Ethics Committee (BREC) at the College of Health Sciences (UKZN).
b. Ethical approval (023/01/2017) was also obtained from College of Medicine Research Ethics Committee (COMREC), University of Nigeria Enugu Campus.
c. Approval was granted by the Abia State Ministry of Education, Umuahia, Nigeria.
d. Permission was obtained from the principals and heads of the various schools that participated in the survey.

e. Parents/guardians of the students gave their consent and the participants voluntarily accepted to participate in the study.
f. Participants were identified by unique numbers and not by names to ensure anonymity.
g. All consent forms and data have been kept in a locked cupboard and will be shredded after 5 years.
h. The computer used for data capturing is password protected and is only known to the researcher. The file will be deleted in five years.
i. The data is the property of the University of KwaZulu-Natal.
j. Overall the study design complies with the tenets of the Declaration of Helsinki on research involving human subjects

3.13 SUMMARY

A cross-sectional study design was employed in this study. This chapter described the sampling methods and sample size calculations for the study. Detailed information on the data collection instruments and procedures that guaranteed valid and reliable data was clearly stated. Information on the statistical methods used in the analysis of findings was also included. The analysis of results and discussions is presented in subsequent chapters mainly in the format of manuscripts.

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CHAPTER FOUR

REFRACTIVE ERROR AND VISUAL IMPAIRMENT AMONG SCHOOL CHILDREN IN ABIA STATE

ABSTRACT

Purpose: To determine the prevalence of refractive errors and visual impairment among school children.

Method: A cross-sectional study was conducted among 537 children (aged 10–16 years) selected from nine schools using multistage, cluster, random sampling. The participants completed a case history questionnaire and eye examinations including the measurement of visual acuity, refraction, cover test, near point of convergence, fusional vergences, accommodative functions and ocular health evaluation.

Results: The prevalences of uncorrected, presenting and best visual acuity ≤ 6/12 in the better eye were 4.1%, 3.5% and 0.7%, respectively. Refractive error prevalences measured in the sample were hyperopia (4.1%), myopia (3.4%) and astigmatism (3.2%) with low magnitude accounting for 86.4%, 88.9% and 82.4% of hyperopia, myopia and astigmatism, respectively. Significant differences between age groups were found in hyperopia and myopia, with the prevalence of hyperopia decreasing with age ($p = 0.03$) while myopia increased with age ($p = 0.01$). Reasons for presenting visual acuity of 6/12 or worse in the better eye were refractive error (78.9%), amblyopia (10.5%), corneal problems (5.2%) and retinal disorder (5.2%). The prevalence of manifest strabismus in the study sample was 0.2%.

Conclusion: The prevalences of refractive errors and visual impairment in school children in Abia State were low, however, the high prevalence of uncorrected refractive error and the frequency of low magnitude of different types of refractive errors is a major concern. Considering their implications on public health and education, vision screening should be an immediate intervention.

Key words: Hyperopia, myopia; astigmatism; visual impairment; school children; Abia State

INTRODUCTION

The burden of visual impairment (VI) and related visual disorders like uncorrected refractive error (RE) has been increasing. Studies in this area on children[1-11] show that a significant amount of uncorrected RE can substantially affect visual acuity (VA) and if not treated on time, vision could deteriorate to permanent VI. In some cases, such as mild hyperopia and low astigmatism where VA is unaffected, children with uncorrected RE may experience momentary blurred vision, headaches, fatigue and decreased span of attention, particularly for close work which can impair reading efficiency and school performance.[12,13]

The national survey on blindness and VI, conducted between years 2005 to 2007, provided an indication of the causes of VI in Nigeria. Uncorrected RE was the most common cause of mild (77.9%) and moderate (57.1%) VI in the adult population.[14] However, the prevalence and causes of VI in children were not extensively reported on. The study[14] was constrained by a nonprobability sampling method for the paediatric population, as school-age children were invited to participate only if they were living in a family of at least one eligible adult. A few school-based studies[4,7] have been conducted across some cities in Nigeria and the prevalence and causes of VI have been found to vary regionally because of differences in socioeconomic development, race and cultural factors, in addition to available intervention strategies.[15]

Abia is one of the five states in the southeast of Nigeria, with a projected population of about 3 584 959 by the year 2017. School-age children account for a large proportion of the population.[16] Subsistence farming is the main occupation of the inhabitants[17] and primary eye care is limited and inaccessible to many, especially those in semi-urban and rural areas. In addition, lack of a comprehensive data set has hindered the development of appropriate child eye health programs.[18] Only Atowa, et al[18] determined the prevalence of RE in the cosmopolitan city of Aba. However, the study included only significant RE in the prevalence estimation. The non-inclusion of low or mild REs in the analysis may underestimate the prevalence of RE in the study population, as well as, exclude those children with visual discomfort due to uncorrected RE.[12,13] The present study is part of the broader survey that assessed the visual status of school children and child eye health provision in Abia State. The aim was to establish the prevalence of RE and VI in children in different areas of the State to provide epidemiological information for the planning, provision and evaluation of child health services.

MATERIALS AND METHODS

Study design

A cross-sectional school-based study was designed to quantitatively describe the prevalence of visual conditions in Abia State school children. Approval for the research protocol was obtained from the College of Medicine Health Research and Ethics Committee, University of Nigeria, Enugu Campus and the Biomedical Research Ethics Committee of the University of KwaZulu-Natal, Durban, South Africa. Detailed information of the procedures and risks involved were provided to all participants, as well as, their parents/guardians. Written informed consent and assent were obtained before examination with the option for withdrawal at any time should they choose to do so. The study adhered to the tenets of the Declaration of Helsinki regarding research involving humans.

Sample selection

The sample size was recruited through multistage cluster and random sampling with the senatorial district as the first stage of the clustering unit. One council area was randomly selected from each of the three senatorial districts in Abia State. The next stage was the selection of one public primary and secondary schools and one private school (with primary and secondary sections) from the listed schools in each selected council area. At the school level, one to two classes of each grade were randomly selected from each school grade of 5–11, with a minimum cluster size of 15. Participation was open to every child in each participating class. If the minimum sample of 15 was not achieved from the first class, students from the second selected class were used to attain the required sample size. Grades 5 – 6 included those in primary schools while grades 7–11 were those in secondary schools. Within a class, the registers were used as the sampling frame where every second or third child starting from the first child in a class register was included until the desired cluster sample size was reached. Students with any known history of systemic diseases that may affect vision or students currently taking any systemic medication that may affect vision were excluded from the study.

The sample size was estimated using the prevalence formula;[19]

$$N = (Z)2\frac{(1.0-p)(p)}{(b)2}$$

where N is the minimum sample size; p is the anticipated prevalence of 8.0% estimate based on a prior study[18] within the geographic area; b is desired error bound considered as 5% and Z = 1.96 for a 95% confidence interval (CI); giving a sample size of 113. After adjusting for a design effect of 2 and a 10% contingency factor to compensate for non-response rate, the sample size was determined to be 373. However, the sample size was increased to 550 to give a greater statistical power. The sample size (550) was proportionally distributed among the participating schools.

Eye Examination

Test stations were set up in a room provided by the authorities in each participating school. The same testing conditions were applied in all stations at each school. Data collection instruments were pilot tested, and problems encountered were addressed prior to the survey. Before the vision test, a questionnaire recording the case history was administered to the children by a trained research assistant independently of the optometrist. The questionnaire consisted of information on ocular and general health, as well as, the history related to near tasks. An experienced optometrist (the principal investigator) conducted all tests including an assessment of VA, stereopsis, ocular motility, non-cycloplegic refraction, accommodation, binocular vision and ocular health.

The testing began with VA measurement at distance and near using Bailey-Lovie logMAR charts (Precision Vision, La Salle, IL, USA). Stereoacuity was assessed using the Randot stereo test (Vision Assessment Corporation USA) and suppression was evaluated at 40 cm using a hand held Worth-4-dot test instrument (Haag-Streit UK). The unilateral cover test was performed with a target at distance (3 m) and near (40 cm) to detect the presence of strabismus or heterophoria. The Ishihara colour vision test was used to detect congenital red-green colour vision deficiency. Anterior and posterior segment examination, as well as, ocular motility and an evaluation of pupillary reflexes was performed with a Heine diagnostic set.

Considering the effect of cycloplegia on accommodation which was also investigated in this study, a cycloplegic refraction was not performed. Refractive error was measured objectively using the Topcon RM-8000B (Topcon Corporation, Tokyo, Japan) autorefractometer in three repeated measures. The average of the findings was then refined subjectively (monocular and binocular) to determine the endpoint which was the maximum plus lens required to achieve best comfortable VA. However, the plus lens (+2.00 D) test was conducted on all subjects to rule out latent hyperopia.

Definition and classification of outcome variables

The classification of RE and VI is presented in Table 1. Uncorrected VA referred to the unaided VA, presenting VA to the spectacle corrected acuity, if correction was worn and presenting VA of 6/12 or less was regarded as VI.[1] Refractive error was defined and categorised using the spherical equivalent refraction (SER) which is equal to the sum of the sphere and half the cylindrical component.[18,20] A child was diagnosed as myopic if there were myopia in one or both eyes; hyperopic, if at least one eye had hyperopia and the other had no myopia.[18]

Table 1: Definition and classification of refractive error and visual impairment

Visual anomalies	**Categories of visual anomalies**	**Criteria**
Visual impairment[1-3,8-11]		Presenting VA ≤ 6/12 in the better eye
Refractive error		
• Hyperopia[20]		≥ +0.50 D
	Mild	0.50 to 1.75 D
	Moderate	2.00 to 4.75 D
	High	5.00 D or more
• Myopia[1,18,20,]		≤ −0.50 D
	Mild	−0.50 to −3.00 D
	Moderate	−3.25 to −6.00 D
	High	−6.25 D or more
• Astigmatism[9,18,20]		At least −0.75 D in minus cylinder notation. However, astigmatism was classified using cylinder of at least −0.25 D
	Low	0.25 to 0.50 D
	Moderate	0.75 to 2.00 D
	High	2.25 D or more
• Anisometropia[20]		− 0.75 D or −0.75 D SER difference between both eyes
Emmetropia[20]		< 0.50 D and < −0.50 D SER

VA - visual acuity, SER - spherical equivalent refraction, D - dioptre

Data analysis

Data was analysed using the Statistical Package for Social Science (SPSS for Windows, Version 23.0, IBM-SPSS, Chicago, IL, USA) software. Descriptive statistics was used to present prevalence estimates, while tables and figures were used to present frequencies and distributions of variables. A *z*-test for two population proportions was applied and a *p*-value of less than or equal to 0.05 indicated a statistically significant difference

RESULT

Sample characteristics

Five hundred and fifty children were randomly selected, of which 537 were examined, giving a response rate of 97.6%. The non-participants included children who were absent during the examination and those who did not return their consent forms. The mean age of the study participants was 13.0 ± 2.0 years and median age was 13 years. A slightly higher percentage of participants were in the Group 2 according to age and there were more female participants. Just over half of the participants were at secondary school level. The sample characteristics are presented in Table 2 according to age group, gender and school level.

Table 2: Characteristics of the study population

Characteristics	**Number of participants (n)**	**Percentage (%)**
Participants	537	97.6
Age		
• Group 1 (10 – 12 [mean:11.1 ± 0.8] years)	225	41.9
▪ Group 2 (13 – 16 [mean:14.5 ± 1.1] years)	312	58.1
Gender		
• Female	282	52.5
▪ Male	255	47.5
School		
• Primary (grades 5 – 6)	234	43.6
▪ Secondary (grades 7 – 11)	303	56.4

Visual Acuity

Most of the children (96.7%) presented with normal or near normal vision (≥ 6/9.5) in the better eye (Table 3). Twenty-two (4.1%) children had uncorrected VA of ≤ 6/12 in both eyes, while 3.5% had presenting VA of ≤ 6/12 or worse in the better eye. With best correction, this decreased to 0.8%. Approximately, 73.7% of the children with VI had visual acuities better than 6/24; 26.3% had visual acuities of 6/24 through 6/60. None of the children presented with VA of less than 6/60 in one or both eyes. Uncorrected vision showed a statistically significant difference between age groups ($p < 0.021$, z-test for two proportions) as older children were more likely to have uncorrected VA of 6/12 or worse.

Table 3: Distribution of uncorrected, presenting and best corrected visual acuity

	Visual acuity		
Categories	**Uncorrected**	**Presenting**	**Best corrected**
≥6/9.5 in at least one eye	517 (96.3%)	518 (96.5%)	533 (99.3%)
6/12 to 6/19 in the better eye	15 (2.8%)	14 (2.6%)	3 (0.6%)
6/24 to 6/60 in the better eye	7 (1.3%)	5 (0.9%)	1 (0.2%)
<6/60 in the better eye	0 (0%)	0 (0%)	0 (0%)
All	537 (100%)	537 (100%)	537 (100%)

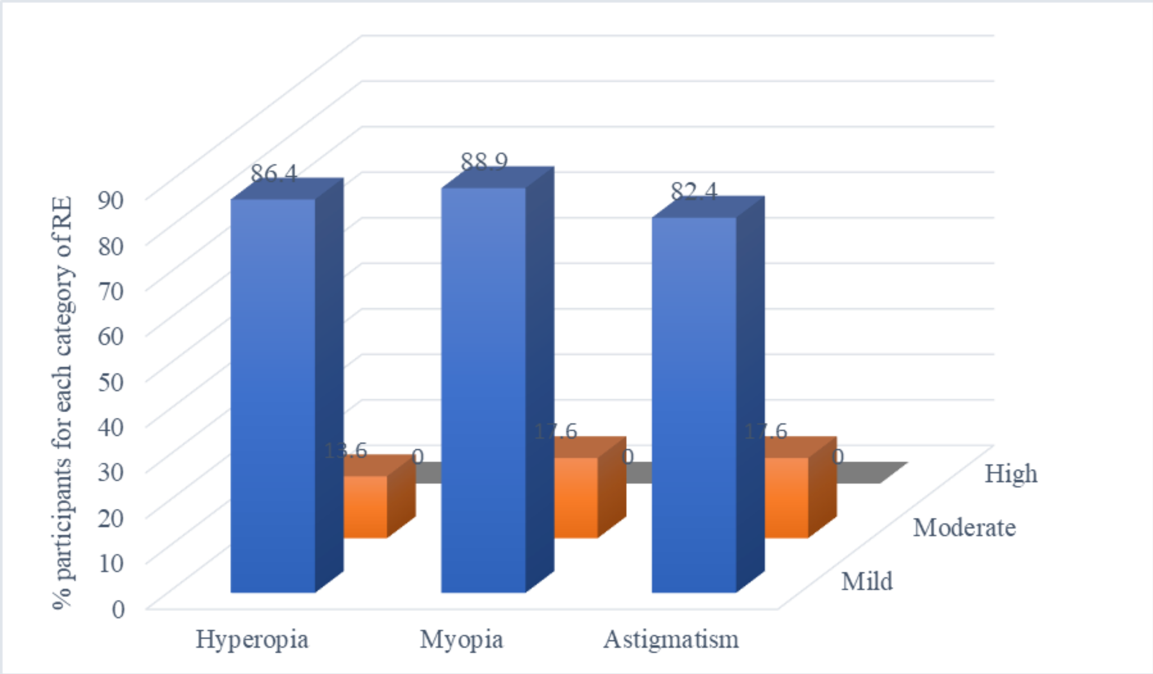
Refractive error

The spread of RE between the two eyes show that hyperopia ranged between +0.50 D to +4.50 D, myopia ranged between −0.50 D to −3.50 D and astigmatism ranged between −0.75 D to −3.00 D. Mean spherical equivalent refraction for right and left eye was 0.00 ± 0.54 D and −0.05 ± 0.50 D respectively. The overall prevalence of RE in the study sample was 10.6%. The prevalence of the different REs is shown in Table 4.

Table 4: Prevalence of refractive errors

	Number of children (n = 57)	**Prevalence %**
Hyperopia	22	4.1
Myopia	18	3.4
Astigmatism	17	3.2
Anisometropia	7	1.3

Of the children with myopia, 88.9% had mild myopia and 11.1% had moderate myopia. Mild and moderate hyperopia was observed in 86.4% and 13.6% of the hyperopic children, respectively. Low and moderate astigmatism was found in 82.4% and 17.6%, respectively. None of the children had a high degree hyperopia, myopia or astigmatism as illustrated in Figure 1.



Myopia: low (−0.50 to −3.00 D), moderate (−3.25 to −6.00 D), high (−6.00 D or more)
Hyperopia: low (0.50 to 1.75 D), moderate (2.00 to 4.75 D), high (5.00 D or more)
Astigmatism: low (0.25 to 0.50 D), moderate (0.75 to 2.00 D), high (2.25 D or more)

Figure 1: Classification of the different refractive errors

The prevalence of different refractive errors by age group, gender and school level are presented in Table 5. Hyperopia and myopia were significantly associated with age group (p = 0.03 for hyperopia and p < 0.01 for myopia). The prevalence of hyperopia was higher in younger (10 – 12 years) children while myopia was higher in older (13 – 16 years) children. Only myopia was associated with school level (p = 0.04) with a 5.2% in secondary school children compared to a 2.0% prevalence in primary school children. There was no significant association between gender and RE. Similarly, astigmatism was not associated with age group or school level.

Table 5: Prevalence of refractive errors by age group, gender and school type

Categories	Hyperopia (≥ +0.50 D) n (%)	Hyperopia p-value	Myopia (≤ −0.50D) n (%)	Myopia p-value	Astigmatism (≤−0.75D) n (%)	Astigmatism p-value
Age group						
▪ Group 1 (10 – 12 years)	14 (6.2)	*0.03	2 (0.9)	*0.01	7 (3.1)	0.93
▪ Group 2 (13 – 14 years)	8 (2.6)		16 (5.1)		10 (3.2)	
Gender						
▪ Male	14 (5.5)	0.11	7 (2.8)	0.47	10 (3.9)	0.37
▪ Female	8 (2.8)		11 (3.9)		7 (2.5)	
School						
▪ Primary (grades 5 – 6)	10 (4.3)	0.67	5 (2.1)	*0.04	6 (2.6)	0.41
▪ Secondary (grade 7 – 11)	12 (4.0)		13 (4.2)		11 (3.9)	

* indicates statistical significance

Causes of visual impairment

Of the 19 children with presenting VA of 6/12 or worse in the better eye, approximately 15 (78.9%) were found to have refractive errors and the remaining 4 (21.1%) had VA of 6/12 or worse as a result of corneal opacity, amblyopia or retinal disorders (Table 6).

Table 6: Causes of uncorrected and presenting visual acuity of 6/12 or worse

Causes	Children with VA ≤6/12: Presenting VA n (%)	Children with VA ≤6/12: Uncorrected VA n (%)
Refractive error	15 (78.9)	18 (81.8)
Amblyopia	2 (10.5)	2 (9.5)
Corneal opacity	1 (5.2)	1 (4.8)
Retinal disorder	1 (5.2)	1 (4.8)
Total	19 (100)	22 (100)

Spectacle coverage

Approximately 12.3% of the children with RE reported history of spectacle wear. However, only 5.3% presented to examination with their spectacles and none were from the younger age group (10 – 12 years). For the older age group (13 – 16 years) the refractive profile of those who reported to vision screening without their spectacles include hyperopia (35.3%), myopia (23.4%) and astigmatism (41.3%). Of the 19 participants with visual impairment 16 reported no history of spectacle wear, one required and updated spectacle prescription and two did not have their spectacles in school during testing.

Other ocular abnormalities

The prevalence of strabismus, corneal opacity, and retinal disorder was 0.2 % each. A small percentage (0.9%) of children had red-green colour vision deficiency. Allergic conjunctivitis and blepharities were found in 5.8% and 0.9% of the children respectively.

DISCUSION

This study established the prevalence and causes of VI among school children in Abia State. The findings show that the prevalence of RE and VI in the study sample is relatively low. Significant differences between age groups were found in hyperopia and myopia, with the prevalence of hyperopia decreasing with age while myopia increased with age. The low categories of myopia, hyperopia, and astigmatism were the most frequent among the children with RE and uncorrected RE was responsible for majority of VI in the school children.

The prevalence of VI (presenting VA $\leq$ 6/12 in the better eye) of 3.5% in the present study differs from two previous studies in school-age children in Nigeria, with older participants. In Calabar, Megbelayin & Asana,[4] found 6.9% VI (presenting VA $\leq$ 6/9) in children aged between 9 and 21 years, while a study in Osun Ajaiyeoba, et al.,[7] reported 1.5% VI in children aged between 4 and 24 years with no stated definition of VI. For studies in other African countries utilizing similar diagnostic criteria, our finding is comparable to 3.5% in Ghana[3] where the participants' age range was similar but lower than the 1.4% reported in South Africa[9] with younger children. These values were lower than estimates reported for school-age children in Malaysia,[6] China[11] and Vietnam[1] with corresponding values of 10.1%, 10.9% and 12.2%. The difference may be because of the different age ranges of the different study participants. Secondly, RE which is a leading cause of VI in children is more prevalent in these populations due to anatomical differences compared to the African population.[21]

The prevalence of myopia of 3.4% in this study is lower than the estimates reported by a study on Nigerian children[18] and higher than those found in other African countries including Mehari & Yimer[2] (6.0%) and Wajuihian & Hansraj[20] (7.1%) wherein older children were examined. A possible reason for the higher prevalence may be due to the increased prevalence of late-onset myopia during high school and teenage years when there is heavier load of near work and rapid physical growth.[1,18,20] The lower prevalence (2.7%) reported by Atowa, et al[18] may be related to the use of cycloplegic refraction technique. Non-cycloplegic refractions which was applied in the present study usually result in myopia and less hyperopia.[3] Compared to studies from other geographic regions, our finding is relatively lower than the estimates reported for Asian children with prevalence ranging from 7.4% in urban India to 42.4% in rural China.[1,8,10] It is also lower than the estimates found in Caucasian children (range of prevalence, 9.2 to 13.1%).[22-24] Considerable regional differences exist from one country to another even within the same geographic location which may be related to genetic and/or environmental factors.[21,22]

Our finding of the prevalence of myopia increasing significantly with age is consistent with the report of several other studies.[1,6,8,10,23] Near-work activities, such as reading and writing, computer use and playing video games, have been indicated to be possible causes of axial length elongation with age, in addition to increased likelihood of developing myopia in older children.[25] Regarding myopia and gender, the lack of no gender influence on the prevalence of myopia observed in the present study agrees with previous studies on the African population, [2,18,20] while some studies elsewhere[6,8,10] revealed a higher prevalence of myopia in female than in male subjects, which may be related to peak height velocity and maturation rate occurring earlier in girls than boys in their study samples.[26]

In relation to previous studies on African populations, the prevalence of hyperopia (4.1%) in the present study was comparable to studies by Ovenseri-Ogbomo & Assien[27] and Wajuihian & Hansraj[20] that applied low criteria and non-cycloplegic objective measuring techniques. However, lower estimates were reported by studies[2,18] that included only significant (+2.00 D) hyperopia in their prevalence estimation. Overall, low prevalences of hyperopia have been reported in Africa and East Asian populations compared to Caucasians because of longer axial length in both Africans and Asians relative to Caucasian subjects.[21] The findings of the present study also revealed a decrease in the prevalence of hyperopia with age which agrees with the findings of other studies.[6,8,23] In contrast, gender has no influence on the prevalence of hyperopia in the present study which corroborates the findings of other studies in African children. Studies in China[8] and India[10] reported gender differences in hyperopia prevalence. The discrepancy in the findings on the relationship between gender and hyperopia in these studies can be explained in relation to gender representativeness. It may also be related to the disparity in the ocular components such as axial length between boys and girls in the studies. Another reason may be due to differences in time spent on outdoor and nearwork activities. Rose, et al.[28] has suggested that hyperopic spherical equivalent refraction is positively associated with less near task and more outdoors activities.

The prevalence of astigmatism (3.1%) was comparable to a study in South Africa.[20] The value was higher than the estimate (2.0%) reported in a study in Ethiopia[1] but lower than the 6.5% reported by a study in Ghana.[27] Another important finding to note in the present study is the high frequency of low categories of RE (Figure 1), which may not be easily detected by traditional distance VA measurement routinely used in vision screening programs. This is of clinical importance, given the association between low categories of hyperopia and astigmatism and visual discomfort due to excessive use of accommodation to maintain normal and comfortable vision.[12,13]

Uncorrected RE was also responsible for majority of the VI in school children in Abia State (Table 6). Its contribution (78.9%) was higher compared to the 58.8% reported for a cosmopolitan city in Osun state, Nigeria with apparently, better eye care services. In addition, spectacle coverage in the present study was lower than the value previously reported in an earlier study[18] in a commercial city of Aba in Abia State. In the earlier study, spectacles were worn by 21.9% of children needing RE correction in one or both eyes compared with 5.3% children in the current study. The disparity could be explained in the context of sample demographics and disproportionate distribution of refractive services. Given that eye care services in Abia State are largely located in the city centres,[18] it is expected that refractive services will be more accessible to children in the urban city of Aba because of their closeness to cosmopolitan centres compared with the study sample in the present study, which are composed of children from urban, semi-urban and rural areas.

The possible limitation of the present study is the non-use of cycloplegia and dilated fundus examination in the assessment of refractive errors and causes of VI, respectively. However, the use of cycloplegics would have affected the accommodation which was also investigated in this study. The intention was to measure accommodation at its natural state and with participants wearing their spectacles if prescribed. Cycloplegics may also cause a significant change in higher-order aberrations from the natural state which could affect the near vision test.[29] In addition, school principals would not have allowed for a second day testing, as it would have interrupted the students' learning sessions. However, to rule out latent hyperopia, the plus lens (+2.00 D) test was conducted on all subjects. In addition, our finding on the causes of VI compared closely with other studies on Nigerian children.[4,7] Another possible limitation is that although testing conditions were standardized as much as possible, it may not always be as close to the usual testing conducted in a clinic setting which enables control of instrumentation.

The strength of the present study includes, choosing a suitable study design based on the existing literature. The applicable sampling method was followed strictly to select participants from different areas of Abia State, by considering the socioeconomic characteristics of the areas. Data was also collected in a detailed and systematic approach using validated instruments. The study included students from both primary and secondary schools which represents the visual characteristics of these two levels of education.

To our knowledge, this is the first study to report on the prevalence and causes of VI in school children in Abia State. As such, it has added substantially to the existing literature on visual anomalies in children. Although, the prevalence of VI in the current study was low (Table 4), treatable causes were responsible for majority of the VI. In addition, our finding of relatively high proportions of low categories of hyperopia and astigmatism is important considering their relationship with near vision task and school performance. This study will have a positive impact on school health services, as it has provided useful information for policy-makers which will help in planning, provision and evaluation of child health services. The implementation of a broad screening strategy targeting common vision conditions in children including near vision anomalies is necessary given the implications for public health and education.

CONCLUSION

The prevalence of RE and VI including the causes of VI in school children in Abia State has been established. Our findings indicate that uncorrected RE was responsible for most of the VI among the children and that spectacle coverage for those with RE was low. Considering the public health implication, vision screening should be an immediate intervention. Vision screening will allow for early detection and successful treatment of vision threatening conditions before it deteriorates to obvious VI or blindness. Furthermore, functional eye care units should be established at every primary health center in the State, to increase access to eye care services.

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CHAPTER FIVE

ACCOMMODATIVE ANOMALIES AMONG SCHOOL CHILDREN IN ABIA STATE, NIGERIA

Atowa UC, Hansraj R, Wajuihian SO. Accommodative anomalies among school children in Abia State, Nigeria. *African Vision Eye Health* 2019,78(1),a465. https://doi.org/10.4102/aveh.v78i1.465

ABSTRACT

Background: Ocular discomfort due to accommodative anomalies can impair reading efficiency and school performance and possibly a person's quality of life.

Purpose: The aim of this study is to determine the prevalence of accommodative anomalies in school children in Abia State, Nigeria and to assess possible associations with sample demographics such as age, gender and school level.

Method*:* Case history questionnaire and vision tests were administered on 537 (255 males, 282 females; mean age 13.0 ± 2.0 years) children randomly selected from nine schools in Abia State. The following vision parameters were measured: visual acuity, non-cycloplegic refraction, cover test, near point of convergence, fusional vergences, accommodative functions and ocular health evaluation. All accommodative and binocular function tests were performed following the subjective refraction with the compensating lenses in place, if prescribed. Anomalies of interest such as accommodative insufficiency, accommodative excess, and accommodative infacility were classified using the findings of accommodative and vergence parameters.

Results: A total of 90 (16.8%) children had accommodative anomalies. Prevalence estimates include; accommodative insufficiency (AIS) 3.9%, accommodative excess (AE) 2.8% and accommodative infacility (AIF) 10.1%. There was no significant difference in the distribution of various accommodative anomalies between age group, gender or school level.

Conclusion: The significant proportion (16.8%) of children with accommodative anomalies in the present study is an important finding given that traditional vision screening programs that only focus on visual acuity are unlikely to detect these critical visual anomalies. The result of this study is expected to direct the development of a common and broad vision screening strategy.

Key words: Accommodative anomalies, accommodative insufficiency, accommodative excess, accommodative infacility, children.

INTRODUCTION

Accommodative anomalies are visual conditions that can affect the eye's ability to alter its dioptric power to bring an object of regard coincident with the retina.[1,2] Clinical signs range from reduced accommodative amplitude (AA), reduced sustainability and accuracy of accommodation and difficulty maintaining clear vision when changing fixation from one point to another with associated symptoms.[1,2,3] The symptoms include blurred vision at near, transient blurred vision when looking at a distant target following performance of near work, headaches, pulling sensation around the eyes, tired eyes and reduced attention span. Because of these symptoms, individuals find themselves attempting to compensate by holding reading material too close or too far away, or simply avoiding near activities altogether.[1,2,4,5,6] These ocular discomforts can impair reading efficiency, school performance and ultimately a person's quality of life.[7,8,9]

A number of studies[3,6,9,10,11,12,13,14,15,16,17,18,19,20] have reported on the prevalence of accommodative anomalies in school-age children in different populations, especially in Caucasian children. For the specific populations indicated in Table 1, the prevalence range for different accommodative anomalies include accommodative insufficiency (AIS, 0.2% – 18.3%), accommodative excess (AE, 1.2% – 5.1%) and accommodative infacility (AIF, 2.5% – 30%). Differences in study designs including the use of single or multiple sign criteria in the definition of specific accommodative anomalies and methodological differences such as small sample sizes, convenience sampling method and exclusion criteria within studies may account for the variability in study findings. Regarding exclusion criteria, the most recurring flaws among the studies are the exclusion of children with uncorrected refractive error (RE). For the studies that did not exclude children with uncorrected RE, it was not clear whether they wore their compensating lenses during testing. This is important, as RE significantly impact the aetiology and influences the measurement and treatment of accommodative anomalies.[1,7,12]

There is also a lack of information in the literature on the influence of age, gender and school level on the prevalence of accommodative anomalies.[6] As early detection remains the best approach for the treatment of visual anomalies and considering the cost for systematic screening,[18] an understanding of the association between accommodative anomalies and sample demographics will allow dedicating available resources and efforts for early detection, such as regular vision screening only on people at risk, thereby reducing the high short-term and long-term costs to the health system and to society. Presently, there are no intervention and management guidelines for accommodative and vergence anomalies in Abia State and Nigeria because the subspecialty of paediatric optometry is relatively new in the country.[21] The clinical implication is that most eye care professionals rarely consider accommodative and vergence disorders as anomalies of interest when screening children for near vision anomalies.

Our study included adequate and representative sample of primary and secondary schoolchildren in Abia State, Nigeria. Accommodative and binocular vision tests were performed with children wearing their compensating lenses, if prescribed. This ensured that uncorrected RE did not negatively impact on the clinical outcome measures. The present study aimed to determine the prevalence of accommodative anomalies in Abia State schoolchildren and to assess possible association with age, gender and school level. The information is expected to guide health policymakers and practitioners in implementing the most appropriate intervention and management strategies, particularly the vision problems that have been associated with educational outcomes.[8,9]

Table 1: A summary of studies reporting the prevalence (%) of accommodative anomalies in school-age children

Authors (year of study)	Setting	Age (years)	Sample size	Prevalence (%)		
				Accommodative insufficiency	**Accommodative excess**	**Accommodative infacility**
Wajuihian & Hansraj[6]	School	13-19	1201	4.5	2.8	12.9
Darko-Takyi et al[3]	School	12-17	627	7.7	1.4	3.8
Hussaindeen[14]	School	7-17	358*	0.2	0.8	7
			562**	0	0	10.7
Davis et al[12]	School	11.7 (mean)	484	32.4	-	–
Jang & Park[13]	School	8-13	589	5.3	1.2	2.5
Shin et al[9]	School	9-13	114	18.3	3.9	13.4
Marran et al[10]	School	11.5 (mean)	299	8.0	–	–
Borsting et al[11]	School	8-15	392	17	–	–
Metsing and Ferreira[15]	School	8-13	112	10	–	12.3
Moodley[16]	School	6-13	264	24	–	30
Abdi et al[20]	School	6-16	264	24.2	–	–
Abdi and Rydberg[19]	School	6-16	120	11.1	–	–
Scheiman et al[17]	Clinic	6-18	1650	2.3	1.2	2.3
Paniccia and Ayala[18]	Clinic	5-20	593	39	5.1	7

(*), rural population; (**), urban population

METHODS

Study participants

This study is part of the broader survey that utilised cross-sectional design to quantified visual conditions in schoolchildren in Abia State. The sampling design and technique have been reported elsewhere.[22] In brief, the prevalence estimation formula was used to calculate an adequate sample size for a projected prevalence of 12.7% and adjustments were made for clustering effects (2.0) and non-participation (10%). A total of 550 schoolchildren with ages ranging from 10 to 16 years were recruited from nine schools (public and private) through a stratified multistage and random sampling starting from the three geographic districts to the classrooms. Children who had systemic diseases or were taking any systemic and/or ocular medications that may affect near vision were excluded from the study.[22]

Procedures

Prior to the start of the vision test, a case history questionnaire[6] covering areas such as the ocular and general health conditions of the participants, including near task characteristics and visual symptoms, was administered to the participants. The interview was conducted by a research assistant properly trained in the administration of the questionnaire. A series of vision tests that included visual acuity (VA) measurements, ocular motility evaluation, stereopsis, suppression test, non-cycloplegic autorefraction, subjective refraction, colour vision assessment, ocular health evaluation, accommodative and binocular vision test were performed by an optometrist (the principal investigator). All testings were conducted in test stations set up in classrooms provided by the school authorities, and test conditions including illumination and test distance were maintained as best as possible at the same level in each station.

Distance and near VA were measured for each eye with logMAR charts held at 3 m and 40 cm, respectively, and all children underwent non-cycloplegic autorefraction and subjective refraction irrespective of their VA. We did not apply cycloplegia as this would have complicated the evaluation of near vision functions, which were the focus of the present study. Alternatively, the plus lens (2 D) test was performed on all children to detect possible latent hyperopia.

Accommodative and binocular function tests were performed in three repeated measures after subjective refraction with the child wearing his or her near correction, if prescribed. Monocular and binocular AA were determined by using Donders' push-up to blur technique with the Royal Air Force (RAF) rule. The target was a single line of letters equivalent to a VA of 6/9 on a reduced target, and the point of first sustained blur was recorded in dioptres (D). Accommodative facility was measured monocularly (MAF) and binocularly (BAF) with a plus or minus 2 D lens flipper at 40 cm. The target was a single line of letters that corresponded to a near VA of 6/9. Accommodative response was measured objectively at 40 cm using the monocular estimation method retinoscopy. For the vergence, parameters including horizontal phoria, AC/A ratio, near fusional vergence ranges and near point of convergence, the description of the test protocols and techniques have been provided in the report on vergence anomalies.[22]

Classification of the outcome variables

Accommodative anomalies were diagnosed as AIS, AE and AIF using the clinical measures of accommodative variables, according to the criteria used by previous studies,[2,6,9,13,14] as shown in Table 2.

Table 2: Classification of accommodative anomalies

Accommodative anomalies	Clinical signs	Diagnostic criteria
Accommodative insufficiency	1. Reduced AA of at least 2.00 D below Hofstetter's calculation for minimum amplitude: 15–0.25 × age (years). 2. High MEM >+0.75 D. 3. Fails MAF testing with −2.00 D with a criterion <6 cycles per minute (cpm).	A minimum of clinical signs (1 and 2) or (1 and 3), or all clinical signs
Accommodative excess	1. Low MEM <+0.25 D 2. Difficulty clearing +2.00 D with MAF with a criterion <6cpm. 3. Fails BAF test with +2.00 D with a criterion <3cpm.	Clinical signs (1 and 2) or (1 and 3)
Accommodative infacility	1. Normal AA 2. Fails MAF using ±2.00 D lenses, with a criterion of MAF <11cpm 3. Fails BAF using ±2.00 D lenses, with a criterion of BAF <8cpm	All clinical signs

Statistical analysis

The data analysis was performed using SPSS for Windows, version 23.0 (IBM-SPSS, Chicago, IL, United States [US]). Descriptive analysis of accommodative findings were presented as means, standard deviations, medians, ranges (minima and maxima), as well as skewness and kurtosis, while frequencies and distributions of outcome measures were presented in tables and figures. Differences in proportions among groups were examined using Pearson's chi-squared tests, whereas differences in the group means between children with and without accommodative anomalies were explored using the two-sample *t*-tests. Differences were considered significant at *p*-values of less than or equal to 0.05.

Ethical considerations

Ethical approval for the study protocol was granted by the College of Medicine Health Research and Ethics Committee, University of Nigeria, Enugu Campus (ethical clearance number: 023/01/2017), as well as the Biomedical Research Ethics Committee of the University of KwaZulu-Natal, Durban, South Africa (ethical clearance number: BE/619/16). The school heads or principals also approved the study. Written informed consent and assent were obtained from parents and children, respectively, after verbal and written explanation of the nature of the study was provided to them. The study was conducted in accordance with the tenets of the Declaration of Helsinki regarding research involving humans.

RESULTS

Sample demographics

Five hundred and thirty-seven children were examined, and four who had strabismus or amblyopia were excluded. Data was analysed for 533 children, and their mean age was 13.0 ± 2.0 years. The participants comprised 223 (41.9%) children with ages ranging from 10 to 12 years (age group 1) and 310 (58.1%) with ages ranging from 13 to 16 years (age group 2); 279 (52.4%) were female and 254 (47.6%) male; 233 (43.8%) were in primary and 300 (56.2%) in secondary school. The prevalence of REs in the study sample was hyperopia (4.1%), myopia (3.4%) and astigmatism (3.2%). All participants had near VA of at least N_5 with mean best-corrected distance VA (logMAR) of the right eye as −0.09 ± 0.04 and left eye as −0.09 ± 0.03. The descriptive statistics for accommodative variables are represented in Table 3.

Table 3: Descriptive analysis of overall accommodative findings

Variables	N	Mean	SD	Median	Minimum	Maximum	Skew
Amplitude of Accommodation *(dioptre D)*							
Monocular (right eye)	533	15.25	3.58	16	4	20	−0.92
Binocular	533	15.46	3.44	16	5	20	−1.48
Accommodative response *(D)*	533	0.47	0.27	0.5	−0.5	1.5	0.73
Accommodative facility *(cycles/minute)*							
−2D monocular	527	11.36	3.35	11	1	20	−0.11
−2D Binocular	529	11.38	3.39	11	1	20	−0.12
+2D monocular	528	11.45	3.94	11.7	0	20	−0.15
+2D binocular	528	11.85	4.15	12	2	21	−0.10
±2D monocular	527	9.04	3.17	9	1.7	18	−0.20
±2D binocular	527	9.27	2.98	9.3	2	18	−0.05

D, dioptre; RE, right eye; cpm, cycles per minute; *n*, number; SD, standard deviation

Prevalence of accommodative anomalies

The prevalence of accommodative anomalies was computed using both single and multiple sign criteria. The prevalence estimation (for multiple sign criteria) was for accommodative anomalies that were not associated with vergence disorders. With the multiple sign criteria, a total of 90 (16.8%) children had accommodative anomalies. The prevalence of the specific types of accommodative anomalies is presented in Table 4. For the single sign criterion, based on some specific clinical measures listed in Table 2, reduced monocular AA was observed in 44 (7.8%) participants, while reduced binocular AA was recorded for 39 (7.3%) children.

Table 4: Prevalence of accommodative anomalies

Accommodative anomaly	Number of children (n)	Prevalence (%)
Accommodative insufficiency	21	3.9
Accommodative excess	15	2.8
Accommodative infacility	54	10.1

A plot of the mean monocular AA as a function of age is presented in Figure 1. The figure shows that AA decreased with age; however, the decrease was not particularly linear. A minimal increase in mean AA was observed from ages 11 to 12 years, while the mean AA was 15.7 at age 13 years and 15.8 at 14 years. Accommodative facility was tested with plus or minus 2 D lens flipper, and the result showed that 96 (18.3%) children failed MAF (right eye), while 235 (44.6%) failed BAF. For accommodative response, 28 (5.2%) children had accommodative lead, whereas 17 (3.1%) had accommodative lag.

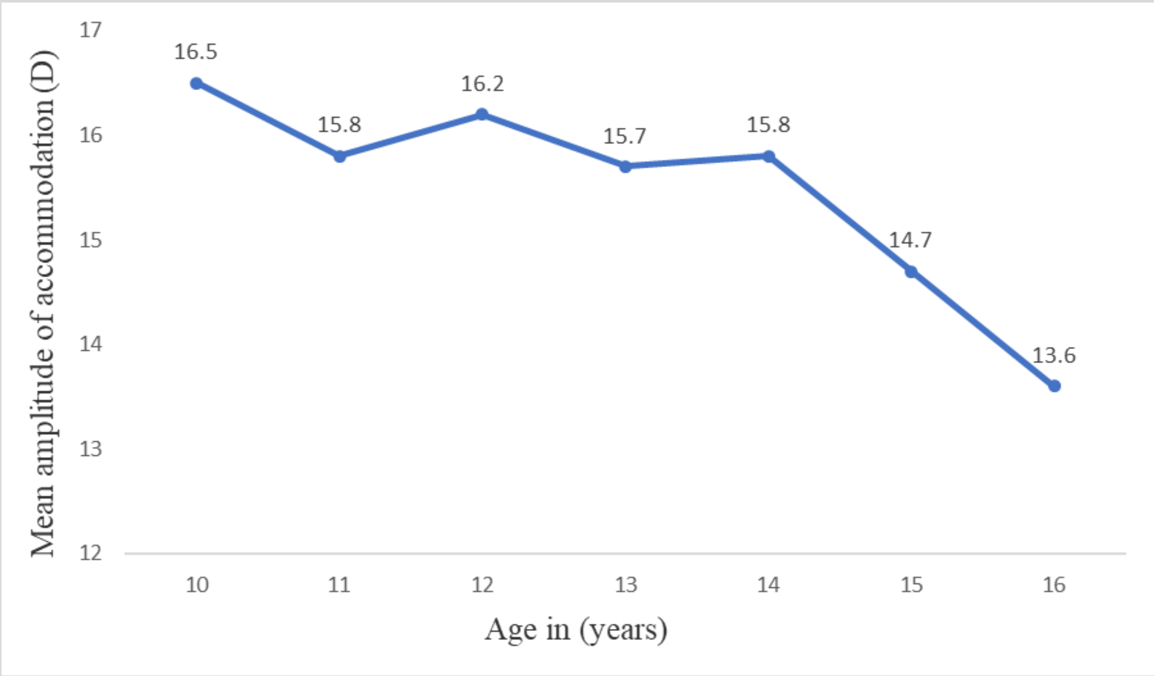
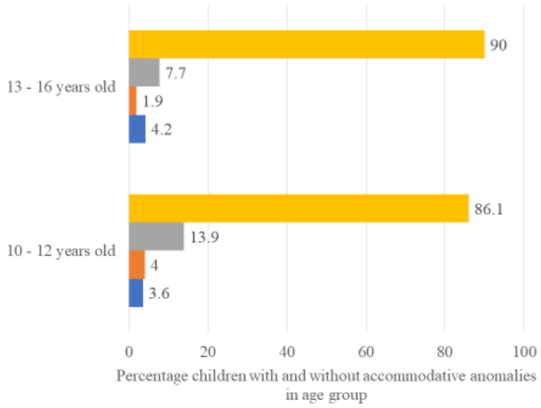


Figure 1. Mean amplitude of accommodation as a function of age

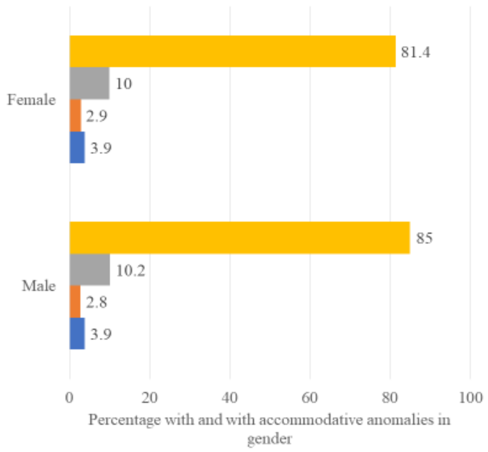
Regarding the effect of age, gender and school level on the prevalence of the AIS, AE and AIF, statistical analysis (Figure 2) showed that despite the marginal differences observed between the groups, none of the accommodative anomalies were associated with age, gender or school level.

A. Age group



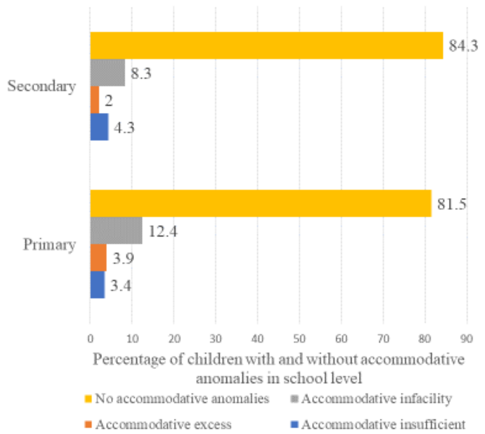
	10-12 y vs 13-16 y group	
	χ2-test	p-value
Accommodative insufficiency	0.1259	0.7227
Accommodative excess	2.0921	0.1481
Accommodative infacility	1.6636	0.1917

B. Gender



	Male vs female	
	χ2-test	*p*-value
Accommodative insufficiency	0.0000	0.9973
Accommodative excess	0.0060	0.9838
Accommodative infacility	0.0115	0.9116

C. School level



	Primary vs secondary	
	χ2-test	*p*-value
Accommodative insufficiency	0.2806	0.5963
Accommodative excess	1.6636	0.1971
Accommodative infacility	2.4367	0.1185

Figure 2: Distribution of specific accommodative anomalies by age, gender and school level

Comparison of accommodative findings and groups

The group mean data for specific accommodative parameters for children with no accommodative anomaly and children with various accommodative anomalies was compared using the two sample *t*-tests (Table 5). Analysis of the mean data of the clinical measures for AIS group revealed that except for accommodative accuracy, which showed a significant increase ($p < 0.001$), all other accommodative parameters were significantly reduced when compared to the no accommodative anomaly group ($p < 0.001$) for all other variables. For AE, the group mean data for accommodative response ($p < 0.001$) and +2.00 D accommodative facility (monocular, $p < 0.001$; binocular, $p < 0.001$) were significantly reduced. Similarly, both monocular and binocular (±2.00 D) accommodative facility variables were significantly reduced (monocular, $p < 0.001$; binocular, $p < 0.001$) in children with AIF anomalies. However, no significant difference was observed for either monocular ($p = 0.08$) or binocular ($p = 0.44$) AA between children with AIF and those without accommodative anomalies.

Table 5: Accommodative findings for various accommodative groups

	No accommodative anomalies			**Accommodative insufficiency**			**Accommodative excess**			**Accommodative Infacility**		
	Mean	SD	median	mean	SD	Median	mean	SD	Median	mean	SD	Median
Accommodative Amplitude (D)												
Monocular (RE)	17.51	4.04	18	7.18	1.31	6	19.26	2.08	18	17.30	3.72	20
Binocular	17.59	3.62	20	7.32	1.28	7.3	19.30	2.04	20	17.66	3.29	20
Accommodative response (D)	0.45	0.23	0.5	0.89	0.16	0.83	−0.20	0.16	0	0.56	0.35	0.5
Accommodative Facility(cpm)												
−2D monocular	12.20	3.21	12	4.40	0.97	5	8.84	0.95	9	8.10	3.36	8
−2D binocular	12.26	3.27	12	4.67	0.90	4.3	8.79	1.14	8.3	8.18	3.38	8
+2D monocular	12.34	3.53	13	8.77	2.83	10	3.87	0.65	4	6.95	2.95	6
+2D binocular	12.79	3.58	13	8.77	2.85	9.3	3.64	0.94	4	7.30	3.43	7
±2D monocular	10.09	2.42	10	4.71	1.09	5	3.48	0.91	4	3.99	1.91	4.5
±2D binocular	10.30	2.21	10	4.83	1.06	5	3.47	0.87	4	4.66	1.61	5

D, dioptres; RE, right eye; cpm, cycle per minute; SD, standard deviation

DISCUSSION

This study reports on the prevalence of accommodative anomalies in a population of children of Abia State, which include AIS (3.9%), AE (2.8%) and AIF (10.1%). There was no significant difference in the distribution of the various accommodative anomalies between age group, gender or school level. The mean AA of 15.46 ± 3.44 D in our study was comparatively similar to the 15.88 ± 3.46 D reported by Ovenseri-Ogbomo and Oduntan[23] on school-age children in Nigeria.

In the present study, the prevalence of AIS (3.9%) using multiple sign criteria was higher than the 2.3% reported by Scheiman et al.[17] and 0.2% by Hussaindeen et al.[14] However, the value is lower than two other studies[6,9] that also utilised more than one clinical sign. The study by Shin et al.[9] estimated AIS in symptomatic participants with a score of 20 or more on the convergence insufficiency symptom survey; hence, the reported prevalence of 18.3% may have been overestimated, while the difference of 4.5% reported by Wajuihian and Hansraj[6] may be attributed to reduction in AA with an increase in age, as their study participants were older than the children in the present study. Further, studies that defined AIS using only one clinical sign (of reduced AA, lower than the expected age norm according to Hofstetter's formula for minimum age) reported significantly higher prevalence rates, ranging between 10% and 24.2%.[15,16,19,20] However, to accurately interpret the accommodative status of children, it is recommended to include the assessment of other accommodative parameters such as accommodative facility and response. This is so because using only reduced AA overestimates the prevalence of AIS,[1,2] because AIS presents more as a syndrome. Moreover, the prevalence of poor monocular (7.8%) and binocular (7.3%) AA reported in this study was lower than the 10% (monocular or binocular) reported by Metsing and Ferreira[15] and the 24% (monocular) and 26% (binocular) reported by Moodley[16] on primary schoolchildren but higher than the 4.6% (monocular) found by Wajuihian and Hansraj[6] in high school children. Although several factors such as sampling methods and sample sizes, inconsistent measuring techniques and diagnostic criteria can play a significant role in differences between studies, the major reason here may be interexaminer variability and age of study participants. Younger children may have more difficulty in reporting blur than the older children, which is the subjective criterion for the measurement of AA.

The findings of this study on AE (2.8%) were consistent with those of Wajuihian and Hansraj[6] on black students in South Africa. However, it should be noted that two other school-based studies in South Korea[9,13] and another in Ghana[3] reported different estimates of 1.2%,[13] 1.4%[3] and 3.7%,[9] respectively. Similarly, Darko-Takyi et al.[3] and Jang and Park[13] reported prevalences of AIF of 3.8% and 2.5%, respectively, which is lower than our finding of 10.1%. Other studies reported higher estimates when compared to the present study. A case in point: in South Korea,[9] the prevalence of AIF was 13.4% while in South Africa[6] it was 12.9%, and in rural and urban India[14] 7% and 10.7% were determined, respectively.

Although marginal differences between groups were observed in the present study, no significant differences were found between the prevalence of AIS, AE, AIF and demographic factors including age, gender and school level, which corroborates the findings of several other studies.[3,9,13,18] The study by Scheiman et al.[17] that found a significant difference in the prevalence of AIS with age was a clinic-based study that was exposed to biased data, making comparison of findings with a randomised school-based study very difficult.

Overall, the differences in relation to findings of these studies can be explained from various contexts. Although most of the studies enumerated in Table 1 were school-based studies, their sample size and sampling method varied considerably. To obtain more accurate prevalence data, it is necessary to have adequate and representative samples of the target population, with a suitable age range that will provide reliable data that can be extrapolated to the entire population. Except for three studies[3,6,13] that utilised randomised samples, all others selected their participants and only a few had an adequate sample size, with Scheiman et al.[17] being a clinical study. Clinic samples and school-based studies with only symptomatic participants are characteristically biased and have the possibility of reporting higher prevalence estimates when compared to an unselected population of children.[22,24] Besides being non-representative samples, participants with complaints of visual discomfort are more prone to having actually visual anomalies.[22,24]

The refractive status of the participants is another important factor to consider in assessing prevalence of an accommodative anomaly. Studies have indicated that uncorrected RE can impact the aetiology and influence accommodative anomalies, as well as their treatment options.[7,12] From this point of view, it may be possible to suggest that RE affects the prevalence and distribution of accommodative anomalies in any population.[25] Myopes have reduced sensitivity to blur compared to hyperopes and emmetropes.[1] Blur adaptation can cause an individual to experience sustained blur at closer distances during push-up testing, resulting in higher values of AA.[1,25] Therefore, adequate correction of RE is critical in the resolution of some accommodative conditions[12,25,26] and is likely to yield more accurate prevalence estimates.[12] To ensure that uncorrected RE does not overestimate the prevalence of accommodative anomalies in our study, children were tested with the correction; however, in some studies[9,10,11,19] information regarding the refractive status of the participants was not indicated. As such, it was not clear whether those with RE were included in the study or whether they were examined with their spectacle compensations in place. Other studies excluded participants with uncorrected VA and RE, thereby limiting the extent to which their samples can be a valid representative of the target population.

Increased variability and reduced reliability associated with accommodative testing could also be the reasons for the variations in findings among studies. Some studies applied a single criterion, while others used two or more criteria to define specific accommodative anomalies. In addition to varying diagnostic criteria, different techniques were applied in measuring the accommodative parameters. Even in studies with similar criteria and measuring techniques, different cut-off points were applied in the detection of participants with specific accommodative anomalies, making it difficult to compare results among studies. Regarding reliability of test results, the measurement of accommodative parameters involves reporting blur experience, which depends on the ability of the subjects to understand the experimental procedures and instructions. Younger children have difficulty in reporting blur experience.[6,22,23] As such the use of only younger (primary school) children by some studies may have influenced their results. With the exception of Jang and Park,[13] school-based studies (Table 1) with younger children reported higher prevalences of AIF compared to those with older children. The difference between the findings of Jang and Park with the present study and others may be related to differences in test procedures, varying diagnostic criteria and cut-off points.

One of the limitations of the present study was the non-use of cycloplegia during refraction. Cycloplegia was contradicted because the study involves the evaluation of accommodative status, and our desire was to examine the children in their habitual state. Instead the plus lens test was applied in the assessment of latent hyperopia. Another possible limitation is that all tests were performed in test stations set-up in each school, rather than an optometry clinic, which would have afforded better control over the test environment. Nevertheless, testing conditions were standardised at each test station in all the schools. In addition, validated and reliable instruments were applied in data collection, with only one examiner conducting all the vision tests. The study included an adequate sample representative of primary and secondary school children representing the learning experience and visual characteristics of these two levels of educations. Furthermore, the study protocol was adapted from recent studies[6,12,14] in this area. Altogether, data from the present study has significant indications for eye care practitioners with respect to clinical management of near vision disorders as well as education and health policymakers in terms of planning and implementation of school health programmes. Given the reported association between school performance and accommodative anomalies,[7,8,9] the accommodative status of every child who presents with near vision related complaints, particularly those having difficulty with academic performance, should be properly evaluated for possible accommodative disorder.

CONCLUSION

The present study has provided a detailed and systematic report on the prevalence of accommodative anomalies in children in Abia State, Nigeria. Our data indicates that a considerable proportion (16.8%) of schoolchildren suffer from at least one of the disorders of accommodative function, which can have a substantial influence on their learning capabilities and academic performance. This is an important finding, given that conventional vision screening programmes that only focus on VA assessment are unlikely to detect these critical visual anomalies. Therefore, the scope of paediatric vision screening programmes should be widened to include test batteries that will identify common visual anomalies, including accommodative anomalies capable of affecting school performance. Overall, the data from this study will apply towards the development of a common and broad-based vision screening strategy.

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CHAPTER SIX

VERGENCE PROFILE AND PREVALENCE OF NON-STRABISMIC VERGENCE ANOMALIES AMONG SCHOOL CHILDREN IN ABIA STATE, NIGERIA

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ABSTRACT

Purpose: To determine the prevalence of non-strabismic vergence anomalies and their relationship with age, gender and school level in children aged 10-16 years.

Method: A cross-sectional study was conducted among 537 (255 male, 282 females; mean age 13.0 ± 2.0, years) children selected from nine schools using stratified, cluster, random sampling. The participants completed a Convergence Insufficiency Symptom Survey (CISS) and eye examinations, including the measurement of visual acuity, non-cycloplegic refraction, cover test, near point of convergence, fusional vergences, accommodative functions and ocular health evaluation. All binocular tests were performed following the subjective refraction with the corrective lenses in place, if prescribed.

Results: The prevalence of low suspect, high suspect and definite convergence insufficiency were 9.6%, 5.8% and 4.1%, respectively. Other prevalence estimates included convergence excess (2.9%), fusional vergence dysfunction (2.6%), basic exophoria (1.7%), basic esophoria (2.8%), divergence insufficiency (0.8%) and divergence excess (0.6%). The prevalence of high suspect ($p < 0.01$) and definite ($p < 0.01$) convergence insufficiency were significantly higher in older than younger children, and as expected, in secondary more so than primary school children ($p = 0.01$). There was no statically significant association between gender and various vergence anomalies.

Conclusion: The study showed that vergence anomalies are common vision conditions among Abia State school children. Given the importance of visual skills in learning and academic achievements, there is a need to develop screening and management strategies that will target those visual conditions to prevent educational and social progress being affected.

Key words: Binocular vision anomalies, convergence insufficiency, convergence excess, exophoria, esophoria, divergence insufficiency, divergence excess, refraction and children.

INTRODICTION

Vergence anomalies, such as convergence insufficiency (CI), convergence excess (CE), fusional vergence dysfunction (FVD), basic exophora (BX), basic esophoria (BS), divergence insufficiency (DI), and divergence excess (DE) are motor disorders of the visual system. Such visual anomalies interfere with the ability of the vergence mechanism to accurately integrate and stabilize retinal images from both eyes into a single representation.[1,2] Children with vergence anomalies have difficulty in sustaining bifoveal fixation, often with symptoms including blur vision at near, diplopia, eye strain, watery eyes, eyes tiring and headaches.[1,3,4] These discomforts are associated with prolonged near work including reading, writing and computer works, as this is when the demand on the binocular vision system is very intense.[1,3,4] Vergence anomalies can cause reduced attention span on near-centred school tasks because children are discouraged from performing tasks they find difficult to do.[3,5] It can also interfere with ability of the children to assimilate information causing them to behave in á manner similar to children with behavioural, emotional or attention deficit problems.[6,7] As a result, these children are often misunderstood and misjudged as having "Attention Deficit Hyperactivity Disorder" (ADHD).[7]

Several school-based studies[8–25] have documented the prevalence of vergence anomalies in different racial groups and populations. Convergence insufficiency was the most reported vergence anomaly among the studies with estimates ranging from 6.5 to 18% for single criterion[8–10] and 2.25 to 31.4% for multiple criteria.[11–22] The range for other vergence anomalies include, CE (0.8 – 5.6%),[11-13,15-19,21,22] BS (0.3 – 4.1%),[12,19,20] BX (1.0 – 4.1%)[12,19,20] and FVD (0.4 – 4.7%).[11,18,22,23] The estimates for each of DI and DE ranged between 0 and 0.9%.[12,19,20] Besides, differences in measurement techniques and diagnostic criteria, there are some limitations inherent in the study designs which may have affected the interpretation of their findings and conclusions. Most importantly some studies[14,15,16,21] excluded children with poor visual acuity and refractive error. Others,[12,14,15,16,19] provided no information on the visual and refractive status of the participants: thus, it is not clear whether those with refractive error were included or whether they were tested with their corrective lenses in place. Furthermore, the use of convenient sampling method[8,9,12-18,20-22] and small sample size[8,9,12,14-16,21] by some studies may have also affected the generalization of their findings to the target population. Overall, there is lack of all-inclusive data on the prevalence of vergence anomalies in children. To our knowledge, available studies[11,12,19] on African children are only for high school and university students. Reports indicate that vergence anomalies begins from later years of primary education[1,3,4] and that refractive error has an influence on the aetiology and treatment of vergence anomalies.[17] The present study included adequate sample representative of primary and secondary school children. Children with refractive error were tested for binocular functions with their corrective lenses in place so that uncorrected refractive error does not result in overestimation of vergence anomalies.

Understanding the vision conditions that are more common in school children in Abia State as well as their relationship with demographic variables will help to identify the population at risk of developing these anomalies[26] and contribute towards the development of a broad screening strategy. This is important, given that vision anomalies have been associated with impaired school performance.[20,21,27] Therefore, the aim of the study was to establish the prevalence of vergence anomalies in school children in Abia State, Nigeria and to investigate any association between age, gender, school level and vergence anomalies.

MATERIALS AND METHODS

Study design

This was a descriptive cross-sectional study that provided quantitative data on the prevalence, and distribution of vergence anomalies in school children from Abia State. The study protocol was approved by the College of Medicine Health Research and Ethics Committee, University of Nigeria, Enugu Campus, as well as, the Biomedical Research Ethics Committee of the University of KwaZulu-Natal, Durban, South Africa. Permission to conduct the survey in schools in Abia State was obtained from the Education Management Board, as well as, the heads of the various schools selected. Informed written consent and assent were obtained from the parents and participants respectively after a detailed explanation of the study had been provided to them by means of information leaflets written in English and the local language. The study was conducted in accordance with the tenets of the Declaration of Helsinki regarding research involving humans.

Study setting and sampling

Setting

The target population was primary and secondary school children in Abia State, Nigeria. The State comprises of 17 local government areas (LGA) which are divided into three geographic districts called senatorial zones. Participants between the ages of 10 and 16 years were recruited from 9 schools using stratified, multistage cluster, random sampling starting from the geographic districts to the classroom. A total of 550 children were recruited from primary and secondary schools. Students with any known history of systemic disease and/or taking any systemic medication that may affect vision were excluded from the study during the case history taking procedure.

Sampling

The sample size was calculated using the single proportion estimation formula;[28]

$$N = (Z)2\frac{(1.0-p)(p)}{(b)2},$$

where N is the minimum sample size; p is the anticipated prevalence of 12.7% estimated based on a prior study[12] within the country; b is desired error bound considered as 5% and Z = 1.96 for a 95% confidence interval; given a sample size of 170. After adjusting for a design effect of 2 and a 10% contingency factor to compensate for non-response rate, the sample size was determined to be 380. However, the sample size was increased to 550 to give a greater statistical power.

Examination procedure

Preliminary test

A case history Questionnaire[11,20] was administered to the children by a trained research assistant independently of the optometrist. The interview covered questions about the child's ocular history, general health, visual symptoms and asthenopia. Following the completion of the interview, an experienced optometrist (the principal investigator) conducted the following vision tests: visual acuity measurements, ocular motility evaluation, suppression, stereopsis, noncycloplegic autorefraction, subjective refraction, colour vision assessment, ocular health evaluation and binocular vision testing in test stations set up in each school. Examination conditions were maintained at the same level in all the test stations.

Distance visual acuity was measured for each eye using a logMAR chart (Precision Vision, La Salle, IL, USA) at three metres and near vision was tested at 40 cm using a logMAR chart. Stereoacuity was assessed using the Randot stereo test (Vision Assessment Corporation USA) and a suppression check was conducted at 40 cm using a hand held Worth-4-dot test instrument (Haag-Streit UK). Ishihara colour vision test was used to detect congenital red-green colour vision deficiency. The unilateral cover test was performed at distance (3 m) and near (40 cm) to detect the presence of strabismus and further binocular testing was discontinued if a child was found to have strabismus. Anterior and posterior segments examination, as well as, ocular motility and pupil evaluation were performed with a Heine diagnostic set.

Refraction

Refraction was performed on all children irrespective of their visual acuity. Objective refraction was carried out using the Topcon RM-8000B (Topcon Corporation, Tokyo, Japan) autorefractometer in three repeated measures. The average of the readings was then refined subjectively to best comfortable visual acuity achievable with maximum plus lens and minimum minus lens. Cycloplegia was not applied as this would have disrupted the evaluation of accommodation which was also investigated in this study. However, the plus lens (+2.00 DS) test were conducted on all subjects to rule out latent hyperopia. Following the subjective refraction, the binocular vision system was evaluated.

Binocular vision

The binocular vision function included horizontal phoria, near point of convergence (NPC), fusional vergence range (FV), vergence facility (VF), accommodative amplitude (AA), accommodative response (AR), accommodative facility (AF), and AC/A ratio. Horizontal heterophoria was assessed with the Howell phoria card[20] and the gradient AC/A ratio was determined by measuring heterophoria through plus and minus 2D lenses with the target at 33 cm. Near fusional vergence ranges were determined in free space using horizontal prism bars (B-16 horizontal prism bars-Gulden Ophthalmics, Elkins Park, PA), with a 6/9 equivalent accommodative target held at 40 cm. Considering the age of the participants and the difficulty in reporting blur experience, the fusional reserve was taken as the break point instead of the blur point.[11,20] The NPC (break and recovery) was measured using the Royal Air Force (RAF) rule with a vertical line as the target point.[11] The amplitude of accommodation was measured monocularly and binocularly using the Donder's push-up method with a RAF rule and a 6/9 row of letters as the target. The target was moved slowly toward the participants, until a sustained blur was reported; three readings were taken and averaged. The accommodative response was assessed using the monocular estimation method (MEM) with dynamic retinoscopy at 40 cm. Because of the varying ability of the children to understand some complex tests, not all participants examined completed all binocular vision tests.

Statistical analysis

Data analysis was performed using the Statistical Package for Social Science software (SPSS for Windows, Version 23.0, IBM-SPSS, Chicago, IL, USA). For all statistical tests, a *p*-value of less than or equal to 0.05 indicated a statistically significant difference.

The primary outcome of this study was vergence anomalies; findings of the binocular vision tests were used to diagnose the anomalies as convergence (CI), convergence excess (CE), divergence insufficiency (DI), divergence (DE), basic exophoria (BX) and basic esophoria (BS) based on the criteria used by previous studies[1,11,15,24] as shown in Table 1. Descriptive statistics were used to present group means, standard deviation and prevalence estimates, while tables and figures were used to present frequencies and distributions of variables. Pearson's chi-squared tests were applied for differences in proportions among groups. The two-sample *t*-tests were applied to examine differences in the means between groups while the analysis of variance (ANOVA) was used for the comparison of differences in means among groups.

Table 1: Classification of vergence anomalies

Vergence anomalies	Clinical signs and diagnostic criteria
Convergence Insufficiency (CI)	***Low suspect CI****: Clinical signs 1 and 2* ***High suspect CI****: Clinical sign 1 and 2 other clinical signs or clinical sign 1 and 2 plus 3 or 4* ***Definite CI****: All clinical signs. The cut-off points for ''symptomatic'' as ≥ 16 score on the Convergence Insufficiency Symptom Score (CISS)* (1) Exophoria at near (2) Exophoria at near ≥4 prism diopter (pd) greater than at distance (3) Insufficient fusional vergence at near: (i) fails Sheard's criteria or (ii) poor positive fusional vergence (PFV) at near ≤12 pd. Base out (BO) to blur or ≤15 pd BO to break. Poor BO to break was used for PFV criteria (4) Receded NPC ≥7.5 cm break or ≥10.5 cm recovery.
Convergence excess	*Clinical sign 1 and minimum of 2 other signs* (1) Esophoria at near is greater than measured at distance, (≥ 2 pd) (2) High AC/A > 5/1 (3) Reduced binocular accommodative facility (BAF) with ± 2.00 D (< 3 cycles/min) (4) Reduced negative fusional vergence (NFV) at near <8/16/7 for blur/break/recovery (at least 1 of 3) (5) High MEM (≥ +0.75) (may show high lag)
Fusional vergence dysfunction	*Clinical sign 1 and 2 other signs* (1) Normal phoria (2) Reduced NFV and PFV at near (3) Reduced vergence facility with both base out and base in (4) Fails BAF with ±2 D lens
Divergence excess	*Clinical sign 1and a minimum of 2 other signs* (1) Exophoria greater at distance than near (≥ 1pd) (2) High AC/A > 5/1 (3) Low negative fusional vergence (break) at near (< 7pd)
Divergence insufficiency	*Clinical sign 1 and a minimum of 2 other signs* (1) Esophoria greater at distance than near (≥1pd) (2) Low AC/A < 3/1 (3) Low negative fusional vergence at distance (< 4 pd) (4) Poor recovery to base in prism at distance (< 2 pd)
Basic Exophoria	*Clinical sign 1 and a minimum of 2 other signs* (1) Equal exophoria at distance and near (2) Normal AC/A (between 3/1 – 5/1 pd) (3) Reduced PFV at near ≤ 12/15/4 (at least 1 of 3) (4) Reduced BAF with ±2.00 D (< 3 cycles/min)
Basic Esophoria	*Clinical sign 1 and a minimum of 2 other signs* (1) Equal esophoria at distance and near (2) Normal AC/A (3/1 – 5/1) (3) Reduced NFV at near ≤ 8/16/7 (at least 1 of 3) (4) Reduced BAF with ±2.00 D (< 3 cycles/min)

RESULTS

Sample characteristics

Four participants who have strabismus or amblyopia were excluded from analysis of non-strabismic vergence anomalies. The mean age of 533 children included was 13.0 ± 2.0 years and median age was 13 years. The participants consisted of 223 (41.9%) in age group 1 (10 – 12 years) and 310 (58.1%) in age group 2 (13 – 16 years); 279 (52.4%) females and 254 (47.6%) males; 233 (43.8%) and 300 (56.2%) were from primary and secondary school level, respectively.

Refractive error

All participants whose data were included for analysis had normal near visual acuity (N_5). The mean spherical equivalent refraction (SER) for the right eyes was −0.01 ± 0.35 D (range, −2.00 to 2.00 D) and left eyes were −0.01 ± 0.34 D (range, −3.00 to 3.25 D). About 4.1% of the children were hyperopic, 3.4% were myopic and 3.2% had astigmatism. The mean best corrected distance visual acuity (logMAR) of the right eye was −0.09 ± 0.04 and left eye was −0.09 ± 0.03. Among the children with RE (myopia, hyperopia and astigmatism) low and moderate categories were 85.9% and 14.1%, respectively. There were no participants with high amounts of RE.

Vergence findings

The descriptive analysis of vergence findings for all children that completed each procedure is presented in Table 2. Some specific vergence findings were further analysed according to clinical criteria and cut-off values listed in Table 1. The results showed that more children were orthophoric at distance and exophoric at near (Figure 1). About 17. 1% of the children had near exophoria greater than 4 prism dioptres. The results of the NPC measurements in 533 children showed that about 102 (19.1%) participants had reduced NPC break point greater than 7.5 cm. Vergence facility was also reduced in 32.8% of the participants. The distribution of children with reduced fusional vergence findings at near is depicted in Figure 2. The results demonstrate that over two-third of children had normal PFV and NFV break and recovery points. The AC/A ratios were calculated for 533 children and ranged between 3/1 and 5/1 which were considered as normal values. Approximately 51.8% fell within the normal values whereas 11.3% and 36.6% were below and above the normal values respectively. For accommodative facility test using ±2.00 D, 96 (18.3%) failed monocular accommodative facility, while 235 (44.6%) failed binocular accommodative facility. Lag and lead of accommodation were recorded for 28 (5.2%) and 17 (3.1%) subjects respectively.

Table 2: Descriptive analysis of overall vergence findings

Variables	**n**	**Mean**	**SD**	**Median**	**Minimum**	**Maximum**	**Skew**
Near point of convergence *(cm)*							
▪ Break	533	6.47	4.20	4	4	24	1.85
▪ Recovery	533	9.45	4.24	7	6	28	1.86
Stereoacuity *(sec arc)*	533	40.80	17.21	40	10	200	1.67
Distance exophoria *(pd)*	533	0.15	0.05	1	0	4	5.01
Distance esophoria *(pd)*	533	0.37	1.21	1	0	5	3.66
Near exophoria *(pd)*	533	2.31	1.73	2	0	10	1.06
Near esophoria *(pd)*	533	0.32	4.00	1.5	0	17	7.97
Diff, near and far exophoria	533	2.16	1.62	2	0	10	0.97
AC/A ratio	533	5.18	2.04	5	1.3	10	0.42
Vergence facility (*cycle/minute*)	523	12.70	3.78	14	3.3	18	−0.43
Negative fusional vergence *(pd)*							
▪ Break	525	17.10	5.24	16	4	40	0.90
▪ Recovery	525	12.41	4.64	12	2	30	0.49
Positive fusional vergence *(pd)*							
▪ Break	525	20.39	6.61	20	4	45	0.30
▪ Recovery	525	14.63	5.61	16	2	35	0.29
Amplitude of Accommodation *(dioptre D)*							
• Monocular (right eye)	533	15.25	3.58	16	4	20	−0.92
• Binocular	533	15.46	3.44	16	5	20	−1.48
Accommodative response *(D)*	533	0.47	0.27	0.5	−0.5	1.5	0.73
Accommodative facility *(cycles/minute)*							
▪ −2D monocular	527	11.36	3.35	11	1	20	−0.11
▪ −2D Binocular	529	11.38	3.39	11	1	20	−0.12
▪ +2D monocular	528	11.45	3.94	11.7	0	20	−0.15
▪ +2D binocular	528	11.85	4.15	12	2	21	−0.10
▪ ±2D monocular	527	9.04	3.17	9	1.7	18	−0.20
▪ ±2D binocular	527	9.27	2.98	9.3	2	18	−0.05

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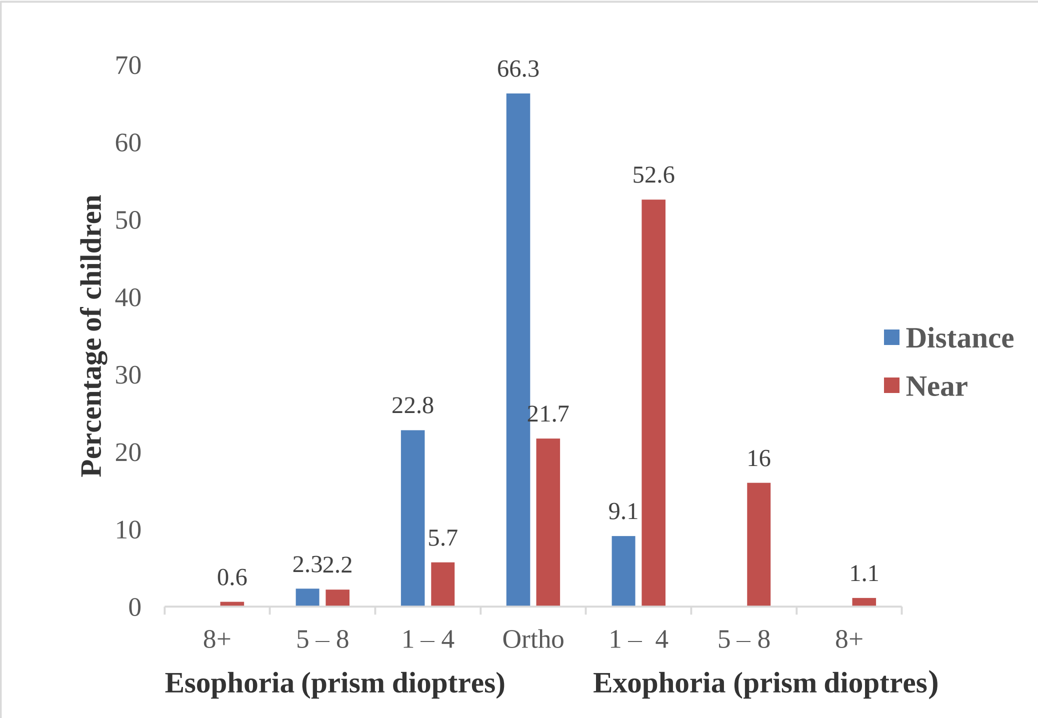

Figure 1: Distribution of children with different types of distance and near phoria

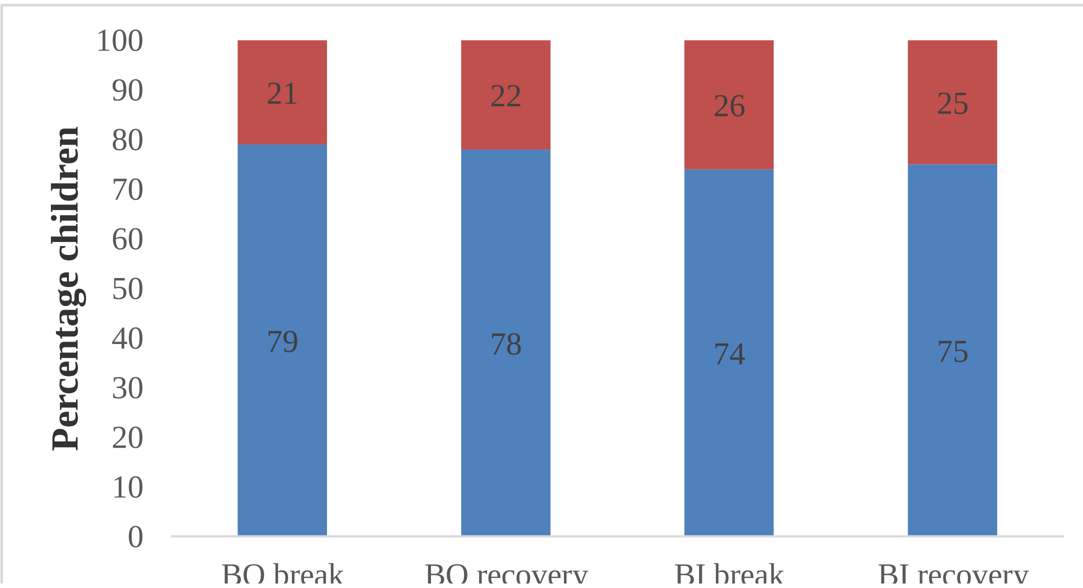

Figure 2: Distribution of normal and reduced near fusional vergence

Prevalence of vergence anomalies

The prevalence of vergence anomalies is presented in Table 3. Convergence insufficiency was the most common vergence anomalies in the study sample. Overall, there was a higher prevalence of convergence than divergence anomalies. Divergence excess and DI with prevalence less than one percent each were not included in further analysis.

Table 3: Prevalence of vergence anomalies

Vergence anomalies	Number of children (n)	Prevalence (%)
Convergence insufficiency		
▪ low suspect	51	9.6
▪ high suspect	31	5.8
▪ definite	22	4.1
Convergence excess	21	3.9
Fusional vergence dysfunction	14	2.6
Basic exophoria	9	1.7
Basic esophoria	15	2.8
Divergence insufficiency	4	0.8
Divergence excess	3	0.6

The prevalence of low suspect CI, high suspect CI, definite CI, CE, FVD, BS and BX by age, gender and school level are depicted in Table 4. The analysis showed that prevalence of these vergence anomalies were not significantly influenced by the sex of the study participants. Regarding age and vergence anomalies, only the prevalence of high suspect CI ($p < 0.01$) and definite CI ($p < 0.01$) was significantly associated with age with a higher prevalence in the older group. Likewise, only high suspect CI ($p = 0.01$) and definite CI ($p = 0.01$) were significantly associated with school level with the higher prevalence in secondary school children as expected due to the association already recorded with age (Table 4).

Table 4: Prevalence of vergence anomalies by age, gender and school level

	NVA (n = 377)	Low suspect CI (n = 51)		High suspect CI (n = 31)		Definite CI (n = 22)		CE (n = 21)		FVD (n = 14)		BS (n = 15)		BX (n = 9)	
	n (%)	n (%)	*P*	n (%)	*p*	n (%)	*p*	%	*p*			%	*p*	%	*p*
All children		51 (9.6)		31 (5.8)		22 (4.1)		21 (3.9)		14 (2.6)		15 (2.8)		9 (1.7)	
Age															
group 1 (10–12 years)	179 (47.5)	20 (8.9)	0.26	6 (2.2)	0.00*	4 (1.8)	0.00*	7 (3.1)	0.20	9 (4.0)	0.22	4 (1.8)	0.10	3 (1.3)	0.40
group 2 (13–16 years)	198 (52.5)	31 (10.0)		26 (8.4)		18 (5.8)		14 (4.1)		5 (1.6)		11 (3.5)		6 (1.9)	
Gender															
Male	177 (46.9)	24 (9.4)	0.98	16 (6.2)	0.61	10 (3.9)	0.89	13 (5.1)	0.18	8 (3.1)	0.45	6 (2.3)	0.49	4 (1.6)	0.88
Female	200 (53.1)	27 (9.8)		15 (5.3)		12 (4.3)		8 (2.8)		6 (2.2)		9 (3.2)		5 (1.8)	
School level															
primary (grades 5–6)	185 (49.1)	23 (9.9)	0.59	8 (3.4)	0.01*	5 (2.1)	0.01*	7 (3.0)	0.16	10 (4.3)	0.10	5 (2.1)	0.29	2 (0.9)	0.11
secondary (grades 7–11)	192 (50.9)	28 (9.3)		23 (7.7)		17 (5.7)		14 (4.7)		4 (1.3)		10 (3.3)		7 (2.3)	

P values in asterisks indicate statistical significance, NVA, no vergence anomalies; CI, convergence insufficiency; CE, convergence excess; FVD, fusional vergence dysfunction; BS, basic esophoria; BX, basic exophoria.

Comparison of group mean data of children with or without vergence anomalies

Table 5 compares the group mean data of clinical outcome measures between children with and those without vergence anomalies. For the CI, the analysis of variance showed that NPC (break and recovery) for high CI and definite CI (ANOVA, $F = 88.21$, $Fcrit = 2.62$, $p < 0.001$ and $F = 93.83$, $Fcrit = 2.62$, $p < 0.001$, respectively) including near exophoria (ANOVA, $F = 156$, $Fcrit = 2.62$, $p < 0.001$) for all the CI categories were significantly higher in the children with CI than those with no vergence anomalies (NVA). The mean PFV at near (break and recovery) were lower as the severity of CI increased (ANOVA, F=28, $Fcrit = 2.62$, $p < 0.001$) but only for high CI and definite CI ($p < 0.001$; for break and recovery). Similarly, monocular AA reduced significantly as the severity of the CI increased (F = 21.44, $Fcrit = 2.62$, $p < 0.001$). Post hoc p values for this group showed that NVA vs low CI = 0.04; NVA vs high CI is < 0.001; NVA vs definite CI is < 0.001. Binocular AA was significantly lower (F=27, $Fcrit = 2.62$, $p < 0.001$) only for high CI ($p < 0.001$) and definite CI ($p < 0.001$). The lag of accommodation increased (poorer accommodative response) but significantly only for definite CI (ANOVA, $F = 8.00$, F = 2.62, $p = 0.001$) (Table 5).

A two-sample *t*-test was used to compare group mean data of the clinical outcome measures of NVA group and vergence groups (CE, FVD, BX, BS) (Table 5). For CE, near esophoria ($p < 0.001$) and AC/A ratio ($p < 0.001$) were significantly higher in CE group compared to the NVA group, while, NFV break ($p < 0.001$) and recovery ($p < 0.001$) were significantly lower (poor performance) in the CE group. No significant change in both monocular ($p = 0.232$) and binocular ($p = 0.084$) AA was observed. However, AF (±2.00 D) decreased significantly ($p < 0.001$) for both monocular and binocular while lag of accommodation increased significantly ($p < 0.001$). Regarding FVD, PFV break ($p < 0.001$) and recovery ($p < 0.001$) as well as NFV break ($p < 0.001$) and recovery ($p < 0.001$) were significantly reduced for the FVD group. Binocular accommodative facility with ±2.00 D lens was also reduced ($p < 0.001$) (Table 5).

In BX, near exophoria was significantly higher than in the NVA group ($p = 0.04$), while both PFV break and recovery were significantly reduced; break ($p < 0.00$) and recovery ($p < 0.000$) (Table 5). Whereas, no significant change was observed for both monocular ($p = 0.618$) and binocular ($p = 0.284$) AA, lag of accommodation ($p = 0.008$) and monocular AF ($p < 0.001$) and binocular AF ($p < 0.001$) were significantly reduced in the BX group compared to the NVA group. Similarly, children with BS had higher mean values of near esophoria compared to the NVA group ($p < 0.001$) (Table 5). The mean values for NFV break and recovery were significantly reduced in the BS than NVA group ($p < 0.001$, in both variable). However, the group mean for AC/A ratio in children with BS was higher than in children with NVA. For accommodative variable, AF (±2.00 D) decreased significantly for both monocular ($p = 0.014$) and binocular ($p = 0.011$) while lag of accommodation increased significantly ($p < 0.001$) (Table 5).

Table 5: Descriptive statistics (mean, SD) for various vergence groups. Data are Mean ± SD.

	NVA	Low CI	High CI	Definite CI	CE	FVD	BX	BS
NPC (break)	6.0±3.4	5.0±1.3	10.6±3.7	15.2±5.3	4.6±1.0	9.3±5.9	8.0±7.5	6.0±5.4
NPC (recovery)	8.7±3.3	7.7±1.1	13.5±3.8	18.6±5.8	7.8±1.3	12.6±6.1	10.1±7.0	8.4±4.2
Stereoacuity	40.2±17.4	40.4±15.8	44.2±12.3	61.5±15.0	44.3±17.3	45.0±16.1	43.3±18.0	48.0±19.0
Distance exophoria	0.6±0.3	0.3±1.1	0.2±0.7	1.5±1.9	0.0±0.0	0.6±1.4	1.2±0.4	0.0±0.0
Near esophoria	0.1±0.4	0.0±0.0	0.0±0.1	0.0±0.0	5.9±3.4	0.7±1.1	0.0±0.0	2.3±1.3
Near exophoria	1.3±1.2	4.6±1.1	4.3±2.5	5.7±2.3	0.0±0.0	2.1±2.9	1.2±0.4	0.0±0.0
Difference, far & near	0.8±1.1	4.4±0.7	4.2±2.4	4.2±3.5	0.0±0.0	1.5±3.1	0.0±0.0	0.0±0.0
AC/A ratio	4.8±1.9	4.1±1.0	4.1±0.9	3.9±1.0	8.1±1.9	5.3±2.5	5.2±2.0	4.1±0.8
Vergence facility	15.8±3.2	12.3±2.8	10.2±3.2	8.8±2.9	15.3±3.2	8.4±2.7	9.3±2.0	10.1±3.7
Negative FV (break)	18.0±5.0	18.1±4.4	16.8±5.4	15.7±4.4	14.0±1.3	11.6±3.7	14.7±1.0	12.4±4.2
Negative FV (recovery)	13.3±4.5	13.1±3.2	12.7±4.1	11.5±4.0	8.0±5.4	7.3±3.3	9.3±2.0	9.1±3.6
Positive FV (break)	21.4±6.4	22.5±5.0	15.0±7.0	10.6±4.0	18.0±3.6	12.6±5.1	18.3±6.6	15.1±7.8
Positive FV (recovery)	15.6±5.3	16.6±4.5	9.8±5.6	6.5±4.0	13.1±4.4	8.1±4.4	12.7±5.3	10.1±5.6
monocular AA (right eye)	15.9±3.4	14.6±3.1	11.7±2.9	11.1±3.7	15.7±3.4	13.8±4.1	15.1±6.4	15.4±3.2
binocular AA	16.0±3.3	14.9±2.8	12.5±3.6	12.2±3.1	15.6±3.2	14.2±4.9	15.3±7.0	15.4±3.0
AR	0.4±0.2	0.3±0.2	0.5±0.3	0.7±0.4	1.1±0.4	0.24±2.7	-0.1±0.2	0.6±0.1
−2D Monocular AF	12.2±3.3	11.6±3.7	9.2±3.7	8.8±3.5	6.4±2.3	8.9±2.9	7.0±3.1	7.3±2.9
−2D Binocular AF	12.3±3.3	11.5±3.5	9.1±3.4	8.8±3.5	6.8±2.5	8.4±3.2	7.3±1.3	7.8±2.9
+2D Monocular AF	11.8±4.1	12.0±3.9	10.5±3.0	9.5±3.5	9.4±4.0	8.7±4.1	7.4±1.3	9.3±3.3
+2D Binocular AF	12.3±4.2	11.9±4.4	10.3±4.3	9.8±3.6	9.0±4.4	8.8±4.1	7.9±1.6	9.2±3.5
±2D Monocular AF	9.1±3.3	10.1±1.8	9.0±3.4	7.7±3.6	8.7±2.5	8.1±3.1	5.3±1.3	7.7±1.8
±2D Binocular AF	9.4±3.0	9.9±1.5	8.9±3.0	8.1±4.	8.9±3.4	6.5±2.3	5.3±1.3	8.8±1.9

NVA, no vergence anomalies; CI, convergence insufficiency; CE, convergence excess; FVD, fusional vergence dysfunction; BS, basic esophoria; BX, basic exophoria; NPC, near point of convergence; AA, amplitude accommodation; FV, fusional vergence; AR, accommodative response; AF, accommodative facility;

DISCUSSION

The findings of the present study showed that specific clinical vergence parameters differ considerably between children without any vergence anomalies and those that have vergence anomalies. Convergence insufficiency is the most common vergence anomalies among the study population. The distribution of high suspect CI and definite CI varied significantly by age groups and as expected therefore with study level.

The prevalence estimates for low CI (9.6%) in the present study was higher compared to the 5.6% reported by Junghans et al[10] but lower than the 11.8% reported by Wajuihian & Hansraj.[11] The estimate for clinically significant CI (minimum of 2 clinical signs) of 9.9% in the present study is consistent with the report of school-based studies in South Korea,[13] Australia,[20] South Africa,[11] that applied similar criteria. However, the value is lower than some studies[15–18] and higher than other studies[12,19] on school samples that also utilized similar criteria. Differences across studies in the reported prevalence of CI: (*i*) may be due to variability in the number of clinical signs and cut-off thresholds applied to define CI in these studies, as CI does not have a standardized diagnostic criterion; or (*ii*) may emerge from methodological differences across the studies. Methodological differences include: (*i*) the use of small sample sizes;[12,15,16,21] (*ii*) exclusion of children with RE and poor visual acuity;[15,16] (*iii*) the use of convenience sampling method;[12,15–18] and (*iv*) reporting for only symptomatic CI.[19,21] Furthermore, the remarkably high prevalence of CI (31.4%) reported by Davis, et al[17] on Native American children may not completely be explained by the diagnostic criteria and methodological differences indicating that there may be an influence of race and ethnicity on CI prevalence.

Our finding for CE of 3.9% is lower when compared to the 5.0% and 5.6% reported by Wajuihian & Hansraj[11] and Marran, et al.,[16] respectively. The study by Wajuihian & Hansraj[11] was conducted on high school children (13 – 19 years) that are exposed to more near work activities than the participants in the present study (10 – 16 years), consisting of primary and secondary school children, while the study by Marran, et al.[16] was carried out on limited sample size. In their study, Wajuihian & Hansraj[11] observed a higher proportion of younger high school participants with near esophoria and attributed such to increase near work activities. Earlier study in Benin city, Nigeria[12] had indicated that the prevalence of CE was 2.8% (6 of 212). Although the previous study in Nigeria[12] provided an insight on binocular vision anomalies in Nigerian students, the relatively small sample size and the convenience sampling method limit generalization of the study findings.

As previously reported by a school-based study in Ghana[19] the estimate for DE and DI were found to be 0.8% and 0.6%, respectively. The prevalence of BS of 2.8% in the present study was also comparable to the 3.1% observed by Porcar & Martinez-Palmoera[23] and 2.1% by Hopkins, et al.[20] in Australian indigenous children. However, 5.1% was observed by Paniccia & Ayala.[22] Similarly, the prevalence of BX of 1.7% in the present study is comparable to another study on an African population[19] while Paniccia & Ayala[22] reported 3.5% in a clinic sample in Puerto Rico which may have been exposed to biased data. About 2.6% children were also found to have FVD in the present study. This finding is lower than 4.7% in Australia[23] on children aged between 13 and 19 years but higher than 0.8% in Ghana on children aged 12 and 17 years. The obvious reason for the differences in findings between these studies may be due to number of clinical signs and cut-off values applied to define FVD in these studies. Overall, the prevalence of DI, DE, BS, BX and FVD are sparse in the literature[18] which suggest that these anomalies have not been extensively evaluated, probably because they are less prevalent than CI and CE.[1,25] Using the single sign criteria of receded NPC break point (≥ 7.5 cm) to classify CI, the 19.1% observed by the present study is higher compared to the 11% (defined as 7.5 cm) reported by Junghans et al.[10] and 6.2% (≥7.5 cm) by Rouse et al..[24] The disparity in the estimated values may be related to the NPC measuring technique. Target type and size as well as measuring point and speed affect NPC results.[20] In the present study, the NPC was measured using RAF rule which has been reported to yield higher NPC break values than other techniques.[11]

Another important point of note is the significant variation in the mean data of some clinical measures between children with no vergence anomalies and those with specific type of vergence anomalies such as the CI categories. Near exophoria significantly differed between the NVA group and the CI categories. The NPC break and fusional vergence were found to be significantly remote with increased severity of CI when compared with the NVA group. To the contrary, these differences were not significant between the various CI categories, which may suggest that all the clinical signs need to be thoroughly evaluated to sufficiently classify clinically significant CI. For instance, 17.1% of the children had considerable amount of near exophoria that can create symptoms of diplopia. Interestingly, over two-thirds of the children had adequate fusional reserves to maintain single binocular vision. Previous studies[12,18] have also found that vergence anomalies occur more frequently as a syndrome of clinical signs. However, for symptomatic patients whose evaluation indicate that other binocular vision parameters are normal, a single criterion may be useful in the diagnosis of vergence anomalies.[11]

There was no association found between gender and various vergence anomalies, which is in agreement with the available data.[11,15,14,18] Regarding age and school level, only CI was associated with older age and secondary school children, as also reported by Scheiman, et al.[25] and Hussaindeen, et al.[18] with participants from both primary and secondary schools. However, low suspect CI was not associated with either age or school level. Near work-induced changes in visual functions are expected to be significant around age 12, when children transition from primary to secondary school due to heavier loads of near work activities .[1,3,10] Advances in technology have also increased the complexity of the near work activity. Many children nowadays use display terminals for computer-aided instructions and smartphones which place greater demand on their visual abilities. This may in part account for the significant difference in the distribution of high suspect and definite CI with age and school level as reported in this study. It is also possible that low CI in primary school could deteriorate to high suspect or definite CI during high school years due to increases in intensity and duration of near visual tasks. In addition, genetic factors can affect population parameters for various ocular characteristics and disease conditions in any given area, and thus, influence the prevalence and distribution of such visual conditions.[29,30] Nonetheless, the differences in prevalence and distribution of vergence anomalies as observed in this study and others could be expected for a visual condition that is characterized by a set of associated clinical signs with no clearly defined aetiological mechanism and diagnostic criteria. The development of a standardised study protocol with common definition, measuring technique and diagnostic criteria for binocular vision anomalies would help to identify the factors responsible for the variations in findings.

A potential strength of this study is the use of adequate sample size, and selection of participants using appropriate sampling method. Validated and reliable instruments were also applied in data collection with only one examiner conducting all the vision tests. The study included students from both primary and secondary schools which represents the learning experience and visual characteristics of these two levels of educations. The study was designed based on a protocol that had already been used by recent studies.[11–20] However, cycloplegic refraction was not performed because, it would have affected the near vision test which was the focus of this study. Another possible limitation is that, to guarantee high participation rate, all vision testing was performed in test stations set-up in each school, instead of at an optometry clinic which may have provided better test environment. Nevertheless, testing conditions were standardized at each test stations in all the schools.

CONCLUSION

The results of this study demonstrate that vergence anomalies are common vision conditions among school children in Abia State. The study adds to the existing literature on visual problems in school children in Abia State and Nigeria and highlights the significance of screening for non-strabismic binocular disorders. In addition, the findings have shown that traditional vision screening programs with focus on distance visual acuity may not be able to detect a significant number of important visual anomalies which may adversely affect learning and academic achievements. Therefore, the development of a comprehensive paediatric vision screening strategy targeting those conditions that are more common in school children is recommended.

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CHAPTER SEVEN

TOWARDS THE DEVELOPMENT OF A UNIFORM AND BROAD SCREENING STRATEGY: ASSESSMENT OF THE PAEDIATRIC VISION SCREENING INITIATIVES OF OPTOMETRISTS IN ABIA STATE, NIGERIA

ABSTRACT

Purpose: To evaluate the coverage, components and referral criteria of the paediatric vision screening programs in Abia State, towards the development of a common screening guideline. A systematic and coordinated screening strategy will ensure adequate coverage, uniformity of service provisions and full utilization of the services offered through the child eye health system.

Methods: Eighty-three registered optometrists practicing in Abia State for at least one year before the study were invited to participate. A self-administered questionnaire was distributed to the optometrists by hand or via email. The questionnaire covered areas such as the participation of optometrists in paediatric vision screening, coverage of the screening programs, screening tools and referral criteria.

Results: Data was analysed for 64 participants that returned their questionnaires giving a response rate of 77.1%. Twenty-eight (43.8%) of the respondents reported to have provided at least one vision screening outside their practice that included children as participants in the last one year before the survey. Among this number: 20 are from the private sector, 20 are based in urban cities of Aba and Umuahia and only 10 have provided paediatric vision screening service more than four times within this period. Visual acuity measurement and ocular health assessment (penlight and ophthalmoscopy) were the main components of the screening batteries of optometrists. While a child with any disease abnormality was referred for evaluation, the referral criteria for a full examination were inconsistent.

Conclusion: The existing paediatric screening programs in Abia State are inadequate, irregular and limited in range. For the few conditions that are screened, varied referral criteria were used in the diagnosis of vision problems. It appears the current screening programs are not meeting the visual needs of the paediatric population. A new strategy may be required to improve the coverage and efficiency of paediatric vision screening in Abia State.

Key words: paediatric vision screening, vision problems, screening coverage, test batteries, referral criteria and Abia State, Nigeria.

INTRODUCTION

Vision screening of children is an invaluable approach, for early detection of potential visual disorders that may impact negatively on the educational, social and psychological development of children. Although screening should not be an alternative to a comprehensive examination, it provides a means for identifying problems in affected children or those who may be predisposed to having specific visual disorders in order to refer them for further evaluation. It is important to identify ocular disorders during the early critical stage of development, as this can allow for proper assessment and effective treatment of vision threatening conditions and is by far preferable to a comprehensive examination after the condition has deteriorated to obvious visual impairment or blindness.[1,2]

Over the past decades screening programs and test batteries have evolved to detect several remediable visual conditions in children. The traditional test battery which consists of only the Snellen visual acuity (VA) test is focused on detecting children with reduced distance VA and have the possibility of missing several other important basic visual skills.[3–5] Consequently, the modified clinical technique (MCT), the New York State Optometric Association (NYSOA) test battery and the computerized vision efficiency rating (known as VERA) screening battery were designed to detect a wider range of learning related vision problems.[5–7] Furthermore, the need to address the inequalities in eye care delivery and enhance the effectiveness of paediatric vision screening programs prompted most countries to promulgate laws and policies that have improved the coverage and participation of vision screening in their domains. In the US, vision and hearing screenings is integrated in every well-child check-up and school health programs.[5] In Canada, Sweden, Australia and United Kingdom, it is recommended that children receive numerous vision screenings before schooling begins and subsequent periodic screenings during the school years. These policy statements have improved the delivery of vision screening programs as reflected by the number of children who are receiving vision screening, as well as, the significant reduction in the prevalence of paediatric vision conditions in these countries.[8–11]

Nigeria is the most populous country in sub-Saharan Africa with an estimated population of about 184 million in 2018. Abia State which is in the southeast geopolitical zone contributes 2.03% of this population.[12] Eye care services are delivered in public and private health facilities by ophthalmologists, optometrists, ophthalmic nurses and dispensing opticians.[13] However, there is inadequate and uneven distribution of facilities and manpower for eye care delivery services in Nigeria.[13,14,15] A review of paediatric eye care in Nigeria by Adio and Komolafe[14] found that there were only 400 ophthalmologists in Nigeria (including those in training) with only 12 of them specializing in paediatric ophthalmology. Similarly, a situational analysis of optometry in Africa[15] indicates that there are approximately 4000 optometrists in Nigeria. In addition, the development of subspecialty in paediatric optometry is relatively new.[16] The reviews[14,15] also highlight the uneven distribution of eye care practitioners. Among the ophthalmologists in Nigeria, 95 – 99% were practising in urban areas and state capitals[14] and according to IABP,[15] 60% of optometrists in Africa are working in their various country capitals and in private settings. Regarding facilities, primary and secondary eye care facilities are not available in some states and where it is provided, it is grossly inadequate and unevenly distributed.[14] For instance, in Abia State, the few eye care (primary, secondary and tertiary) facilities are in the cosmopolitan cities of Aba and Umuahia. In addition, school eye health has not received adequate attention from the government. The unavailability and inaccessibility of eye care services to many children warrants the need for regular screening programs especially in the underserviced and under-resourced rural areas of Abia State and Nigeria as a whole.

Currently, vision screening programs in Abia State and Nigeria are mainly organised by individual eye care practitioners including optometrists. Such screening programs lack strategic coordination and are mainly for economic reasons and rarely focus on the paediatric population. Consequently, some prevailing visual conditions such as near vision anomalies not affecting VA are constantly overlooked. Given the already established association between visual status and school performance,[17–21] it is important to have a common and broad screening strategy with valid, reliable, age appropriate test batteries and an adequate referral system. However, no standard vision screening protocol or guidelines were found for school children in Nigeria and particularly in Abia State.[13,14,16] The purpose of this study was to evaluate the vision screening service provisions to school-age children in Abia State by individual optometrists. The findings are expected to direct the development of a common and broad paediatric vision screening strategy.

METHODS

Participants

All registered optometrists currently practising in public and private eye care facilities in Abia State were invited to participate in this study. The public health facilities comprised a state owned Abia State University Teaching Hospital (ABSUTH), a Federal Medical Centre, secondary health facilities and primary health care (PHC) centres across the state.[22] According to the secretariat of the Nigerian Optometric Association (NOA), Abia State chapter, the total number of registered optometrists in the State was about 110. Optometrists were contacted either by email, telephone or visitation during the bimonthly meeting of NOA Abia State chapter and at their individual offices to participate in the study. A follow-up, contacts were made via phone calls and visitations at their various offices, in addition to the initial contact.

Ethical considerations

Approval for the research protocol was obtained from the College of Medicine Health Research and Ethics Committee, University of Nigeria, Enugu Campus and the Biomedical Research Ethics Committee of the University of KwaZulu-Natal, Durban, South Africa. Permission was also obtained from the Nigerian Optometric Association (NOA) Abia State chapter before the distribution of questionnaires to various optometrists and participants who were required to give their consent. The study adhered to the tenets of the Declaration of Helsinki regarding research involving humans.

Procedures

A vision screening questionnaire[23] comprising of mainly open format questions was distributed to registered optometrists in Abia State.

The self-administered questionnaire was distributed to registered optometrists by hand or email and the principal investigator was available to provide further clarifications on any of the questions. The participants were given time to complete and return the questionnaires at their convenience and none of them were obligated to participate in the survey. Returned questionnaires were included in the analysis if they were completed by registered optometrists currently practising in Abia State in the last one year before the study and excluded if the optometrist had participated in the initial pilot exercise. The questionnaire covered areas such as the participation of the optometrist on paediatric vision screening, location of the screenings, the age of children being screened, tests performed and referral criteria. Information on the number of children seen by the optometrist in their practice who were referred from a screening program and the reason for referral were also included in the questionnaire.

Statistical analysis

Data were entered into a Microsoft Excel database and data cleaning and consistency checks were conducted by the principal investigator. Analysis of data were performed, and results were presented in frequency tables and figures.

RESULTS

Respondents' characteristics

Out of a total of 83 registered optometrists that were contacted for the survey, 64 responded, giving a response rate of 77.1%. The distribution of participants organized by practice location and sector (public or private) are presented in Table 1. Approximately 87.5% were from the two cosmopolitan cities of Aba and Umuahia and71.9% were from private eye care facilities across the state.

Table 1: Respondents demographics by practice location and setting as well as optometrists that have participated in at least one vision screening in the last one year

Practice location/sector	Number of responses		Optometrists involved in screening	
	N	**%**	**N**	**%**
Location				
• Aba	20	31.3	8	40.0
• Umuahia	36	56.3	12	33.3
• Other	8	12.5	8	100.0
Sector				
• Public	14	21.9	7	50.0
• Private	46	71.9	20	43.5
• Both	4	6.3	1	25.0

Vision screening delivery and coverage

Twenty-eight (43.8%) participants reported to have provided at least one vision screening outside their practice that included children as participants in the last one year before the survey. Among this number, 20 (71.4%) are from the private sector and 20 (71.4%) are based in either Umuahia or Aba (Table 1). Table 2 shows the various centres where the screening exercises were conducted. The majority (57.1%) of the optometrists involved in screening exercises have provided vision screening in a school setting. However, the frequency of the vision screening service delivery was low. In the last one year prior to the study 10 (35.7%) of these optometrists have been involved in not more than two paediatric vision screening exercises, another 10 (35.7%) have provided vision screening service more than four times, while 6 (21.4%) have been involved in three screening exercises.

Analysis of the responses of the optometrists' participation in vision screening of school children also show that among those participants, 4 (14.3%) were involved in screening organised by themselves, 3 (10.7%) were involved in the one organised by schools, 9 (32.1%) were involved by screening organised by non-governmental organisations (NGO) and one optometrist each participated in the screening exercise organised by government and politicians, respectively. Furthermore, participants were asked to provide additional information on vision screening services provided to school-age children in their areas. One respondent reported that school vision screening services are mainly done by private practitioners (optometrists) who want to create awareness and improve their clientele base. In other instances, it is carried out by residents in optometry or ophthalmology who are collecting data for a research study. On the other hand, vision screening exercises that are carried out by NGOs and politicians as a social responsibility across communities also include school children as patients.

As a way of improving the coverage of paediatric vision screening, one respondent suggested that vision screening should be legislated and become a policy, just like the National Programme on Immunization. Another suggested that teachers and parents need to be given basic knowledge in eye care to help in early detection of children with oculovisual problems. There is also a call for improvement in the delivery of PHC by getting more optometrists and other eye care practitioners involved.

Table 2: Number of optometrists who performed vision screening in various screening centres

Screening centres	**Number of optometrists**	**Percentage (%) (n = 28)**
School	16	57.1
Community	8	28.6
Religious places	6	21.4
Others	2	7.1%

Note: The total number of responses by optometrists for the screening centres (n = 32) is more than the number of optometrists who have participated in at least one vision screening (n = 28) in the last one year before the study because some optometrists have participated in more than one screening sites.

Components (test batteries) of vision screening programs

The screening tools included in the test batteries of the optometrists that have provided at least one vision screening program in the last one year prior to the study are presented in Table 3. The analysis of the responses showed that VA and ocular health (penlight and ophthalmoscopy) assessment procedures were the major components of the screening battery of optometrists. We also asked respondents to provide further information on their screening batteries. One respondent reported that because of the large number of patients, eye examinations are done using the problem-oriented approach and that tests like retinoscopy, stereopsis, colour vision are not carried out. Participants that need such examinations are usually referred to a clinic where such examinations are carried out.

Table 3: Number of optometrists that performed specific vision tests in paediatric vision screenings

Screening tools	Optometrists n = 28	%
Visual acuity/refractive status		
• Distance visual acuity	28	100
• Near visual acuity	20	71.4
• Hyperopia (plus lens test)	0	0
• Refraction (retinoscopy/autorefraction)	4	14.2
Binocular vision test		
• Strabismus (cover test/Hirschberg test)	10	35.7
• Ocular motility	4	14.3
• Near point of convergence	0	0
• Phoria measurement	0	0
• Stereoacuity	0	0
Accommodative amplitude	0	0
Colour vision test	0	0
Ocular health		
• External (Penlight) examination	28	100
• Ophthalmoscopy	20	71.4
• Other	0	0

Referral criteria

The referral criteria adopted by individual optometrists for each of the tests that are included in a screening battery are presented in Table 4. Only screening tests (visual acuity, cover test, ocular motility and ocular health) which are reported in Table 3 are presented here. The result shows no definitive criteria for the test batteries.

Table 4: Referral criteria applied by optometrists for various test protocols.

Test batteries	Criteria	Optometrists n = 28	%
Visual acuity/refractive status			
• Distance visual acuity	<6/6	21	75
	<6/9	7	25
• Near visual acuity	$< N_6$	20	71.4
Binocular vision test			
• Strabismus (cover test/Hirschberg test)	Not reported	0	0
• Ocular motility	Not reported	0	0
Ocular health			
• External (Penlight) examination	Any abnormality	28	100
• Ophthalmoscopy	Any abnormality	20	71.4

Other responses (Follow-up and referral from a vision screening program)

Furthermore, we analyse responses for children (6 – 18 years) seen by the optometrists in their various practices who were referred for comprehensive evaluation and treatment from a vision screening program in the last one month. Of the 61 optometrists that responded to the question 18 (29.5%) had seen at least one child in their clinic who was referred from a vision screening program. Among these optometrists, 16 (88.9%) reported that the children were referred from vision screening conducted by optometrists while 2 (11.1%) did not know who referred the children. None of the respondents reported to having seen children referred by ophthalmologists or nurses. Forty percent of the optometrists reported that the children who presented to their clinic from a vision screening program were mostly from primary school (Figure 1). The reasons for the referrals of the children seen by optometrists in their clinics are presented in Table 5.

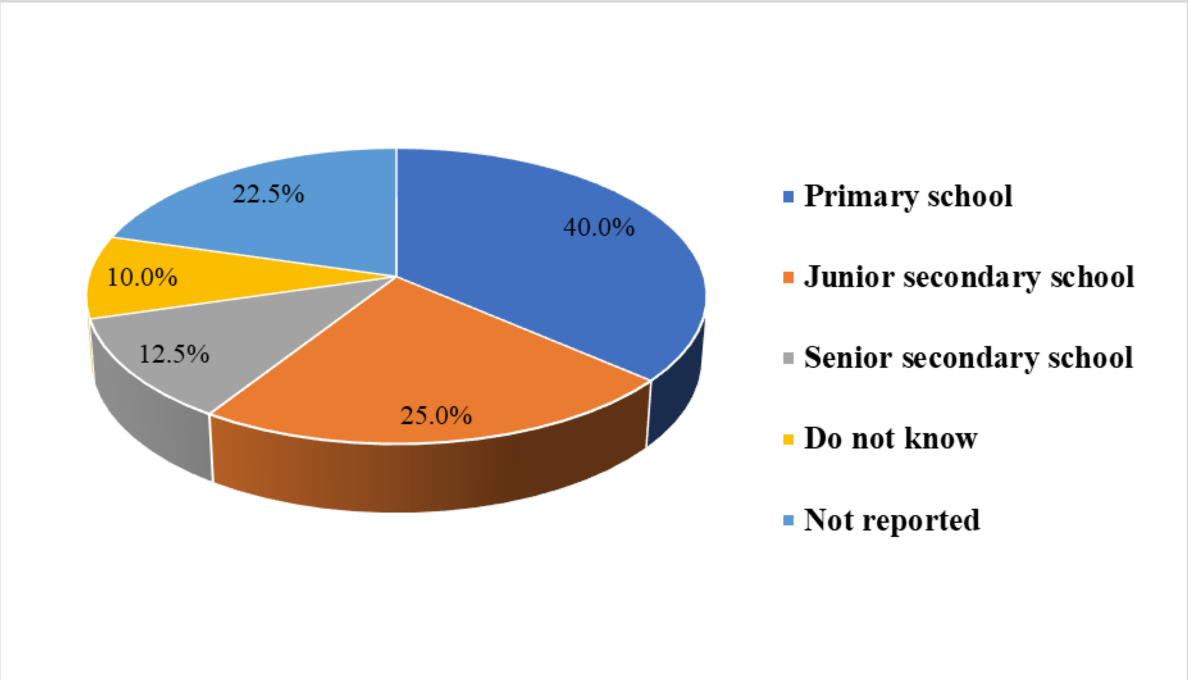

Figure 1: Level of education of children seen by optometrists in their clinics who were referred for complete evaluation from a vision screening program in the last one month.

Table 5: Reasons for referral of children seen in optometric clinics from vision screening programs

Reasons for referral	Number of optometrists
Distance visual acuity	17
Near visual acuity	8
Tropia/phoria	5
Pathology	8
Others	0

Note: The total number of responses by optometrists for reasons for referral (n = 38) is greater than the number of optometrists who have attended to children referred for comprehensive evaluation from a vision screening program in the last one month (n = 18) in the last one year before the study, because some optometrists reported for more than one reason.

DISCUSSION

In this study, the coverage, components and referral criteria of paediatric vision screening programs in Abia State by optometrists is evaluated. The findings indicate that the provision of paediatric vision screening is irregular and only a small number of children may be receiving vision screening services from the current system. Visual acuity measurement and ocular health assessment (penlight and ophthalmoscopy) were the main components of the screening batteries of optometrists. While a child with any ocular disease was referred for a comprehensive evaluation, the referral criteria for a full examination were inconsistent.

Current situation of child eye care in Abia State

In agreement with available reports[14,15] on the disparity between the distribution of eye care facility and manpower between rural and urban areas and between public and private facilities, 87.5% of the respondents in the present study are practising in the metropolitan cities of Umuahia and Aba and 71.9% of the respondents are working in the private eye care facilities. Abia State like other States in Nigeria follows the national health care delivery system which includes the provision of primary, secondary and tertiary health care services. Although, there are about 501 primary health care (PHC) centres across the state,[22] primary eye care services are provided in only two and they are located in the cosmopolitan cities of Aba and Umuahia. The secondary and tertiary public eye health facilities including the State owned Abia State University Teaching Hospital (ABSUTH) and the Specialist Hospital in Umuahia, as well as, the Federal Medical centre in Umuahia are also in the urban cities. With less than one percent of the public health institutions having an eye care unit, eye care services are provided mainly by private health institutions. The location of private eye care facilities in the urban centres is not surprising given that the private eye clinics operate on a commercial basis as urban cities offer them economic advantages over the rural communities. The consequences of this scenario are that eye care services are unavailable and unaffordable to many children especially those living in rural communities. Therefore, there is need to provide more eye care services to the residents.

Provision and coverage of vision screening programs

Regarding provision of vision screening, a smaller proportion of the respondents (43.8%) had participated in one or more vision screening that included paediatric population in the last one year before this study. Although the vision screening programs were conducted in both rural and urban areas, considering the number of optometrists involved (Table 1), the frequency of participation and the population of children in Abia State, it is possible that not all school-age children are screened by optometrists in Abia State. In addition, the focus of some of the screening programs was not on the paediatric population.

As suggested by some respondents, more eye care practitioners need to be involved in vision screening and screening should be delivered in several locations across the state, especially in rural areas. However, given the population of Nigeria and the number of registered optometrists and ophthalmologists, the ratio of the people per one optometrist and/or ophthalmologist in Nigeria is expected to be far below the recommended benchmark. As at 2010, one optometrist was needed for every 100,000 people and by 2020 the ratio would be 50,000 people per one optometrist.[25] Interestingly, adequately trained non-ophthalmic practitioners can competently screen children and refer those who fail screening tests for professional eye examination.[9] Integrating adequately trained community health nurses in paediatric vision screening, in addition to having functional eye units in the various PHC centers will help to increase the number of screeners and improve coverage of vision screening in Abia State. Since the community health nurses are part of the work force at PHCs in Abia State including rural areas, they will complement the efforts of optometrists by providing screening services to underserviced communities while promptly referring children that fail screening tests to relevant eye care personnel.

Another important point of note is that the current vision screening programs are mainly organised by individual eye care practitioners (Table 1). Such programs lack strategic coordination and are aimed at increasing the clientele base of the individual involved and it is often not frequent. Overall, there are no guidelines and the policy statement on when, how and on who to conduct a vision screening in Abia State and Nigeria. Implementation of policies that are able to coordinate and guide service provision can address the disparities in healthcare delivery.[26] In Sweden, it is recommended that children receive numerous vision screenings before school entry. By this policy, children are expected to have undergone six vision screenings before the age of four and subsequently two more screenings during primary school according to recommended guidelines. With the series of vision screenings, a greater proportion (99%) of four-year-old children have received one or more vision screening services which resulted in a significant decrease in the prevalence of amblyopia from 2.0% in 1970 to 0.2% in 1992,[9,27] In British Columbia, Canada, a province-wide vision screening was established to detect vision problems in children, not more than six years of age using uniform guidelines and criteria. An appraisal of the screening program over a four-year period revealed that the program reached over 35,000 kindergarten children annually, which is equivalent to roughly 9 out of 10 enrolled students.[11] In Australia, Queensland health authorities recommend that all children be screened for reduced VA and strabismus at age 4 – 5 years, as well as receive up to seven vision screenings between the ages of 0 – 3.5 years by the child health nurse.[8] A law was also passed in the state of Kentucky in the United States of America in the year 2000 requiring every child who is between 3 – 6 years to have a vision assessment by an eye care practitioner prior to entering public school. Overall, paediatric vision screening is part of the regular assessment of every child health visit and school health programs in the US,[5] because it affords the opportunity of wider vision screening coverage.

Vision screening protocols

The findings of this study indicate that VA (100%), penlight assessment (100%) and ophthalmoscopy (71.4%) were the main test batteries included in the paediatric vision screening programs conducted by individual optometrists in Abia State. Only few optometrists performed retinoscopy (14.2%) ocular motility evaluation (14.3%) and a cover test (35.7%) examination and test batteries such as plus lens test (for latent hyperopia), convergence point at near, accommodation amplitude, phoria measurements and colour vision test were not included in any previous screening protocols (Table 3). The use of a problem-oriented approach in vision screening as reported by one respondent defeats the purpose of paediatric vision screening, which is to detect problems in children who have or probably are at risk of developing specific visual disorders and to refer them for further evaluation and treatment.[1,2] Many children with critical vision problems that are not aware of their condition are likely to be missed.

As part of the present study, we assessed visual conditions in school children in Abia State and found that vergence and accommodative anomalies were common visual conditions. These findings have been discussed elsewhere. Regarding refractive error we found that low categories of hyperopia and astigmatism were more prevalent compared to other categories. Atowa, et al.[13] also found a higher prevalence of mostly low degree refractive errors in school children in Aba, Abia State. With refractive error (RE), visual discomfort is more common in children with low degrees of hyperopia and astigmatism because of excessive use of accommodation to maintain normal vision.[28,29] Other studies in Nigeria have also reported a considerable proportion of children having vergence and/or accommodative anomalies. Ovenseri-Ogbomo and Ovigwe[16] reported a prevalence of previously undiagnosed vergence dysfunction of 12.7% in a sample of first year students in Benin City, while Ihekaire and Anyanwu[30] reported that 44.5% of the children in their study sample had symptoms of accommodative vergence anomalies and 75% had problems with ocular motility. Studies show that vergence and accommodative disorders can impair reading efficiency and school performance and overall development of a child.[17–21,31] In view of these findings, it is highly possible that the tests included in paediatric vision screenings programs by optometrists are not meeting the most important visual needs of children in Abia State.

Although screening batteries that can detect a broader range of learning related vision problems are available, the VA chart has continued to dominate the paediatric vision screening battery of optometrists in Abia State and Nigeria (Table 3). A summary of the documented screening batteries including a comparison of the sensitivity and specificity of the protocols with their complete test batteries and with only VA measurement is depicted in Table 6.

Table 6: Sensitivity and specificity of different screening protocols

Screening protocol	**Vision problems screened**	**Completion time per child**	**Screening personnel**	**With complete protocol**		**With only visual acuity**	
				Sensitivity (%)	**Specificity (%)**	**Sensitivity (%)**	**Specificity (%)**
Orinda MCT[6]	Reduced visual acuity (VA), refractive error, strabismus and ocular pathology	5 – 6 minutes	Optometrists or ophthalmologists	96	98	27	99
Portsea MCT[1]	Orinda MCT protocols, fusional vergence ranges, accommodative facility, ocular motility, stereopsis, colour vision test	5 – 6 minutes	Optometrist or ophthalmologists	Not reported	Not reported	Not reported	Not reported
NYOSA screening battery[34]	Distance and near VA, hyperopia, convergence, fusion, stereopsis, saccadic skills, visual motor integration and colour vision	15 minutes	Trained parent volunteer	72	65	25	Not reported
Visual Efficiency Rating (VERA)[7]	NYOSA test protocols plus binocular vision, accommodative and ocular motor disorders	12 – 15 minutes	Nurses	45	83	Not reported	Not reported
VERA (with Convergence insufficiency symptom survey)[7]				65	100		

Referral criteria and follow-up

Among the 28 optometrists who performed distance VA testing in vision screening, 75% considered VA of less than 6/6 as criterion for referral, whereas 25% considered VA of less than 6/9 as the criterion for referral (Table 4). The difference in referral criteria is expected considering that there are no vision screening guidelines in Abia State and Nigeria. However, when deciding on the optimum VA expected of a child consideration should be given to the age. The mean VA in 6-year-old children was estimated to be 6/7.5[35] and studies[35,36] show that the mean VA in children differs by one line between 6-year-old and 12-year-old children. Based on this finding, the screening criterion for distance VA (< 6/6) adopted by most optometrists will likely result in many false positives referrals for younger participants. A retrospective analysis of referral accuracy of paediatric vision screening in New Zealand reflected a poor positive predictive value which was related to the poor specificity of the screening test and the acuity criteria applied, as many children with normal vision failed screening with the cut-off criterion of uncorrected VA worse than 6/9. However, modelling of data suggests an acuity of less than 6/12 would have provided a more appropriate referral criterion.[37]

The Orinda study and its modified clinical technique applied a VA referral benchmark of 6/12 or worse for primary school children with good positive (0.90) and negative (0.99) predictive values.[1,6] In addition, several paediatric vision screening programs have utilized a VA criteria of at least two line or more difference between the two eyes.[38,39] It is important to note that for children with a VA of 6/6 who present with visual symptoms, it would be advisable to perform cycloplegic refractions because significant hyperopia may be found in children with good accommodative ability and normal VA.[28,29] From the available data, it may be inferred that a VA of 6/12 or worse for younger children, and 6/9 or worse for the older children, or a two line or more difference between the two eyes, may be acceptable VA referral criterion for children, whereas those with normal VA but symptomatic would be referred for cycloplegic refraction. Regarding the follow-up of those referred for complete examination, it would be difficult to establish the rate of referral of screening initiatives where there are no proper documents and uniform guidelines. However, the findings of the present study show that the main reason for referral for those children who presented for complete evaluation at an optometric clinic was reduced distance VA. This may not necessarily imply that reduced VA was the main problem among the children screened but that the VA test was the major component of the screening batteries of optometrists in Abia State as shown in Table 3.

The findings of the present study demonstrate strict adherence to research protocol and eligibility criteria. Respondents were recruited from both public and private eye care facilities as well as from rural and urban areas. In addition, data were collected using a validated questionnaire consisting of both open and closed format questions, which ensured that participants had the freedom to provide a wide range of responses. However, there may be error of memory recall bias in the estimation of the frequency of respondent's participation in vision screening, number of children being screened including the components of screening batteries over a one-year period, especially for vision screening programs where the participants are not directly involved in the organisation. Considering that there are no uniform guidelines, these factors may vary depending on the focus of the vision screening and the screening centres. An on-going evaluation through the development of uniform guidelines and proper documentation of vision screening data may provide a better assessment of paediatric vision screening in Abia State in the future.

In summary, the existing screening programs in Abia State are irregular and unevenly distributed and are mainly focused on the detection of reduced distance VA and pathological problems. The implication is that many children with common paediatric eye conditions including those that have been linked to reduced academic achievements are not routinely screened. For the few conditions that are screened, dissimilar referral criteria were applied in classifying participants as having vision problems and no systematic follow-up process was in place, to ensure that those identified as having problems are receiving the recommended comprehensive evaluation. Overall, it appears the current screening programs are not meeting the visual needs of the paediatric population indicating that a new strategy is required to increase the coverage and effectiveness of paediatric vision screening in Abia State. Thus, a coordinated and broad screening strategy with the goal of improving service provision as well as to detect a wide range of vision problems is recommended.

VISION SCREENING MODEL

Based on the findings of the present study we proposed a paediatric vision screening model that will ensure a coordinated approach which will enhance performance and target vision conditions common in children. The objectives of this model include: (i) access to vision screening services to many children across the state through public-private sector partnership (ii) utilization of uniform screening guidelines and referral criteria throughout the state (iii) follow-up on all referrals where evaluation and/or treatment is recommended (iv) maintain vision records on children and document vision screening activities.

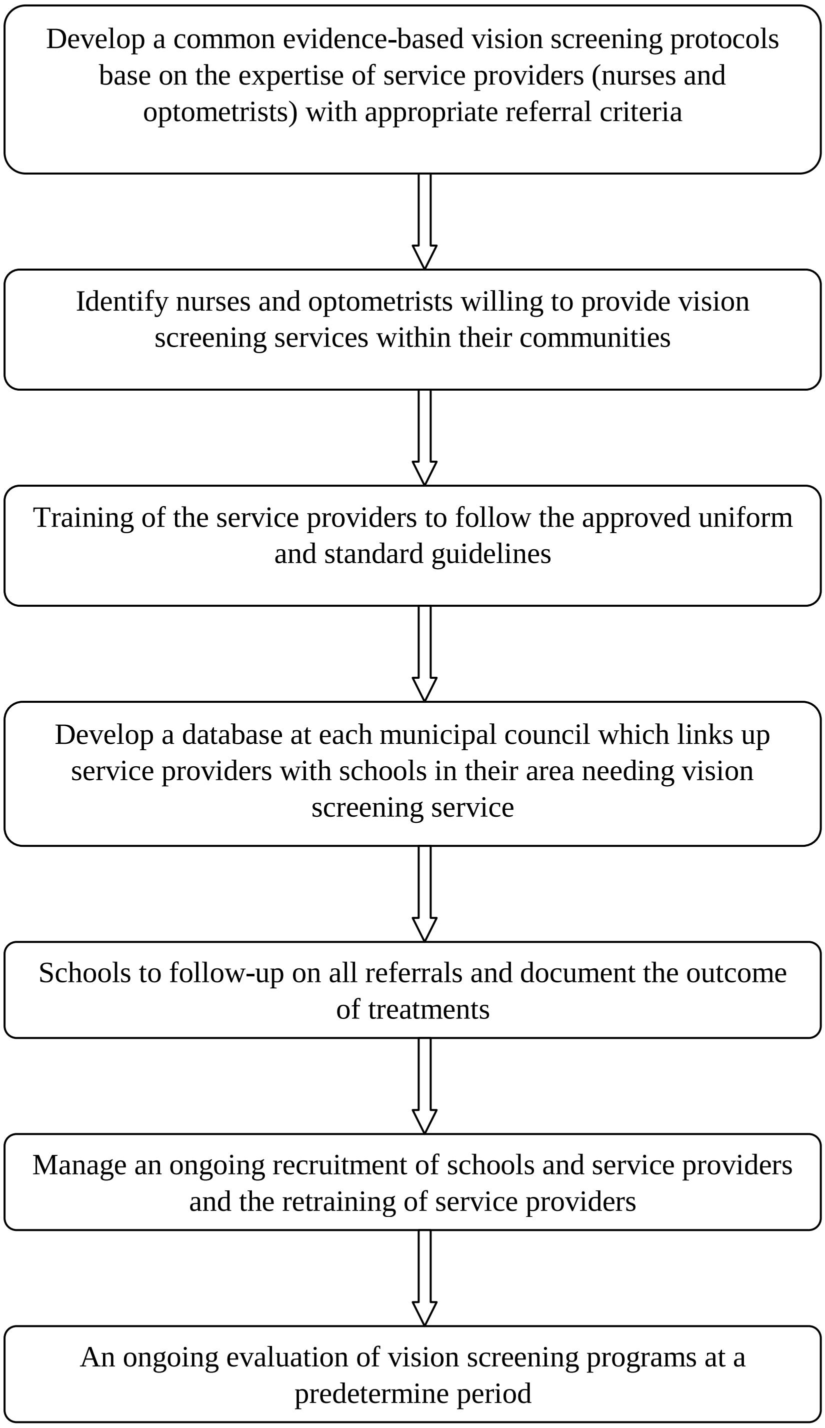

Figure 2: A schematic representation of the proposed vision screening service delivery model

Provision of vision screening services across Abia State

Securing the cooperation of school personnel, the child, the parents, the eye care practitioners and relevant government agencies (ministry of health and ministry of education) will ultimately facilitate an effective vision screening program. The first step in this regard will be to address the inequalities in the provision of vision screening in the state especially between urban and rural areas where a greater population of children are living. As eye care provision is a component of the PHC in Nigeria, functional eye care units with fundamental vision screening tools should be provided in the PHC centres that are located in the various communities in Abia State. Although screening can be done in various settings, it is mostly recommended to be done in schools for the following reasons: i) Large numbers of children of varied ages are readily accessible in schools and can be tested in a short period of time with relative ease; ii) School screening is far less expensive than a comparable service performed in another eye care delivery system setting; iii) Schools afford the opportunity to screen children who have not been previously screened/identified. Therefore, the PHC centres will serve as resource and service centres for the provision of vision screening to schools in their domain and the utilization of the community health nurses working within the existing system will help to reduce cost.

The second step will be to address the inadequate manpower for vision screening provision. Given that there is insufficient professional eye care practitioners, community health nurses already working in the PHC centres with interest in children vision screening can be trained in basic vision screening skills and ocular health education to compliment the efforts of optometrists especially in the rural communities. Adequately, trained health nurses have been shown to competently screen younger school children in Sweden while referring children with visual problems to optometrists or ophthalmologists.[9] Optometrists interested in the provision of paediatric vision screening can then be assigned to coordinate and supervise the activities of trained nurses either at political ward level, state constituencies or local government areas (LGA). This strategy where the nurses screen younger school children, will allow the few optometrists to focus on older school children who require more complex procedures and professional expertise. However, different vision screening service delivery models would be required for both optometrists and nurses. It will also require the cooperation and assistance of relevant professional bodies and government agencies. The ministry of health and ministry of education through their various local government health and education authorities are expected to oversee the regulation of this exercise. A database which will be managed by either the health or education authority at each of the LGA will help to document the schools that have been serviced and the frequency of service provision. The heads of the schools in the area are expected to request for vision screening exercises through the education authorities. The education authority through the health authority will contact the optometrists responsible for vision screening in the political ward or area. In collaboration with the local nurse, the optometrist will provide the vision screening service to the school in question. It is important to note that vision screening personnel within the systems would need government assistance in terms of creating awareness and educating children and families within their area of coverage to ensure full utilization of the services offered through their system of care.

Another important step will be for the government (in association with eye care professional organisations) to issue a policy statement which will recommend vision screening to children before and during the school years. This policy statement will clearly define the ages at which a child is expected to be screened and the procedures that are expected to be performed. Countries such as Sweden, Canada, United Kingdom, Australia, East Timor and USA have implemented such policies and reports[5,9] indicate that the policies have impacted positively on the coverage of children vision screening in those countries. Overall, it is anticipated that this strategy will be cost-effective. It will also guarantee efficient, sustainable and regular school vision screening services across the state. The vision screening provision will adhere to ethics and regulations and protect children from being exploited by individual eye care practitioners.

Uniform vision screening batteries

The development of a uniform and suitable set of vision tests for identifying common vision conditions in Nigerian children and appropriate referral guidelines to reduce false positives and negatives would increase the efficiency and coverage of paediatric vision screening in Abia State and Nigeria. A uniform guideline and referral criteria would be determined through the collaborative efforts of various associations of eye care practitioners. The best approach may be to set up a special committee comprising representatives of the ophthalmologists', optometrists', nurses' association and other relevant bodies. To save cost the special committee could be integrated into the Nigeria National Program for Prevention of Blindness (NPPB).

In developing the uniform and appropriate vision test protocols, several factors would have to be considered which include: i) common paediatric vision conditions in Nigeria. ii) the expertise and experience of the screener (nurse versus optometrist); iii) the age group of children to receive the intended screening by considering their ability to understand the test procedures and instructions; iv) conditions common in the age group to be screened; v) the validity and reliability of the test battery to detect the vision conditions it is expected to detect.

Therefore, the committee would require comprehensive information on paediatric vision conditions among Nigerian children. This would highlight the common vision problems that are capable of affecting the development and quality of life of children and the age group that are mostly at risk for each of the vision problems.

Regarding expertise, nurses and optometrists would need different tests batteries. Optometrists have more training and expertise in the provision of eye care and vision screening services and would be expected to perform a wide range of vision tests including complex procedures. In addition, consideration would be given to the age group of the children to be screened. Younger children may not be able to understand or follow through with certain conventional protocols that are regularly used in vision screening programs. Therefore, age appropriate test batteries would be required to accurately detect these conditions thereby reducing false positive and false negative outcomes. Furthermore, considering the varying visual demands for different age groups, some groups of children may be more predisposed to developing some visual conditions than others. For instance, near vision problems which requires complex test procedure may be common among older children than younger children because of heavier loads of near work activities. As such screening protocol for this age group would be expected to have a wider range of test batteries. Nonetheless, an optimum test protocol for the two groups of screeners and for all age groups of children is fundamental for effective utilization of available skills and manpower for each profession, as well as ensuring utmost coverage for all children across Abia State.

Training programs are also needed to ensure that service providers adhere to established uniform and standardized guidelines. The special committee would also be charged with the responsibility of designing training and retraining programs for both optometrists and nurses. Newly recruited services providers would be required to undergo initial program training and subsequent periodic trainings. Instructional and relevant field materials including uniform screening guidelines, consent forms, report forms, parent reports and follow-up card would be made available to all service providers through the various professional associations and health authorities in various LGAs. This would ensure the standardization of tests administered especially for nurses if they are not too familiar with most of the test protocols as well as to eliminate any disparity in the quality of service provision across Abia State and Nigeria.

Follow-up on all referrals where evaluation and/or treatment is recommended

The success of any vision screening strategy would also depend on the availability of a systematic follow-up process. Other than in exceptional cases, or when there is a critical problem requiring prompt attention, the child needs to be retested before making a referral. If the child fails the test for a second time, then the parents would be notified in writing through the school authorities of the outcome of their wards vision screening. The notification letter would include the uniform referral and evaluation forms according to standardized guidelines. The child would be referred to a qualified eye care practitioner with no recommendation to any individual, facility or specific class of practitioner (optometrist or ophthalmologist). In the referral letter, the eye care practitioner will be advised to complete and return the evaluation form to the school through the parents of the child after the evaluation is completed. The school authorities are expected to keep a record of the visual problems of each child and the outcome of the evaluation as reported by the eye care practitioner. In order, to ensure that the parents' follow-up with the referral, the school authorities will be required to maintain contact with the parents and assist where necessary to ensure the child receives the needed evaluation and treatment. In cases of refusal of any parent to take a child for a comprehensive eye examination, the school authorities would be required to obtain a written statement from the parent/guardian indicating reason for the refusal which should be included in the child's health record. This follow-up strategy will ensure that a greater number of children identified as having vision problems are receiving comprehensive examinations. In addition, the report of the evaluation will help the school authorities to know if any adjustment is needed to be made to accommodate the child's educational needs.

Evaluation of vision screening programs

Evaluation of vision-screening program is an on-going process and requires thorough appraisal of the planning, implementation, referral process and outcomes. Proper documentation of the outcome data of the vision screening program and referrals would help to establish the efficiency of the program. Regarding the proposed strategy, information that can be gathered in the evaluation process which will determine the success includes:

- The number of children screened, the number of referrals, the types of vision problems identified and the number of children who have received the recommended complete examination from an eye care practitioner.
- The number of optometrists and nurses who are involved in vision screening and the number of schools covered through this system including their locations.

- The uniformity and comprehensiveness of the screening batteries for both optometrists and nurses.
- In the long term it will be determined whether the strategy has contributed to decrease in the prevalence of unidentified vision problems in children in Abia State.

CONCLUSION

The existing paediatric vision screening system in Abia State is not providing adequate coverage for the children. The number of eye care practitioners involved in vision screening is highly insufficient and their services are irregular and unevenly distributed across the State. A public-private partnership strategy as proposed in this study will help to provide greater access to vision screening services across the state. The main objective is to provide a coordinated approach that will ensure early detection and successful treatment as well as prevention of critical vision problems that can have a negative impact on child development and overall health and wellbeing.

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CHAPTER EIGHT

CONCLUSION

8.1 INTRODUCTION

Although, visual anomalies can interfere with learning and academic performance, the prevalence of common vision conditions in children in Abia State and Nigeria remains largely unknown.[1,2,3,4,5] The focus of the limited school-based cross-sectional studies on children have been mainly to quantify RE, while the prevalence of strabismus, amblyopia, accommodative anomalies and vergence disorders, most of which have been associated with reduced academic-related performance has not been established. Moreover, early detection and successful treatment of these problems before functional performance of children is affected is very important. An invaluable approach will be through a coordinated and standardized common strategy that will involve valid and reliable test batteries. However, no standard vision screening protocol or guidelines were found for school children in Nigeria and particularly in Abia state.[1,2,3,4,5,6,7]

The present study was motivated by the need to provide information on visual anomalies in school children and paediatric vision screening programs of individual optometrists, to direct the development of a common and comprehensive paediatric vision screening model. The study consisted of two parts. Part one described the prevalence of visual anomalies in school children in Abia State. In part two, vision screening programs provided to the paediatric population by individual optometrists were evaluated to determine the coverage, scope and referral criteria. Using the information on the prevalence of visual anomalies in children, it was determined whether vision screening services provided by individual optometrists are targeting conditions common in school children. Based on the findings, a new strategy that will improve vision screening delivery across Abia State was recommended. A summary of the major findings including the significance of the study as well as limitations and recommendation for further studies are presented below.

8.2 SUMMARY AND MAJOR FINDINGS

In part one of the study, a total of 537 school children (10 – 16 years) recruited from 9 schools (public and private) through a systematic random sampling method were examined for visual problems. The age group of children was preferred because they belong to the group ‘read to learn’. This group of students read for longer periods of time and the print size of the letters are usually small, in that they need more visual effort in focusing and comprehending what they read.[8] Over time, this may trigger many symptoms, especially when associated with visual anomalies. In addition, the study sample comprised primary and secondary school children which represent the learning experience and visual demands of children in these two levels of education, as well as, presents adequate age range to adequately explore the relationship between age and visual anomalies.

The findings show that the prevalence of RE (10.6%) in the study sample is relatively low. Significant differences between age groups were found in the prevalence of hyperopia and myopia, with the prevalence of hyperopia decreasing with age while myopia increased with age. Among the different REs, low categories of myopia, hyperopia, and astigmatism were the most frequent with corresponding values of 88.9%, 86.4% and 82.4% respectively. None of the children had a high degree hyperopia, myopia or astigmatism. This might be of clinical importance, given the reported association between low degrees of hyperopia and astigmatism and visual discomfort due to excessive use of accommodation to maintain normal vision.[9,10] Spectacle coverage in the present study was also low, only 5.3% of the children with RE presented for examination with their spectacle correction. A review of the literature indicates that there is inadequate skilled manpower and inequalities in the distribution of eye care services in Abia State and Nigeria. The eye care facilities are mainly restricted in the cosmopolitan centres which therefore suggest that eye health services may be inaccessible to many children in Abia State and may account for the low uptake of refractive services among the study sample. The prevalence of strabismus, corneal opacity, and retinal disorder was 0.2 % each whereas that of allergic conjunctivitis and blepharities was 5.8% and 0.9% respectively. In addition, a small percentage (0.9%) of children had red-green colour vision deficiency. The prevalence of VI (3.5%) as expected was equally low and uncorrected RE contributed to 78.9% of the VI in the study sample. Other causes of VI include amblyopia (10.5%), corneal opacity (5.3%) and retinal disorder (5.3%). Although the prevalence of VI and RE was low, the high proportion of uncorrected RE in the study sample is a major concern. Children within the age group of 10 to 16 years are in stages of rapid growth and intensive education which can complicate RE progression. As such undetected and untreated RE, may progress to sight threatening complications or permanent vision loss.

On the other hand, a considerable proportion of children were affected by accommodative and vergence anomalies. Clinical CI (high suspect CI and definite CI) (9.9%) and AIF (10.1%) were the most common accommodative and vergence anomalies among the study population. Others include AIS (3.9%), AE (2.8%), CE (3.9%), FVD (2.6%), BX (1.7%), BS (2.8%), DI (0.8%), and DE (0.6%). This might also be of clinical importance, due to the reason that the subspecialty of paediatric optometry was recently introduced in Nigeria, there is insufficient data on accommodative and vergence anomalies for proper clinical management.[2] While there were no significant differences in the distribution of the various accommodative anomalies between age group, gender or school level, the distribution of high suspect CI and definite CI varied significantly by age groups and as expected therefore with study level. There was no significant association between CI and gender. Likewise, no significant association was found between age, gender and all the other vergence anomalies.

Another important finding is the significant variation in the mean data of some clinical measures between children with no vergence or accommodative anomalies and those with specific types of vergence or accommodative anomalies particularly the CI categories. To the contrary, these differences were not significant between the various CI categories, which may suggest that all the clinical signs need to be thoroughly evaluated to sufficiently classify clinically significant CI. For instance, 17.1% of the children had considerable amount of near exophoria that can create symptoms of diplopia. Strikingly, over two-thirds of this number had adequate fusional reserves to maintain single binocular vision. Consistent with available data[2,11,12,13,14,15] accommodative and vergence anomalies occur more frequently as a syndrome of clinical signs; thus, a comprehensive assessment of accommodative and vergence parameters are recommended to accurately diagnose these anomalies. However, for symptomatic patients whose evaluation indicate that other binocular vision parameters are normal, a single criterion may be useful in the diagnosis of the anomalies.[14] Collectively, the findings of part one of the study warrants for efficient vision screening strategy to identify and treat these anomalies in children.

In part two of the study, 83 out of a total of 110 registered optometrists in Abia State were contacted to participate in the survey and 64 responded, giving a response rate of 77.1%. The optometrists were from both public and private eye care facilities across the state and have been practising for the last one year before the study. A comprehensive review of child eye health provision in Nigeria indicate that the number of eye care practitioners in Nigeria falls far below the WHO benchmark and that majority of them are working in the capital cities and in private sectors. As previous reports indicate, 87.5% and 71.9% of the optometrists surveyed are working in cosmopolitan cities and private eye care facilities respectively. This further highlights the inequalities in the provision of eye care services in Abia State, additional to the unavailability of eye care services to many children especially those living in rural communities and warrants the need for regular vision screening services. However, only 28 optometrists had participated in one or more vision screening that included children in the last one year before this study and only 10 have provided vision screening services more than four times. Sixteen optometrists have provided vision screening in a school setting while another 16 have been involved in other settings. Although, the vision screenings in settings other than school included children, the focus of such screening exercises is not always on paediatric conditions. Based on these findings, it is highly unlikely that the current vision screening system is providing adequate coverage for children of Abia State.

The present study also found that VA testing, penlight assessment and ophthalmoscopy were the main test batteries included in the paediatric vision screening programs conducted by individual optometrists in Abia State. Only few optometrists performed retinoscopy ocular motility and cover test examination and test batteries such as plus lens test (for latent hyperopia), convergence point at near, phoria measurements, accommodation amplitude and colour vision test were not included in the screening protocols. In most instances, screening was administered using the problem-oriented approach and some important tests like retinoscopy and the plus lens test were not always performed. The findings of the present study on common vision conditions in children in Abia State indicate that accommodative and vergence anomalies were the most common vision conditions in children (Figure 1). In addition, a higher frequency of low degree RE was common among those with RE (Figure 1 of Chapter 4). These visual anomalies cannot be detected by VA measurement alone. Therefore, the components of the screening batteries of individual optometrists in Abia State are inadequate to identify conditions common in children most of which have been found in previous studies to have a negative effect on school performance.

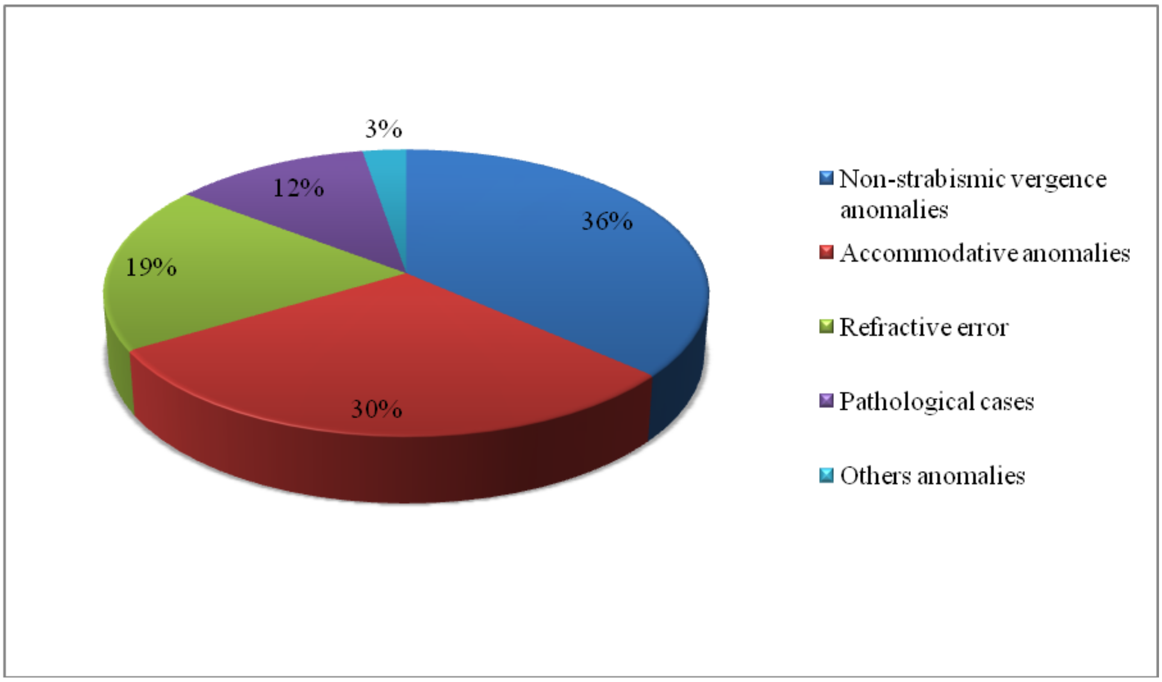

Figure 1: Distribution of visual anomalies

Regarding referral criteria, the findings of the present study showed inconsistent referral criteria which may be attributed to lack of common screening guidelines in Abia State and Nigeria. Of the 28 optometrists who performed distance VA testing during vision screening, 75% considered VA of less than 6/6 as the criterion for referral, whereas 25% considered VA of less than the 6/9 as criterion for referral. In addition, the VA criteria adopted (less than 6/6 and less than 6/9) would likely result to many false positive referrals for certain age groups of children especially the younger ones. Available data indicate that a referral criterion of 6/12 or worse for younger children, and 6/9 or worse for the older children, or a two line or more difference in acuity between the two eyes, may be appropriate, whereas those with normal VA but symptomatic would be referred for cycloplegic refraction. The follow-up of those referred for complete examination, could not be established in the present study due to lack of uniform guidelines and improper documentation. Overall, the findings of the present study suggest that a new strategy is needed to increase the coverage and effectiveness of paediatric vision screening in Abia State.

8.3 SIGNIFICANCE OF THE STUDY

The findings of the present study have important implications for both eye care practitioners in terms of the clinical management of paediatric visual problems and relevant authorities in terms of planning and implementation of school eye health programs. Presently, there are no available evidence-based management guidelines, particularly for accommodative and vergence anomalies because the sub-specialty of paediatric optometry in Nigeria is still evolving. Comprehensive information on common paediatric conditions in Abia State as provided by this study can guide eye care practitioners in the assessment of visual anomalies in children, particularly those that have been linked with academic achievements outcomes.

This study also highlighted the importance of increased access to eye care services across the State especially the rural areas. This could be achieved by the provision of functional eye care units in the PHC centres located in the various communities across the state. Although, it should not be an alternative for a complete examination, provision of coordinated vision screening services is also an important method of increasing access to eye care services. Currently there are inadequate skilled manpower for the provision of vision screening services. This study has emphasized the need to incorporate trained community health nurses in the existing primary health care system to complement the efforts of eye care practitioners in the provision of vision screening services.

The need for a new vision screening strategy that will provide greater coverage and uniform service provision across the State was highlighted. This study also demonstrated the importance of screening for common visual anomalies such as uncorrected refractive errors, accommodative and binocular vision dysfunctions in children to minimise potential functional disadvantage in school. Therefore, eye care professional associations can use the data from the present study to develop screening models for both nurses and optometrists according to their expertise and training. Health and education authorities can also use data from the present study in drawing up plans for regular vision screening exercises and ocular health education in schools, and eye care delivery services, in the wider communities.

8.4 LIMITATIONS

A limitation of the present study is the non-use of cycloplegia and dilated fundus examination in the assessment of refractive errors and causes of VI, respectively. It is possible that cycloplegic refraction would have revealed more latent hyperopia than the plus lens (+2.00 D) test applied in the present study. Nonetheless, the use of cycloplegics would have affected the accommodation which was also investigated in this study and school principals would not have allowed for a second day testing, as it would have interrupted the student’s learning sessions. Cycloplegics may also cause a significant change in higher-order aberrations from the natural state which could affect the near vision test.[16]

Another possible limitation is the estimation of the frequency of respondent's participation in vision screening, number of children being screened including the components of screening batteries over a one-year period using a questionnaire. This may have introduced error of recall bias or reporting bias, especially for vision screening programs where the participants are not directly involved in the organisation. Considering that there are no uniform guidelines, these factors may vary depending on the focus of the vision screening and the screening centres and may have affected the generalizability of the findings of the study on vision screening programs. An ongoing evaluation through proper documentation of vision screening data over a given period would have provided a better assessment of paediatric vision screening in Abia State.

8.5 RECOMMENDATIONS AND FUTURE STUDIES

In view of the proportion of children in this study that were affected by low categories of RE and accommodative and vergence anomalies, it is recommended that children who present with near vision related symptoms be properly evaluated for visual anomalies such as RE that may not necessarily result in reduced VA (mild hyperopia or astigmatism) and accommodative and/or vergence anomalies. In relation to accommodative and vergence anomalies all the parameters of accommodative and vergence functions should be properly evaluated to make a definitive diagnosis.

As these anomalies have been shown to be detrimental to functional performance in children elsewhere, it is important in the future to assess how they affect the educational outcome (in addition to reading outcomes) of school children in Abia State. Given that, genetic and environmental factors can influence the prevalence and distribution of vision conditions, it is also possible that the impact of visual anomalies on school performance could vary across different places. First, a standardized examination and/or validated reading assessment test specifically for Nigerian children would have to be developed. Future studies can also investigate the association between visual anomalies and visual symptoms using a standardised symptom survey questionnaire. Determining the symptoms that are specific to a visual anomaly will deepen the understanding of these conditions and help in differential diagnosis of near vision anomalies.

It is highly recommended that primary eye care which is a component of the PHC system of Nigeria be overhauled for efficiency and effectiveness. At least one community health nurse trained in the art and science of vision care is needed in each of the PHC centres to help in early detection of vision problems, provision of basic ocular health education and prompt referral to an eye care specialist. At the state level, government should engage the services of optometrists and ophthalmologists at its secondary and tertiary health facilities respectively. Qualified health professionals should coordinate the activities of the PHC centres to ensure proper delivery of eye care services.

Vision screening will help in the early detection of common visual anomalies, to minimize potential functional disadvantage in school children. However, lack of coordination and a limited range of tests of the screening protocol measures significantly against effective vision screening programs. A public-private partnership as recommended in the present study will address the problem of low coverage of child eye health services. A uniform screening guideline with full range of test batteries are also required to makes sure that eye conditions common to children in Abia State are identified and treated on time. The screening guidelines should include test for accommodative amplitude, accommodative facility, fusional ranges and vergence facility considering that classroom activities are heavily dependent on these visual skills. In addition, clinical techniques such as plus lens test and retinoscopy (at near point and distance) should be part of the vision screening protocol to identify uncorrected REs that may possibly influence school performance.

Finally, education authorities should ensure that regular vision screening program is carried out in both primary and secondary schools within their area of jurisdiction and that those identified as having vision problems are receiving full examination. It is therefore important for decision makers to formulate policies that will increase access to appropriate and affordable eye care in schools and communities. Children should be required to undergo a series of vision screening before and during the school years. Such policies can be implemented at national level and would require comprehensive information on common paediatric conditions in Nigeria. Therefore, the present study can be expanded to include other states of Nigeria to provide national data on paediatric vision conditions. Participants can be randomly selected from the six geopolitical zones of Nigeria taking into consideration the socioeconomic characteristics of the constituent states.

8.6 CONCLUSION

The present study has systematically characterised the prevalence of vision conditions in children in Abia State and efforts that have been made at their early detection through vision screening. Generally, the findings from the study demonstrated that vision anomalies which do not necessarily affect VA are common among school children and that the existing paediatric vision screening services are not focusing on the most important vision conditions in children in Abia State. The implication is that many children with common paediatric eye conditions including those that have been linked to reduced academic achievements are not routinely screened. The few existing screening programs in Abia State are uncoordinated and the test batteries are restricted to mostly distance VA and ocular health assessment. Therefore, the scope of paediatric vision screening programs should be widened to include the detection of a full range of learning related problems capable of affecting the development of a child. A public-private partnership strategy as proposed in this study will help to provide greater access to vision screening services across the State. This model is expected to provide a methodological approach that will ensure early detection and successful treatment as well as prevention of critical vision problems that can have a negative impact on the development of children and of their overall health and wellbeing.

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APPENDIX A

Case history questionnaire

Survey No: ___________ **Class:** __________ **Age:** ______

School Type: 1. Public_________ 2. Private _____________

Sex: 1**.** Male _________ 2. Female________________

Mobile no ____________________

Instruction: Please provide the correct answers

I- Ocular history

1) **Have you ever attended a vision screening or had an eye test?**

1. Yes ☐ 2. No ☐

If yes, please advise your age when examined _______ and where _______________ (optometrist/school/medical centre)?

2) **Have you ever had spectacles?** 1. Yes ☐ 2. No ☐

If yes, please advise your age when examined _______________, and what for _______________(reading/distance/all the time)?

3) **Have you ever had medical/surgical treatment to your eyes?** 1. Yes ☐ 2. No ☐

If yes, please provide details

---

4) **Is there a family history of eye problems e.g. turned or lazy eyes or glaucoma?** 1. Yes ☐ 2. No ☐

If yes, please provide details

II- Visual symptoms

	Questions on visual symptoms	1.Never	2.Infrequent	3.Sometimes	4.fairly	5.Always
I	Do your eyes feel tired?					
Ii	Do you usually have headaches when you read or study?					
Iii	Do you feel sleepy when you read or study?					
Iv	Do you have difficulty remembering what you have read?					
V	Do you have double vision or see words split into two when you read or study?					
Vi	Do you see words wiggle, jump, swim, or appear to float on the page when you read or study?					
Vii	Do you tend to hold book too close while reading?					
Viii	Do you hold book away while reading?					
Ix	Do you see things as blurry (not clear) when you read at near or use the computer?					
X	Do you feel like you read slowly?					
Xi	Do you feel dizzy when you read?					
Xii	Do your eyes hurt or feel sore when you read or study?					
Xiii	Do you notice the words blurring or coming in and out of focus when you read or study?					
Xiv	Do you have to re-read the same line of words when you read?					
Xv	Do you feel a “pulling” feeling around your eyes when reading or doing close work?					
Xvi	Do your eyes water when you read?					
Xvii	Do you have problems when you look on the chalkboard, back to your textbook, and back to the chalkboard again?					
Xviii	Do you suffer from headaches after school?					
Xix	Does your eye turn red after reading?					
Xx	Do you feel like abandoning reading completely due to discomfort with your eyes during reading?					
Xxi	Do you frown or “squint” or “squeeze” your face when you read?					
Other?						

III- Near work activities

5) **On the average, how many hours do you spend reading each day outside of school hours (for leisure or homework)?**

0	1	2	3	4	5	6	7	8	9	10

Other, specify ______________________________

6) **On the average, how many hours do you spend on the computer or video games outside of school hours?**

0	1	2	3	4	5	6	7	8	9	10

Other, specify ______________________________

IV- General History

7) **Do you have any general health problems?** 1. Yes ☐ 2. No ☐

If yes, please provide details ______________________________

8) **Have you experienced hearing/ear problems in the past?** 1. Yes ☐ 2. No ☐

9) **Is there anything about your eyes or how you see that worries you?** 1. Yes ☐ 2. No ☐

If yes, please provide details ______________________________

APPENDIX D

Clinical assessment results sheet

Survey No: _______ **Class:** ________ **Age:** _____ **Sex**: M/F **Mobile no**_____________

History taking: Yes/ NO

1) Visual acuity (VA):

		Distance VA	Near VA
Uncorrected VA	R		
	L		
Presenting VA	R		
	L		
Best corrected	R		
	L		

Spectacle power (R) ___________________________ L _________________________

Plus Lens test (+2.00 D) VA (R) ______________ (L) __________ (Pass/Fail)

2) Stereopsis:

Randot stereopsis none/250secs of arc/500secs of arc

Graded circles ______________ secs of arc

Colour vision – Ishihara

Number of errors _________________________________

3) Refraction: **IPD** ___________________

		Sphere	Cylinder	Axis
Autorefraction	R			
	L			
Subjective	R			
	L			

4) Vergence functions

i) NPC

Measurements	First (cm)	Second (cm)	Third (cm)	Average (cm)
Break point				
Recovery point				

ii) Cover test: Distance __________________. Near ______________________

iii) Horizontal phoria: Distance ____________. Near _____________________

iv) AC/A:

Measurements	+2.00 D	−2.00 D	AC/A ratio
Frist			
Second			
Third			
Average			

v) Fusional vergence

		Blur	Break	Recovery
Distance	BO			
	BI			
Near	BO			
	BI			

vi) Vergence facility

Vergence facility (cycle/minute)	First	second	Third	Average
• 12 BO/3BI				
• 12 BO				
• 3 BI				

5) **Accommodative functions**

Accommodative: -				
Amplitude (D)				
• Monocular RE (MAA)				
• Binocular (BAA)				
Response (RE) (D)				

Accommodative facility (cycle/min)	First	Second	Third	Average
With −2.00 D				
• Monocular (MAF)				
• Binocular (BAF)				
With +2.00 D				
• Monocular (MAF)				
• Binocular (BAF)				
With ±2.00 D				
• Monocular (MAF)				
• Binocular (BAF)				

6) **Ocular health**

Pupil assessment: RAPD Yes/No PERRLA__________

Funduscopy____

____

____

APPENDIX C

Vision screening questionnaire: optometrists

Instructions: Please select correctly the options applicable to you

Please do not answer any question that does not apply to you

A) Demographics

1. Are you male or female? 1.Male ☐ 2. Female ☐

2. How many years has it been since you graduated as an optometrist?

0	1	2	3	4	5	6	7	8	9	10	>10

3. From which university did you graduate?

1.Abia state University ☐ 2.Imo state University ☐ 3.University of Benin ☐

4.Madonna University ☐ 5. Other, specify ________________

4. Which city do you practise in? ________________________

5. In which sector do you work?

1 Public ☐ 2 Private ☐ 3 Both ☐

B) Patient profile

6. How many patients do you see in your practice on average each week?

<10	11	12	13	14	15	16	1 7	18	19	20	>20

7. How many school children (6 – 18 years old) do you see in your practice on average each week?

0	1	2	3	4	5	6	7	8	9	10	>10

C. Vision screening referrals

8. In the last year, have you seen any school children (6 - 18 years old) who were referred for an eye examination from a vision screening conducted by you or any other practitioner?

1 Yes ☐ 2 No ☐

9. In the past month, approximately how many school children (6 - 18 years old) have you seen who presented for an eye examination from a vision screening?

0	1	2	3	4	5	6	7	8	9	10	>10

10. What school level were the children who had been referred from a vision screening?

1) Primary ☐ 2) JSS ☐ 3) SSS ☐ 4) Don't know ☐

11. Who conducted the vision screening?

1) Optometrist ☐ 2) Ophthalmologist ☐ 3) GP ☐

4) Nurse ☐ 5) Don't know ☐ 6) Other, specify ______________

12. What were the main reasons for referrals from the vision screenings?

1) Monocular distance VA ☐ 2) Colour vision ☐ 3) Distance tropia/phoria ☐

4) Monocular near VA ☐ 5 Pathology ☐ 6) Near tropia/phoria ☐

7) Stereopsis ☐ 8) Other, specify ___________

13. Approximately what proportion of children who were referred from a vision screening required the following optometric management?

	1) >75%	2) 50 -75%	3) 25 -50%	4) <25%
Spectacles				
Vision therapy				
Specialist referral				
No management at this stage, review within 2 weeks				
No management required				

14. Please feel free to provide any further information on vision screening services provided to school children in your area.

____

____

____

D. Vision screening participation.

15. In the last year, have you been involved in any vision screenings on school children outside your practice?

1) Yes ☐ 2) No ☐

16. Where was the vision screenings conducted?

1)School ☐ 2) Community centre ☐ 3) Religious centre ☐ 4) Other specify____

17. In the past, which area have you participated in vision screening outside your practice?

1 Urban ☐ 2 Rural ☐ 3 rural/urban ☐

18. How many vision screenings do you participate in outside your practice in a year?

0	1	2	3	4	5	6	7	8	9	10	>10

19. Approximately how many children are seen at each vision screening?

1) Less than 20 ☐ 1) 30 - 50 ☐ 2) 50 – 100 ☐ 2) More than 100 ☐

20. Who coordinates the vision screenings?

1) Yourself ☐ 2) School ☐

3) Non-Governmental Organisation (NGO) ☐ 4)Public or government ☐ 5) Other, specify ________________

21. Which of the following tests are included in the vision screenings?

	Screening tests	1) included	2) not included
1	Monocular distance VA		
2	Monocular near VA		
3	Distance cover test		
4	Binocular distance VA		
5	Binocular near VA		
6	Near cover test		
7	Ocular health exam		
	i. External (Penlight) exam		
	ii. Ophthalmoscopy		
	iii. Other, specify		
8	Stereopsis		
9	Colour vision test		
10	Amplitude of accommodation		
11	Near point of convergence		
12	Ocular motility		
13	Phoria measurement		
14	Plus lens test		
15	Refraction		
	i. Subjective		
	ii. Retinoscopy		
	iii. Auto-refraction		
16	Other, specify		

22. At the vision screenings, what are the pass/fail criteria for the individual tests?

	Screening tests	3) Pass criteria	4) Fail criteria	5) Not included
1	Monocular distance VA			
2	Monocular near VA			
3	Distance cover test			
4	Binocular Distance VA			
5	Binocular near VA			
6	Near cover test			
7	Ocular health exam			
	i. External (Penlight) exam			
	ii. Ophthalmoscopy			
	iii. Other, specify			
8	Stereopsis			
9	Colour vision test			
10	Amplitude of accommodation			
11	Near point of convergence			
12	Ocular motility			
13	Phoria measurement			
14	Plus lens test			
15	Refraction			
	i. Subjective			
	ii. Retinoscopy			
	iii. Auto-refraction			
16	Other, specify			

23. Please feel free to provide further information on any vision screenings in which you have participated.

____

____

____

____

E. Final remarks.

24. If you haven't participated in any vision screenings outside your practice, please select from the answers below which best describes you.

1) Not applicable	
2)Would not like to get involved	
3)Would like to but don't know how to get involved	
4)Don't have enough time to get involved	
5)Other, please specify	

25. Any further comments.

____

____

Thank you for your time and co-operation in completing this questionnaire

APPENDIX D

Published papers

· Review Article ·

Visual problems: a review of prevalence studies on visual impairment in school-age children

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Abstract

● **Childhood visual impairment (VI) have a significant impact on the educational achievement, career choices and social life of affected individual, and in children, is mainly due to either preventable or treatable causes. Reliable data on the prevalence and causes of VI in children will guide the development of a systematic vision screening program for its early detection and successful treatment of possible causes. The purpose of this literature review is to summarize the available data on prevalence and causes of VI in school-age children from various regions globally. A discussion on the major findings highlighting the definition criteria, classifications and limitations for further studies is also presented.**

● **KEYWORDS:** visual impairment; school-age children; vision screening; school performance

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INTRODUCTION

Visual impairment (VI) has a considerable impact on the lives of the affected individuals as well as their families and society. Its effect on development and learning is more significant when it is present at birth or shortly afterwards compared to when it is acquired later in life. Loss of vision in children influences their academic opportunities, career choices, and social life, with defective near vision influencing their ability to perform a variety of tasks that involve reading[1-2]. As more than 85% of what a child learns in school is through visual presentation, their ability to perform optimally will be affected[3-4]. Visual field deficits also affect the child's ability to accomplish tasks that require ambulation in challenging environments or the application of peripheral vision[1]. In addition, approximately 90% of visually impaired children are not receiving adequate education due to factors that include discrimination, stigmatisation and lack of access to appropriate schools[5-6].

Reports suggests that in both developed and developing countries, the majority of VI is either preventable or treatable[7-8]. Early detection and effective treatment of underlying causes at the 'sensitive' period of visual development therefore remains an important approach for preventing VI[9-11]. Reliable data on the prevalence and causes of VI in children are necessary for developing a systematic vision screening program with valid and reliable test protocols. Such data will help to direct the application of available resources and efforts for early detection to people who are at risk, thereby reducing the high short- and long-term costs to the health system and society. The purpose of this literature review is to document the prevalence and causes of VI in school-age children from various regions globally. A discussion on the major findings highlighting the definition criteria, classifications and limitations for further studies is also presented.

METHODS

The online databases of PubMed, Medline, OVID, Google Scholar, Science Direct and Embase were explored for the keywords, and VI (prevalence and causes) in school children. The search was restricted to primary research published in the English language and in peer-reviewed journals. Only epidemiological studies with stated the measures of prevalence and causes of VI among school-age children between 5-18y of age were included. However, two studies on VI among Nigerian children with participants in the age groups 4-24y[12] and 9-21y[13] were included due to insufficient data on visual anomalies in these age groups in Nigeria.

In this narrative review, a summary of each study that met the outlined criteria is presented first and then evaluated in relation to other studies. Parameters of interests for review included: sample size and sampling method; participant characteristics, including gender and age; prevalence rates and causes of VI; information on diagnostic criteria and measurement techniques. The studies were compared according to geographic regions or ethnicity.

Prevalence studies on visual impairment

Table 1 Prevalence of childhood visual impairment across various countries

Study	Country	Age (y)	Sample size (n)	VA threshold	Prevalence (%)		
					Uncorrected VA	Presenting VA	Best corrected VA
Abdull *et al*[14]	Nigeria	10-15	5371	<6/12	Not reported	Not reported	1.2
Ajaiyeoba *et al*[12]	Osun, Nigeria	4-24	1144	Not reported	Not reported	1.5	Not reported
Megbelayin and Asana[13]	Calabar, Nigeria	9-21	1175	≤6/9	Not reported	6.9	Not reported
Kumah *et al*[18]	Ghana	12-15	2435	≤6/12	3.7	3.5	0.4
Naidoo *et al*[17]	South Africa	5-15	4238	≤6/12	1.4	1.4	0.32
Taylor *et al*[26]	Australia	5-15	1694	<6/12	Not reported	Not reported	1.7
Robaei *et al*[27]	Sydney, Australia	6	1740	<6/12	4.1	Not reported	Not reported
Murthy *et al*[21]	India (urban)	5-15	6447	≤6/12	6.4	4.9	0.81
Dandona *et al*[22]	India (rural)	7-15	4074	≤6/12	2.7	2.6	0.78
Paudel *et al*[19]	Vietnam	12-15	2238	≤6/12	19.4	12.2	Not reported
Goh *et al*[20]	Malaysia	7-15	4634	≤6/12	17.1	10.1	1.4
Salomao *et al*[23]	Brazil	11-14	2441	≤6/12	4.8	2.7	0.41
O'Donoghue *et al*[24]	United Kingdom	6-7	392	<6/12	Not reported	1.5	Not reported
		12-13	661			3.6	
Sauer *et al*[25]	Peru	5-18	380	≤6/9	Not reported	8.9	Not reported

VA: Visual acuity.

Table 2 Causes of childhood visual impairment across various countries

Study	Percentage of participants (%)						
	Refractive error	Amblyopia	Corneal opacity	Retinal disorder	Cataract	Other causes	Unexplained causes
Ajaiyeoba *et al*[12]	58.8	5.9	11.8	0	11.8	11.8	-
Megbelayin and Asana[13]	61.1	0.3	0.2	0.7	0	0.6	-
Kumah *et al*[18]	71.7	9.9	4.6	5.9	0	1.88	-
Naidoo *et al*[17]	63.6	7.3	3.7	9.9	0	3.1	12.0
Murthy *et al*[21]	81.7	4.4	-	4.7	-	3.3	5.9
Dandona *et al*[22]	61.0	12.0	-	-	-	15.0	13.0
Paudel *et al*[19]	92.7	2.2	0	0.4	0.7	1.5	2.6
Goh *et al*[20]	87.0	2.0	0	0	0	0.6	10.4
Salomao *et al*[23]	76.8	11.4	0	5.9	0	2.7	7.7
Taylor *et al*[26]	47.0	19.0	0	0	0	0	34.0
Robaei *et al*[27]	69.0	-	-	-	-	-	-

Studies on School-Age Children

African region Table 1 shows the various studies that have reported on prevalence and causes of VI in paediatric populations in Africa and elsewhere, while Table 2 presents the major causes of VI for these studies, where available. The exact prevalence and causes of childhood VI and blindness are difficult to establish due to the infrequent occurrence of relevant pediatric eye conditions and the lack of well-designed epidemiological studies, particularly in developing countries. For instance, in Nigeria, a national survey[14] on blindness and VI conducted between 2005 and 2007 reported only on the causes of VI in an adult population. In addition, the study was constrained by the sampling method used to identify the paediatric population, which limits the generalization of findings, as the school-age children were invited to participate only if they were living in a family of at least one eligible adult[14-16]. In the study, blindness was defined as presenting visual acuity (VA) of 6/120 or worse in the better eye, while VI was defined as presenting VA of less than 6/12 in the better eye. Of the 5371 children who were examined, the prevalence of blindness was 0.6%, with a higher prevalence in females (0.89%) than males (0.33%). The study also reported that the prevalence of mild, moderate and severe VI was much lower than that of blindness[14-16].

Two cross-sectional studies[15-16] were reported in some Nigerian cities, although with an older population than the studies included in this review. The studies were limited by poor diagnostic criteria, with that by Megbelayin and Asana[13] defining VI as presenting VA of 6/9 or less in one or both eyes and reported a prevalence of VI of 6.9%. The definition criteria they adopted has the potential of overestimating the prevalence of VI in the study sample. In the earlier study by

Ajaiyeoba *et al*[12], the prevalence of VI was estimated to be 1.5%, but it provided no clearly defined criteria. However, in both studies[12-13], refractive error (RE) was the major cause of VI.

In a large-scale Refractive Error Study in Children (RESC) study in a South African population, Naidoo *et al*[17] reported on the prevalence of uncorrected (1.4%), presenting (1.2%) and best corrected VA of ≤6/12 (0.32%) in children 5-15y of age in the Durban area. A geographically defined cluster sampling design and a door-to-door enumeration survey was applied to recruit the participants. RE (63.6%) was the major cause of VI, with only 12 (19.0%) of those affected wearing spectacles during examination. A more recent school-based RESC study was conducted in the Ashanti Region of Ghana[18] on children whose ages ranged from 12-15y. Reliable VA testing was possible in all but one of the 2454 children examined for VI and RE, with 119 children having VI in one or both eyes. Approximately, 3.7%, 3.5%, and 0.4% had uncorrected, presenting and best VA of 6/12 or worse in the better eye respectively, with RE being the major cause of reduced vision.

Asian region The prevalence of VI and RE in school children 12-15y of age was studied in Ba Ria, Vung Tau Province, Vietnam[19]. The authors examined each subject with a standardized test protocol and found that 87.8% of 2258 children had normal or near normal vision (≥6/9.5) in the better eye. A total of 434 (19.4%) children had uncorrected VA of ≤6/12 in both eyes, with 71 (3.2%) being blind, while the prevalence of VI (presenting vision ≤6/12 in the better eye) was 12.2%, including six blind children. However, with best-corrected VA, no children were found to be blind. RE was the major cause of VI in 92.7% of the vision-impaired children, and amblyopia was responsible for 2.2%. A comparatively similar result was obtained by Goh *et al*[20] in multi-ethnic population, including Malay (70.3%), Chinese (16.5%), Indian (8.9%) and others (4.3%) in Malaysia. The prevalence of uncorrected, presenting, and best-corrected VI (VA≤20/40) in the better eye was 17.1%, 10.1%, and 1.4%, respectively. In eyes with reduced vision, RE was the cause in 87.0%, amblyopia in 2.0%, other causes in 0.6%, and unexplained causes, suspected to be amblyopia, accounted for another 10.4%.

In India, a population-based study involving a random selection and door-to-door enumeration of children aged 5-15y from 22 geographically defined clusters found that RE (81.7%) was a major contributor to the cause of VI in children in New Delhi. The prevalence of uncorrected, presenting, and best corrected VA of 6/12 or worse in the better eye was 6.4%, 4.9%, and 0.81%, respectively[21]. A similar study with children aged 7-15y from rural India found a lower prevalence of uncorrected, presenting and best corrected VA of 6/12 or worse in the better eye, with corresponding values of 2.7%, 2.6%, and 0.78%. RE (61%) was also the major causes of reduced vision in eyes with VI[22]. The difference between these two studies, despite the age ranges differing by only two years, may be related to a higher prevalence of RE, especially myopia, in urban compared to rural areas, due possibly to differing education systems and the children's exposure to near-work activities.

Americas and European region Salomao *et al*[23] examined 2825 school children aged 11-14y sampled by cluster random technique from 374 schools in three districts of Sao Paulo, Brazil. VA was measured at 4 m using a standardized protocol, with the prevalence of uncorrected, presenting, and best-corrected VA of 6/12 or worse in the better eye being 4.82%, 2.67%, and 0.41%, respectively. RE contributed to 76.8% of children with VI in one or both eyes. O'Donoghue *et al*[24] reported on the Northern Ireland Childhood Errors of Refraction study, where VA was measured using a logarithm of the minimum angle of resolution (logMAR) protocol on 392 (6-7y) and 661 children (12-13y). Approximately, 3.6% of presenting VI in the better eye was found in the older (12-13y) children, which was higher than the 1.5% in the younger (6-7y) group. Approximately 25% of the children with RE presented for examination without spectacle correction.

A cross-sectional survey of children aged 5-18y living in a resource-poor community in Peru reported a high prevalence of VI, which may be attributed to its definition criteria. Participants completed a socio-demographic and health risk factor questionnaire and were screened for reduced distance VA, stereopsis, external eye examination and colour vision deficiency, with VI being defined as VA less than 0.2 logMAR (≤6/9). Of the 380 children who were examined, the mean uncorrected VA was found to be 0.07±0.13 logMAR, the findings indicating that 8.9% of the children were visually impaired in both eyes and 26.3% in one eye. Severe VI (<6/60) in both eyes was 0.3% and 0.7% in one eye, with the study recommending the performance of regular vision screening of children in Peru[25].

Oceania region Taylor *et al*[26] assessed low vision and blindness in 1694 Australian indigenous school-age children aged 5-15y, with a VA measurement of scholars randomly selected from 30 geographic areas. The rate of low vision, defined as best VA of less than 6/12 and equal to 6/60 was 1.5%, and the rate of blindness of best VA of less than 6/60 was 0.2%, with RE accounting for the most of their low vision. Relative risk of vision loss and blindness in the indigenous compared with the wider population children in Australia were found to be 0.2 and 0.6, respectively. In another school-based survey in Sydney, Australia, the prevalence of non-correctable

VI (VA<6/12) was only between 0.03% and 0.08%, which was 45 times lower than that reported in adults[27]. RE was responsible for 69.0% of the VI in the children.

Limitations of Previous Studies While all studies (Table 1), except for Sauer *et al*[25], included large sample sizes and traditional VA chart measuring technique, some flaws inherent in the study designs may have affected the generalizability of their findings. Some of the studies failed to state the eligibility criteria for participant recruitment[12]. In others, amblyopia was identified as a major cause of VI with no stated definition criterion[13,17,19-20], while others[14,25,27] failed to provide detailed information on the causes of VI in their study samples. In addition, the study by Ajaiyeoba *et al*[12] did not indicate the definition criteria used to identifying participants with VI. In relation to RE, the emphasis in some studies was on VI with RE[14,18,26], thereby undermining the quantification of children at risk of developing VI due to RE and preventing the development of screening and intervention strategies to prevent VI in this cohort.

DISCUSSION

Definition of Visual Impairment The definition criterion for identifying children with VI is very important. Until recently, the definition of VI was predicated on the second revision of the 10th ICD edition[28], which followed from a 1972 World Health Organization (WHO) study of blindness and demonstrated that the best corrected VA should be used as the basis for estimating VI[29]. At that stage, RE was not considered a priority and a major cause of VI, and was excluded from reports of the total number of persons with VI. However, data from recent population-based studies indicates that uncorrected RE contributes significantly to the total number of persons with VI[30]. Accordingly, the WHO adopted a new definition of VI in the revised ICD-10 version: 2016, and uses presenting VA and visual loss from uncorrected RE[31]. Under this classification, low vision (moderate and severe impairment) is defined as a presenting VA of less than 6/18, but equal to or better than 6/120, or a visual field loss to less than 20 degrees diameter in the better eye with best possible refractive correction.

In the reviewed studies (Table 1), although VI was mostly defined as a VA of less than or equal to 6/12, a broad range of definition criteria was applied in its diagnosis: from a VA of 6/9 or less to less than 6/12, including Ajaiyeoba *et al*[12], who did not indicate the definition criterion for VI. The use of a VA of 6/9 by some studies will overestimate the prevalence of VI and weigh heavily on the cost of intervention services for affected individuals, and cause considerable psychological effect on the affected children and their families. When compared to other studies on African children, Megbelayin and Asana[13], who defined VI as a VA of 6/9 or less, reported a higher prevalence of VI than other studies[14,17-18] that utilized a VA of 6/12 or worse. The trend was also observed in the studies conducted in the Americas, where the study in Peru[25] that applied a VA threshold of 6/9 or less reported a higher prevalence of VI than another study in Brazil[23]. Studies have reported that the mean VA in young children was 6/7.5[32], and that an acuity of 6/12 or less would have a harmful effect on their vision[33] and potentially reduce their functional performance. When compared with the WHO definition of VI, the VA of 6/12 or less used by the RESC studies provides a better indicator to accurately estimate the magnitude of VI due to RE and a proper assessment of the demand for eye care services[34], including those with mild VI. Its use will also ensure timely detection and treatment of the underlying factors of mild VI before they progress to permanent.

Classification of Visual Impairment The categories of VI adopted by the majority of the studies reviewed suggest that a person with a presenting VA of worse than 6/60 should be regarded as blind. However, a substantial number of children who are classified as blind still have usable vision and can sustain activities of daily living independently[35]. Reports indicate that in developing countries, such as in Africa, approximately 20% of children categorized as blind were found to have significant residual vision[36-37]. The implications for rehabilitation and education is that children with low vision may be educated using techniques that are appropriate for those who are totally blind, despite their having some useful vision that can support other activities of daily living if they can be taught how to use it appropriately[38-39]. For instance, approximately 66% and 1.45% of children who were initially classified as blind but reading with the aid of Braille were found to have low and normal vison, respectively, after best refraction[40]. In view of the importance of functional vision, the WHO in 1992 added another perspective to the definition of VI that covers both distance and near vision[35]. The definition states that: a person with low vision is one who has impairment of visual functioning even after treatment and/or refractive correction, and has a vision in the better eye of less than 10 degrees from the point of fixation (or 20 degrees across), but who uses or is potentially able to use vision for planning or execution of a task. This functional definition ensures that people who have low vision, but with a VA of less than 6/120, are included in low vision programs and are eligible for appropriate services.

Regional Variations in the Prevalence and Causes of Visual Impairment The prevalence and causes of VI varied across the different regions[1] (Table 2). A lower prevalence of VI was reported for African children compared to other regions, especially Southeast Asian countries. This may be explained by the lack of robust epidemiological studies in developing countries such as Africa. The higher prevalence of VI in Southeast Asian countries compared to other regions may be related to the reported high prevalence and severity of myopia in these populations. Myopigenic factors including: 1) genetic predisposition, such as ethnicity and a family history of high myopia; 2) intensive near work activities due to competitive education and schooling systems are common among Southeast Asian children[41], with myopic eyes being at risk of developing functional VI at a relatively young age[42]. In addition, the causes of VI varied widely among studies, which may be attributed to differences in socio-economic developments as well as the availability of efficient and broad screening strategies. These factors can all influence the prevalence and causes of VI in different regions.

Causes of Visual Impairment in School-Age Children Uncorrected RE is a leading cause of VI and the second leading cause of treatable blindness among people of all age groups[43]. This is evident in the reviewed studies (Table 2), where 47%-92.7% of the reduced vision in school-age children was caused by uncorrected RE, and 0.3%-19.0% were caused by amblyopia. The risk factors for amblyopia include strabismus, anisometropia and congenital cataract or the less prevalent media opacification. Unlike VI associated with amblyopia, simple RE (RE not associated with amblyopia) is correctable with the use of appropriate spectacles and is thought to not affect normal visual development. According to the WHO, there would be over 19 million children less than 15y of age with VI worldwide, with 12.8 million being due to uncorrected RE. Consequently, Vision 2020 initiative: The Right to Sight, identified the correction of RE as one of its major objectives. The initiative advocates vision screening in schools with the provision of affordable spectacles[44]. Similarly, amblyopia can also be effectively treated with early detection and correction of the underlying amblyogenic risk factor[45].

However, the available evidence indicates that amblyopia is treatable, even in the teenage years[45-46]. Other studies show that improvements in binocularity and VA in the amblyopic eye can also be realized in adulthood[47-48]. Available treatments for amblyopia include patching or atropine therapy of the affected eye; surgery for strabismus and cataracts; and RE correction with spectacles or contact lenses. Overall, treatable causes were responsible for majority of the VI in the study populations (Table 2).

CONCLUSION

The present review has highlighted the prevalence and causes of VI in various countries as well as some methodological concerns regarding the reported studies. Diagnostic criteria for VI varied across the studies, and in some cases, the adopted definition criteria can overestimate the prevalence of VI. As the variation in diagnostic criteria can make comparing the results very difficult, it is important to develop a standard and uniform diagnostic criterion that is appropriate for detecting children at risk of developing a VI. Nonetheless, regional variations in the prevalence of VI were significant, and may be attributed to differences in socio-economic development, race, cultural factors, as well as, the availability of interventions, and implies that the prevalence data in one population cannot necessarily be extrapolated to another. The review also demonstrated that treatable causes were responsible for the most of the VI in the study populations, and highlights the need for adequate strategies that will promote vision screening in school children and the wider community, with the goal of timely detection and treatment of common visual problems.

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Vision problems: A review of prevalence studies on refractive errors in school-age children

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Background: Refractive errors are common eye disorders and are leading causes of visual impairment in the general population. Children with uncorrected refractive error may experience reduced visual acuity, transient blurring, headache and persistent ocular discomforts particularly for close work which can impair reading efficiency and school performance.

Aim: This article documents the prevalence of refractive errors in school-age children of different ethnic origins. The goal is to identify possible variation in measuring techniques and diagnostic criteria, as well as limitations of studies, to provide a clear direction for future studies.

Methods: The review was undertaken through a detailed evaluation of peer-reviewed publications of primary research on this topic. The keywords for the search included 'refractive error', 'hyperopia', 'myopia', 'astigmatism' and 'school children'. Only epidemiological studies with participants between 5 and 18 years of age were included.

Results: Although several population and school-based studies have been conducted in various racial groups and populations, their findings were diverse owing to inconsistencies in the methods applied in identifying children in need of refraction, measurement techniques and diagnostic criteria for refractive errors. There are also some limitations associated with the sampling design and characteristics, which may have influenced the outcome measures.

Conclusion: Despite the problems inherent in the studies, the review indicates that refractive error in school-age children is a public health concern in those populations and warrants additional research that will provide reliable data for proper planning of intervention strategies.

Keywords: hyperopia; myopia; astigmatism; school-age children; school performance.

Introduction

Refractive errors (REs) including myopia, hyperopia and astigmatism are common eye disorders and are leading causes of visual impairment and treatable blindness in the general population.[1] Myopia is characterised by axial length elongation and positive image position relative to the retina and is often associated with structural changes of the retina and choroid. Myopia causes a reduction in visual acuity (VA) that cannot be overcome by accommodation.[2,3] In addition, highly myopic eyes, that is, of –6 dioptres (D) or more, may develop sight-threatening complications, leading to visual impairment at a young age.[4] Hyperopia, by contrast, is a condition in which the eye is shorter.[4] Although distance VA may be unaffected, especially in mild hyperopia, it can create visual disturbances which can affect optimum functional performance of school children.[4,5] Hyperopia is also a predisposing factor to convergent strabismus, esophoria, amblyopia and angle closure glaucoma in young children.[6] Astigmatism is a condition that causes a certain degree of blurred vision at all distances including other near vision-related symptoms.[7,8] If uncorrected during early development, astigmatism induces a form of visual deprivation that can result in meridional amblyopia[7,8] and possibly permanent visual impairment.[8]

This article presents a review of the prevalence of REs in school-age children, along with their association with age and gender. A discussion about variation in measuring techniques and diagnostic criteria, as well as limitations of studies, is provided to direct future studies. Considering the implications of uncorrected RE to academic achievement and overall well-being, this review could provide useful information for policymakers and can help in planning, provision and evaluation of child eye health services.

Methods

A literature search was conducted on the online databases of PubMed, Medline, OVID, Google Scholar, ScienceDirect and Embase from November 2016 to November 2017 using the following keywords: refractive error, hyperopia, myopia, astigmatism and school children. The review was restricted to primary research published in English and in peer-reviewed journals. Only epidemiological studies with stated measures of prevalence of corresponding RE among school-age children between 5 and 18 years of age were included.

In this narrative review, findings from studies that met the outlined criteria were reviewed. Variables of interests for review included the following: sample size and sampling method, participant characteristics including gender and age, prevalence rates of corresponding RE, information on diagnostic criteria and measurement techniques. A summary of each study was first presented and evaluated in relation to findings from other studies. Eligible studies on myopia, hyperopia and astigmatism were compared according to geographic regions or ethnicity.[9]

Previous studies on school-age children

Prevalence of hyperopia

African population

Table 1 shows the prevalence of hyperopia from selected countries in various geographic regions. Lower prevalence of hyperopia in African populations was reported by studies that included only significant RE in their prevalence estimation. In Nigeria, Atowa et al.[10] reported 0.9% hyperopia in 1197 school children aged 8–15 years, with only 29.1% of the children with RE wearing spectacles during examination. Hyperopia was defined as a spherical equivalent refraction (SER) of 2 D or more in one or both eyes, if none of the eyes were myopic. All the study participants underwent cycloplegic refraction. Similarly, Mehari and Yimer reported 0.3% hyperopia (SER $\geq$ 2 D) in 4238 school children between the ages of 7 and 18 years in Ethiopia.[11] Non-cycloplegic retinoscopic refractions were performed on all participants, and VA thresholds of 6/9 or worse in the better eyes were applied to identify those in need of refractive correction. Two studies on African populations included hyperopia of 0.50 D in their prevalence estimation and reported a prevalence of hyperopia of 5.0% in Ghana[12] and South Africa[13] each in high school children. It is important to note that the inclusion of low categories of REs is of clinical significance because such refractive anomalies can possibly impair reading efficiency and school performance.[13]

Asian population

As with studies on African populations, prevalence studies on children from other geographic locations also reported varied results. Although the studies in Asia utilised a logMAR protocol, common definition of SER 2 D or more, large sample sizes, differences in age group of the study participants and study locations (rural or urban) may have influenced the reported prevalence of hyperopia in the various studies reviewed. In rural China,[14] the prevalence was 1.2% in children aged between 13 and 17 years, while in urban China[15] the prevalence was 5.8% in participants between 5 and 15 years. Likewise, in rural India,[16] the prevalence of hyperopia in children aged between 7 and 15 years was 0.4% and in urban India[17] it was 7.7% in children aged 5–15 years. The prevalence of hyperopia in a suburban area of Malaysia[18] was 1.6% in participants aged between 7 and 15 years, whereas in high school children aged between 12 and 15 years in Vietnam,[19] the prevalence was 0.4%. A study in Saudi Arabia[20] reported a prevalence of 0.9% hyperopia in primary school children aged 6–13 years in Al-Qassim region. The authors considered only children with a VA of $\leq$ 6/12 as needing RE assessment. Norouzirad et al. reported a prevalence of 12.9% in school children between the ages of 6 and 15 years in Iran, with all children refracted irrespective of VA.[21] The evaluation of the refractive status of all children is important because this enables the detection of children with significant hyperopia even when VA is unaffected but the

TABLE 1: Prevalence of hyperopia among school-age children in selected countries from various geographic regions.

Study	Country	Ethnicity	Age (years)	Sample size (N)	Definition criteria	Measurement technique	Prevalence (%)
Atowa et al.[10]	Nigeria	African	8–15	1197	SER ≥ 2.00	Cycloplegic autorefraction	0.9
Ovenseri-Ogbomo and Assien[12]	Ghana	African	11–18	595	SPH ≥ 0.75	Non-cycloplegic retinoscopy	5.0
Mehari and Yimer[11]	Ethiopia	African	7–18	4238	SER ≥ 2.00	Non-cycloplegic retinoscopy	0.3
Wajuihian an d Hansraj[13]	South Africa	African	13–18	1586	SER ≥ 0.50	Non-cycloplegic autorefraction/ Subjective refraction	5.0
Aldebasi[20]	Saudi Arabia	Middle East	6–13	5176	SER ≥ 2.00	Cycloplegic autorefraction	0.9
Norouzirad et al.[21]	Iran	Middle East	6–15	1130	SER ≥ 2.00	Non-cycloplegic retinoscopy	12.9
He et al.[14]	Rural China	Asian/East	13–17	2454	SER ≥ 2.00	Cycloplegic autorefraction	1.2
He et al.[15]	Urban China	Asian/East	5–15	4347	SER ≥ 2.00	Cycloplegic autorefraction	-
Paudel et al.[19]	Vietnam	Asian/South East	12–15	2238	SER ≥ 2.00	Cycloplegic autorefraction	0.4
Goh et al.[18]	Malaysia	Asian/South East	7–18	4634	SER ≥ 2.00	Cycloplegic autorefraction	1.6
Dandona et al.[16]	Rural India	Asian/South	7–15	3976	SER ≥ 2.00	Cycloplegic autorefraction	0.4
Murthy et al.[17]	Urban India	Asian/South	5–15	6447	SER ≥ 2.00	Cycloplegic autorefraction	7.7
Zadnik et al.[24]	USA	Caucasian	6–14	2583	SER ≥ 1.25	Cycloplegic autorefraction	8.6
Kleinstein et al.[23]	USA	Caucasian	5–17	2523	SER ≥ 1.25	Cycloplegic autorefraction	12.6
O'Donoghue et al.[25]	United Kingdom	Caucasian	6–7	392	SER ≥ 2.00	Cycloplegic autorefraction	20.6
			12–13	661			14.7
Czepita et al.[26]	Poland	Caucasian	6–18	5724	SER ≥ 2.00	Cycloplegic retinoscopy	4.0
Ip et al.[27]	Australia	Caucasian	11–14	2352	SER ≥ 2.00	Cycloplegic autorefraction	5.0
Fotedar et al.[28]	Australia	Caucasian	12	2233	SER ≥ 2.00	Cycloplegic autorefraction	5.0

SER, spherical equivalent refraction.

development of convergent strabismus and amblyopia because of excessive use of accommodation to maintain normal (6/6) VA may be possible.[22]

Caucasian population

For studies conducted on caucasian populations, diagnostic criteria and age ranges of the study samples affected the reported prevalence of hyperopia (Table 1). Two studies in the United States that adopted a common definition of hyperopia of 1.25 D or more in both meridians reported a prevalence of 12.8%[23] and 8.6%,[24] respectively. Differences between the findings can at least be accounted for by the different age ranges of the study populations. The study by Kleinstein et al.[23] had a larger age range (5–17 years) compared with the study by Zadnik et al.[24] (6–14 years). In Europe, the Northern Ireland Childhood Errors of Refraction study examined 1053 white children (392 aged 6–7 years old and 661 aged 12–13 years old) and reported that the prevalence of hyperopia (SER ≥ 2 D) was 20.6% and 14.7%, respectively.[25] An earlier study in Poland[26] had found a prevalence of hyperopia (SER 1 D) of 38.0% in 5721 school children between the ages of 6 and 18 years. The differences in findings by the studies on the European population may be attributed to the differences in definition criteria for hyperopia, population age group and sample size. Similarly, two studies in Australian children with different age ranges reported different prevalence estimates for hyperopia. The study by Ip et al.[27] conducted with children between the ages of 11 and 14 years reported a prevalence of 5.0%, whereas Fotedar et al.[28] reported a 3.5% prevalence of hyperopia in 12-year-old children.

Prevalence of myopia

African population

Except for two studies in the United States,[23,24] myopia was defined as -0.50 D or worse in all the studies reviewed (Table 2). However, measuring techniques and participants' ages in addition to geographic variations appear to have an influence on the reported prevalence of myopia, with a significantly higher prevalence in Asian children compared with other ethnic backgrounds. For studies on African populations, Mehari and Yimer[11] and Wajuihian and Hansraj[13] included older children and reported a higher prevalence of myopia (6.0% and 7.1%, respectively) compared with the reported 2.7% by Atowa et al.[10] with younger children. Although the prevalence of myopia increases with age because of more involvement and longer duration of near-work activities during high school years,[10,13,19,20] the non-cycloplegic refraction technique applied by the two studies[11,13] tends to overestimate myopia in children.[19] However, Ovenseri-Ogbomo and Assien[12] reported a prevalence of 2.6% in children aged between 11 and 18 years. The low prevalence despite older children and the performance of non-cycloplegic retinoscopic refraction may be related to the use of least myopic corneal meridian in quantifying myopia.

Asian population

Variations in the prevalence of myopia in Asian children have also been widely reported, with considerable differences existing between various countries and study locations. Overall, the studies reviewed showed that myopia is more prevalent in East Asian and South-East Asian countries than in other parts of the world. For instance, studies by He et al. using cycloplegic autorefraction found that 35.1% and 42.4% of school-age children in rural[14] and urban[15] China, respectively, were myopic. These values are higher when compared with the estimates reported for South-East Asian population, such as 20.7% in Malaysia[18] and 20.4% in Vietnam.[19] In contrast, studies on the South Asian population reported a much lower prevalence of myopia than other Asian regions. In rural India,[16] myopia prevalence was 4.1% and in urban India[17] it was 7.4%. Two studies in the Middle East reported a prevalence of 6.5% (Saudi Arabia)[20] and 14.1% (Iran)[21] in children in the age range of 6–15 years.

TABLE 2: Prevalence of myopia among school-age children in selected countries from various geographic regions.

Study	Country	Ethnicity	Age (years)	Sample size (*N*)	Definition criteria	Measurement technique	Prevalence (%)
Atowa et al.[10]	Nigeria	African	8–15	1197	SER ≤ -0.50	Cycloplegic autorefraction	2.7
Ovenseri-Ogbomo and Assien[12]	Ghana	African	11–18	595	SPH ≤ -0.50	Non-cycloplegic retinoscopy	2.6
Mehari and Yimer[11]	Ethiopia	African	7–18	4238	SER ≤ -0.50	Non-cycloplegic retinoscopy	6.0
Wajuihian and Hansraj[13]	South Africa	African	13–18	1586	SER ≤ -0.50	Non-cycloplegic autorefraction	7.1
Aldebasi[20]	Saudi Arabia	Middle East	6–13	5176	SER ≤ -0.50	Cycloplegic autorefraction	6.5
Norouzirad et al.[21]	Iran	Middle East	6–15	1130	SER ≤ -0.50	Non-cycloplegic retinoscopy	14.9
He et al.[14]	Rural China	Asian/East	13–17	2454	SER ≤ -0.50	Cycloplegic autorefraction	42.4
He et al.[15]	Urban China	Asian/East	5–15	4347	SER ≤ -0.50	Cycloplegic autorefraction	35.1
Paudel et al.[19]	Vietnam	Asian/South East	12–15	2238	SER ≤ -0.50	Cycloplegic autorefraction	20.4
Goh et al.[18]	Malaysia	Asian/South East	7–18	4634	SER ≤ -0.50	Cycloplegic autorefraction	20.7
Dandona et al.[16]	Rural India	Asian/South	7–15	3976	SER ≤ -0.50	Cycloplegic autorefraction	4.1
Murthy et al.[17]	Urban India	Asian/South	5–15	6447	SER ≤ -0.50	Cycloplegic autorefraction	7.4
Zadnik et al.[24]	USA	Caucasian	6–14	2583	SER ≤ -0.75	Cycloplegic autorefraction	10.1
Kleinstein et al.[23]	USA	Caucasian	5–17	2523	SER ≤ -0.75	Cycloplegic autorefraction	9.2
O'Donoghue et al.[25]	United Kingdom	Caucasian	6–7	392	SER ≤ -0.50	Cycloplegic autorefraction	2.3
			12–13	661			17.1
Czepita et al.[26]	Poland	Caucasian	6–18	5724	SER ≤ -0.50	Cycloplegic retinoscopy	13.1
Fotedar et al.[28]	Australia	Caucasian	12	2233	SER ≤ -0.50	Cycloplegic autorefraction	9.8

SER, spherical equivalent refraction.

Caucasian population

As with studies on African and Asian populations, the prevalence of myopia in Caucasian children was also influenced by the definition criteria and participants' ages (Table 3). A comparatively similar finding was reported by two studies[18,24] in the United States that defined myopia as -0.75 D or worse in participants of similar age group. However, studies in Europe, which defined myopia as SER ≤ -0.50 D, reported varied results, possibly because of dissimilar age ranges of the study participants. O'Donoghue et al.[25] found that 2.3% of children who are between 6 and 7 years old are myopic compared with 17.7% of 12 to 13-year-olds. Czepita et al.[26] reported a myopia prevalence of 13.0% in children between 6 and 18 years in Poland, which was 1.9% in 6-year-olds and 31.9% in 18-year-olds. In Australia, Fotedar et al.[28] found a myopia prevalence of 9.8% in 12-year-old students.

Prevalence of astigmatism

African population

Previous studies exploring the prevalence of astigmatism in school-age children have also shown marked variations in prevalence levels (Table 3). Although most of the studies[10,11,12,13] on African children defined astigmatism as cylindrical error of at least -0.75 D, different measuring techniques (retinoscopy or autorefraction) were applied in the detection of astigmatism. For studies that performed autorefraction technique, Atowa et al.[10] who applied cycloplegia reported a higher estimate compared with Wajuihian and Hansraj[13] who utilised non-cycloplegic refraction method, which was followed by subjective refraction. Similarly, two studies that utilised non-cycloplegic retinoscopic technique reported varied results. Ovenseri-Ogbomo and Assien[12] with a smaller sample size and older children reported a higher prevalence value compared with Mehari and Yimer[11] with a larger sample size and younger children.

Asian and Caucasian populations

The studies on Asian populations were consistent in the definition of astigmatism and the use of cycloplegic objective measurement methods. In most of the studies, both objective (retinoscopy and autorefraction) methods were applied and the results showed that autorefraction technique yielded higher values compared with the retinoscopic technique (Table 3). In using cycloplegic retinoscopic technique, the prevalence of astigmatism ranged between 3.8% and 33.6%, while with cycloplegic autorefraction technique the estimates ranged between 9.7% and 42.7%. Overall, a higher prevalence of astigmatism was reported for East Asian children compared with other regions of Asia as well as other continents (Table 3).

For studies on Caucasian children, the prevalence of astigmatism was also influenced by the definition criteria and measurement methods (Table 3). Two studies[23,29] that applied cycloplegic autorefraction method and defined astigmatism as cylindrical error of at least -1.00 D reported comparatively similar findings, whereas a study in Poland[26] which defined astigmatism error of at least -0.50 D determined by cycloplegic refraction reported a prevalence of 4.0% in children aged between 6 and 18 years.

Age and refractive errors

Most of the studies showed that the prevalence of hyperopia decreases significantly with age.[14,15,18,20,21,24,25,26] In using the same RE definition and logMAR protocol to assess children aged 5–15 years, Murthy et al.[17] and He et al.[15] revealed that early significant hyperopia decreases rapidly from age 5 years to an insignificant level by the age of 15 years, with a noticeable myopic shift taking place around age 12. This agrees with the views of Saunders et al.[30] and Borish[31] that infants are usually born with some amount of hyperopia which tends towards emmetropia and possibly myopia as they grow older.

Regarding myopia, several studies reviewed were consistent in reporting a significant age increase in the prevalence of myopia.[15,16,17,18,19,20,21,24,25,26] Atowa et al.[10] reported that 12 to 15-year-old children had a 1.2 times higher risk of developing

TABLE 3: Prevalence of astigmatism among school-age children in selected countries from various geographic regions.

Study	Country	Ethnicity	Age (years)	Sample size (*N*)	Definition criteria	Measurement technique	Prevalence (%)
Atowa et al.[10]	Nigeria	African	8–15	1197	≤ -0.75	Cycloplegic autorefraction	4.4
Ovenseri-Ogbomo and Assien[12]	Ghana	African	11–18	595	≤ -0.75	Non-cycloplegic retinoscopy	6.5
Mehari and Yimer[11]	Ethiopia	African	7–18	4238	≤ -0.75	Non-cycloplegic retinoscopy	2.0
Wajuihian and Hansraj[13]	South Africa	African	1318	1586	≤ -0.75	Non-cycloplegic autorefraction	3.0
Aldebasi[20]	Saudi Arabia	Middle East	6–13	5176	≤ -0.75	Cycloplegic autorefraction	11.2
He et al.[14]	Rural China	Asian/East	13–17	2454	≤ -0.75	Cycloplegic autorefraction	25.3
He et al.[15]	Urban China	Asian/East	5–15	4347	≤ -0.75	Cycloplegic retinoscopy	33.6
						Cycloplegic autorefraction	42.7
Paudel et al.[19]	Vietnam	Asian/South East	12–15	2238	≤ -0.75	Cycloplegic autorefraction	20.4
Goh et al.[18]	Malaysia	Asian/South East	7–18	4634	≤ -0.75	Cycloplegic retinoscopy	15.7
						Cycloplegic autorefraction	21.3
Dandona et al.[16]	Rural India	Asian/South	7–15	3976	≤ -0.75	Cycloplegic retinoscopy	3.8
						Cycloplegic autorefraction	9.7
Murthy et al.[17]	Urban India	Asian/South	5–15	6447	≤ -0.75	Cycloplegic retinoscopy	7.0
						Cycloplegic autorefraction	14.6
Kleinstein et al.[23]	USA	Caucasian	5–17	2523	≤ -1.00	Cycloplegic autorefraction	28.4
Czepita et al.[26]	Poland	Caucasian	6–18	5724	≤ -0.50	Cycloplegic retinoscopy	4.0
Robaei et al.[29]	Australia	Caucasian	12	2353	≤ -1.00	Cycloplegic autorefraction	21.8

myopia than those aged 8–11 years. Near-work activities, such as reading, writing, computer use and playing video games, have been indicated in the significant increase in the prevalence of myopia as well as increased risk for developing myopia.[32] The prevalence of astigmatism has been found to vary with age. Some studies[28,33] associated astigmatism with older age children, while others[14,15,18,26] associated astigmatism with younger age children.

Gender and refractive errors

It has been suggested that, on average, women have shorter axial length when compared with men.[27,34,35] As such, women are more likely to be hyperopic when compared with men. These findings are consistent with the observations of studies in China,[14,15] India[17] and Malaysia[18] that found more hyperopia in women than in men. In Australia,[27] the significant increase in hyperopia prevalence with women compared with men were only found in younger children (6 years old) and not in older children (12 years old). In contrast, a study in Saudi Arabia[20] found that the prevalence of hyperopia was higher in boys than in girls. For the study participants, physiological maturation occurred faster in girls than in boys.[20] Several studies[10,11,13] on African children found no difference between gender and myopia risk, whereas studies in Asia[14,15,17,18,20] revealed that the prevalence of myopia was significantly higher in female subjects than in male subjects. Some studies have also found astigmatism to be significantly higher in boys than in girls.[20,21] He et al.[15] and Dandona et al.[16] reported contrary results.

Limitations of previous studies

There are some limitations associated with the studies reviewed, which may have influenced the interpretation of their findings and conclusions. All studies except Atowa et al.[10] and Wajuihian and Hansraj[13] failed to indicate how sample sizes were derived. The use of small sample sizes,[21,24] limited age range of participants[25,28,29] and non-use of cycloplegia or the plus lens test to screen for latent hyperopia[11] may have affected the results of some studies. Although the study by Ovenseri-Ogbomo and Assien[12] applied a random sampling approach at classroom level, the use of convenience sampling technique in selecting the participating schools may limit the generalisation of findings of the study.

Discussion

This literature review has highlighted the prevalence of RE in school-age children in various countries. However, inconsistent methods were applied across studies in identifying children in need of refraction. Although a VA threshold of 6/9 or less can reliably detect myopia in school-age children, there is no reliable VA threshold for clinically significant hyperopia and astigmatism. High amounts of hyperopia (> 5 D) and astigmatism (> 1.5 D) have been reported in children who were able to read 6/6 (20/20) on the VA chart.[20,21] Reports indicate that uncorrected hyperopia, which is less likely to cause a reduction in VA, is a risk factor for strabismus, amblyopia and angle closure glaucoma.[4,5,22] Therefore, to determine the actual prevalence of RE in a study sample, refraction should be performed on all children irrespective of VA.

There is no consensus on the most appropriate method for the measurement of RE. Some studies reported myopia and hyperopia in terms of the spherical component, while others reported them based on the SER (sphere + ½ cylindrical components). Although an objective method (retinoscopy or autorefraction) was the preferred measuring technique, the use of cycloplegia was not a constant factor. Instead some studies utilised the plus lens test to screen for latent hyperopia because cycloplegia was contraindicated as accommodative tests were also included in their evaluations or for concerns of ethical issues.[11,12,13] For the studies that adopted the plus lens technique, analysis was based on the subjective findings, while that of the cycloplegic refraction technique was based on cycloplegic findings. In addition, most studies identified an individual as having RE after binocular examination, but others use the eyes separately as unit samples or examine only one of the eyes (usually the right eye) relying on evidence of good correlation between ametropia in both eyes. To facilitate comparison of findings among studies, a better approach will be to develop a standardised method of measuring RE in children.

A wide variety of criteria were applied in the diagnosis of individuals with different types of RE, with many studies focusing mainly on RE that significantly affects VA (Tables 1–3).[10,11,12,13,14,15,16,17,19,20,21,23,24,25,26,27,28,29] Overall, myopia was defined as -0.50 D or -0.75 D or more; hyperopia definition ranged between 0.50 D and 2 D and astigmatism varying from -0.50 D to -1 D. Given the progressive nature of myopia during the teenage years,[10] all myopic eyes are at risk for complications.[4] Likewise, visual discomfort is more common in children with low degrees of hyperopia and astigmatism because of excessive use of accommodation to maintain normal vision.[5,6] For high school children who are engaged in intensive reading and longer duration of near-work activities, it will be difficult to comfortably sustain normal vision for long periods of time, especially at close distances where reading takes place. As a result, the child may lose interest in reading and other near-vision-related academic tasks which may affect his or her school performance. It is, therefore, important to include low categories of RE in prevalence estimations as this will provide comprehensive data for proper planning and implementation of intervention strategies.

The studies[14,15,18,20,21,24,25,26] consistently reported a significant age-related decrease in hyperopia prevalence and a significant age-related increase in prevalence of myopia. Hyperopia in infants usually decreases to emmetropia as they grow, with myopia starting to develop around age 6 years when school begins.[29,31] However, myopia becomes significant during high school and teenage years when there is rapid growth and heavier load of near work.[10,19,20] Regarding gender and different types of REs, variations in trends were observed for men and women by some studies, which may be partly related to gender representativeness in these studies. Differences in growth spurts and maturation rate between genders may also explain the gender differences in the prevalence of REs. Peak height velocity is associated with earlier axial length peak and spherical equivalent velocity[20,36] and some studies noted that peak height velocity was commonly earlier in women.[14,15,17,20] In these studies, physiological maturation occurred faster in female participants than in male participants; therefore, a higher prevalence of myopia was found in women and a higher prevalence of hyperopia was found in men as women would have already undergone emmetropisation with men lagging slightly behind. Cultural distinctiveness and lifestyle characteristics, such as number of hours spent on near work and outdoor activities, between men and women have also been shown to affect gender pathogenesis of RE in each geographic area.[10,20] It has been suggested that hyperopic SER is more common in children who dedicated less time to near activities and more time to outdoor activities.[37]

The disparity in the RE prevalence by regions and study locations can be explained by ethnicity and geographical factors. Hyperopia prevalence was low in African and East Asian populations compared with Caucasians. Similarly, myopia and astigmatism were higher in East and South-East Asian populations compared with other regions. Reports indicate that South-East Asian children are genetically predisposed to having myopia because of the influence of ethnicity, family history of myopia and schooling system.[10,19,38] About ocular components, axial length in both African and Asian children is longer than in Caucasian children.[38] In addition, reports show that populations with high myopia prevalence rates, like in China, generally have a low hyperopia prevalence.[13,14,15,31] The higher prevalence of hyperopia and low prevalence of myopia in rural populations may be because of their involvement in more outdoor activities. Competitive education may also be a contributory factor to the higher prevalence of myopia reported for East Asian and South-East Asian children. The implications are that, even within the same country, RE estimates in one population cannot necessarily be extrapolated to another population.

Conclusion

This article indicates that the prevalence of RE in school-age children is a public health concern in the various study locations. The methodological differences, such as inappropriate study designs, variations in defining and quantifying the RE and improper measuring techniques, complicate the comparison of the corresponding findings. The article highlights the gaps in knowledge in this area of study, including the non-inclusion of low categories of RE, non-inclusion of all children for refraction within some studies, non-application of cycloplegia or the plus lens test, limited age range, small sample size and inappropriate sampling methods. The review of the literature also reveals regional variations in the prevalence of RE, which may be related to differences in socio-economic development, race, cultural factors as well as availability of interventions. Considering the implication of visual anomalies for academic achievement, as well as overall well-being, this review could provide useful information for policymakers and can help in planning, provision and evaluation of child health services. Future research should include near vision anomalies which are capable of affecting school performance even when VA is not affected. This would assist in developing broad interventions and management strategies targeting these conditions in school-age populations.

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Competing interests

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Authors' contributions

U.C.A. wrote the article. R.H. and S.O.W. provided feedback on the structure and content of the manuscript.

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· Review Article ·

A review of paediatric vision screening protocols and guidelines

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Abstract

● Vision screening plays an important role in the early detection of children who have or probably are predisposed to have specific visual problems. The validity and reliability of the screening batteries in relation to the age group to be screened, and the person administering the test as well as the referral and follow-up criteria contribute to the overall outcome of the vision screening. Despite the long history of vision screening and significant improvement in the development of screening protocols, no agreement exists concerning the age at which children should be screened, the exact test batteries that should be included and who should conduct the screening. This review highlights some important aspects of the history of paediatric vision screening and available evidence in support of their use to detect visual conditions in children. It also examines some of the barriers against the development of paediatric vision screening models especially in low and medium income countries.

● KEYWORDS: vision screening; children; visual problems; screening batteries

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INTRODUCTION

The primary goal of pediatric vision screening is to detect children with unsuspected remediable visual conditions, to implement early treatment and reduce the impact that any untreated condition may have on their educational and social progress[1-2]. Starting with the first approved vision screening program in Connecticut in 1899[3] that utilized the traditional visual acuity (VA; Snellen) chart, screening programs and test batteries have evolved over the years. Despite the significant improvements, the value of paediatric vision screening programs and the ideal protocol to be adopted has continued to dominate scientific and health policy discussions. While it is generally accepted that the detection of vision anomalies in children depends on the availability of valid and reliable test batteries, no agreement exists concerning the age at which children should be screened, the exact test batteries that should be included and who should conduct the screening. This review highlights some important aspects of the history of paediatric vision screening and available evidence in support of their use to detect visual conditions in children. It also evaluates some of the more contentious issues against the development of paediatric vision screening guidelines.

THE NEED FOR VISION SCREENING

According to the recommendations of the World Health Organisation, effective screening programs should include tests to detect conditions that are common and can present serious health problems. Such conditions can easily be detected through cheap and reliable screening tests that are available. It should also be economically amenable to treatment[4].

Significant refractive error (RE) is a leading cause of visual impairment in childhood and its detection is the main target of vision screening programs[5]. A series of Refractive Error Study in Children (RESC) surveys, conducted in several countries on children of comparable age group and by utilizing common diagnostic criteria and measurement methods observed that uncorrected RE was responsible for about 56%-94% of cases of reduced vision in children[6]. The studies suggest that the vision of those children would have been effectively treated with early detection and spectacle correction. There are over 19 million children less than 15 years of age with visual impairment worldwide with 12.8 million of them due to uncorrected RE[6].

Amblyopia is also a common cause of vision loss in children. It is mostly cause by strabismus, RE and congenital cataract[7-8]. Testing for amblyopia is one of the focus areas of many screening programs because of its prevalence, its effect on children and society, and the effectiveness of amblyopia treatment. It is estimated that 2%-4% of people in developed nations are affected by amblyopia depending on the population and study[9-10]. Individuals with amblyopia are more likely to have bilateral vision impairment compared to non-amblyopic persons which exacts a significant burden on the individual and society[11-12]. Amblyopia can be easily treated by cost effective means including optical correction of any significant RE, patching of the non-amblyopic eye, or use of atropine in the non-amblyopic eye[8,13]. Available studies indicate that amblyopia can be treated later in life but is most effectively treated, and can only be prevented, in early childhood[7-8,13].

The condition of strabismus or misalignment of the eyes is related to amblyopia and therefore, there may also be a "critical period" after which permanent vision loss may occur without early intervention. For instance, to avoid confusion of receiving two disparate retinal images, the brain can ignore or suppress the image from one eye which could remotely lead to amblyopia. Once the visual system in the brain is fully developed, however, such adaptations are not possible[7]. Colour vision deficiency (CVD) is rarely included in screening protocols considering that congenital CVD are untreatable and not always considered as a disease. However, some people argue that CVD testing should be included as part of screening batteries as CVD can affect the development of a child. As such early identification will help to counsel the affected child of possible career choices thereby reducing the psychological effect this may have in the future[14]. Screening for accommodative and binocular dysfunction is preferable, as there is some evidence in support of an association with impaired school performance. Other conditions targeted in paediatric vision screening programs include ocular pathology such as trachoma, vitamin A deficiency, cataract, glaucoma and retinoblastoma[5].

HISTORICAL DEVELOPMENT OF VISION SCREENING PROTOCOLS

Traditional Methods The first state approved school vision screening program that included only a Snellen chart was established in Connecticut in 1899. However, this achievement was marred by poor test results owing to the under-standardization of the testing conditions. In 1934, a series of slides that were used in the assessment of VA, fusion and stereopsis was developed[3]. The development marked an important point in the history of vision screening, as it became the first commercially available stereoscope, after incorporating it into the Keystone Ophthalmic Telebinocular Vision Testing instruments. Similarly, the tests results were considered unacceptable by the American Medical Association in 1939 due to its high failure rates of 85%[3].

The idea of incorporating ocular examination into screening programs, as well as ensuring a wider coverage through rapid and precise methods led to the development of the Massachusetts Vision Test in 1938, which included tests for VA using the Snellen chart, hyperopia using +1.00 D lenses, and heterophoria using the Maddox rod. Teachers were entrusted with the responsibility of identifying children in need of vision correction and promptly referring them to the ophthalmologist. The screening maintained good correlation with ophthalmologists producing agreements of 86% of those who passed and 93% of those who failed. The main challenge for this screening test was the inability to develop consistent and reliable passing criteria[15].

Contemporary Methods Using the concept of the Massachusetts Vision Test, optical companies started producing commercially available vision screening instruments that included the Massachusetts School Vision Screening Test, the modified Keystone Telebinocular, the modified Bausch and Lomb School Ortho-Rater, and the Titmus Optical School Vision Tester in 1955. Although these instruments provided a cost-effective and rapid testing approach, the issue of who should administer the test, how often it should be performed, and the referral and follow-up criteria were still controversial[3].

The first comprehensive and systematically validated children's vision screening tool known as the Modified Clinical Technique (MCT) was developed from a three-year study period in the Orinda School District in California, USA. Starting from 1954, parents, teachers, nurses and optometrists utilized a combination of assessment procedures to re-examine a single cohort of primary school children seven or eight times in every subsequent year of the study. The Orinda study identified reduced VA, RE, binocular vision dysfunction (strabismus) and ocular pathology as specific problems that should be prioritised for screening by either optometrists or ophthalmologists[16-17]. Interestingly, the test protocol can be completed in about 5 to 6min per child[14]. The remarkably high sensitivity (98%), specificity (99%) and good predictive value (positive predictive value of 0.90 and negative predictive value of 0.99) of the Orinda Study and its MCT has gained wide acceptance as it is considered as the "gold standard" vision screening procedure for school-aged children[14,18].

However, tests for non-strabismic binocular dysfunction were not part of the MCT and ophthalmic-trained personnel (ophthalmologists and optometrists) are required to perform RE assessment with a retinoscope and to screen for ocular disorders[19]. With the exception of distance and near cover test, no other functional and performance-oriented testing was included in the MCT battery[19]. In addition, the high sensitivity and specificity reported for the Orinda MCT has not been replicated in subsequent studies that applied the MCT battery[14,18]. This may be due to the lack of a definitive pass/fail criterion for the MCT in the Orinda study. A child is considered to have passed or failed the test based on the decision of two independent optometrists after reviewing the results of the series of tests. In case of any disagreement between the optometrists, four additional vision care experts are consulted[14]. Given that the MCT cannot be administered by non-ophthalmic trained vision screeners including the non-replication of its sensitivity and specificity values, the status of a "gold standard" vision screening protocol has been questionable[18].

A modified version of the Orinda MCT (Portsea MCT) was introduced in vision screening programs between 1980 and 1983 as part of a larger public health initiative at Portsea in Victoria, Australia[14]. In the Portsea MCT fusional vergence ranges, accommodative facility, ocular motility, stereopsis and colour vision tests were added to the Orinda battery to provide a comprehensive assessment of visual parameters associated with reduced school performance[20]. However, the added test protocols did not increase the time efficiency of the Portsea MCT when compared to the Orinda MCT[20-21]. Similarly, when compared to other screening programs that utilized the Orinda MCT the referral rate from the Portsea study of 17.7% and 10.4% was classified as unsatisfactory and borderline, respectively[16-17,22].

In 1985 a screening battery that uses a functional vision screening approach to detect learning related vision problems was developed by the New York State Optometric Association (NYSOA)[23]. The test battery included distance and near VA, as well as screening tests for hyperopia, convergence, fusion (with the Keystone Telebinocular), stereopsis, saccadic skills, visual motor integration, and colour vision and was designed to be administered by parent volunteers trained by an optometrist. A validation study for the screening protocol observed a sensitivity of 72% and specificity of 65% when compared to professional eye examination, and that the Snellen test missed 75% of the visual problems that were detected in the full examinations. Concerns about the practical applicability of this screening protocol apparently contributed to its lack of acceptance by schools. The test battery is long and involves both optometrists and trained parent volunteers, as school nurses cannot alone administer the screening and schools may not be able to provide enough of their own personnel for the screening[14,23].

Computerized Methods The development of computerised screening protocols helped to tackle some of the issues which has been a major drawback for screening programs. For instance, a computer software known as Visual Efficiency Rating (VERA) was developed to address some of the concerns of NYOSA test batteries, so that school nurses could screen for binocular, accommodative, and ocular motor disorders in addition to hyperopia and VA. The protocol involves a 2-level testing approach in which children must pass VA, hyperopia, and stereopsis screening tests before the performance of a visual skills battery. The visual skills screened are vergence facility, accommodative facility and saccadic tracking. VERA screening batteries were designed to increase specificity and can be completed in about 12 to 15min per a child. A study was conducted by Gallaway and Mitchell[24] to validate the VERA visual skill test. Initially, the sensitivity of VERA in detecting visual skills problems was 45%, and the specificity was 83%. The sensitivity increased to 64% and specificity to 100% in professional eye examination data in 28 subjects when the symptom survey (Convergence Insufficiency Symptom Survey), reading level and a classroom behaviour survey (completed by the teacher) were included. The analysis was not limited to visual skills data but also comprised of acuity and refractive data. It was noted that VERA was an acceptable alternative to other protocols for screening visual skills and could be efficiently administered by a school nurse.

Although several vision screening protocols that can detect broad range of paediatric vision problems have been developed, there sensitivity/specificity, time efficiency and level of expertise required for their administration differs[14,16,23]. For instance, MCT which takes only about 5 to 6min per child requires some qualified ophthalmic personnel to administer, whereas the NYOSA test batteries which can be administer by a train non-ophthalmic personnel takes about 12 to 15min to complete per child[23]. Therefore, in developing optimum screening guideline, it is important to strike a balance between sensitivity/specificity and time efficiency[14].

VISION SCREENING MODEL IN SELECETED COUNTRIES AND REGIONS

Vision screening programs are in existence in most developed countries across the world[8,14,25-27]. However, the debate on the fundamental components and nature of the screening programs has not been resolved. Even within a country, there has not been any agreement about when children should be screened, which conditions should be targeted, which protocols should be used, and which screening personnel are best equipped to provide services. In addition, traditional VA test protocol has continued to be the fundamental of test batteries for these screening programs, despite significant improvement in the screening protocols. The implication is that the screening programs that mainly assess distance VA are likely to miss other basic visual skills necessary for optimum school performance[14]. A summary of screening programs from selected countries are presented in Table 1[1,8,14,25-28].

Non-governmental organisations working in eye health have also recommended screening guidelines to be adopted by specific countries in their regions of operation. In Eastern Mediterranean region[29] and India[30], the recommended guidelines for school vision screening prioritised the detection and correction of significant RE to reduce the prevalence of preventable blindness and low vision due to uncorrected RE

Table 1 Summary of paediatric vision screening guidelines from selected countries

Country	Age screened	Screening test	Screening personnel
British Columbia, Canada[8]	3y	Amblyopia, strabimus (eye check HOTV), Randot preschool stereo test, sure sight vision screener; reduced VA	Public health staff
Manitoba, Canada[25]	Kindergarten to Grade 1	Stereoacuity, vertical or lateral heterophoria, reduced VA	School health nurse
	Grade 3 and above	Vertical or lateral heterophoria, reduced VA, plus lens test (+2.25 D)	School health nurse
Kansas, USA[26]	Birth to 6mo	Eyelid reflex, fixation, tracking, pupil response, corneal reflex test	School health nurse, volunteers
	6-18mo	Tracking pupil response, corneal reflex test, cover test, NPC, Teller card acuity	School health nurse, volunteers
	18mo-3y	Fixating, tracking pupil response, corneal reflex test, cover test, NPC, Teller card acuity, fusion (Worth-4-dot), stereopsis, HOTV	School health nurse, volunteers
	3-5y	Fixating, tracking pupil response, corneal reflex test, cover test, NPC, Teller card acuity, fusion (Worth-4-dot), stereopsis, HOTV, colour vision test	School health nurse, volunteers
	5-8y	Fixating, tracking pupil response, corneal reflex test, cover test, NPC, Teller card acuity, fusion (Worth-4-dot), stereopsis, distance VA, colour vision test, plus lens test, near VA	School health nurse
	8-12y	Pupil response cover test, NPC, stereopsis, distance VA, colour vision, plus lens, near VA	School health nurse
Alaska, USA[27]	Distance VA: preschool, kindergarten, Grade 1 to 12	Sloan, LEA or HOTV, occluder	
	Binocular vision: Preschool, kindergarten, Grade 1	Stereofly or butterfly test, random dot ‘E’ Cover test or Hirschberg, paddle ocluder and fixation target	
	Photoscreen: preschool or kindergarten, special needs population	Valid photoscreen instrument	
Queensland, Australia[14]	0-18mo	Visual behaviour, Hirschberg test (6-18mo)	Well child visit, health nurse
	2.5-3.5y	Hirschberg test, vision, near cover test	School entry screening; child health nurse
	4-5y	Hirschberg test, vision, near cover test, distance and near cover test, vision: LEA/HOTV/STYCAR	Child health nurse
	6-12y	Vision-Snellen chart	Referred by parents; child health nurse
United Kingdom[1]	Pre-kindergarten, kindergarten	logMAR crowded test	Orthoptics
Spain[28]	4-5y	LEA charts, ocular alignment test, ocular motility test, Random dot stereo test	Qualified healthcare professional

VA: Visual acuity; LEA and HOTV: VA chart for children; STYCAR: Screening test for young children and retardates; NPC: Near point of convergence.

in the region. However, the guidelines fail to specify the age of children to be screen, the screening tools to use and who should administer the screen.

Recently a standard guideline for comprehensive school eye health programs in low and medium income countries was developed by International Agency for Prevention of Blindness (IAPB)[5]. The guideline was a revised version of an earlier document develop by a coalition of non-governmental organisations working in the field of eye health. The guideline was designed to provide direction in planning and implementation of efficient and sustainable school eye health programs through step by step approach that will be implemented base on the availability of resources and the nature of existing child eye health service in any given system. The guideline recommends that health care professionals and trained non-health professionals such as school teachers should be involved in the provision of school health programs and that schools should be visited every 1-2y[5]. Although common childhood eye conditions including eye infections, lid infections and allergies were recommended to be screened, the focus of the screening strategy is on visual conditions that can cause reduced VA and loss of vision in children (Recommendation of the IAPB for school eye health program)[5]. Visual problems such as accommodative and vergence disorders which can reduce functional performance and overall quality of life of a child are not among the conditions to be screened.

VISION SCREENING PROGRAMS AND CHILD EYE HEALTH IN NIGERIA

Early detection and treatment of potential visual impairment and blinding diseases is a key factor in the actualization of children rights, particularly the right to the highest attainable health and ensuring their protection against preventable diseases[31]. While the expanded program on immunization against measles and vitamin A supplementation have impacted positively on child eye health, the realization of efficient and a sustainable child eye health program in Nigeria has not been achieved.

Eye care services in Nigeria are delivered in public and private hospitals, however, reports indicate that eyecare services are mainly provided by private health institutions[32-33]. A situational review of paediatric eye care in Nigeria report that there were only 400 ophthalmologists in Nigeria (including those in training) with only 12 of them specializing in paediatric ophthalmology[32]. Similarly, a situational analysis of optometry in Africa, indicates that there are approximately 4000 optometrists in Nigeria[34]. The reviews[32,34] also emphasized on the uneven distribution of eye health facilities and eyecare practitioners. Among the ophthalmologists in Nigeria, 95%-99%[32] were practising in urban areas and state capitals and according IAPB[34] 60% of optometrists in Africa are working in their various country capitals with only 40% practising mainly in urban areas of the constituent states or provinces.

Although, eye health is included as one of the components of primary health care (PHC) in Nigeria, eyecare services are only provided in few PHC centres across the country. In some states secondary eye care services are non-existent and where it is provided, it is grossly under-resourced and limited by inadequate human resource capacity, equipment and referral opportunities to tertiary level services. The few tertiary centres are not adequately prepared to support the child eye health in Nigeria. The two most active and equipped tertiary paediatric centres are privately owned and are in the north central and south west geopolitical zones. In addition, only a few states have functioning blindness prevention programs and school eye health is not a priority of all the three tiers of government in Nigeria[32-33]. Thus, the provision of eyecare services including school eye health programs is mainly by private eyecare facilities. Vision screenings delivered in school settings, as well as religious centres by local eye care practitioners, are often driven by commercial interest and availability of time of the individuals involved. There is no strategic coordination between eyecare practitioners and no screening guidelines on how and when children should be screened, the screening batteries that should be included and the appropriate referral criteria. Furthermore, some prevailing eye disorders including accommodation and vergence anomalies, low amount of hyperopia and astigmatism are not necessarily included by individual eyecare practitioners. Altogether, the screening programs administered by private individuals in Nigerian are unmethodical and irregular.

MAJOR CHALLENGES TO THE DEVELOPMENT OF A VISION SCREENING MODEL

Evidence for Childhood Vision Screening One of the major challenges facing vision screening programs of school children is the lack of direct evidence demonstrating the effectiveness of childhood vision screening in reducing the prevalence of ocular disorders or in improving visual outcomes. For instance, a Cochrane review of literature from 1966 to 2004 on screening for correctable VA impairment in school-aged children and adolescents concluded that there were no available robust trials that can be used in evaluating the advantages of school vision screening. The harmful effect of reduced VA on schooling needs to be quantified. The authors suggest that in assessing the impact of a screening program, consideration will be given to the geographical and the socio-economic environment in which it is administered[35]. This however does not imply that there is no benefit derived from screening programs, rather the impact has not been systematically tested in randomized controlled trial[36]. In contrast, a convincing series of indirect evidence supports the early detection of sight threatening visual condition[36-37]. In addition, the American Academy of Ophthalmology and the American Academy of Paediatrics recommend visual assessment from birth and at all routine health visits[38].

Components of Vision Screening Protocol Even though computerized methods of vision screening are now available, the VA chart has continued to be one of the basic tools of a vision screening protocol especially in the developing countries where the acquisition of computerized instruments is not always easy. While children with uncorrected myopia can easily be detected through measures of unaided distance VA, it is not always same for those with near vision anomalies such as hyperopia, astigmatism, accommodative and binocular vision dysfunction[39-40]. A validation study[40] for VA protocol and RE detection recorded a high sensitivity and specificity for myopia detection in 12-year-old children but was not effective in detecting hyperopia or astigmatism. Children with good accommodative ability were still able to read a 6/6 (20/20) letters on the VA chart, despite having high amount of hyperopia and astigmatism. However, with increasing age and excessive near work activities, these children may experience some visual discomforts[38-39]. In another study involving high school children with poor reading ability in California, only 17% had reduced VA of less than 20/40 or worse in at least one eye, whereas 80% had deficiency in at least one of the clinical measures of accommodative and vergence functions including, near fusional amplitude, accommodative facility and near point of convergence[41]. Likewise, a significant increase in the prevalence of binocular vision problems was found among public school children in New York City[42]. The implication of these findings is that with traditional VA measurement which is mostly used in school vision screening programs, many children with impaired reading ability would be missed. Consequently, Bodack *et al*[42] had reiterated the importance of periodic screening and rescreening for hyperopia and binocular vision anomalies in addition to distance visual acuities.

Provision of Vision Screening Vision screening conducted by adequately trained health professionals is vital for the detection of vision problems in children[5,43]. An assessment of screening programs in Sweden[44] and Vietnam[45] revealed that adequately trained non-ophthalmic personnel can competently screen 4-year-old children, while children who fail screening tests should be referred to an ophthalmologist[44]. A study on the SureSight vision screener found an inverse relationship between the experience of the screeners and the referral rate. In this case, the referral rate decreased as the volunteers gained more experience. At the beginning, the average referral rates for the screeners were 10.6% which overtime decreased markedly to 7%[46]. Although, the study did not assess the sensitivity, specificity, or positive predictive values of the screeners, it revealed that vision screenings are mostly subjective, and the accuracy of screening results will depend greatly on the experience of the screener. Overall, these studies revealed that the sensitivity of the test administered by different people varied depending on the protocol adopted and the age of the children being screened. However, adequate training is necessary to achieve a reliable result.

The Vision in Preschoolers Study compared the performance of vision screening tests in 3- to 5-year old by trained nurses and lay screeners, using the results of examination administered by an ophthalmologist or optometrist as the gold standard. The screening tests performed included SureSight, Retinomax, crowded linear LEA Symbols, single LEA Symbols (administered by lay screeners only) and stereo smile II test[47]. Except for linear LEA symbols which were significantly higher, the sensitivities of all other tests were not statistically significant, even though the sensitivities were marginally higher when administered by nurse screeners than lay screeners. In contrast, lay screeners achieved a considerably higher sensitivity with the Single LEA Symbols VA test than did nurses or lay screeners using the Linear LEA Symbols VA test. These findings indicate that similar results can be achieved by adequately trained nurses and lay screeners in preschool vision screening[47].

The Age to Administer Vision Screening There is no consensus on the ideal age at which screening should be administered in children. In Australia, vision screening is mostly conducted at school entry which for most children is about 5 to 6 years of age. This guarantees a wider coverage and early detection of amblyopia, as children are readily available[11,39]. Sjöstrand and Abrahamsson[48] recommend vision screening for amblyopia at 5 years of age because at that age children can be properly screened with a linear acuity chart and adequately treated, with less psychosocial burden for the child and the family. Besides, treatment at this age can result in a better visual outcome as children are still in the critical period of visual development[11,39]. According to Hartmann *et al*[46] the chance of achieving a better test result is higher in older children, as screening in younger children is more difficult. Due to the subjective nature of most screening protocols, screening younger children may be difficult and lengthy especially for the inexperienced screener.

Preschool vision screening has also received some support, as it allows for timely detection and treatment of amblyopia before schooling begins[49-50]. Screening for amblyogenic factors in school-aged children is also warranted because amblyopia can be effectively treated into the teenage years and beyond[51]. While there may be some disadvantage in delaying the detection of amblyopia until school entry, the reliability of the screening is higher and the costs significantly less. It is more difficult for a preschool age group to follow test procedures and instructions. Thus, there is more likelihood of having a higher false positive rate from preschool vision screening than for that performed at school entry[43]. However, some others have recommended the performance of vision screening at regular intervals. For example, the American Academy of Ophthalmology and the American Academy of Paediatrics recommend eye health screening from birth and at all routine health visits[40]. The guidelines on school eye health recently developed by IAPB recommend that schools be visited at least once in every two years to screen new intake and to rescreen those given spectacle the previous year[5]. Similarly, Bodack *et al*[42] have stressed the relevance of periodic screening and rescreening for various ocular defects.

CONCLUSION

Vision screening of children is a valuable approach for the detection of potential visual disorders that may impact negatively on the overall development of a child. The specific test batteries, the age group to be screen, and the personnel administering the test all contribute to the overall outcome of the vision screening. While the VA chart is a traditional screening tool, it may not be effective in the detection of some visual disorders like, hyperopia, astigmatism and anomalies of binocular function. Since children of different age groups present with varying degrees of visual problems, it may be necessary to use age appropriate test batteries to assess vision in the different age group of children. There seems to be no agreement as to who should be administering the children's vision screening programs and the age at which it should be administered. Perhaps, a collaborative effort of eye care professionals, nurses and lay screeners (while keeping the cost very low) may be ideal. This will require the development of test protocols for each of the group of screeners base on their expertise and knowledge. As indicated in the reports, eye care professionals are better equipped to provide complex screening procedures. Overall, the studies reviewed emphasized on adequate training of the vision screener as being essential in achieving a reliable screening result. In addition, screening of all children at school entry age may offer a wider coverage, as the children can reliably cooperate with vision screening tests and are readily accessible. Subsequent periodic screening as recommended by the American Academy of Ophthalmology and the American Academy of Paediatrics will be essential. The lack of randomized controlled data has not helped the evaluation of the effectiveness of vision screening. However, no studies have observed any risk associated with screening: the tests can detect the defects they are meant to detect, and there are effective treatments for these vision defects.

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Accommodative anomalies among schoolchildren in Abia State, Nigeria

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Background: Ocular discomfort resulting from accommodative anomalies can impair reading efficiency, school performance and possibly a person's quality of life.

Aim: The aim of this study is to determine the prevalence of accommodative anomalies in schoolchildren in Abia State, Nigeria, and to assess possible associations with sample demographics such as age, gender and school level.

Setting: The study was conducted in primary and secondary schools in Abia State, Nigeria.

Methods: Case history questionnaires and vision tests were administered to 537 (mean age 13.0 ± 2.0 years) children randomly selected from nine schools in Abia State. The following vision parameters were measured: visual acuity, non-cycloplegic refraction, cover test, near point of convergence, fusional vergences, accommodative functions and ocular health evaluation. All accommodative and binocular function tests were performed following the subjective refraction with compensating lenses in place, if prescribed. Anomalies of interest such as accommodative insufficiency, accommodative excess and accommodative infacility were classified using the findings of accommodative and vergence parameters.

Results: A total of 90 (16.8%) children had accommodative anomalies. Prevalence estimates include accommodative insufficiency (3.9%), accommodative excess (2.8%) and accommodative infacility (10.1%). There was no significant difference in the distribution of various accommodative anomalies between age group, gender or school level.

Conclusion: The significant proportion (16.8%) of children with accommodative anomalies in the present study is an important finding, considering that paediatric vision screening programmes that only focus on visual acuity are unlikely to detect these critical visual anomalies. The result of this study is expected to direct the development of a common and broad vision screening strategy.

Keywords: accommodative anomalies; accommodative insufficiency; accommodative excess; accommodative infacility; children.

Introduction

Accommodative anomalies are visual conditions that can affect the eye's ability to alter its dioptric power to bring an object of regard coincident with the retina.[1,2] Clinical signs range from reduced accommodative amplitude (AA), reduced sustainability and accuracy of accommodation and difficulty maintaining clear vision when changing fixation from one point to another with associated symptoms.[1,2,3] The symptoms include blurred vision at near, transient blurred vision when looking at a distant target following performance of near work, headaches, pulling sensation around the eyes, tired eyes and reduced attention span. Because of these symptoms, individuals find themselves attempting to compensate by holding reading material too close or too far away, or simply avoiding near activities altogether.[1,2,4,5,6] These ocular discomforts can impair reading efficiency, school performance and possibly a person's quality of life.[7,8,9]

A number of studies[3,6,9,10,11,12,13,14,15,16,17,18,19,20] have reported on the prevalence of accommodative anomalies in school-age children in different populations, especially in Caucasian children. For the specific populations indicated in Table 1, the prevalence range for different accommodative anomalies include accommodative insufficiency (AIS, 0.2% – 18.3%), accommodative excess (AE, 1.2% – 5.1%) and accommodative infacility (AIF, 2.5% – 30%). Differences in study designs including the use of single or multiple sign criteria in the definition of specific accommodative anomalies and methodological differences such as small sample sizes, convenience sampling method and exclusion criteria within studies may account for the variability in study findings. Regarding exclusion criteria, the most recurring flaws among the studies are the exclusion of

TABLE 1: A summary of studies reporting the prevalence (%) of accommodative anomalies in school-age children.

Authors	Setting	Age (years)	Sample size	Prevalence (%)		
				Accommodative insufficiency	Accommodative excess	Accommodative infacility
Wajuihian and Hansraj[6]	School	13–19	1201	4.5	2.8	12.9
Darko-Takyi et al.[3]	School	12–17	627	7.7	1.4	3.8
Hussaindeen[14]	School	7–17	358†	0.2	0.8	7.0
			562‡	0.0	0.0	10.7
Davis et al.[12]	School	11.7 (mean)	484	32.4	-	-
Jang and Park[13]	School	8–13	589	5.3	1.2	2.5
Shin et al.[9]	School	9–13	114	18.3	3.9	13.4
Marran et al.[10]	School	11.5 (mean)	299	8.0	-	-
Borsting et al.[11]	School	8–15	392	17.0	-	-
Metsing and Ferreira[15]	School	8–13	112	10.0	-	12.3
Moodley[16]	School	6–13	264	24.0	-	30.0
Abdi et al.[20]	School	6–16	264	24.2	-	-
Abdi and Rydberg[19]	School	6–16	120	11.1	-	-
Scheiman et al.[17]	Clinic	6–18	1650	2.3	1.2	2.3
Paniccia and Ayala[18]	Clinic	5–20	593	39.0	5.1	7.0

†, rural population.
‡, urban population.

children with uncorrected refractive error (RE). For the studies that did not exclude children with uncorrected RE, it was not clear whether they wore their compensating lenses during testing. This is important, as RE significantly impact the aetiology and influences the measurement and treatment of accommodative anomalies.[1,7,12]

There is also a lack of information in the literature on the influence of age, gender and school level on the prevalence of accommodative anomalies.[6] As early detection remains the best approach for the treatment of visual anomalies and considering the cost of systematic screening,[18] an understanding of the association between accommodative anomalies and sample demographics will allow dedicating available resources and efforts to early detection, such as regular vision screening only on people at risk, thereby reducing the high short-term and long-term costs to the health system and to society. Presently, there are no intervention and management guidelines for accommodative and vergence anomalies in Abia State and Nigeria because the subspecialty of paediatric optometry is relatively new in the country.[21] The clinical implication is that most eye care professionals rarely consider accommodative and vergence disorders as anomalies of interest when screening children for near vision anomalies.

Our study included an adequate and representative sample of primary and secondary schoolchildren in Abia State, Nigeria. Accommodative and binocular vision tests were performed with children wearing their compensating lenses, if prescribed. This ensured that uncorrected RE did not negatively impact on the clinical outcome measures. The present study aimed to determine the prevalence of accommodative anomalies in Abia State schoolchildren and to assess possible association with age, gender and school level. The information is expected to guide health policymakers and practitioners in implementing the most appropriate intervention and management strategies, particularly for vision problems that have been associated with educational outcomes.[8,9]

Methods

Study participants

This study is part of the broader survey that utilised cross-sectional design to quantified visual conditions in schoolchildren in Abia State. The sampling design and technique have been reported elsewhere.[22] In brief, the prevalence estimation formula was used to calculate an adequate sample size for a projected prevalence of 12.7% and adjustments were made for clustering effects (2.0) and non-participation (10%). A total of 550 schoolchildren with ages ranging from 10 to 16 years were recruited from nine schools (public and private) through a stratified multistage and random sampling starting from the three geographic districts to the classrooms. Children who had systemic diseases or were taking any systemic and/or ocular medications that may affect near vision were excluded from the study.[22]

Procedures

Prior to the start of the vision test, a case history questionnaire[6] covering areas such as the ocular and general health conditions of the participants, including near task characteristics and visual symptoms, was administered to the participants. The interview was conducted by a research assistant properly trained in the administration of the questionnaire. A series of vision tests that included visual acuity (VA) measurements, ocular motility evaluation, stereopsis, suppression test, non-cycloplegic autorefraction, subjective refraction, colour vision assessment, ocular health evaluation, accommodative and binocular vision test were performed by an optometrist (the principal investigator). All testings were conducted in test stations set up in classrooms provided by the school authorities, and test conditions including illumination and test distance were maintained as best as possible at the same level in each station.

Distance and near VA were measured for each eye with logMAR charts held at 3 m and 40 cm, respectively, and all

TABLE 2: Classification of accommodative anomalies.

Accommodative anomalies	Clinical signs	Diagnostic criteria
Accommodative insufficiency	• Reduced AA of at least 2.00 D below Hofstetter's calculation for minimum amplitude: 15–0.25 × age (years) • High MEM > +0.75 D • Fails MAF testing with −2.00 D with a criterion < 6 cpm	A minimum of clinical signs (1 and 2 or 1 and 3, or all clinical signs)
Accommodative excess	• Low MEM < +0.25 D • Difficulty clearing +2.00 D with MAF with a criterion < 6 cpm • Fails BAF test with +2.00 D with a criterion < 3 cpm	Clinical signs (1 and 2 or 1 and 3)
Accommodative infacility	• Normal AA • Fails MAF using ± 2.00 D lenses, with a criterion of MAF < 11 cpm • Fails BAF using ± 2.00 D lenses, with a criterion of BAF < 8 cpm	All clinical signs

D, dioptre; MEM, monocular estimation method; MAF, monocular accommodative facility; cpm, cycles per minute; BAF, binocular accommodative facility; AA, amplitude accommodative.

children underwent non-cycloplegic autorefraction and subjective refraction irrespective of their VA. We did not apply cycloplegia as this would have complicated the evaluation of near vision functions, which were the focus of the present study. Alternatively, the plus lens (2 D) test was performed on all children to detect possible latent hyperopia.

Accommodative and binocular function tests were performed in three repeated measures after subjective refraction with the child wearing his or her near correction, if prescribed. Monocular and binocular AA were determined by using Donders' push-up to blur technique with the Royal Air Force (RAF) rule. The target was a single line of letters equivalent to a VA of 6/9 on a reduced target, and the point of first sustained blur was recorded in dioptres (D). Accommodative facility was measured monocularly (MAF) and binocularly (BAF) with a plus or minus 2 D lens flipper at 40 cm. The target was a single line of letters that corresponded to a near VA of 6/9. Accommodative response was measured objectively at 40 cm using the monocular estimation method retinoscopy. For the vergence, parameters including horizontal phoria, AC/A ratio, near fusional vergence ranges and near point of convergence, the description of the test protocols and techniques have been provided in the report on vergence anomalies.[22]

Classification of the outcome variables

Accommodative anomalies were diagnosed as AIS, AE and AIF using the clinical measures of accommodative variables, according to the criteria used by previous studies,[2,6,9,13,14] as shown in Table 2.

Statistical analysis

The data analysis was performed using SPSS for Windows, version 23.0 (IBM-SPSS, Chicago, IL, United States). Descriptive analysis of accommodative findings were presented as means, standard deviations, medians, ranges (minima and maxima), as well as skewness and kurtosis, while frequencies and distributions of outcome measures were presented in tables and figures. Differences in proportions among groups were examined using Pearson's chi-squared tests, whereas differences in the group means between children with and without accommodative anomalies were explored using the two-sample *t*-tests. Differences were considered significant at *p*-values of less than or equal to 0.05.

Ethical considerations

Ethical approval for the study protocol was granted by the College of Medicine Health Research and Ethics Committee, University of Nigeria, Enugu Campus (ethical clearance number: 023/01/2017), as well as the Biomedical Research Ethics Committee of the University of KwaZulu-Natal, Durban, South Africa (ethical clearance number: BE/619/16). The school heads or principals also approved the study. Written informed consent and assent were obtained from parents and children, respectively, after verbal and written explanation of the nature of the study was provided to them. The study was conducted in accordance with the tenets of the Declaration of Helsinki regarding research involving humans.

Results

Sample demographics

Five hundred and thirty-seven children were examined, and four who had strabismus or amblyopia were excluded. Data were analysed for 533 children, and their mean age was 13.0 ± 2.0 years. The participants comprised 223 (41.9%) children with ages ranging from 10 to 12 years (age group 1) and 310 (58.1%) with ages ranging from 13 to 16 years (age group 2); 279 (52.4%) were female and 254 (47.6%) male; 233 (43.8%) were in primary and 300 (56.2%) in secondary school. The prevalence of REs in the study sample was hyperopia (4.1%), myopia (3.4%) and astigmatism (3.2%). All participants had near VA of at least N_5 with mean best-corrected distance VA (logMAR) of the right eye as −0.09 ± 0.04 and left eye as −0.09 ± 0.03. The descriptive statistics for accommodative variables are represented in Table 3.

Prevalence of accommodative anomalies

The prevalence of accommodative anomalies was computed using both single and multiple sign criteria. The prevalence estimation (for multiple sign criteria) was for accommodative anomalies that were not associated with vergence disorders. With the multiple sign criteria, a total of 90 (16.8%) children had accommodative anomalies. The prevalence of the specific types of accommodative anomalies is presented in Table 4. For the single sign criterion, based on some specific clinical measures listed in Table 2, reduced monocular AA was observed in 44 (7.8%) participants, while reduced binocular AA was recorded for 39 (7.3%) children.

A plot of the mean monocular AA as a function of age is presented in Figure 1. The figure shows that AA decreased

TABLE 3: Descriptive analysis of overall accommodative findings of schoolchildren in Abia State.

Variables	*n*	Mean	SD	Median	Minimum	Maximum	Skew	Kurtosis
Amplitude of accommodation (D)								
Monocular (RE)	533	15.25	3.58	16.0	4.0	20.0	−0.92	−0.39
Binocular (RE)	533	15.46	3.44	16.0	5.0	20.0	−1.48	0.92
Accommodative response (D)	533	0.47	0.27	0.5	−0.5	1.5	0.73	4.94
Accommodative facility (cpm)								
−2 D monocular	527	11.36	3.35	11.0	1.0	20.0	−0.11	−0.28
−2 D binocular	529	11.38	3.39	11.0	1.0	20.0	−0.12	−0.37
+2 D monocular	528	11.45	3.94	11.7	0.0	20.0	−0.15	−0.67
+2 D binocular	528	11.85	4.15	12.0	2.0	21.0	−0.10	−0.59
±2 D monocular	527	9.04	3.17	9.0	1.7	18.0	−0.20	0.90
±2 D binocular	527	9.27	2.98	9.3	2.0	18.0	−0.05	0.57

D, dioptre; RE, right eye; cpm, cycles per minute; *n*, number; SD, standard deviation.

TABLE 4: Prevalence of accommodative anomalies among Abia State schoolchildren.

Accommodative anomaly	Number of children (*n*)	Prevalence (%)
Accommodative insufficiency	21	3.9
Accommodative excess	15	2.8
Accommodative infacility	54	10.1

with age; however, the decrease was not particularly linear. A minimal increase in mean AA was observed from ages 11 to 12 years, while the mean AA was 15.7 at age 13 years and 15.8 at 14 years. Accommodative facility was tested with plus or minus 2 D lens flipper, and the result showed that 96 (18.3%) children failed MAF (right eye), while 235 (44.6%) failed BAF. For accommodative response, 28 (5.2%) children had accommodative lead, whereas 17 (3.1%) had accommodative lag.

Regarding the effect of age, gender and school level on the prevalence of the AIS, AE and AIF, statistical analysis (Figure 2) showed that despite the marginal differences observed between the groups, none of the accommodative anomalies were associated with age, gender or school level.

Comparison of accommodative findings and groups

The group mean data for specific accommodative parameters for children with no accommodative anomaly and children with various accommodative anomalies were compared using the two sample *t*-test (Table 5). Analysis of the mean data of the clinical measures for AIS group revealed that except for accommodative accuracy, which showed a significant increase ($p < 0.001$), all other accommodative parameters were significantly reduced when compared to the no accommodative anomaly group ($p < 0.001$) for all other variables. For AE, the group mean data for accommodative response ($p < 0.001$) and +2.00 D accommodative facility (monocular, $p < 0.001$; binocular, $p < 0.001$) were significantly reduced. Similarly, both monocular and binocular (±2.00 D) accommodative facility variables were significantly reduced (monocular, $p < 0.001$; binocular, $p < 0.001$) in children with AIF anomalies. However, no significant difference was observed for either monocular ($p = 0.08$) or binocular ($p = 0.44$) AA between children with AIF and those without accommodative anomalies.

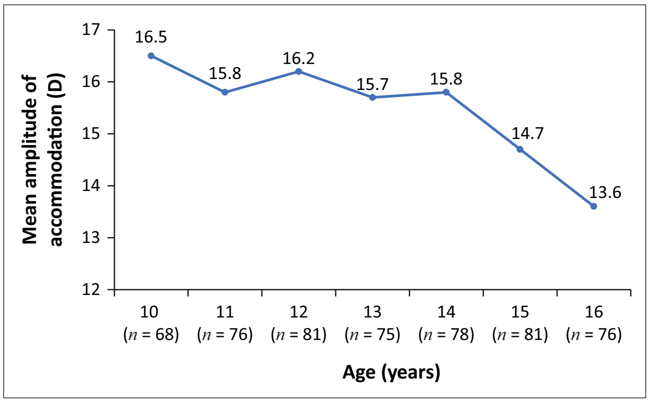

FIGURE 1: Mean monocular amplitude of accommodation as a function of age of schoolchildren ($N = 533$) in Abia State.

Discussion

This study reports on the prevalence of accommodative anomalies in a population of children of Abia State, which include AIS (3.9%), AE (2.8%) and AIF (10.1%). There was no significant difference in the distribution of the various accommodative anomalies between age group, gender or school level. The mean AA of 15.46 ± 3.44 D in our study was comparatively similar to the 15.88 ± 3.46 D reported by Ovenseri-Ogbomo and Oduntan[23] on school-age children in Nigeria.

In the present study, the prevalence of AIS (3.9%) using multiple sign criteria was higher than the 2.3% reported by Scheiman et al.[17] and 0.2% by Hussaindeen et al.[14] However, the value is lower than two other studies[6,9] that also utilised more than one clinical sign. The study by Shin et al.[9] estimated AIS in symptomatic participants with a score of 20 or more on the convergence insufficiency symptom survey; hence, the reported prevalence of 18.3% may have been overestimated, while the difference of 4.5% reported by Wajuihian and Hansraj[6] may be attributed to reduction in AA with an increase in age, as their study participants were older than the children in the present study. Further, studies that defined AIS using only one clinical sign (of reduced AA, lower than the expected age norm according to Hofstetter's formula for minimum age) reported significantly higher prevalence rates, ranging between 10% and 24.2%.[15,16,19,20] However, to accurately interpret the accommodative status

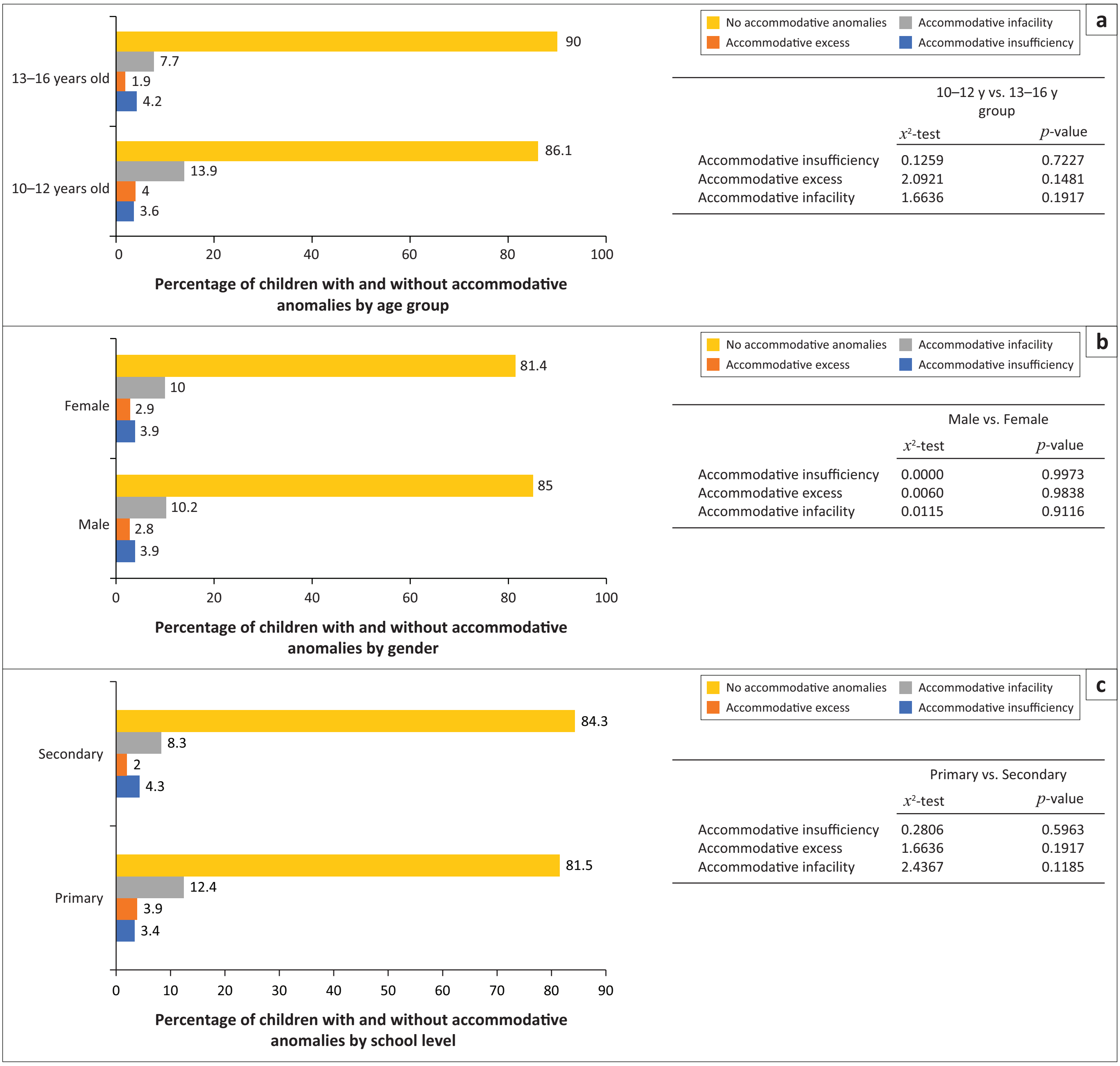

FIGURE 2: Distribution of specific accommodative anomalies by (a) age group, (b) gender and (c) school - level.

TABLE 5: Accommodative findings for various accommodative groups.

Variable	No accommodative anomalies (n = 443)			Accommodative insufficiency (n = 21)			Accommodative excess (n = 15)			Accommodative infacility (n = 54)		
	Mean	SD	Median	Mean	SD	Median	Mean	SD	Median	Mean	SD	Median
Accommodative amplitude (D)												
Monocular (RE)	17.51	4.04	18.00	7.18	1.31	6.00	19.26	2.08	18.00	17.30	3.72	20.00
Binocular	17.59	3.62	20.00	7.32	1.28	7.30	19.30	2.04	20.00	17.66	3.29	20.00
Accommodative response (D)	0.45	0.23	0.50	0.89	0.16	0.83	−0.20	0.16	0.00	0.56	0.35	0.50
Accommodative facility (cpm)												
−2 D monocular	12.20	3.21	12.00	4.40	0.97	5.00	8.84	0.95	9.00	8.10	3.36	8.00
−2 D binocular	12.26	3.27	12.00	4.67	0.90	4.30	8.79	1.14	8.30	8.18	3.38	8.00
+2 D monocular	12.34	3.53	13.00	8.77	2.83	10.00	3.87	0.65	4.00	6.95	2.95	6.00
+2 D binocular	12.79	3.58	13.00	8.77	2.85	9.30	3.64	0.94	4.00	7.30	3.43	7.00
±2 D monocular	10.09	2.42	10.00	4.71	1.09	5.00	3.48	0.91	4.00	3.99	1.91	4.50
±2 D binocular	10.30	2.21	10.00	4.83	1.06	5.00	3.47	0.87	4.00	4.66	1.61	5.00

D, dioptres; RE, right eye; cpm, cycle per minute; SD, standard deviation.

of children, it is recommended to include the assessment of other accommodative parameters such as accommodative facility and response. This is so because using only reduced AA overestimates the prevalence of AIS,[1,2] because AIS presents more as a syndrome. Moreover, the prevalence of poor monocular (7.8%) and binocular (7.3%) AA reported in this study was lower than the 10% (monocular or binocular) reported by Metsing and Ferreira[15] and the 24% (monocular) and 26% (binocular) reported by Moodley[16] on primary schoolchildren but higher than the 4.6% (monocular) found by Wajuihian and Hansraj[6] in high school children. Although several factors such as sampling methods and sample sizes, inconsistent measuring techniques and diagnostic criteria can play a significant role in differences between studies, the major reason here may be interexaminer variability and age of study participants. Younger children may have more difficulty in reporting blur than older children, which is the subjective criterion for the measurement of AA.

The findings of this study on AE (2.8%) were consistent with those of Wajuihian and Hansraj[6] on black students in South Africa. However, it should be noted that two other school-based studies in South Korea[9,13] and another in Ghana[3] reported different estimates of 1.2%,[13] 1.4%[3] and 3.7%,[9] respectively. Similarly, Darko-Takyi et al.[3] and Jang and Park[13] reported prevalences of AIF of 3.8% and 2.5%, respectively, which is lower than our finding of 10.1%. Other studies reported higher estimates when compared to the present study. A case in point: in South Korea,[9] the prevalence of AIF was 13.4% while in South Africa[6] it was 12.9%, and in rural and urban India[14] 7% and 10.7% were determined, respectively.

Although marginal differences between groups were observed in the present study, no significant differences were found between the prevalence of AIS, AE, AIF and demographic factors including age, gender and school level, which corroborates the findings of several other studies.[3,9,13,18] The study by Scheiman et al.[17] that found a significant difference in the prevalence of AIS with age was a clinic-based study that was exposed to biased data, making comparison of findings with a randomised school-based study very difficult.

Overall, the differences in relation to findings of these studies can be explained from various contexts. Although most of the studies enumerated in Table 1 were school-based studies, their sample size and sampling method varied considerably. To obtain more accurate prevalence data, it is necessary to have adequate and representative samples of the target population, with a suitable age range that will provide reliable data that can be extrapolated to the entire population. Except for three studies[3,6,13] that utilised randomised samples, all others selected their participants and only a few had an adequate sample size, with Scheiman et al.[17] being a clinical study. Clinic samples and school-based studies with only symptomatic participants are characteristically biased and have the possibility of reporting higher prevalence estimates when compared to an unselected population of children.[22,24] Besides being non-representative samples, participants with complaints of visual discomfort are more prone to having actual visual anomalies.[22,24]

The refractive status of the participants is another important factor to consider in assessing prevalence of an accommodative anomaly. Studies have indicated that uncorrected RE can impact the aetiology and influence accommodative anomalies, as well as their treatment options.[7,12] From this point of view, it may be possible to suggest that RE affects the prevalence and distribution of accommodative anomalies in any population.[25] Myopes have reduced sensitivity to blur compared to hyperopes and emmetropes.[1] Blur adaptation can cause an individual to experience sustained blur at closer distances during push-up testing, resulting in higher values of AA.[1,25] Therefore, adequate correction of RE is critical in the resolution of some accommodative conditions[12,25,26] and is likely to yield more accurate prevalence estimates.[12] To ensure that uncorrected RE does not overestimate the prevalence of accommodative anomalies in our study, children were tested with the correction; however, in some studies[9,10,11,19] information regarding the refractive status of the participants was not indicated. As such, it was not clear whether those with RE were included in the study or whether they were examined with their spectacle compensations in place. Other studies excluded participants with uncorrected VA and RE, thereby limiting the extent to which their samples can be a valid representative of the target population.

Increased variability and reduced reliability associated with accommodative testing could also be the reasons for the variations in findings among studies. Some studies applied a single criterion, while others used two or more criteria to define specific accommodative anomalies. In addition to varying diagnostic criteria, different techniques were applied in measuring the accommodative parameters. Even in studies with similar criteria and measuring techniques, different cut-off points were applied in the detection of participants with specific accommodative anomalies, making it difficult to compare results among studies. Regarding reliability of test results, the measurement of accommodative parameters involves reporting blur experience, which depends on the ability of the subjects to understand the experimental procedures and instructions. Younger children have difficulty in reporting blur experience.[6,22,23] As such the use of only younger (primary school) children by some studies may have influenced their results. With the exception of Jang and Park,[13] school-based studies (Table 1) with younger children reported higher prevalences of AIF compared to those with older children. The difference between the findings of Jang and Park and the present study and others may be related to differences in test procedures, varying diagnostic criteria and cut-off points.

One of the limitations of the present study was the non-use of cycloplegia during refraction. Cycloplegia was contradicted because the study involves the evaluation of accommodative status, and our desire was to examine the children in their habitual state. Instead the plus lens test was applied in the assessment of latent hyperopia. Another possible limitation is that all tests were performed in test stations set up in each school, rather than an optometry clinic, which would have afforded better control over the test environment. Nevertheless, testing conditions were standardised at each test station in all the schools. In addition, validated and reliable instruments were applied in data collection, with only one examiner conducting all the vision tests. The study included an adequate sample representative of primary and secondary school children representing the learning experience and visual characteristics of these two levels of educations. Furthermore, the study protocol was adapted from recent studies[6,12,14] in this area. Altogether, data from the present study have significant indications for eye care practitioners with respect to clinical management of near vision disorders as well as education and health policymakers in terms of planning and implementation of school health programmes. Given the reported association between school performance and accommodative anomalies,[7,8,9] the accommodative status of every child who presents with near vision related complaints, particularly those having difficulty with academic performance, should be properly evaluated for possible accommodative disorder.

Conclusion

The present study has provided a detailed and systematic report on the prevalence of accommodative anomalies in children in Abia State, Nigeria. Our data indicate that a considerable proportion (16.8%) of schoolchildren suffer from at least one of the disorders of accommodative function, which can have a substantial influence on their learning capabilities and academic performance. This is an important finding, given that conventional vision screening programmes that only focus on VA assessment are unlikely to detect these critical visual anomalies. Therefore, the scope of paediatric vision screening programmes should be widened to include test batteries that will identify common visual anomalies, including accommodative anomalies capable of affecting school performance. Overall, the data from this study will apply towards the development of a common and broad-based vision screening strategy.

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Competing interests

The authors report no conflicts of interest that may have influenced the writing of this article.

Authors' contributions

The manuscript was written by U.C.A., with R.H. and S.O.W. providing feedback on the structure and content of the manuscript.

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