UNIVERSITY OF CAPE COAST

DETERMINANTS OF VISUAL IMPAIRMENT CAUSED BY UNCORRECTED REFRACTIVE ERROR AMONG 5-15 YEAR-OLD CHILDREN ATTENDING SCHOOLS IN COASTAL AREAS OF CAPE COAST, GHANA

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BY

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DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original research and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature.......................................Date 16/10/18

Name: Dr Alex Ileche

Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

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ABSTRACT

Epidemiological study of determinants of vision problems is important in developing strategies for the prevention of visual impairment. This study set out to assess the determinants of visual impairment caused by uncorrected refractive error among children aged between 5-15 years attending primary schools in the coastal areas of Cape Coast. Random selection of public and private schools in geographically defined clusters was used to identify a cross-sectional sample of 3,088 eligible school children (M = 9.44, SD = 2.17) for visual acuity measurement and in-school ophthalmic examination. Potential determinants of visual impairment including age, gender, type of schooling, body mass index, socio-economic status (SES), school academic achievement, parental refractive status, and amount of near work were examined in multivariate logistic regression models. Prevalence of uncorrected, presenting, and best visual acuity was 10.3, 9.9 and 2.1% respectively. Prevalence of visual impairment due to uncorrected refractive error was 2.7% (n=83). Older age, attending private school, belonging to middle and high SES, and being overweight were the predictive factors. Being of older age was the strongest determinant of visual impairment due to uncorrected refractive error in children attending schools around the coastal areas of Cape Coast, Ghana. School health programs should be augmented to incorporate regular in-school eye screening services.

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DEDICATION

To my wife, Mrs Jennifer Ilechie and my mother, Mrs Roseline Ilechie

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LIST OF ACRONYMS

WHO: World Health Organization

BCVA: Best corrected visual acuity

RESC: Refractive Error Study in Children

VA: Visual acuity

BMI: Body mass index

SES: Socio economic status

TV: Television

LogMAR: Logarithm of minimum angle of resolution

AMD: Age-related macular degeneration

UNICEF: United Nations International Children's Emergency Fund

IQ: Intelligent quotient

OR: Odds ratio

GSS: Ghana statistical service

SE: Spherical equivalent

MOH: Ministry of Health

NHI: National health insurance

NEHP: National Eye Health Programme

PHC: Primary health care

GDP: Gross domestic product

CHAPTER ONE

INTRODUCTION

Background to the Study

Children are born with an immature visual system and need clear focused images to be transmitted to the higher visual centers of the brain for normal visual maturation. Any condition that deprives clear vision or interferes with normal visual development will result in amblyopia, which can eventually lead to permanent dullness of vision (blindness). As a result, experts consider childhood eye conditions as developmental emergencies because of the level of urgency in treating them to prevent amblyopia (Gilbert & Foster, 2001). The indications are that childhood visual impairment is a significant public health problem that is more challenging than visual impairment in adults because it manifests at a younger age resulting in a lifetime of impairment or blindness of the child, with all the associated emotional, social and economic costs to the child, the family, and the society (Gilbert & Foster, 2001). For this reason the control of refractive error blindness in children is considered a high priority within the World Health Organization's (WHO's) VISION 2020-titled "The Right to Sight programme" (WHO, 1998).

Over the past years, uncorrected refractive error as a cause of visual impairment has been overlooked because the previous estimates which were based on best corrected visual acuity (BCVA) were very low (Resnikoff, Pascollini, Mariotti, & Pokharel, 2008). With presenting visual acuity, Resnikoff et al. (2008) estimated that the number of children aged between 5 and 15 years who were visually impaired due to uncorrected refractive error was in excess of 12.8 million. This is an indication that uncorrected refractive error should be considered to be the leading cause of visual impairment in children.

As noted in Resnikoff et al. (2008) comprehensive review, uncorrected refractive error accounts for over 48% (153 million) of the 314 million cases of visual impairment worldwide. Majority of these cases are in low- and middle-income countries. According to Resnikoff et al (2008), these are also the countries with limited access to refractive and optical services. The situation is particularly critical in the rural areas of these countries where affordability is a significant issue and refractive correction programs are accorded low priority in the face of other immediate pressing problems such as food shortages and tropical diseases (Resnikoff et al., 2008). Further, there is evidence that more than two-third of children are in need of vision correction in Africa (Kumah et al., 2013; Naidoo et al., 2003; Ovensiri-Ogbomo & Omuemu, 2010; Opubiri & Pedro-Egbe, 2013). Moreover, school children represent a particular vulnerable group due to the visual demands of traditional classroom based education (Resnikoff et al., 2008).

Among the few surveys in Ghana (Kumah et al., 2013; Ovensiri-Ogbomo & Omuemu, 2010), approximately 7 million (70%) of the 10 million estimated population of school children less than 15 years of age are in need of prescription glasses. Calculations project a dramatic increase in this magnitude by 2020 as additional resources are directed towards achieving gross enrollment targets in primary education (Ghana Statistical Service, 2010). This is particularly worrying given that uncorrected refractive error has significant economic and educational consequences on the individual. For example, it contributes to poor academic performance and career prospects, and reduced social participation (Glewwe, Park & Zhao, 2016). The economic cost to society in lost productivity, of visual impairment caused by uncorrected refractive errors is estimated to be 269 billion dollars per year (Smith, Frick, Holden, Fricke & Naidoo, 2009). The impact of childhood visual impairment caused by uncorrected refractive is even more significant due to the fact that the number of years of visual impairment in the affected children will be alarmingly high, accounting for twice as many blind-persons per year compared to adulthood visual impairment or blindness (Naidoo, 2007). Without timely detection and intervention with simple spectacles childhood visual impairment can lead to amblyopia that may lead to permanent blindness. Blindness can diminish the child's potential tremendously during the formative years and can reduce employability and generally impair quality of life in later years (Smith et al., 2009).

Information on the magnitude of visual impairment caused by uncorrected refractive error in children has been collected using different protocols and this makes comparison across population difficult (Resnikoff et al., 2008). In addressing the lack of representative and comparative data, a harmonized survey methodology called the "Refractive Error Study in Children (RESC) was developed by the WHO (Negrel, Maul, Pokharel, Zhao & Ellwein, 2000). The aim is to assess the magnitude and determinants of visual impairment caused by uncorrected refractive error in children in various population groups of ethnic origins and environmental settings. Negrel et al.

(2000) proposed obtaining population-based cross-sectional samples of children aged between 5 and 15 years through cluster sampling with main outcome measures to include uncorrected and best corrected visual acuity. Since then, a series of RESC surveys in school-age children have been carried out in countries as varied as Nepal (Pokharel, Negrel, Munoz & Ellwein, 2000), China (Zhao et al., 2000), Southern India (Dandona et al., 2002), Northern India (Murthy et al., 2002), South Africa (Naidoo et al., 2003) and Ghana (Kumah et al., 2013). Results of the RESC studies showed that uncorrected refractive error was the cause of visual impairment in 83% of children in an urban area of New Delhi, India (Murthy et al., 2002), 70% of children in a rural district near Hyderabad, India (Dandona et al., 2002) and 93% of children in a semi-rural county outside of Beijing, China (Zhao et al., 2000). Other results showed that uncorrected refractive error was the cause of visual impairment in 55.1% of children in a rural district in Eastern Nepal (Pokharel, Negrel, Munoz & Ellwein, 2000), 55% of the children in an urban area of Santiago, Chile (Maul, Barroso, Munoz, Sperduto & Ellwein, 2000) and 63.6% of the children in a semi-rural area of KwaZulu-Natal, South Africa (Naidoo et al., 2003). In rural areas of these countries, uncorrected refractive error as a cause of visual impairment was found in 86% of children in India (Dandona et al., 2002), 92% in Eastern Nepal (Pokharel, Negrel, Munoz & Ellwein, 2000), 58% in China (Zhao et al., 2000), 46% in Chile (Maul, Barroso, Munoz, Sperduto & Ellwein, 2000), and 71% in South Africa (Naidoo et al., 2003). The consensus was that uncorrected refractive error, particularly myopia, is the major cause of visual morbidity in children (Cockburn et al., 2012; Pascolini & Mariotti, 2012). These findings have promoted research into the determinants of uncorrected refractive errors among children. Despite the array of studies conducted, to date only a few studies dealt with the determinants of visual impairment due to uncorrected refractive error. An issue that is important for planning preventive strategies.

Studies on refractive error in children are characterized by significant variability in visual acuity definitions. For example, visual acuity of 6/12 or worse (Kumah et al., 2013; Naidoo et al., 2003), and visual acuity worse than 6/12 (Abdul et al., 2009; Khare & Sinha, 2013; Nangia, Jones, Gupta, Khare & Sinha, 2013) have been used. However, the widely acceptable definition for visual impairment due to uncorrected refractive error is presenting visual acuity (VA) in the better seeing eye of worse than 6/12 that could be improved to equal or better than 6/18 by refraction or pinhole (Resnikoff et al., 2008).

Globally, the majority of cases of childhood visual impairment from uncorrected refractive error have been managed effectively with a simple pair of corrective spectacles. However, the condition has to be detected early (Thulasiraj, Aravind & Pradhan, 2003). Amblyopia caused by delay in treatment have been documented in 5% children in China (Zhao et al., 2000), 6.5% in Chile (Maul et al., 2000), 4.4% in New Delhi, India (Murthy et al., 2002), 1.9% in Southern China (He, Zeng, Liu, Xu & Pokharel, 2004). Another, 7.3% children in South Africa (Naidoo et al., 2003) and 9.9% children in Ghana (Kumah et al., 2013). There is evidence that a spectrum of social factors such as limited access to eye care services, high cost of corrective spectacles and poor compliance to spectacle wear are responsible for refractive errors remaining uncorrected (Brien, Sylvie & Kylie, 2000; Faderin & Ajaiyeoba, 2001; Odera, Wednar, Shigongo, Nyalali & Gilbert, 2008). Lack of awareness and recognition of the problem and cultural disincentives have also been reported (Odera, Wednar, Shigongo, Nyalali & Gilbert, 2008).

Despite the array of blindness and visual impairment studies worldwide, only a few provided sufficient data on some of the familial and environmental factors associated with refractive errors in children. However, older age was consistently associated with higher prevalence and a greater likelihood of uncorrected refractive error in most of the surveys (Dandona et al., 2002; Murthy et al., 2002; Naidoo et al., 2003). The roles of other potential risk factors including body mass index (BMI), socio-economic status (SES), near-work, parental myopia and type of schooling, in the occurrence of visual impairment caused by uncorrected refractive error particularly among children in Africa is still contentious. For instance, increasing near-work was found to be positively associated with myopia in some (Deng, Gwiazda & Thorn, 2010; Guo, Liu, Xu, Tang & Feng, 2013) but not in all cross-sectional studies among Asian and white populations (Lu et al., 2009; Wu, Tsai, Hu & Yang, 2010). Experts consider near work as the activities done at short working distance such as reading, studying (doing homework, writing), computer use/playing video games, or watching television (Mutti et al., 2002; Saw et al., 2000; Zadnik, Satariano, Mutti, Scholtz & Adams, 1994). Among 681 Chinese children aged 5 to 13 years, Guo et al. (2013) demonstrated that children who spent more time indoor studying had 33% higher odds of developing myopia. Also, Deng et al. (2010) studied 147 white American children aged 6 to 18 years and found that children with myopia spent more time watching TV (12.78 ± 9.28 hours/week) than children without myopia (8.91 ± 5.95

hours/week. In contrast, Lu et al. (2009) found that myopic children in rural China did not spend more time in near work activities than non-myopic children. In a more recent study among 386 Chinese children aged 6 to 12 years in Beijing, Wu et al (2010) found no significant difference in amount of near work between myopic and non-myopic children.

The influence of gender in the occurrence of myopia is also contentious. The RESC studies among children in urban China (Zhao et al., 2000), rural Southern China (He et al., 2004), rural India (Dandona et al., 2002), central Nepal (Sakpot, Adhikar, Pokharel, Poudyai & Ellwein, 2006), Tanzania (Kingo & Ndawi, 2009), Malaysia (Goh, Abqariyah, Pokharel & Ellwein, 2005) and Singapore (Quek et al., 2004) concluded that females have a significant higher risk of myopia. In contrast, studies carried out in Ghana (Kumah et al., 2013), South Africa (Naidoo et al., 2003), and Chile (Maul et al., 1998) found no differences in prevalence of myopia between males and females.

Views concerning the relationship between schooling, socioeconomic status (SES), and body mass index (BMI), and having myopic parents also vary among authors. Among 2321 Indian children aged 5 to 15 years, Dandona et al. (2002) reported a significantly higher prevalence of myopia in children belonging to middle and upper SES strata. Sakpot et al. (2006) among 4,282 Nepal children also reported that the prevalence of visual impairing myopia was higher in children of high SES than in children of low SES. These results are in contrast with Robaei et al. (2005), who reported a higher prevalence of visual impairing myopia among children of low SES, among Australian school children. Type of schooling, BMI, and school academic achievement was also associated with the occurrence of myopia (Robaei et al., 2005; Sakpot et al., 2006).

Identification of modifiable risk factors associated with the presence of a disease condition is necessary for proper planning of preventive and treatment strategies for elimination of the disease. Resnikoff et al. (2008) noted that despite the importance of studying the burden and risk indicators of visual impairment due to uncorrected refractive error, there is lack of comprehensive information in Africa. They commented that the limited pool of literature on uncorrected refractive error in Africa and other resource deficient settings is a key challenge in developing cost effective intervention strategies for its elimination. Therefore, this study will help close the knowledge gap on the magnitude and determinants of visual impairment caused by uncorrected refractive error among school-going children in the coastal areas of Cape Coast, in the Central Region of Ghana. Furthermore, it would provide data from which the scope and priorities for prevention and treatment can be planned in the area.

Statement of the Problem

Refractive error can simply be diagnosed, measured and corrected with the aid of spectacles to provide optimum vision for children to have full educational achievements. Uncorrected refractive error in children may lead to amblyopia resulting in permanent vision loss. Affected children might suffer critical setbacks in personality development that may result in severe economic and social consequences for families and societies (Gilbert & Foster, 2001). School children represent a particular vulnerable group because of the visual demands of traditional classroom based education. In consequence, poor vision may have detrimental impact on their academic performance and career prospects.

Data from several reports suggest that more than 90% of the children with uncorrected refractive error worldwide live in rural and low-income countries (Gilbert & Foster, 2001; Naidoo & Jaggernath, 2012). Several studies have shown that uncorrected refractive error is responsible for most visual impairment among school children in Ghana (Kumah et al., 2013; Ovensiri-Ogbomo & Omuemu, 2010). Among 152 school children in Ghana, more than 71.7% of visual impairment was caused by uncorrected refractive error (Kumah et al., 2013). This magnitude is expected to increase with increasing school enrolment rates in the country unless an effective and sustainable system for delivery of refractive services/vision correction is put in place. Reliable estimate of the magnitude and determinants of uncorrected refractive error is the basis for designing such a system. However, the challenge in Ghana and other countries in the developing world is the dearth of representative data for implementing effective planning of eye health services. The few available reports in Ghana were from studies which either failed to use the RESC protocol (Ovensiri-Ogbomo & Omuemu, 2010) or were carried out on older children (> 12 years) only (Kumah et al., 2013). These population segments do not entirely represent the exact situation among children in Ghana (defined in Ghana as < 15 years old). Further, the previous refractive error studies in Ghana did not examine determinants of visual impairment caused by uncorrected refractive error among the children with uncorrected refractive error, since their focus was mainly on the magnitude of refractive errors. The present study was motivated by the paucity of data on the magnitude and determinants of visual impairment caused by uncorrected refractive error to guide the efficient mobilization of refractive services in Ghana and elsewhere on the African continent. The study was carried out among children aged between 5 and 15 years as this age group is in their formative years and intervention programs can therefore be appropriately targeted.

Purpose of the Study

The purpose of this study was to assess the determinants of visual impairment due to uncorrected refractive error among children attending primary schools in coastal areas of Cape Coast, Central Region of Ghana, and to provide corrective spectacles to the affected children.

Research Questions

The following research questions were formulated to guide the study:

1. What is the prevalence of visual impairment and blindness with uncorrected, presenting, and best corrected visual acuity among children attending primary schools in the coastal areas of Cape Coast, Ghana?
2. What is the prevalence and distribution of uncorrected refractive error among children attending primary schools in the coastal areas of Cape Coast, Ghana?
3. What is the prevalence and distribution of visual impairment due to uncorrected refractive error among children attending primary schools in the coastal areas of Cape Coast, Ghana?

Main Research Hypothesis

There is a significant association between visual impairment caused by uncorrected refractive error and the following determinants of refractive error: child's age, gender, socio-economic status, school type, BMI, school academic performance, parent refractive status, and amount of near work activity.

Sub-hypotheses

1. There is a significant association between visual impairment caused by uncorrected refractive error and age of children attending primary schools in the coastal areas of Cape Coast.
2. There is a significant association between visual impairment caused by uncorrected refractive error and gender of children attending primary schools in the coastal areas of Cape Coast.
3. There is a significant association between visual impairment caused by uncorrected refractive error and socio-economic status of children attending primary schools in the coastal areas of Cape Coast.
4. There is a significant association between visual impairment caused by uncorrected refractive error and type of school attended by children in the coastal areas of Cape Coast.
5. There is a significant association between visual impairment caused by uncorrected refractive error and the BMI of children attending primary schools in the coastal areas of Cape Coast.
6. There is a significant association between visual impairment caused by uncorrected refractive error and academic achievement of children attending primary schools in the coastal areas of Cape Coast.

7. There is a significant association between visual impairment caused by uncorrected refractive error and parents' refractive status of children attending primary schools in the coastal areas of Cape Coast.
8. There is a significant association between visual impairment caused by uncorrected refractive error and amount of near-work of children attending primary schools in the coastal areas of Cape Coast.

Significance of the Study

This study is important for the following reasons:

1. It will contribute to the body of knowledge on the magnitude and determinants of uncorrected refractive error and reinforce our understanding of risk factors for childhood visual impairment.
2. It will provide current data to Ghana's Ministry of Health essential for the planning of childhood blindness prevention programs as set out in Ghana's VISION 2020: The Right to Sight objectives.
3. It will also reduce the burden of visual impairment caused by uncorrected refractive error on the community through provision of refractive services and corrective glasses and raise awareness on the need for increased eye care services to children in deprived areas of Ghana.
4. It will provide country-specific data to bodies like the WHO, which is necessary for estimating the burden of visual impairment caused by uncorrected refractive error among children globally and locally.
5. It will provide the basis for priority setting in intervention programs
6. It will serve as baseline information for future population-based studies on visual impairment due to uncorrected refractive error

Delimitations

The following statements describe the delimitations of the research:

1. The study area was delimited to public and private primary schools along the coastline in Cape Coast.
2. The research questions focused on the prevalence, distribution and associated factors of visual impairment caused by uncorrected refractive error
3. The research hypothesis was delimited to only those factors found to be associated with development of refractive errors in theory.
4. The sample eligibility criteria used for the study was delimited to visual acuity $\leq$ 6/12 in the better eye. Eligible children in the enumerated sample with reduced visual acuity of 6/12 or worse due to ocular disorders such as cataract and glaucoma, amblyopia, systemic conditions and keratoconus were excluded from the study. Also, children were excluded for scheduling constraints.
5. The statistical analyses used in the study was delimited to chi-square and binary logistic regression analyses.

Limitations

The school-based design of this study meant that children who were not attending school were excluded. However, school enrolment rates throughout Ghana are reportedly high in this age group since the introduction of the school feeding program. Therefore, selection biases introduced because of school-based rather than population-based sampling are likely to be insignificant. Areas of high school attendance have been shown to provide data essentially equivalent to that obtained with population- based sampling (Negrel et al., 2000).

Non-participants might also be children with uncorrected refractive error. The inability to collect data from them due to their unwillingness to provide information is another limitation that could have overestimated the strength of the associations reported. Nevertheless, the demographic similarities of participants and non-participants provides some assurance that the study sample was likely to be fairly representative of the population of primary school children in the coastal areas of Cape Coast. Thus, selection bias, if any, was likely to be insignificant.

Reliance on questionnaire data for assessment of near-work and parental refractive status could have led to recall bias. Data on near work were obtained from a questionnaire survey rather than direct measurements. However, the pilot study showed high reliability of the questionnaire. Extracting verbal data from children especially the younger ones who were about 5 and 6 years of age was very difficult as they were not completely forthcoming in answering the questionnaires. Even with the help of interpreters, they were not outspoken. This might result in miscommunication that might lead to skewed results. However, there were very few children in this subgroup thus the effect of recall bias on the accuracy of the results was likely to be insignificant.

It is likely that the small number of children with visual impairment in some subgroups compared to the others in the same category limited statistical power to observe a significant difference. This form of bias was probably rather small considering that the data were still of sufficient quality to allow for significant findings in inferential statistical techniques.

The study was cross-sectional rather than experimental. The cross-sectional nature did not allow for exploration of cause-effect. It is possible that associations might have been confounded by some unmeasured factors/variables. These results therefore should be applied with caution.

Visual acuity in this study was measured with a tumbling E Snellens's chart rather than the logarithm of minimum angle resolution (logMAR) chart which enables more accurate measurement of acuity in research studies. In spite of the advantages of the logMAR over the Snellen chart in clinical practice and research, the tumbling E Snellen chart is still widely acceptable as a standard test for measuring visual acuity in children particularly in settings where the children cannot read.

Definitions of Terms

Presenting Vision: is defined as the distance visual acuity using currently available refractive correction, if any (WHO, 2009).

Better Seeing Eye or better eye: refers to the eye that sees better between both eyes of an individual.

Visual Impairment: for each person is defined as presenting vision in the better seeing eye of worse than 6/12 but better than 3/60.

Mild Visual Impairment: is defined as presenting vision in the better seeing eye of worse than 6/12 but equal to or better than 6/18.

Moderate Visual Impairment: is defined as presenting vision in the better seeing eye of worse than 6/18 but equal to or better than 6/60.

Severe Visual Impairment: is defined as presenting vision in the better seeing eye of worse than 6/60 but equal to or better than 3/60.

Blindness: for each person is defined as presenting vision in the better seeing eye of worse than 3/60.

Visual impairment caused by uncorrected refractive errors: is defined as presenting vision in the better seeing eye of worse than 6/12 that could achieve a $\geq$ 2- line improvement with refraction or pinhole better than 6/12 by refraction or pinhole.

Burden of Visual Impairment: refers to magnitude, impact and distribution of visual impairment in a community and is defined by the difference between presenting and best corrected vision.

Normal vision: refers to presenting vision in the better eye of 6/9 or better.

Best-corrected vision: is the distance visual acuity in the better eye achieved by participants tested with pinhole or refraction.

Reduced vision: is defined as presenting visual acuity of 6/12 or worse.

Refractive error: is defined as unaided vision (without correction) of 6/12 or worse in one or both eyes, and achieving a ≥ 2- line improvement with refraction in the affected eye.

Uncorrected refractive error: for each person is defined as presenting vision of 6/12 or worse in at least one eye and achieving a ≥ 2- line improvement with refraction in the affected eye.

Under-corrected refractive error: is defined as presenting vision (with any form of correction) of worse than 6/12 in the better eye and achieving a ≥ 2-line improvement with refraction in the affected eye.

Corrected refractive error: refers to presenting vision of better than 6/12 in the better eye with optical correction of spectacles or contact lenses.

Myopia: is defined as cycloplegic spherical equivalent cut-off points of -0.75D diopter (D) in the worse eye.

Amblyopia: was considered the cause of visual impairment in eyes with best corrected vision of worse than 6/12 without any apparent organic lesion except for presence of tropia.

Childhood blindness: is a general term used to embrace all occurrences of blindness in children from 0 to 16 years of age.

Avoidable blindness: is defined as blindness which could be either treated or prevented by known cost effective means (Salomao et al., 2008).

Congenital Cataract: is a lens opacity that develops in a child, either from birth or soon thereafter.

Developmental Cataract: is described as a lens opacity that develops in a child; generally after the age of 2years.

Determinants/risk indicators: Any, characteristic or exposure of an individual that increases the likelihood of developing a disease or morbidity. These include both the etiology and risk factors.

Organization of the Study

The thesis was structured into five chapters. Chapter one comprise the background to the study, statement of the problem and purpose of the study. The chapter looked at the specific research questions that the study aimed to answer as well as the definition of terms used in the study. It also covered the significance of the study, the scope and limitations of the study as well. Chapter two examined the theoretical framework and reviewed literature pertaining to the study. This included a broad discussion of the global magnitude and causes of blindness and visual impairment, prevalence and causes of blindness and visual impairment in children worldwide. Others include childhood blindness and visual impairment in developing countries, global magnitude of visual impairment due to uncorrected refractive error and demographic and health structure of Ghana as well as magnitude of visual impairment due to refractive errors in Ghana. Chapter three discussed the research methodology as well as research design employed in the study. It also outlined the research instrument, sampling size and technique as well as a detailed description of procedure for data collection and data analysis, and ethical considerations. Chapter four focused on the results, its interpretations and implications. Chapter five was devoted to summary of findings, conclusions arrived at and recommendations.

CHAPTER TWO

LITERATURE REVIEW

The purpose of this study was to assess the prevalence, distribution and determinants of visual impairment due to uncorrected refractive error in children aged 5 to 15 years attending primary schools in the coastal areas of Cape Coast, Central Region of Ghana. This chapter reviewed the literature related to the topic in four main parts. First is an overview of theories and theoretical framework adopted for this study. The framework covered 3 main theories explaining the development of uncorrected refractive error and the inter-connectivity among these three individual theories. In the second part, literature on visual impairment and its associated factors as well as visual impairment caused by uncorrected refractive error was reviewed to identify the magnitude and causes at global and local levels. Three theories of refractive error development are presented as the theoretical framework that guides the study. The justification for these theories and current research developments which relate to these theories are discussed. Third was a review of relevant studies on trends of visual impairment and uncorrected refractive that have been conducted in Ghana. The fourth part presented the methodologies in literature used in carrying out related studies. The literature was reviewed under the following headings:

1. Theoretical framework of study
2. Determinants of uncorrected refractive error in previous studies
3. Global prevalence and causes of visual impairment for all ages

4. Global magnitude of visual impairment due to uncorrected refractive error
5. Refractive errors
6. The country Ghana
7. Magnitude of visual impairment in Ghana
8. Magnitude of visual impairment due to uncorrected refractive error in Ghana
9. Reasons for non-correction of refractive errors
10. Visual development and assessment of visual function in children
11. Design of refractive error studies in children
12. Visual acuity cut-off points

Theoretical Framework of the Study

The three major theories in existing literature that have attempted to explain the development of refractive error dates back to the 18^{th} century. These are the biological-statistical theory, the use-abuse theory, and the theory of emmetropisation. The biological-statistical theory views the development of refractive error as the result of genetically determined characteristics of eye tissues (Steiger, 1913) whereas the theory of emmetropisation explains the coordination of eye growth such that changes in ocular components occur together to bring about little or no change in refractive error.

In Steiger's (1913) biological-statistical theory, refractive state was thought to be inherited, so there was no role for other factors. This theory considered myopia as a genetic consequence of variations of different ocular component such as lens thickness, corneal curvature, anterior chamber depth and axial length. Steiger's (1913) proposed that refractive errors resulted from the combination of ocular elements, with the particular properties of each component being genetically determined. Steiger's theory promoted research into the biological and environmental basis for myopia onset and development which formed the basis for the so called "nature and nurture" debate. The first evidence in support of the role of genetic factors in the pathogenesis of myopia was provided by Pacella, McLellan and Grice (1999) and was derived from a 24-year longitudinal study which commenced in infancy in a cohort of 609 largely Caucasian children. They found an odds ratio of 5.09 for two myopic parents *versus* no myopic parent, which clearly demonstrated the impact of parental myopia on child's myopia. In addition, changes in ocular biometric features have also been shown to accompany familial predisposition. For example, a study of non-myopic children found increased eye size for those with myopic parents compared to those whose parents were not myopic (Zadnik, Satariano & Mutti, 1994). Presently several prospective studies have shown that myopic parents tended to have myopic children (Dirani et al, 2006; Liang, Yen & Su, 2004; Mutti et al., 2002; Zadnik et al., 1994). Some cross-sectional studies reported a higher prevalence of myopia in children with two myopic parents compared to children with one myopic parent (Mutti et al., 2002). Perhaps the strongest evidence for an important role of genes in development of myopia was found in a comprehensive twin study by Hammond, Senider, Gilbert and Spector, (2001). Hammond et al. (2001) used genetic modeling to analyze data for 226 monozygotic (identical) and 280 dizygotic twins (non-identical) twins. The authors found that identical twins are significantly more alike in refractive status than non-identical twins. Although the results of these studies pointed to a genetic inheritability of refractive errors in support of Steiger's (1913) theory, some authors still argue that similarities in refractive status between parents and children reflects the shared environments as well as the shared genes (Mutti et al., 2002; Saw et al., 2001; Young, 2009). The biological-statistical theory becomes even more contentious with the reports that many Asians were found myopic without any family history of the condition (Wu & Edwards, 1999). Several authors examining further the issue of heritability of myopia confirmed the role of environmental influences in the pathogenesis of refractive error (Mutti et al., 2002; Saw et al., 2001; Young, 2009).

A contrasting theory to Steiger's biological theory for development of refractive error is the use-abuse theory (Cohn, 1886; Young, 1962) or "near-work" hypothesis (as reviewed by Criswell & Goss, 1983; McBrien & Barnes, 1984). The "near-work" hypothesis held that excessive amount of near work such as reading and watching television at close distance induces too much accommodation in the eye thus resulting in myopia. In other words, myopia onset was an adaptation to use or abuse of the eyes during sustained near vision. The strong association between near work and myopia was first recognized by Young (1962) as the use-abuse theory, and became the most popular theory on the pathogenesis of myopia. The theory was informed by the observation of increasing amounts of myopia in 10,000 German school-children as they progressed to higher grade levels. It was observed that in the youngest children there was a low prevalence of myopia, which increased with age. Young (1962) concluded that the observed high prevalence of myopia in the older children resulted from eye strain due to increased educational demands in the higher grades, a substantial portion of which entailed reading and other close work. Several studies in the past have observed strong correlations between education and myopia (Fulk, Cyert & Parker, 2002; Saw et al., 2006; Saw et al., 2002). Saw et al. (2002) reported that the number of books read per week was associated with higher levels of myopia in Singaporean children aged between 7 and 9 years. Correlations as detailed as faster rates of progression following periods of intense study and slower rates during school holidays have also been reported (Fulk et al., 2002; Goss & Eskridge, 1988; Tan et al., 2000).

Support for an important role of excessive accommodation during near-work also comes from animal studies, in which increased ocular growth and myopia was readily induced in neonatal chicks (Irving et al., 1992, Irving et al., 1991; Schaeffel & Howland, 1988), tree shrews (Abbott, Grumert, Pianta & Mc-Brien, 2011; Amedo & Norton, 2011; Norton, Siegwart & Amedo, 2006) and monkeys (Smith, 2013), although Norton et al. (1994) and Troilo and Wallman (1991) have presented evidence to the contrary. These authors found that myopia could develop in an eye with the retinal output to the rest of the brain blocked (Norton et al., 1994) or severed (Troilo & Wallman, 1991). This suggested that accommodation was not a stimulus for myopia development. This perspective is further supported by the fact that attempts to reduce the progression of myopia with reading glasses or contact lenses and bifocals have not been successful (Saw et al., 2002). Further studies are warranted in this area as the results obtained so far seem to suggest that excessive accommodation may not be the only factor in the pathogenesis of myopia.

Van-Alphen explains that given the higher prevalence of emmetropia than ametropia in the population, there is a possibility that the components of the eye do not grow independently, but rather undergo a process of coordinated growth. The theory of emmetropisation by Hofstetter (1969) and Van-Alphen (1961) posit that eye growth is a coordinated process that has been shown to consist of an infantile phase whereby, in the first three years of life, the cornea and the lens had to compensate for any increase in axial length, to bring about emmetropia. The authorities (Hofstetter, 1969; Van-Alphen, 1961) proposed that during infancy there is an inherent system of regulation and stabilization of the inherent mismatch between the optical power of the cornea/lens and the axial length of the eyeball. According to Van-Alphen (1961), the inherent mismatch between the optical power of the cornea/lens and the axial length of the eyeball is inherently corrected to produce normal vision through a vision-dependent process known as emmetropisation. The theory explains that most animals including humans are born with hyperopic errors due to the small eye balls of a newborn. In other words, with an eye that is too short for the optical power of the eye and lens. McBrien, Gentle and Cottrail (1999) posit that this theory emerged as a response to objections to the biological and use-abuse theory and recommends a realistic explanation of the high prevalence of emmetropia despite the inherent mismatch between the optical power of the cornea/lens and the axial length of the eyeball in infancy.

There is considerable evidence in support of the role of emmetropisation in the development of refractive error. Animal studies using chicks (Schaeffel, Troilo, Wallman & Howland, 1990), tree shrew (Norton, 1999; Siegwart & Norton. 1999) as well as monkeys (Smith & Hung, 1999) have provided clear evidence of the mechanism of emmetropization.

Recent evidence by McBrien, Gentle and Cottrail (1999) seem to suggest that all 3 individual theories are interconnected and complimentary and follow a common theme that genetic (parental myopia) and environmental factors (age, gender, near-work, school achievement, BMI and SES) play important role in the development of refractive errors. They (McBrien et al., 1999) argued that the presence of a significant refractive error at birth may indicate an initial axial length too great to be corrected by emmetropisation. The current study was grounded in the 3 individual theories.

To understand the relevance of emmetropisation to the etiology of human refractive errors, it is necessary to first define how refraction develops from birth to adulthood. At birth, neonates are mostly longsighted (hyperopic) due to their small eyeballs. Within the first year during infancy, there is a substantial reduction in hyperopia. This is synonymous with eye growth that results in changes in major determinants of refractive power namely: corneal curvature, axial length, and lens power (Smith & Hung, 1999). The reduction in hyperopia cannot only be attributable to simple scaling effects (or passive emmetropisation) as it appears to also involve modulation to axial growth (Norton, 1999; Siegwart & Norton. 1999). Emmetropisation continues at a slower rate after this early rapid phase and by 6 years of age it is largely complete. By age 6, the two principal determinants of refraction are the refraction at birth and the degree of emmetropisation that has occurred in the intervening years. The presence of a significant refractive error at age 6 can therefore be considered as primary failures of emmetropisation attributable to any of the following scenarios: an initial refractive error too great to be corrected by emmetropisation; an initial refraction within the normal range but deficient emmetropisation, or a combination of both (McBrien, Gentle & Cottrail, 1999).

For many years these theories were largely hypothetical, but in recent years a number of studies have provided direct evidence in support or objection of the theories in animals including humans. The inter-connection of these theories is explained in Figure 1.

Determinants of Uncorrected Refractive Error in Previous Studies

Age as a determinant of uncorrected refractive error

Several landmark studies have shown that age is the single most important determinant of the distribution of refractive error in a given population (Philander & Thenmozhi, 2015; You et al., 2012). The prevalence of myopia among school-age children was found to increase with age in most populations studied till date (Kumah et al., 2013; Naidoo et al., 2003; Zhao et al., 2000). Several studies have also shown that only a very small proportion of infants are myopic at birth, and much of this neonatal myopia is associated with prematurity (Bartmann & Schaeffel, 1994; Blackie & Howland, 1999; Flitcroft, 1998; Norton, 1999), thus justifying the theory of emmetropisation. The results presented in most studies suggest that the emmetropisation process occurs mainly in early infancy and is largely complete by age 6 (Blackie & Howland, 1999; Flitcroft, 1998). Blackie and Howland (1999) commented that refractive errors that exist by age 6 years can be considered failures of emmetropisation or an initial refractive error too great to be corrected by emmetropisation such as congenital glaucoma in Sticklers syndrome.

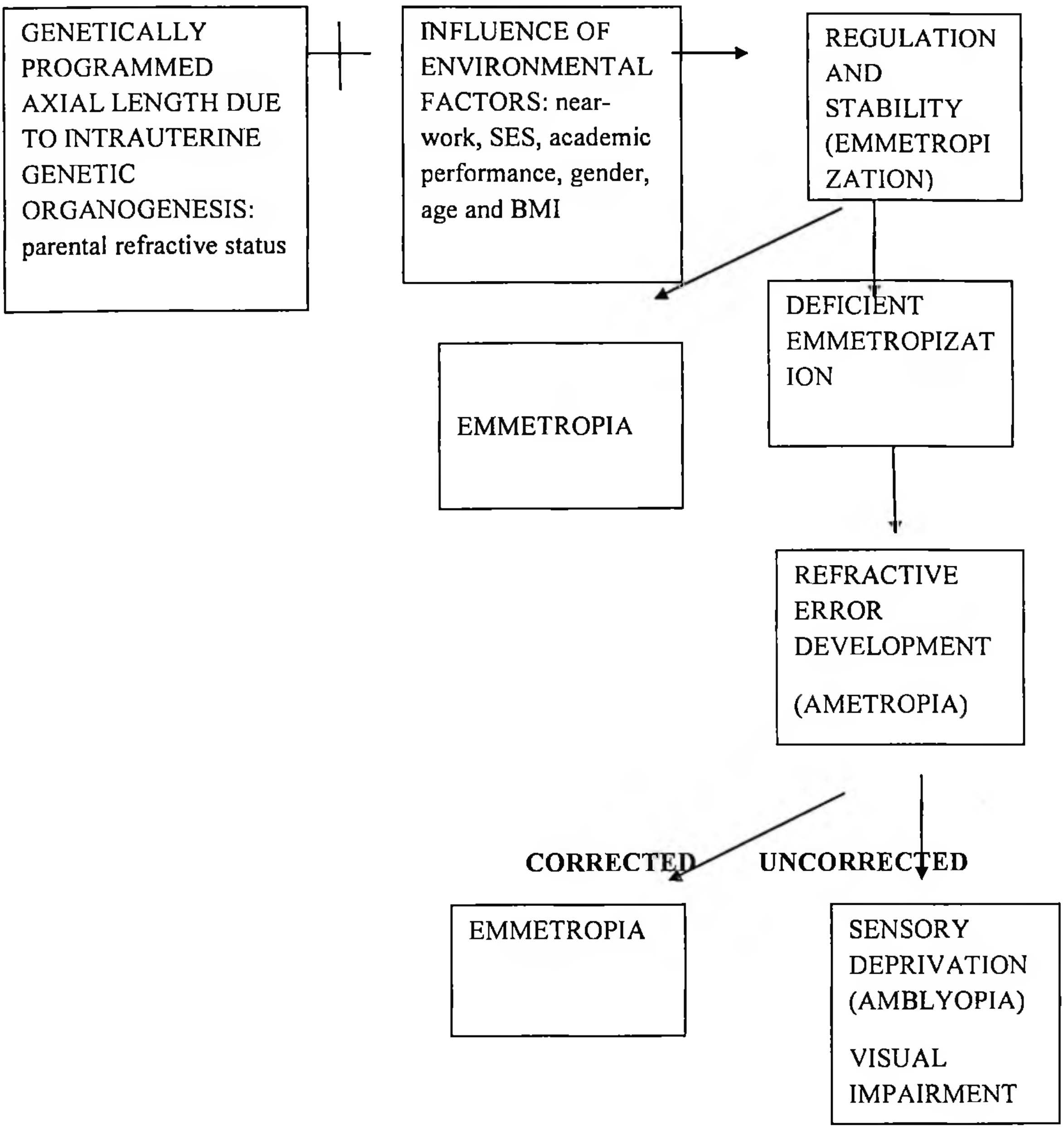

Figure 1: Conceptual Framework for the Study - Adopted from the Biological-Statistical, Use-Abuse, and Emmetropisation Theories (Researcher Developed)

These studies (Blackie & Howland, 1999; Flitcroft, 1998) also reported that even by the time school-children enter formal schooling by age 6, they are generally not myopic. However, during the ensuing 6 to 8 years, low to moderate myopia is first observed and progresses. The rate of progression was found to be -0.40 (±0.25) D on the average (Richdale, Bullimore, Sinott, & Zadnik, 2016). The trends indicated by recent data clearly suggest that the progression is due to increases in axial length with increasing age (Larsen, 1971; Mutti et al., 2007; Mutti et al., 2005; Norton, 1999). Accordingly, this study hypothesized that increasing age is significantly associated with the prevalence of uncorrected refractive error among children attending primary schools in Coastal area of Cape Coast.

Gender as determinant of uncorrected refractive errors

The trends in refractive error distribution seen with gender, as opposed to age, are not as well defined and may in fact be confounded by age. In other words, gender has not been consistently associated with refractive errors, although a few studies have found the female gender to be significantly associated with refractive error (Sewunet, Aredo & Gedefew, 2014; You et al., 2012). In majority of the RESC studies, myopia occurred more frequently in girls than in boys (Dandona et al., 2002; Murthy et al., 2002; Naidoo et al., 2003; Zhao et al., 2001) and this was attributed to the influence of puberty and earlier maturation typically found in girls whereas in other studies like the one in Mozambique (Ruiz-Alcocer, Madrid-Costa, Perez-Vives, Albarran & Gonzalez-Meijoma, 2011) the reverse was the case. More research is therefore needed to further examine the relationship between gender and uncorrected refractive error among children.

Body mass index as a determinant of uncorrected refractive error

The association of body mass index with refractive errors is grounded on the theoretical basis relating axial length and development of refractive error (Hirsch & Weymouth, 1991). These authorities (Hirsch & Weymouth, 1991) argued that since body mass index (BMI) also affects the eye size, it may have an impact on development of refractive error. Larsen (1971) showed that axial length increases early in life and concomitant with overall growth and development of the child. In addition, Saw et al. (2002) found that axial length and corneal curvature were related to body mass index. They (Saw et al., 2002) observed that eyes in children who were heavier or who had high BMIs tended to develop myopia. Also, the study by Yang et al. (2016) demonstrated that BMI levels were associated with the prevalence of visual impairment, with a higher BMI level resulting in a higher prevalence of visual impairment. However, some studies have presented evidence to the contrary. For example, whereas some studies have indicated that myopia appears to be more common in taller (Johansen, 1950) and heavier children (Gardiner, 1954) suggesting that axial lengths are longer among these children, other studies (Rosner & Belkin, 1995) have found no associations..

The discrepancy among the previous studies may be due to a combination of small sample sizes, selection bias in clinic-based studies and other methodological variations. Further studies are needed to confirm this relationship. The inconsistent results presented suggest that the relationship between ocular dimensions and BMI is not conclusive.

Parental myopia as a determinant of uncorrected refractive error

The expression of a disease may depend on the presence of a critical number of genes that are inherited independently (polygenic disorders). Studies of identical twin eyes showing up to 90% correlation of refraction provide the strongest evidence of the inheritability of refractive components

(Hammond et al., 2001; Kimura, 1965). These authors (Hammond et al., 1995) compared monozygotic and dizygotic twins and found that identical twins are significantly more alike in refractive status than non-identical twins and the calculated heritability values from these data was high. Kimura (1965) demonstrated that genetic factors play a significant role in the incidence of myopia by showing strong correlations in corneal power and axial length, between parents and children and between siblings. The study of Schwartz, Haim and Skarsholm, (1990) further implicated several genes in the myopic inheritance which include an X linked recessive form of myopia on the following chromosomes: Xq28, 21q22, 18p11.31, 12q21-23 and PAX6. Even in the elderly population, refractive error and myopia were found to be hi ghly heritable (Wojciechowski, 2011). Several longitudinal studies also reported a positive relationship between parental myopia and myopia development in children, thereby confirming inheritability of refractive error (Fan, He & Morgan, 2012; Zhang, Qu & Zhou, 2015). These findings are grounded on the biological theory of Steiger (1913).

Near-work as a determinant of uncorrected refractive error

Near-work is considered as the activities done at short working distance such as reading, studying (doing homework, writing), computer use/playing video games, or watching TV (Morgan & Rose, 2013; Mutti et al., 2002). The role of these activities in the development of refractive error is predominant in literature although significant associations were not consistently observed in all studies (Low et al., 2010; Lu & Congdon et al., 2009; Zhang et al., 2010). Several cross-sectional studies showed that excessive amounts of near work activities increased the prevalence of myopia in children 6-18 years old (Mutti et al., 2002; Saw et al., 2006). Among Chinese children aged 8-9 years, Saw et al. (2000) reported that myopic children performed more near work activities than non-myopics. The results from Singapore (Saw et al., 2002) and Sydney (Ip et al., 2008) also showed that the odds of having myopia was higher in children who do more near work activities than those who do fewer of such activities. However, other cross-sectional studies did not find any association between near work and myopia development (Lu et al., 2009; Rose et al., 2008). The study by Lu et al. (2009) on rural China children demonstrated that myopic children did not spend more time on near work activities compared to non-myopic children. A recent study by Rose et al. (2013) revealed that the prevalence of myopia was similar among children aged between 6-12 years who do excessive near work activities and those who do not. Even among cohort studies, results regarding excessive near work as a risk factor of myopia were inconsistent. Whereas French, Morgan, Barlutsky, Mitchell and Rose (2013) demonstrated that near work activity increased the risk of developing myopia, Saw et al. (2006) and Iwu et al. (2013) found no correlation. Therefore, further studies are needed to understand the relationship between near work and development of refractive error.

School academic performance/achievement as a determinant of uncorrected refractive error

Studies by Young (1963), Grosvenor (1970) and Saw et al. (2001) have documented the associations between intelligence/academic performance, school environment, and myopia. These studies contend that myopes tend to have higher scores on tests of intelligence, cognitive ability and better grades than do non-myopes. In Saw et al. (2001) study of Singapore school-going children, educational level' and academic performance positively related to myopia. Thus, achieving high intelligence test scores and high educational levels and reading more books per week significantly influence refractive error. Perhaps, a possible source of this association is the relationship between near work and myopia. Those who are more intellectually inclined and who succeed in school are probably also doing more near work than those who are not successful academically.

Socioeconomic status as a determinant of uncorrected refractive error

The association between socioeconomic status (SES) and refractive error is well documented in literature (Saad & El-Bayoumy, 2007; Saw et al., 2002; You et al., 2012). Many socioeconomic factors such as parent occupation, parent education and income have been documented for having possible associations with risks of developing myopia. Saw et al. (2002) was among the first to make a report that myopia was significantly associated with higher educational status and higher family income. In that study, Saw et al. showed that children of high SES were more likely to develop myopia than those of low SES. One possible source of this association is the association between intelligence, education, and myopia. It is unclear whether this association represents environmental or genetic influences. However, there is dearth of information in developing countries regarding socioeconomic status as risk factors for myopia development as most data in literature come from affluent countries.

Global Prevalence and Causes of Visual Impairment and Blindness for all Ages

As noted in the WHO (2013) recent comprehensive review, one of the core functions of the WHO is to provide periodic estimates of prevalence of diseases including blindness and visual impairment at global level. These estimates cover all six WHO regions for age groups 0 to 14 years, 15 to 49 years and 50 years and older. These estimates are monitored periodically and used as a tool for setting policies and priorities for the prevention and elimination of visual impairment and the improvement of eye health globally. In the first global estimate of magnitude of blindness and visual impairment, the WHO (1990) revealed that 148 million people were visually impaired and 38 million people were blind. Subsequent updates in 2002 through 2010 based on the result of new studies carried out in nearly all six WHO regions indicated 191 million people were visually impaired and 32.4 million were blind (Pascolini & Mariotti, 2010). The trends indicated by the data suggest that the relative prevalence of visual impairment and blindness has dropped from 4.58% in 1990 to 3.37% in 2013 since the early estimates in 1990. These estimates were derived from population-based studies carried out in individual countries and may suggest that so far significant improvement has been made in the campaign for elimination of avoidable blindness.

The leading causes of visual impairment were reported to be uncorrected refractive errors, cataracts and glaucoma (Pascolini & Mariotti, 2010). Significant differences in the prevalence of blindness and visual impairment across regions were also reported despite identical classification criteria. For example, China, in the Western Pacific Region, is reported to have the highest rate of visual impairment worldwide followed by India in the South East Asian Region, 55.4 million and 53 million people, respectively. The report also showed that the East Mediterranean Region comprising Iran, Oman, Pakistan and Qatar, had the highest rate of blindness followed by the

African Region, 8.5 million and 7.3 million people, respectively. This is in contrast with low rates of blindness of 3.5 million and 3 million people reported for highly industrialized regions of America and Europe, respectively, and of visual impairment of 29.1 million and 31.7 million people.

The WHO estimates also revealed gender differences. In all regions, women were reported to be affected more often by visual impairment and blindness than men. However, the sex disparity in the report was not so pronounced in the sub-Saharan African (SSA) regions (1.11:1.13) and the South Asia region (1:1.26) (WHO, 2013). The report indicated that the global age standardized prevalence of blindness and visual impairment for older adults decreased from 3% worldwide in 1999 to 1.9% in 2010 and from 14.3% worldwide to 10.4%, respectively (WHO, 2013).

The trends indicated in the WHO (2013) data suggest that the major causes of visual impairment globally were uncorrected refractive errors and cataract with a prevalence of 43% and 33%, respectively. Other causes recorded in the WHO report were glaucoma (2%), age related macular degeneration (AMD), diabetic retinopathy, trachoma and corneal opacities, all accounting for about 1% of visual impairment. A large proportion of causes, 18%, were undetermined. Cataract was reported to be the principal cause of blindness accounting for 51% of all blindness worldwide, followed by glaucoma, 8%, AMD, 5%, corneal opacities and childhood blindness, 4%. Other causes of blindness recorded were uncorrected refractive errors and trachoma, 3% and diabetic retinopathy 1%. In addition, undetermined causes for blindness and visual impairment account for 21% and 18% respectively (WHO, 2013).

Global Prevalence and Causes of Blindness in Children

The UNICEF report in the year 2010 defined a child as an individual aged less than 16 years. The report further emphasized the importance of normal vision in the general development of the child (UNICEF, 2010). According to the report, any impairment in vision at this stage has detrimental impact on the general development of the child, community and nation (Day, 1997; Cass, Sonksen & McConachie, 1994),

There are indications in literature that the changing trends of prevalence of visual impairment and blindness in all ages apply to that of childhood blindness and visual impairment. For instance, the WHO (2010) estimated that about 1.4 million children in the world are blind with an incidence of 500,000 children per year. Almost 80% of these blind children live in the poorest regions of Africa and Asia (WHO, 2010). Since that report, more recent reports indicate that the total population of blind children in the individual WHO regions has dropped significantly in the past decades from 1.4 million in 2010 to about 1.2 million at the present time (WHO, 2013).

Significant differences in the prevalence of childhood blindness and visual impairment were reported between countries, being largely determined by levels of socioeconomic development. For example, the prevalence of blindness for the industrialized countries varied from 3.4 to 4.0 per 1,000 children, and visual impairment between 5.4 and 8.7 per 1,000 children whereas in sub-Saharan Africa and Asia, the blindness rate quoted by Gilbert, Anderton, Dandona and Foster (1999) was 15 per 1,000 children. According to these researchers (Gilbert et al., 1999), such data suggest that there may be a ten-fold difference in prevalence of childhood visual impairment between the developed countries of the world and the poorest ones, ranging from 0.3 per 1,000 children in wealthiest countries to 1.5 per 1,000 children in the poorest countries.

Although the prevalence rates quoted here for childhood blindness accounts for only a small percentage (3.2%) of the burden of global blindness, the WHO (2004) insisted that childhood blindness should be listed in the priority areas of the WHO's VISION 2020 for three major reasons. First, Resnikoff et al. (2008) and Harsha and Kalyan, (2008) make the case that because the majority of blindness in children happens before the age of 5 years - a period when 75 per cent of learning is through sight, visually impaired children have a longer lifetime of blindness than visually impaired adults. Shamanna and Muralikrishnan (2004) estimated it as 70 million person years of blindness. In other words, the number of blind years resulting from blindness in children is alarmingly high. Second, childhood blindness is found to be strongly associated with increase in child mortality. Reports indicate that 60% of children in the developing countries die within 2 years of becoming blind (Gilbert et al., 1999). Lastly, but perhaps the most important is that blindness in children is an emergency in that irreversible loss of vision may occur from amblyopia if the cause of blindness is not treated early but this is not the case with adult blindness (Gilbert & Foster, 2001).

The trend in causes of childhood blindness also presents a similar picture to its prevalence. The few population surveys available in literature which included children demonstrated a wide regional variation in the cause-specific prevalence of blindness. Gibert et al. (1999) commented that the variations are largely determined by levels of socioeconomic development, under-5 year mortality rate in children and the availability of primary health care services. Gilbert and Foster (2001) comprehensive review of studies on childhood blindness revealed that corneal scarring from measles, vitamin A deficiency, use of harmful traditional eye remedies, ophthalmia neonatorum and rubella cataract were the commonest causes of childhood blindness in low-income countries whereas in middle income countries, retinopathy of prematurity, glaucoma, cataract and lesions of optic nerve were the most frequent factors causing of childhood blindness. This is in contrast to the high income countries, where life expectancy and earning capacity are high, glaucoma, hereditary retinal dystrophies and lesions of the optic nerve are the most frequent (Gilbert & Foster, 2001). An International Agency for Prevention of Blindness Report (IAPB) in 1984 listed ignorance, poverty, superstition, and adverse cultural practices, as factors which determine the gravity of childhood blindness in developing countries (Wilson, 1984).

In Asia and SSA where most of the blindness and visual impairment are reported to occur (WHO, 2013), the prevalence and causes of blindness is entirely different from that in other continents. Asia is a vast and diverse continent whose countries have extreme diversity geographically and socioeconomically. They include the technically advanced Japan, rapidly growing China and India, and other developing countries. The rates of development seem to reflect in the causation of childhood blindness. In Southern India, Dandona and Dandona (2003) found a prevalence of 0.17% for childhood blindness among 6,935 children. Refractive error was an important cause and accounted for 33.3% of the cases. The single most important cause of visual impairment and blindness in India was documented in that report to be Vitamin A deficiency affecting 18.6% of children (Dandona & Dandona, 2003). The corresponding figures reported for China, for childhood visual impairment and blindness were 1.1 per 1,000 and 0.33 per 1,000 children respectively (Fu, Yang, Bo & Na, 2004). In southern India, a prevalence of childhood blindness of 1.06/1,000 children was found among 13,241 children below 16 years of age, with 14 children being bilaterally blind (Dorairaj, Bandrakilli, Shetty, Misquith & Ritch, 2008). In a study conducted in the Czech republic among 229 children aged 6-15years attending school for the visually handicapped, it was found that 20.5% had severe visual impairment while 69.5% were blind (Kocur, Kuchynka, Rodnyet, Barokova & Scwartz, 2001).

Sub-Saharan Africa has a dearth of comprehensive information on childhood blindness in most of their countries. There are no national surveys regarding the magnitude and causes of blindness. The few studies available were either carried out in school for the blinds (Kello & Gilbert, 2003; Kingo & Ndawi, 2009) or were small population surveys (Nkanga & Dolin, 1997; Sudha, William & Graham, 2010) which were not representative of the larger population. Corneal scarring, ophthalmia neonatorum, congenital cataract and congenital glaucoma are highly expressed in blind school surveys (Kingo & Ndawi, 2009). These reports (Kello & Gilbert, 2003; Kingo & Ndawi, 2009) suggest that over 70% of blindness in sub-Saharan Africa was due to corneal scarring, the main causes of which were measles and Vitamin A deficiency. This pattern is similar in so many other African countries such as Kenya, Malawi, Tanzania and Nigeria (Lewallen & Courtright, 2001). However, many disparities in childhood blindness prevalence rates across African countries have also been demonstrated. The rates reported for Malawi (67.2%), Uganda (56.7%), South Africa (38.8%), and Kenya (28.8%) affirms this view (Lewallen & Courtright, 2001). In Western Nigeria, Ajaiyeoba, Isawumi, Adeoye and Oladeye (2007), found a prevalence of blindness or visual impairment of 1.48% among primary and secondary school children. In Eastern Nigeria, the prevalence of visual impairment among primary school children was found to be 0.7% and that of blindness was 0.05% (Nkanga & Dolin, 1997). An earlier study carried out in 1993 among 905 children in three developing countries in West Africa, Chile and South India found 806 (89%) children with blindness or severe visual impairment (Gilbert & Canovas, 1993). In Younde, Cameroon, Ebelle, Epe and Koki (2009) undertook a hospital-based study into the causes of blindness among children aged 6 to 15 years. Of the 1,266 children examined, 60 (4.7%) had unilateral childhood blindness. Reports from East and Central Africa also demonstrated varying patterns of blindness. Shirima et al. (2009) conducted a survey in the Kilimanjaro region of Tanzania. The aim was to estimate the numbers of blind children for planning services. They found a prevalence of blindness of 0.17 per 1,000 children among the 95,040 children in 72 villages. In Kibaha, Tanzania a screening for low vision among the school children found a prevalence of low vision of 9.5% (Kingo & Ndawi, 2009). In Ethiopia, 295 (94.5%) among 312 children attending schools for the blind were diagnosed with blindness or severe visual impairment (Kello & Gilbert, 2003). In another study carried out among children in schools for the blind in Kenya, Malawi, Tanzania, and Uganda, out of 1062 children examined, 361 (34%) were found with blindness or visual impairment (Kingo et al., 2009). In Chikwawa district in Malawi, the prevalence of childhood blindness was 0.09 % (Kalua, 2007). A survey in Botswana reported a prevalence of 32.8% (79 out of 241 children recruited) for unilateral visual impairment or blindness and 67.2% (162 of 241) for bilateral visual impairment or blindness (Sudha, William & Graham, 2010).

Ophthalmia neonatorum was a significant cause of childhood blindness in sub-Saharan Africa in the past (Gilbert et al., 1999). It is usually caused by *Neisseria gonorrhoeae* and *Chlamydia trachomatis*. Infants acquire these infective agents as they pass through the birth canals of their mothers during the birth process, from attending nurses or from contaminated bed sheets (Kalpana& Hampton, 2010). If not properly managed, the causative agents may cause corneal ulceration that may lead to irreversible blindness. However, recent studies have demonstrated that the role of Ophthalmia neonatorum, congenital cataract, as well as retinopathy of prematurity in recent times have diminished due to improved management modalities (Gilbert et al., 1999; Silvana, Shane & Erika, 2009).

Global Magnitude of Visual Impairment due to Uncorrected Refractive Error

The reports presented in literature suggest that significant progress has been made in avoiding blindness and visual impairment, particularly from cataract and infectious diseases. However, refractive error as a cause of visual impairment remains a major global health issue with about 153 million people over 5 years of age visually impaired from uncorrected refractive error, of whom 8 million are blind according to Dandona and Dandona (2006). A recently published report presents a higher figure of 2.3 billion people with visual impairment due to refractive error including 1.5 million children between the ages of 4-14 years (Donatella & Marrioti, 2012). For these reasons, it was recognized by the WHO as the main cause of visual impairment globally (Donatella & Marrioti, 2012; WHO, 2014), and listed in the priority areas of Vision 2020 (WHO, 1998).

Before the recognition of refractive error as a significant cause of visual impairment, several reports in the past indicated that congenital cataract was the leading cause of childhood visual impairment worldwide (Gilbert et al., 2001; Gilbert et al., 1999). Refractive error as a cause of visual impairment or blindness was largely overlooked because the definitions of visual impairment or blindness was based on best corrected visual acuity in the better eye. Using best corrected distance visual acuity in the better eye rather than presenting vision, it was recognized that the magnitude of visual impairment at global level was significantly underestimated (Resnikoff et al., 2008).

Resnikoff et al. (2008) highlighted the difficulties in comparing results across studies owing to significant variability in the definition of visual acuity across studies. Further, Resnikoff et al. (2008) proposed that the extent of visual impairment resulting from uncorrected or inadequately corrected refractive errors will be appreciated if visual impairment is assessed based on presenting vision, that is, visual acuity obtained with currently available refractive correction, if any. The WHO agreed with Resnikoff and his colleagues' argument after a consultative meeting in 2003 and recommended that the definition of visual impairment be amended so that "presenting VA" be substituted for best corrected visual acuity, considering the effect of visual impairment and blindness on economic and educational opportunities and quality of life (Resnikoff et al., 2008). Taking account of the recommendations, the WHO proposed a standard definition of visual impairment as presenting visual acuity worse than 6/18 but equal to or better than 3/60, with best correction in the better eye (ICD -10 visual impairment categories 1 and 2). This definition presupposes that everybody wears their most appropriate optical correction all the time. The only visual impairment to consider is that which remains after the provision of the best correction.

Using "presenting" vision, Resnikoff and his colleagues conducted a systematic review to estimate the prevalence of visual impairment from uncorrected refractive for all ages above 5 years. The results showed that for age group 5 to 15 years, the global prevalence was 0.96% (12.8 million people) with the highest prevalence in urban South East Asia and China. For the 16 to 39 year group, a prevalence of 1.1% (27 million people) was estimated (Resnikoff et al., 2008). Studies from urban India estimated that about 493 million of those aged 15 years and more may have refractive errors (Dandona et al., 1999) and that uncorrected refractive error is the most common cause of avoidable blindness in that country.

Refractive Error Studies in Children (RESC)

The RESC studies and other epidemiological studies covered specific regions and population subgroups worldwide. Estimates from these studies indicate that uncorrected refractive errors are an important cause of visual impairment in many countries (Dandona et al., 2002; Naidoo et al., 2003; Zhao et al., 2001). As mentioned earlier, the estimates were based on the prevalence of visual acuity of less than 6/18 in the better eye with currently available refractive correction that could be improved to equal or better than 6/18 by refraction or pinhole.

In a RESC study conducted in Durban, to assess the prevalence of refractive error and visual impairment in school-aged South African children aged between 5-15 years, out of the 4,890 students examined, refractive error was the cause in 63.6% of the 191 eyes with reduced vision (Naidoo et al., 2003). Other major causes of visual impairment found in the study were amblyopia (7.3%), retinal disorders (9.9%), and corneal opacity in (3.7%). The overall prevalence of uncorrected, presenting and best-corrected visual acuity of 6/12 or worse in the better eye was 1.4%, 1.2%% and 0.32%, respectively.

In a RESC study conducted by Zhao et al. (2000) in the metropolitan area of Southern China to assess the prevalence of refractive errors and visual impairment in school-aged children aged between 5-15 years, results showed that refractive error was the cause of visual impairment in 94.9% of the 2,335 eyes with reduced vision and amblyopia in 1.9%. According to Zhao et al. the prevalence of uncorrected, presenting, and best-corrected visual acuity of 6/12 or worse in the better eye was 22.3%, 10.3%, and 0.62%.

In South Africa, refractive error was the cause of visual impairment in 63.6% of children. Amblyopia contributed 7.3%, retinal disorders 9.9% and corneal opacity 3.7%. "Other" causes were responsible for 3.1% and in 12.0% the cause was unexplained (Naidoo et al., 2003).

A RESC study was carried out in the Ashanti Region of Ghana to assess the prevalence of refractive error and visual impairment. The participants included private school children aged 12 to 15 years (Kumah et al., 2013). Of the 2,435 children examined in that study, prevalence of uncorrected, presenting, and best visual acuity of 20/40 or worse in the better eye was 3.7, 3.5, and 0.4% respectively. Refractive error was the cause of reduced vision in 71.7% of 152 eyes, followed by amblyopia 9.9%, retinal disorders in 5.9%, and corneal opacity 4.6%. In addition, myopia (at least -0.50D) in one or both eyes was present in 3.2% of children measured with retinoscopy and in 3.4% measured with auto-refraction. The study concluded that reduced vision in Ghanaian private school children due to uncorrected refractive error was low (Kumah et al., 2013).

Apart from the RESC studies (Kumah et al., 2013; Naidoo et al., 2003; Zhao et al., 2001), several cross-sectional studies which did not adopt the RESC protocol demonstrated that uncorrected refractive error was a major cause of visual impairment among children in various settings.

A study to assess the prevalence of childhood blindness and visual impairment in school children in rural Malawi revealed that, out of the 1,000 secondary school children, aged 11-19 years, who were screened, 39 students were visually impaired, with refractive errors as the cause of the impairment in 12 (85.7%) cases. Of the 16 people with refractive error, only 4 had spectacles (Sherwin, Dean & Met Calfe, 2011). In a cross-sectional study conducted in Sao Paulo, Brazil to assess the prevalence and causes of visual impairment among 2,441 school children aged 11 to 14 years from low-middle income areas in the country, found a prevalence of visual impairment of 7.9%. Refractive error was the cause in 76.8% of the children with visual impairment. Other major causes were amblyopia (11.4%) and retinal disorders (5.9%). The prevalence of uncorrected, presenting, and best-corrected visual acuity 6/12 or worse in the better eye was 4.82%, 2.67% and 0.41%, respectively. However, spectacles were used by 144 (5.9%) children (Salomao et al., 2008).

In the cross-sectional study conducted in Kibaha District of Tanzania to determine the magnitude and causes of low vision among primary school children, it was revealed that, out of 400 children aged 6-17 years screened, 38 (9.5%) had visual impairment. Of the 55% of children aged 6-11 years who were found with refractive error, 8 (54%) had visual impairment caused by uncorrected refractive errors while the rest (46%) were due to other types of refractive errors (Kingo & Ndawi, 2009).

Among school children aged 12 to 15 years in Kilungu division of Makueni District, Kenya, refractive error was responsible for 92.6% of all causes of poor eye sight. The prevalence of significant refractive error was 5.2% (Muma et al., 2009). In a study to assess determinants of spectacle acceptance and use among rural Chinese children, over 50% (339 of 674) of the children requiring glasses had none. Out of the 597 (88.6%) who were prescribed glasses, only 30.7% purchased them. The main reasons for non-purchase was found to be "satisfaction with current vision", followed by "concerns over price" or "parental refusal" and "fear that glasses would weaken the eyes" (Li et al., 2008).

Dandona et al. (2002) conducted a cross sectional study to assess the prevalence of refractive error and related visual impairment in rural school children in Hyderabad, India. Out of the 4,417 children who were selected from 4,876 households, the prevalence rate of myopia was 4.1%, hyperopia 0.8% and astigmatism 0.98%. Refractive error was the cause in 61% of eyes with vision impairment.

A descriptive study was carried out to assess the prevalence of refractive errors in children aged 5-15years, from 11 schools (5urban; 6 rural) in Ludhiana city and district of India. A total of 19,610 students were examined over 3 years. Of these, 11,200 were males and 8,410 were females. There were 8,834 students in the age group of 5-10 years. The number of students who had decreased vision (visual acuity of 6/9 or less) was 2,485, comprising 1,366 myopes; 748 hyperopes; 284 with astigmatism and 87 amblyopic children (Bhatra, Kaushal & Gill, 2007).

In rural block of Haryana in North India, Seema, Vashist, Meenakshi and Manish (2009) conducted a study to assess the prevalence of refractive errors in school children. Out of 1,265 students examined, myopia was present in 12.1%, hypermetropia, 1.5% and astigmatism was present in 5.46%). In a similar study conducted to determine the prevalence of visual impairment due to refractive errors and ocular eye diseases among 4,029 school children aged 3-18years in southern India, the prevalence of myopia was 8.6%, hyperopia 22.6% and astigmatism10.3% (KaliKivayi, Naduvilath, Bansal & Dandona, 1997).

In Iran, a cross-sectional study was conducted from 2002-2008 among 5,913 school children in the city of Qazvin. The examination included visual acuity measurements and retinoscopy. The distribution of refractive errors was myopia 65%, hyperopia 12.46% and astigmatism 16.1%, respectively. An increased prevalence of refractive error, especially myopia was found in this study (Khalaj, Gasemi & Zeidi, 2009).

In Uganda, Kawuma and Mayeku, (2002) conducted a cross sectional descriptive study among a multi stage sample of 649 lower primary school children in Kampala district. Seventy three children (11.6%) were found to have significant refractive errors. The commonest single refractive error was astigmatism which accounted for 52% of all refractive errors followed by hypermetropia. Myopia was infrequent.

In Nepal, out of the 5,067 children examined, myopia, hyperopia and astigmatism was found in 2.9%, 2.85 and 1.4% of children, respectively (Pokharel et al., 2000). Dandona and Dandona (2001) estimated that 12.3% total blindness was due to uncorrected refractive error. It is also responsible for a large number of blind years lived by a person than most other causes if left uncorrected. In another report, Dandona and Dandona (2001) estimated that blindness due to refractive error resulted on an average of 30 years of blindness for each person as compared with 5 years of blindness due to untreated cataract for each person.

The study by Kalikivayi et al. (1997) was aimed to determine the frequency of impaired vision in school children in southern India. The aim was to correct the problem at the initial phase. Of the 115 children with impaired visual acuity of <6/18 vision, 109 (94%) improved by 6/18 with refraction.

There is scanty information on the burden of uncorrected refractive error in Africa. Publication on determinants of uncorrected refractive error is even sparser yet estimates from the few available studies indicate that Africa has the highest proportion of children with uncorrected refractive error (Pokharel et al., 2000; Resnikoff et al., 2008). Several studies contend that the high magnitude of visual impairment from uncorrected refractive errors in some countries is a reflection of the poor quality of eye care services in those countries (Pokharel et al., 2000; Zhao et al., 2000; Maul et al., 2000) The views expressed in most studies (Smith et al., 2009; Zhao et al., 2000) is that visual impairment from uncorrected refractive errors can have immediate and long term consequences in children and adults, such as lost educational and employment opportunities, lost economic gain for individuals, families and societies, and impaired quality of life. .

Refractive Errors

Of the five senses, the sense of sight (vision) is seen by many school of thoughts as the most important indicator of health and quality of life. Many experts believe that vision is an integral part of effective learning, education and development. This is because 85% of the information received from the environment is visual (Harley, 2005). According to Resnikoff et al. (2008), vision problems have a significant impact in terms of long-term health, emotional/social development and school performance, resulting in academic underachievement. Perhaps, this will eventually impact significantly on professional and social fulfillment.

Refraction is the process by which, the optical elements of the eye focuses light rays directly on the retina to bring about clear vision. Emmetropia or normal vision is the state of an eye without errors of refraction in which parallel rays of light come to focus on the retina with the eye at rest (unaccommodating eye). With refractive error, the optical system of the unaccommodating eye is unable to bring the parallel rays of light to a focus on the fovea. Such abnormalities in refraction cause refractive errors (Atchinson & Smith, 2000). Refractive error is a state in which the optical system of the eye fails to focus parallel rays of light directly on the retina. In myopia and hyperopia (hypermetropia) the rays come to a focus in front or behind the fovea respectively. Astigmatism results from unequal curvature of the outer corneal surface leading to the focusing of light sharply in only one meridian in the visual plane. Presbyopia is the condition when nearer objects cannot be focused on the retina because of failure of accommodation in the fourth and fifth decades of life. These conditions result in blurred vision because there is improper focusing on the fovea (Atchinson & Smith, 2000).

Myopia (shortsightedness) is the commonest form particularly in individuals who are schooling. It usually starts around the age of 9 to 10 years, progressing in severity throughout adolescence. Hyperopia (long sightedness) which is more common in younger children usually resolves around the age of 10 years. Astigmatism (distorted vision measured in cylinders) affects all age groups and does not change overtime. Individuals with myopia or hyperopia may have some degree of astigmatism. One of the standard ways of reporting refractive error is to use spherical equivalent calculated as half the cylindrical power added to the sphere in diopters (Atchinson & Smith, 2000).

Refractive error can be easily diagnosed, measured and corrected with spectacles or contact lenses to attain normal vision. If, however, they are not corrected or the correction is inadequate, the result is reduced vision. Reduced vision can be so severe that it causes visual impairment. Uncorrected refractive errors refer to cases of refractive error but they have no spectacles, or their spectacles do not support full correction. It is the second major cause of vision problems in the world after cataract (Resnikoff et al., 2008).

The Country Ghana

Ghana lies in West Africa bordered by the Gulf of Guinea to the South, Togo to the East, Cote d'Ivoire to the West and Burkina Faso to the North, covering a total area of 238, 537 sq./km. The tropical climate is a function of low altitude and proximity to the equator. However, the rainy season differs by region being highest in the forested areas of the Southwest and lowest in the North. It falls within the months of May to September in the North, and in the South there are two rainy seasons which fall within May and June and from September to October. Dust blows from the Sahara in the Northeast during the dry season to herald the Harmattan season (Country Profile, 2008).

Estimates from 2013 population growth rate indicate an increase of 1.927%. Ghana's population is estimated to be about 25,199,609 in 2016, with males comprising 49.5% and females 50.5%. The rapid growth of the population has resulted in a youthful population with two in every five people in the country being less than 15 years. Children constitute a huge proportion (38.3%) of the population of Ghana with a higher proportion of male children than female children. The proportion of the population classified as children in the rural areas is by far higher than that in the urban areas. About 20% of the population are children under 5 years of age and 27.3% are children between 5 and 15 years {school-aged} (Country Profile, 2008).

Over 70% of the population live in rural areas and are mainly engaged in agriculture and fishing. The infant mortality rate is estimated at 38.52 deaths per 1,000 live births and life expectancy at birth is 65.75 years in 2014 (Ghana Demographic Profile, 2014). The literacy rate is 71.5%. There are several ethnic groups with diverse cultures, perceptions, religious beliefs and practices that may influence their attitudes and practices towards health seeking behaviors. These include Akan (47.5%), Mole-Dagbon (16.6%), Ewe (13.9%), Ga-Dangme (7.4%), Guan (3.7%), Gurma (5.7%), Grusi(2.5%), Mande-Busanga (1.1%), and other tribes 1.6% (Ghana Demographic Profile, 2014).

Ghana, formerly known as Gold Coast before independence in 1957, is divided into 10 administrative regions and 138 administrative districts. The districts were subdivided into an average of 7 sub-districts with each sub-district comprising an area of about 20,000 to 30,000 people. The regions are namely Greater Accra, Central, Western, Volta and Eastern. The rest are Ashanti, Brong-Ahafo, Northern, Upper West and Upper East Regions.

Cape Coast is the administrative capital of Central Region, one of the 10 administrative regions of Ghana. With an estimated population of 1.6 million people, Central Region has an annual growth rate of 2.1% and a population density of 162.2 persons per square kilometer (Country Profile, 2008). The coastal zones in Ghana with about 17 towns namely Newtown, Half Assini, Esiama, Axim, Sekondi-Takoradi, Elmina, Cape Coast, Saltpond, Winneba, Accra, Teshi, Tema, Ada, Ada, Anloga, Keta and Aflao, represents only about 7% of the total land areas of the country. However, these towns are homes to about 25% of the nation's total population (Ghana Statistical Service, 2010).

The economy of most of the indigenes revolves around fishing, farming and petty trading. According to statistics from the district assembly, 78% of the population is engaged in farming and fishing (Ghana Statistical Service, 2010). The Ghana Statistical Service (2010) report indicates that schools in the coastal communities have witnessed an increase in enrolment and in the number of basic and secondary schools as a result of the free feeding programme initiated in schools. Cape Coast, in the Central Coastal district comprise three coastal communities (Ola, Bakanu, and Cape Coast) with 29 public primary school and 20 private primary school serving a population of 11, 289 children. Out of this number, 7,226 are in the public schools whiles 4,058 children are in private schools, respectively. The distribution of the primary school children across the three communities are as follows: Ola-public 1,883, private 2,363; Bakanu-public 2,947, private 373; Cape Coast-public 2,396, private 1,322 (Ghana Statistical Service, 2010).

The country's GDP-real growth rate is 6 percent and the GDP-per capita is $ 1,400. Agriculture is the backbone of the economy with gold and cocoa being the most important export commodities and major sources of foreign exchange. The labour force is 11.29 million with 56% in agriculture, 15% in industry and 29% in other services. Nearly 28.5% of the population is below the poverty line (Country Profile, 2008).

Health-Care Structure in Ghana

The Ministry of Health (MOH) has the overall responsibility for the total health services of the country. This includes policy formulation and monitoring and evaluation of progress in achieving targets. The Ghana Health Service (GHS) is the implementing agency of the ministry responsible for health service delivery. Health management in Ghana is decentralized within the GHS and involves management teams at regional and district levels, with institutional/health facility management teams complimenting this arrangement. Each region is headed by a Regional Minister (the political head in the region) under whom the Regional Director of Health Service works (Ghana Statistical Service, 2010).

Although health services in Ghana are delivered at the primary, secondary and tertiary level, it is mostly based on the primary health care system (PHC) delivered at the primary level by the District Health System, with non-governmental institutions (NGOs) and other private and developmental partners playing lead roles in some areas that are not adequately covered by the formal system. The district hospitals serve as the first referral points with other institutions (clinics, health centers and hospitals) and individuals at the peripheral level. The Regional hospitals serve at the secondary level offering specialized services to patients referred from the district hospitals and other peripheral institutions. At the tertiary level, the teaching hospitals form the apex of specialized care (Ghana Statistical Service, 2010).

Eye Care in Ghana

Until 1988, eye care provision in Ghana was largely institutional-based and run by a few institutions in big cities like Accra and Kumasi and other urban areas. Access to quality eye care was limited and only available to about 60% of the people residing in these areas who could afford the cost of care. Thus leaving the remaining 40% to self-medicate, seek care from traditional healers or other non-medical sources (Osei, Akazili & Asenah, 2014). Today however, the number of eye care centers and trained eye care practitioners has improved tremendously. For instance, only 9 centers in the country provided eye care services in 1991. However, at the end of 2000 the number of eye care centers had increased to 53 and subsequently 66 by the end of 2010 (Sulzbach, Garshon & Owusu-Banahene, 2005). Sulzbach et al. (2005) contend that eye care services in the country have seen a lot of progress. Eye care service in communities has often been delivered through collaboration and partnership with non-profit organizations, particularly in deprived communities. According to Sulbach et al. (2005) report, Sight Savers International, Christoffel Blinden Mission, Swiss Red Cross/Lions Club International and Sight First have supported the national programmes for several years at base hospitals and on outreach basis. In addition, Valco Trust, Shell Limited, Rotary Clubs Ghana and International, International Trachoma Initiative, Carter Centre, World Vision International, are other partners have supported training of eye care service providers and the establishment of Ophthalmic Nursing Training Schools. Further, Ghana was among the first countries in Africa to endorse and launch the WHO Vision 2020 "The Right to Sight" initiative in October, 2000 through the National Eye Health Programme (NEHP). The objective of the NEHP is to reduce avoidable blindness through the strengthening of capacities that ensure affordable and available eye care services to all people living in the country (Sulzbach et al., 2005). The top priorities for action to reduce childhood blindness in the context of NEHP were refractive error, cataract related amblyopia, and corneal diseases. The public health approach that evolved to control childhood blindness in the country included primary prevention to stop the disease from occurring, secondary prevention to prevent the blindness from occurring due to the disease and tertiary approach to treat the blindness caused by the disease where possible. The goal of this programme was to be achieved mainly through primary eye care which included promotion of eye health, preventing conditions which cause blindness through community actions, and identification of children by community health workers for referral to trained practitioners for treatment (Sulzbach et al., 2005). Ande-Deminique and Leon (2000) posit that strategies such as establishment of primary eye care centers, empowering local communities in early case detection, educating parents on childhood eye diseases and their prevention, training pediatric eye care teams, provision of appropriate technology and essential equipment for pediatric eye care will have long term impact on reducing avoidable blindness in children. Through these initiatives several programmes have been developed in other resource-poor countries to control blindness in children. The views expressed from the experiences gained in the existing programmes are that there should be urgency about treating childhood eye diseases as delays may lead to amblyopia. Second, assessment of children's eyes requires time and experience on the part of the examiner. Gilbert and Foster (2001) report recommended that children's eyes should not be considered as smaller versions of adult eyes, because they respond differently to treatment.

Overcoming the barrier of lack of human resource is a big challenge in reaching the goal of Vision 2020 in Ghana and some developing countries. Presently there are about 97 ophthalmologists in Ghana, some of whom are either in administrative positions or no longer in active practice. The majority of those in service delivery are in the capital cities, leaving the rural areas underserved. Ophthalmic nurses and optometrists are the main personnel who work in eye units at the district hospitals or in urban polyclinics. Eye health services are delivered by other health service providers who have been trained in Primary Eye Care (PEC). In 2004, there were about 216 ophthalmic nurses serving a population of 20,000,000 in the country with 50% of these eye specialists based in Accra (Ghana Eye Foundation, 2005-2008). As a result, the ophthalmologist to population ratio in Ghana was 1.5 per 500,000, ophthalmic nurse was 1 to 100,000 and for optometrists 1 to 250,000 (Ghana Eye Foundation, 2005-2008). Although these ratios meet WHO Vision 2020 targets for countries at that time, the irrational distribution in which many of these practitioners are located in urban areas leaves the rural communities grossly underserved. This makes eye care service delivery grossly inadequate in these areas where services are most needed.

Currently Ghana has two optometry schools, one ophthalmic nursing school and one post graduate training college in ophthalmology. Thus, the current optometrist to population ratio has improved to 1:82,000 (Boadi-Kusi, Ntodie, Mashige, Owusu-Ansah, Osei, 2014). The number of ophthalmologists in the country has also increased from 42 in 2004 to 74 in 2014, although majority of them are still based in the big cities with 50% in the Accra, the capital city of Ghana (Ministry of Health, 2014).

To improve access to quality health care services including eye care in Ghana, the National Health Insurance act was launched by the Ghana Government in 2003 (NHI Scheme-Health Care for All, 2014). The aim of the scheme is to enable every Ghanaian to have at least basic health care without paying cash at the health facility as was required by the cash and carry system prevailing at the time. The scheme has recorded increased coverage ranging from 27% in 2005, 38% in 2006 to 41% in 2014 (NHI Scheme-Health Care for All, 2014). However, the scheme is only limited to certain conditions because of cost implications. Optical aids (spectacles), hearing aids, beautification aids and others are not covered currently because they are expensive. About 40% of Ghanaians assess medical care using the national health insurance scheme (NHIS) which covers only refraction, visual field test, cataract surgery, eyelid surgery, A-Scan and Keratometry in eye care (National Health Insurance Authority, 2014).

Gilbert and Foster (2001) contend that prevention of avoidable visual impairment will lead to substantial long-term savings in public health care and social expenditures, in proportion to the number of individuals who no longer need medical or social assistance. They (Gilbert & Foster, 2001) asserted that savings also occur from the significantly reduced commitment made by family members caring for a visually impaired person. These authors further opined that control of childhood visual impairment and blindness conditions together with significant refractive errors and provision of services for correction of visual impairment is a priority for all institutions including private, government and NGOs. It leads to substantial gains in human development.

Magnitude of Visual Impairment in Ghana

Ghana like many other countries in sub-Saharan Africa differs from the high income countries in many dimensions such as socio- economic and under-5 mortality rate. Reports indicate that there is a noticeable inadequacy in eye care services in Ghana compared to countries like Nigeria in the same sub-Region (Lewallen & Courtright, 2001). Although Ghana has been successful in achieving satisfactory indices in basic indicators of health, its impressive health statistics does not seem to extend to eye health services. For example, infant mortality declined over the past 15 years, falling from 64 per 1,000 live births in 2000 to 39.7 per 1,000 live births in 2013. Again, the rate of overall life expectancy increased from an average of 58 years in 2003 to 65.32 years in 2013 (Ghana Health Service, 2004-2008). However, over 1% of individuals in Ghana are blind and of these, childhood blindness accounts for 5% to 10% (WHO, 2009). This rate has not shown any significant change in recent years even though over 75% of the cases are avoidable (WHO, 2009). There is no national population based blindness survey that has been conducted till date except for small population based surveys carried out in the Volta, Northern and Upper West regions. The figures usually stated for causes of blindness in Ghana are still estimates using prevalence of blindness of 1% as earlier mentioned. For a population growth rate of 1.927%, Ghana's population is estimated to be about 26,000,000 in 2016, meaning 260,000 are estimated to be blind from all causes with cataract responsible for 45-50%, glaucoma 15-20%, trachoma 5%, onchocerciasis 5%, childhood blindness 5-10%, refractive errors and low vision 5%, and others 10-15%.

Generally, there are few blindness surveys on the African continent. The few available studies were either focused on adults or carried out in schools for the blind. It wasn't until 1950's when small surveys were organized to address the paucity of data in Ghana, Nigeria, Sierra Leone and Central and East Africa. Due to lack of population based survey it was impracticable to compile a comprehensive list on blindness in the early 20th century (Pascolini & Mariotti, 2012). A systematic review of the studies carried out over the past 20 years in Ghana showed a prevalence of blindness of 1% in 2001. Of these, refractive error was a significant cause of visual impairment {which was defined as visual acuity of less than 6/18 but better than 3/60} (Susan & Courtright, 2001). The review further showed a trend of increase in rates of visual impairment and blindness in Ghana. For example, the prevalence of blindness reported in the Brong-Ahafo Region of Ghana in the early 1991s was 1.7% (Moll, 1994). A later study in the Volta Region indicated a prevalence of 4.4% (Guzek, Anyomi, Fiadoyor & Nyonator, 2005). In addition, cataract (0.5%) is documented as the leading cause of avoidable blindness in Ghana, while glaucoma, refractive errors and childhood blindness accounted for 0.15%, 0.05% and 0.04% respectively (Ghana Eye Foundation, 2005-2008).

The pattern of causes and prevalence rates of childhood blindness and visual impairment in Ghana is similar to that in children in schools for the blind in other developing countries. However, data from these studies represent the causes over so many years back and probably may not reflect the current situation. Although a national blindness and visual impairment study has not been conducted in Ghana, analysis of epidemiological data on the pattern of blindness in population groups which included only children suggest that uncorrected refractive error is the most important cause of visual impairment and blindness among children, followed by congenital cataract and glaucoma (WHO, 2000). For instance, Ntim-Amponsah (2007) assessed the contribution of refractive error to visual impairment among 1,069 visually impaired children aged 6 to 15 years attending the Korle-Bu Teaching Hospital, Ghana. He reported that refractive error was the cause in 44.3% of the children with visual impairment, followed by cataract (23.15%), glaucoma (7.95%) and corneal lesion (4.26%). Amponsa-Acchiano, Lartey, Nti-Boateng and Tetteh, (2006) undertook a hospital based study to determine the prevalence of visual impairment among 780 eye clinic attendees in the Ejura-Sekyedumasi District, Ghana. Out of the 780 patients examined, 16.2% were found to be visually impaired.

In a recent survey of 2,435 children attending private schools in the Ashanti Region, out of 89 children who were found to be visually impaired, 79 were due to uncorrected refractive error and 4 were due to amblyopia (Kumah et al., 2013). The prevalence of visual impairment in the population was 3.66%. This trend was confirmed by another recent study among 1,029 children in Cape Coast which found a prevalence of visual impairment of 4.6% with refractive error as the major cause accounting for 78.7% of the visually impaired children (Abu, Yeboah, Ocansey & Abokyi, 2015). Other causes were amblyopia 8.5%, retinal disorders (8.5%) and corneal disorders [4.3%]. According to the Ghana Eye Foundation (GEF) 2008 report, principal causes of childhood blindness in Ghana in the past include nutritional deficiencies especially vitamin A, measles, infections of the cornea and the use of harmful traditional medicines and injuries. The current high and improved measles immunization coverage rates have led to a reduction in corneal scaring in Ghana (Ghana Eye Foundation, 2005-2008).

Informed by the priority areas of Vision 2020, the Ghana Eye Foundation is particularly targeting the elimination of uncorrected refractive errors in school-aged children before the year 2020. Against this backdrop, campaign and advocacy for the development of refractive error services to reach all those who need it is being strengthened (Ghana Eye Foundation, 2005-2008).

Magnitude of Visual Impairment Due to Uncorrected Refractive Error in Ghana

The few available population-based studies involving children in Ghana which gave brief account of participants with visual impairment caused by uncorrected refractive error were those by Moll (1994), Guzek et al.

(2005), Ilechie and Papa (2010), Ovensiri-Ogbomo and Omuemu (2010). Others are Kumah et al. (2013), Afari (2014), Abu et al. (2015), Abokyi and Ilechie et al. (2015). Moll (1994) studied the prevalence of major blinding disorders in 1,425 adults in the Wenchi district in the Brong Ahafo Region, Ghana in 1991. A prevalence of blindness of 1.7% was revealed, with 4.2% of this attributable to refractive errors. The researcher (Moll, 1994) found cataract to be the largest single cause of blindness affecting 62.5% people. Guzek et al. (2001) surveyed three districts of the Volta Region of Ghana to determine the prevalence of blindness and glaucoma. Out of the 2,400 adults examined, the prevalence of refractive errors/uncorrected aphakia was 16.7%. Ilechie and Papa (2010) undertook a survey of the Wa and Akropong Schools for the blind in Ghana. The aim was to identify the major causes of childhood severe visual impairment and blindness. The study revealed that 8 (3.9%) of the 206 children examined had visual loss associated with refractive error. The three major causes of blindness accounting for about 50% of blindness were found to be cornea scar 40 (19.4%) followed by cataract (17.4%) and glaucoma 17 [8.3%]. Ovensiri-Ogbomo and Omuemu (2010) also undertook a study to determine the prevalence and distribution of refractive error among school children aged between 5 and 9 years in the Cape Coast Municipality of Central Region of Ghana. Out of the 957 school children examined, 25.6% had refractive errors. The major types were myopia 135 (14.1%) followed by astigmatism 135 (14.1%) and hyperopia 66 (6.9%). The prevalence of low vision and blindness in that study was 0.9% and 0.1%, respectively (Ovenseri-Ogbomo & Omuemu, 2010). They concluded that uncorrected refractive error was the major cause of visual impairment among the school children examined. Abu et al. (2013) undertook a cross-sectional study into the epidemiology of ocular disorders and visual impairment among junior high school children in the Cape Coast Metropolis, Ghana, and reported a prevalence of visual impairment of 4.6%, with refractive error accounting for 78.7% of the cases. Kumah et al. (2013) studied 2,435 older children aged between 12 and 15 years in the Ashanti Region and found that refractive error accounted for 71.7% of the cases of visual impairment. The prevalence of visual impairment in that study was 3.6% (Kumah et al., 2013). In an unpublished study in the Ashanti region, Afari (2014) conducted a rapid assessment of visual impairment in 24 communities. Out of the 1,420 participants aged 18 years and older, the prevalence of visual impairment was found to be 16.5%. Refractive error was the leading cause of visual impairment in 41.7% of the participants. Similarly, a recent study was conducted to determine the prevalence of visual impairment attributable to refractive errors among 3,437 youths in a tertiary institution in Cape Coast. Abokyi and his team of researchers reported a prevalence of refractive error of 96.2% among the 106 participants with visual impairment (Abokyi et al., 2016). So, the evidence presented here suggests that refractive error is a significant cause of visual impairment in Ghana.

Reasons for Non-correction of Refractive Errors

The correction of refractive errors with appropriate spectacles is among the most cost-effective interventions in eye health care. Thylefor (1987) posits that various factors are responsible for refractive errors remaining uncorrected in most resource poor countries such as Ghana. These factors include lack of awareness and recognition of the problem at personal and family level, as well as at community and public health level, non-availability of and/or inability to afford refractive services for testing, insufficient provision of affordable corrective lenses, and cultural disincentives to compliance (Thylefor, 1987). In children, according to Resnikoff et al. (2008), the most important reasons for non-correction of refractive errors are lack of screening, and the availability and affordability of refractive corrections, although cultural disincentives also play a role as indicated in surveys from countries where provision of spectacle corrections are free of charge or easily accessible, and yet compliance was found to be low (Congdon et al., 2006). However, slow rates of spectacle utilization have been documented in developing countries (Sharme, Cogdon, Patel & Gilbert, 2010; Lil et al., 2010). This is often reasoned to be associated with cost, teasing, negative parental attitudes, lost or broken spectacles, lack of perceived need and the myth that regular wear harms the eyes (Gogate et al., 2013). In a study carried out in Swedru in Cape Coast, only 0.6% of the children examined had previously undergone eye examination indicating a great need for eye screening in schools and provision of refractive error services. (Ovenseri-Ogbomo & Omuemu, 2010).

Research suggests that the burden of refractive error in children varies by country, ethnicity, socio-economic status, amount of near work, age and gender (Resnikoff et al., 2008). Socio-economic factors such as poverty, level of parental education and the inability to access treatment have been shown to influence the prevalence of refractive errors. In a study conducted to evaluate the preventable environmental risk factors of refractive error among 1292 Egyptian school children aged 7-15 years, it was revealed that living in an area with many sources of environmental pollution, age, sex, family history of refractive error, socio-economic status, school level and amount of near work (hours/day) were significantly associated with refractive error (Saad & El-Bayouny, 2007). A similar study was conducted among school-aged children with low socio-economic status in Southern Turkey. The aim was to determine the prevalence and associated factors of amblyopia and refractive errors. It was revealed that myopia was associated with older age, female gender, and higher parental education (Caca et al., 2013). Nutrient intake has also been found to be critical to the development of good vision. In a study on the relationship between obesity index and refractive power in adolescents, refractive power and BMI showed a statistically significant correlation in the ages 15 to 18 years (Lee, Ye & Shun, 2013). These findings underscore the need for eye health education and other related health promotional activities in communities.

Visual Development and Assessment of Visual Function in Children

Because of the rapid structural and functional changes taking place in infancy, the visual system at this stage is very vulnerable to insults. In effect "critical periods" exists during which treatment must be initiated to have substantive effect, otherwise irreversible injuries or changes occur. At birth, eye function is limited and the visual system is relatively immature but it matures fully during the early years. Development is rapid in the infant and continues into childhood. Peripheral vision is intact in the newborn. The macula, the area of keenest vision, is absent at birth but starts developing by four months and is mature by eight months. Eye movements may be poorly coordinated at birth but by three to four months of age, the infant establishes binocularity and can fixate on a single image with both eyes simultaneously (Foster & Gilbert, 1997). Most neonates (80%) are born farsighted which gradually decreases after age seven to eight years. Generally, the eyeball reaches adult size by eight years, but a child with normal eye development should attain adult levels of visual function at about five years (Day, 1997). Thus children are born with an immature visual system and, for normal visual development to occur, they need clear focused images to be transmitted to the higher visual centers. Failure of normal visual maturation (amblyopia) which usually results from insults in the visual system cannot be corrected in adult life. Therefore, there is a level of urgency about treating childhood eye disease which does not necessarily apply to adult conditions.

It is well known that assessment of visual functions in children, particularly preverbal children, is very challenging as young children easily become disinterested. However, measures of visual functions are less problematic in children five years and above although the problem of inattentiveness might also slow the test process. The visual function most frequently measured is distance visual acuity. Most visual impairment studies were conducted using the Snellen's chart or logarithm of minimum angle of resolution chart (logMAR) chart. As a result of their high sensitivity and reliability, these charts have been found ideal for assessing visual acuity in children aged four years and above (Petra, 2004). However, choice of vision test depends on the child's age, ability, milestones and behavior (Petra, 2004). Preverbal children cannot tell what they can see and preferential looking is the best method used for assessing their vision. The type of chart used in most RESC studies is the logMAR chart.

Design of Refractive Error Studies in Children

All population based refractive error studies in children (RESC) surveys (Zhao et al., 2000; Maul et al., 2000; Naidoo et al., 2003) employ a standard methodology as harmonized by the WHO (Negrel et al., 2000). The standard methodology is described in details in the “Methods” section of this study. Further, the RESC studies have shown that factors such as SES of the family, BMI, type of school probably related to the emphasis on reading and other near vision tasks, age and sex of the child, are related to the occurrence of visual impairment. These factors need to be investigated in refractive error studies.

The WHO RESC document indicates that surveys utilizing house to house enumeration of children are not necessary in areas where essentially all children attend school (Negrel et al., 2000). According to the document school-based sampling will provide data essentially equivalent to that obtained with geography based sampling in areas of high attendance. The authors (Negrel et al., 2000) advised therefore that school attendance data within the study area should be reviewed to support this claim.

Considering the association with SES, the harmonized methodology by WHO suggested that the study population should emphasize the inclusion of middle to high SES level schools, and for representativeness, the document suggests that children from low, middle and high income areas should be included because of differences in the prevalence of myopia between these area. The WHO recommends that low SES children should be recruited from public schools and middle/high SES children from private schools (Negrel et al., 2000).

A number of methods have been recommended for survey of near work in school children including objective and subjective methods (Mutti & Zadnik, 2009; Ip et al., 2008; Leung et al., 2011; Saw et al., 2001). The objective form of assessment of near work where research assistants monitor the child to document the number of hours spent doing near work during and outside school hours is useful for small population based studies. This form of assessment eliminates recall bias compared to the use of questionnaire surveys. On the other hand, the subjective form of assessment using questionnaire data is subject to recall bias but very feasible in large population studies. The subjective form of assessment with questionnaire survey has been used in previous studies and is widely acceptable (Ip et al., 2008; Leung et al., 2011; Mutti & Zadnik, 2009; Saw et al., 2001).

Visual Acuity Cut-off Points

According to Resnikoff et al. (2008), the definition of visual impairment in the previous surveys was based on best-corrected vision. That is visual acuity obtained with the best possible refractive correction if any, thus, excluding uncorrected refractive error as a cause of visual impairment. With best corrected visual acuity, visual impairment was substantially reduced, ranging from 0.09% in the China study to 0.28% in India whereas with presenting vision, the prevalence of visual impairment increased from 0.42% in China to 1.79% in the India. Based on presenting visual acuity, uncorrected refractive error was the cause of visual impairment (<6/12 in the better eye) in 1.4% of children in South Africa (Naidoo et al., 2003), 22.3% in Southern China (Zhao et al., 2000) and 4.82% in Sao Paulo, Brazil (Salomoa et al., 2008). With presenting visual acuity uncorrected visual acuity < 6/18 in the better eye ranged from 0.46% to 3.25%. Thus, very little attention was paid to the extent of visual impairment caused by uncorrected refractive error using best corrected vision. Resnikoff et al. (2008) are in agreement that the recognition of uncorrected refractive error as an important cause of visual impairment emphasized the burden of refractive error worldwide to be substantially higher.

Another important observation in literature was the disparity in visual acuity cut-off points for defining visual impairment. This disparity is compounded by the fact that the WHO RESC document did not make a clear distinction between mild and normal visual impairment categories (Negrel et al., 2000). This created a leeway for researchers to choose different operational limits for classifying mild and normal visual impairment. Some aut hors particularly from Africa, defined visual impairment as visual acuity of 6/12 and worse in the better eye (Naidoo et al., 2013, Kumah et al., 2013, & Abdull et al., 2009) while others, especially in North America, used VA worse than 6/12 in the better eye (Nangia et al., 2013; Chou et al., 2013; Robinson et al., 2013).

Appraisal of Literature Review

The results of studies adopting the RESC protocol reveal substantial geographical and socioeconomic differences in magnitude of uncorrected refractive error. There are indications that the burden of uncorrected refractive error is greater among children in low income settings. However, there is a general lack of information on the determinants of uncorrected refractive errors among children aged between 5 and 15 years. The previous studies on refractive errors in Ghana did not fully investigate the determinants of uncorrected refractive error as a cause of visual impairment. Second, socio-economic status was not considered in identifying school children that are broadly representative of the study area. For instance, the study by Kumah et al. (2013) was carried out in private schools, where supposedly myopia will be highly prevalent because of intense educational activities, whilst the study by Ovensiri et al. (2010) was carried out on children attending public schools, where supposedly myopia will not be as prevalent because of less intense educational activities. Again, the Kumah et al. (2013) study was carried out on older school children aged between 12 and 15 years in an urban area of the Ashanti region. Such a data may not be extrapolated to other regions with contrasting ethnic and socio-cultural specificities as the prevalence and associated factors of visual impairment caused by uncorrected refractive errors in children have been shown in literature to vary between cities within the same country.

The current study was carried out to determine the prevalence and determinants of visual impairment attributable to uncorrected refractive errors among school going children in coastal communities of Cape Coast, Central Region of Ghana, using the RESC protocol. A secondary aim was to provide corrective services free of charge to the affected children. Such intervention is useful for designing good prevention and control programs in public health.

Summary

The literature review touched on magnitude and associated factors of uncorrected refractive error across the globe, and the experience in Africa as well as Ghana. The review indicates that 285 million people are visually impaired worldwide and 39 million of these are blind. Majority of blind children live in the developing world of Africa and Asia. The principal causes of visual impairment were uncorrected refractive errors (43% or 120 million people) and cataract (33%). The principal cause of childhood blindness is cataract, whereas the principal cause of visual impairment in children is uncorrected refractive error. The review further showed that prevalence of childhood blindness and visual impairment vary from region to region with the West Pacific and South East Asian Region recording the highest prevalence of visual impairment, and the East Mediterranean and African Regions having the highest prevalence of blindness. The lowest rates of visual impairment and blindness are recorded in high income regions of America and Europe.

The causes of childhood blindness differ by income level of countries. In high-income countries, glaucoma, hereditary retinal dystrophies and lesions of the optic nerve were found to be the most frequent eye disorders. In the low-income countries, corneal scarring from measles, vitamin A deficiency and use of harmful traditional eye remedies were the most common.

The pattern of causes of visual impairment in children also changes with time. In Africa, there is a recent shift from congenital cataract to uncorrected refractive error although cataract still remains a significant cause of visual impairment worldwide. There is evidence that uncorrected refractive error affects a large proportion of the Ghanaian population, irrespective of age, sex and ethnic group. Monitoring its trends is essential for developing strategies aimed at elimination of avoidable blindness.

There is limited information on the causes of childhood blindness in SSA because very few nationally representative studies on blindness and visual impairment have been carried out. The few available surveys in literature in the developing world appear to be overestimated (almost 40 to 95%) because they were obtained from examining children in schools for the blind. At present many developing countries do not have sufficient data on the magnitude and causes of childhood blindness and visual impairment. In this case the scope and priorities for elimination of blindness becomes impossible to be identified. As optometrists are an integral part of health care, it is their prime responsibility to carry out various school health programmes, especially eye screening programmes. The aim would be to identify children who are visually impaired from refractive errors and prevent further disabilities.

CHAPTER THREE

RESEARCH METHODS

The purpose of this study was to determine the prevalence and determinants of visual impairment attributable to uncorrected refractive error in children aged between 5 and 15 years attending primary schools in the coastal areas of Cape Coast, Central Region of Ghana. This chapter explains how the study was conducted. The study design chosen, population and data collection instruments were discussed. Sampling methods and the various clinical procedures and protocols also employed to examine patients, data collection procedures and analyses explained.

Research Design

The study adopted a descriptive cross-sectional, school-based survey design to describe the prevalence, distribution, and determinants of visual impairment due to uncorrected refractive errors in children attending primary schools in the coastal areas of Cape Coast, Ghana. This type of design was suitable for the nature of the research problem being investigated. This is because it allowed for collection of data on the study population at a single point in time to examine the relationship between having uncorrected refractive error and the variables of interest. Abramson and Abramson (2000) described cross-sectional studies as "snapshot" studies because they provide a snapshot of the frequencies and associated factors of a disease in a population at a given point in time and are therefore particularly useful in informing the planning and allocation of health resources.

A major limitation of cross-sectional studies is that it is difficult to determine cause-effect relationships. Also, non-response and selection-bias is a particular problem affecting cross-sectional studies. This can result in bias of the measure of outcome thus limiting generalizations from the findings. This is a particular problem when the characteristics of non-respondents differ from respondents (Kesley, Whittemore, Evans & Thompson, 1996). To circumvent these problems the study was conducted in a setting where school enrolment was high. Furthermore, a cluster sampling procedure was employed to ensure that the sample was representative of the study population, and that generalizations of the findings will have validity. Also, the sample size used for the study was statistically determined using the appropriate standard formula, with design effect for cluster sampling factored in. This ensured that the sample was sufficiently large enough to estimate the prevalence and associated factors of uncorrected refractive with adequate precision. In addition, specific inclusion and exclusion criteria were established at the design stage. This ensured that children with uncorrected refractive error were correctly identified. Finally, the data collection methods included questionnaires and interviews, as well as medical examinations. The standard RESC protocol and data collection instruments were used to collect data. These procedures ensured that the variables of interest were correctly identified to answer the research questions. The study focused on primary school children between the ages of 5 and 15 years. The reason for using this age range was to be able to compare the data with results of school-based RESC studies from other countries, particularly African countries.

Study Area

The study was conducted in primary schools located along the coastal shores of Cape Coast, in the Central Region of Ghana. The Central Region of Ghana has an estimated population of 2,201,863 in the 2010 census (Ghana Statistical Service, 2010). It is the second most densely populated region after Greater Accra. It occupies an area of 9,826 square kilometers which is about 6.6% of the land area of Ghana. However, about 63% of the region is rural hence the region is classified as the poorest in Ghana (Ghana Statistical Service, 2010). The Central Region has an adult literacy rate of 51.9%.

Cape Coast has a population of 169,894 consisting of 48.7% (82,810) males and 51.3% (87084) females. Twenty three percent (39,546) of the people are in rural locations. Cape Coast is famous for its ancient slave-trading and castles, beautiful coconut palm shaded beaches and many fishing villages. Indigenous residents are mainly of Fante ethnicity and the economy of the vast majority (78%) of the indigenes revolves around fishing, farming and petty trading (Ghana Demographics Profile, 2013). However, it is one of the most historical cities in Ghana. The Cape

Coast Castle is one of the biggest of the trade and slave castles on the coastline of Ghana. Most of the oldest and best schools in Ghana are in

Cape Coast. This makes the city a hub of tourism and education in south Ghana. It was the center of British Administration and capital of the Gold Coast by 1700 until 1877 when the capital was moved to Accra (Ghana Statistical Service, 2002). Health indicators such as under-five mortality rate of 5.19 in every 1,000 people, is the lowest in the Central Region. Regarding marital status in relation to education level, one out of every six married persons had never had any form of formal education; thus the literacy rate is low among the married persons. The phenomenon of working children is also a problem in the Cape Coast district. About 5% of children under age 15 years are engaged in economic activities and 27% is in primary schools (Ghana Demographic Profile, 2013). The coastal areas of Cape Coast was purposively chosen for the study because the contrasting socio-economic status that was presented by children in public and private schools presents unique demographics for studying refractive errors and associated factors; the public schools in the area comprise of children attending schools from all types of low-income settlements including small fishing communities that make up the coastline, whereas the private schools are densely populated by children from high SES families.

In the Coastline of Cape Coast, as in other low-income settings, school health services are scanty and refractive eye services are poor. Previous data showed that uncorrected refractive error is the major cause of visual impairment among children in Cape Coast (Abu et al., 2015, Ovenseri-Ogbomo & Omuemu, 2010). The distribution of eye care facilities in the region does not favour people living along the coast. Basic refractive eye services are available only in high-priced optical shops including an eye center supported by the Anglican diocese, which has resulted in most of the population finding refractive services unaffordable.

As a consequence many poor people settle for traditional medicine in the form of herbs and leaf extracts, salt solutions, and breast milks, which are at best ineffective in the correction of refractive errors (Ghana Demographic Profile, 2013). The map showing the study area is presented in Figure 2.

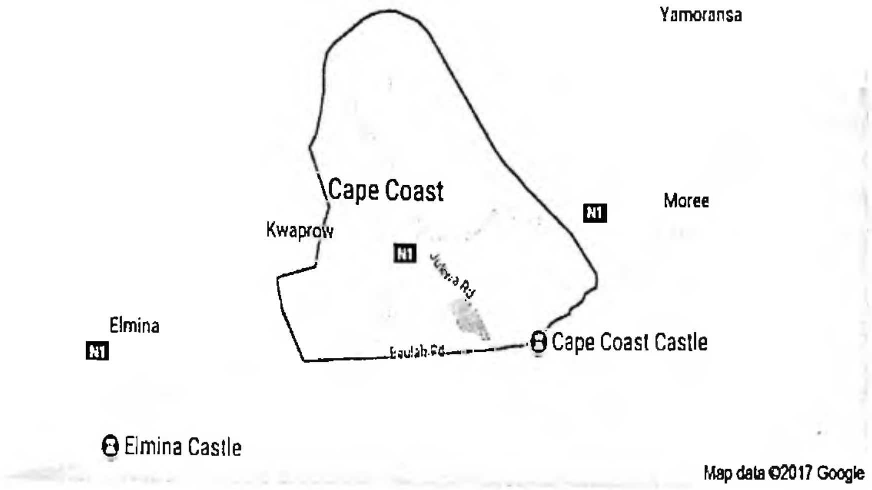

Figure 2: Map of Cape Coast Showing the Study Area

Population

The target population comprised all school children (11,284) aged between 5 to 15 years attending public and private primary schools within the coastal communities. This include 7,226 (64%) in public primary schools and 4,058 (36%) in private primary schools (Ghana Statistical Service, 2010). Primary school attendance in Cape Coast has increased from 9,249 in the past to 21,178 currently, since the introduction of the school feeding program by the government in 2005. In Ghana, children officially attend primary school at age 6 to 12 years, then junior high school at age 13 to 15 years, and senior high school at age 16 to 18 years, before entering tertiary institutions. The 5-15 years age range for children used in this study was to allow for direct comparison with other RESC studies and in fact this age group is consistent with the onset of refractive error; myopia typically begins at six to eight years of age and progresses through 15 to 16 years of age according to previous studies (Goss, 1988; Tan et al., 2000).

The population pyramid however indicates that the study area is largely characterized by a large proportion of children attending primary schools outside the official age range due to late entry and grade repetition. Only about 21% of primary school pupils are in the appropriate grade for their age. Over 70% of the male pupils and 67% of the female pupils are over - age (Ghana Statistical Service, 2010).

Three thousand four hundred and twenty primary school children aged between 5 and 15 years from 19 primary schools located around the coastal areas of Cape Coast were enumerated and eligible to participate in the study. Of the 3,420 eligible children, 3,088 children were available for complete examination, representing a response rate of 90.3%. This response rate was unexpected, considering that the survey was conducted in an area where a large majority would opt out on explanation of the side effects of cycloplegia. The informational session organized for parents of enumerated classes and the cooperation of the teachers and school authorities might have helped in alleviating hesitancy in participation caused by concern about side effects of cycloplegia. The increase in school attendance rates since the school feeding program wherein free food is provided to children at school, and the right to free and compulsory education act came into force, also contributed to the high participation rate. Majority of the participants were from Ola Presby Basic (11.7%, n=362), Sammo Primary School (11.4%, n=350) and Pere Planque Primary School (11.3%, n=350). The total number of participants in the respective schools is shown in Figure 3. Three hundred and thirty two (9.7%) were absent or not willing to participate. The main reasons for non-participation in the study were absenteeism and lack of parental consent. Most of the children who did not participate could not come to school because they were sick. Owing to the high response rate recorded in this study, the sample likely represents the target population, thus the biases introduced because of school-based rather than population-based sampling are likely to be insignificant. Non-participation was more among female children (9.2% vs. 10.4%); younger children (5-9 years old, 10.3% vs. 9%) and children attending private schools (13.6% vs. 7.6%). Non-participants were similar to participants in age, gender and type of schooling (Wilcoxon signed-rank test $p > .05$). The primary analyses for this study were based on data from the 3,088 participants.

The sample included for analysis had a higher proportion of females 1,744 (56.5%) compared to males 1,344 (43.5%). However, the female to male ratio reflects the gender distribution of primary school attendance in Cape Coast of 28.4% females compared to 25.8% males and also coincides with the gender distribution of more female children than male children in the general Ghanaian population (Ghana Statistical Service, 2010). This trend is also consistent with findings in the previous RESC study in Ghana (Kumah et al., 2013). The sample consisted of more young children 1,674 (54.2%) vs. 1,414 (45.8%) and fewer private school children 1,046 (33.9%) vs. 2, 042 (66.1%). There was 92.4% coverage of the enrolled children from public schools and 86.4% coverage of enrolled children from private schools. The proportional mix of private schools, where supposedly refractive error will be highly prevalent because of intense educational activities and public schools, and public school children, where supposedly refractive error will not be as prevalent because of less intense educational activities, was an indication of the strength of this study. Table 1 shows the distribution of the participants and non-participants by age, gender and type of school.

Table 1: Distribution of Participants and Non-participants by Age, Gender and Type of School (Figures are numbers (percentages) of children)

Variables	Enumerated N (%)	Non- Participant N (%)	Participant N (%)
Age group			
5-9 years	1867 (54.6%)	193 (58.1%)	1674 (54.2%)
10-15 years	1553 (45.4%)	139 (41.9%)	1414 (45.8%)
Mean ± SD	9.08 ±1.65	9.47 ± 2.25	9.44 ± 2.17
Total	3420	332	3088
Gender			
Male	1500 (43.9%)	156 (47%)	1344 (43.5%)
Female	1920 (56.1%)	176 (53%)	1744 (56.5%)
Total	3420	332	3088
School			
Public	2210 (64.6%)	168 (50.6%)	2042 (66.1%)
Private	1210 (35.4%)	164 (49.4%)	1046 (33.9%)
Total	3420	332	3088

N=3088

The total number of participants in the respective schools is shown in Figure 3.

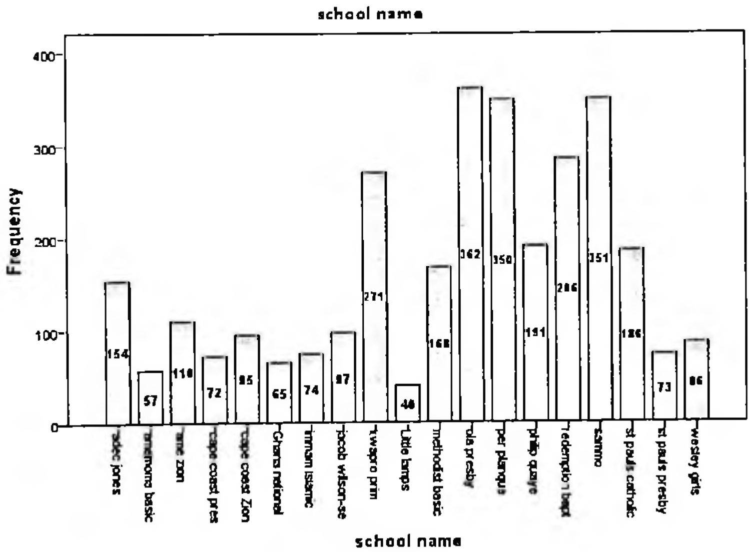

Figure 3: Total Number of Participants in Respective Schools

The least represented ages were the 5-year old (n= 13), 14-year old (n=70) and 15-year olds (n=46). There was an abundance of the 9 year olds (n=566). The older children of 13, 14 and 15 year olds were under-represented in the sample because majority of children in this age group have progressed to secondary schools as these ages coincide with secondary school age in the general population. Also, the apparent deficit

of the 5 year olds was because majority of children of this age were still in Kindergarten. Children start Kindergarten in Ghana at an average of 4 years of age and it lasts for two years (Ghana Statistical Service, 2010).

The age-specific distribution of participants is shown in Figure 4. The mean ± SD age of the participants was 9.44 ± 2.17 (95% CI 9.36 – 9.52).

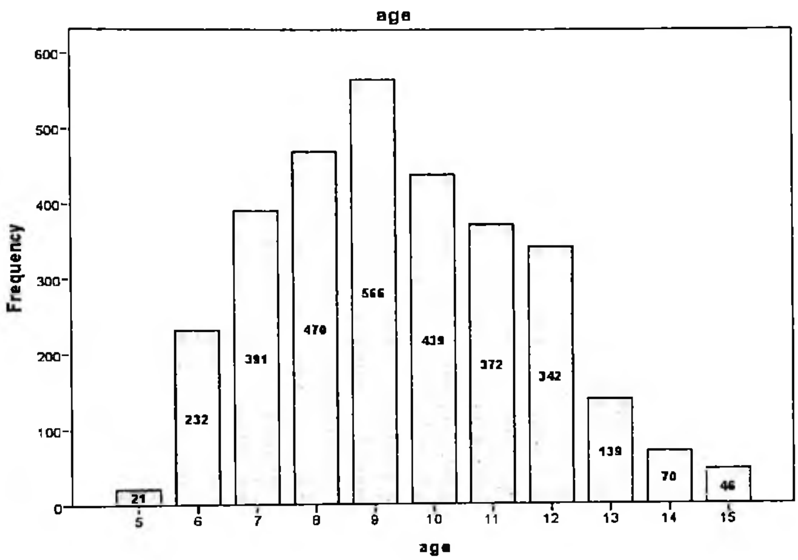

Figure 4: Age Distribution of Participants

Sampling Procedure

The sample size was estimated for a prevalence of visual impairment caused by uncorrected refractive error of 3.7%. This was based on the only RESC survey conducted in Ghana (Kumah et al, 2013). The sample size was determined using the formula (Charan & Biswas, 2013): $N = Z^2 \, p \, q / d^2$, where N is the minimum sample size, Z is the value of Z statistic at 95% confidence level =1.96, p is the estimated prevalence of 3.7% (0.037), q is 1-p = 0.963 and d is the precision level set at 3%. $N = 1.96^2 \times 0.37 \times 0.963 / 0.03^2 = 1520$. The sample was adjusted for an anticipated 20% absenteeism and non-participation rate (1,520 x 0.2 = 1,824) and a design effect of 1.5 (1,824 x 1.5= 2,736) to arrive at required minimum sample size of 2,736 children.

The study sample was obtained through a school based cluster sampling strategy with schools as the primary sampling unit. The cluster sampling technique was most suitable in this case because the population of interest is concentrated in natural clusters. It is usually used when a researcher can't get information about the population as a whole, but they can get information about the clusters. Further, this sampling technique is cheap, quick and easy. It enables the researcher to allocate his limited resources to the few randomly selected clusters. The researcher can also increase his sample size with this technique, since they are easily accessible. However, this sampling technique is least representative of a population. Also, there is the tendency of individuals within a cluster to have similar characteristics. This might lead to underrepresented or overrepresented cluster which can skew the results of the study. Furthermore, there is also a possibility of high sampling error. This is brought about by the limited clusters included in the sampling leaving out a significant proportion of the population un-sampled (Ahmed, 2009). For RESC studies however, Negrel et al. (2000) proposed obtaining population-based cross-sectional samples of children aged between 5 and 15 years through cluster sampling.

Upon review of geographical boundaries of the study area, as well as data from the Ghana Education Service, it was recognized that there are three designated educational circuits with a total of 49 primary schools, 29 public and 20 private primary schools [n= 11,284 children] (Ghana Statistical Service, 2010). The list of schools in each circuit constituted the sampling frame. There were a minimum of 12 schools in each circuit. After the listing was concluded, each circuit was considered a cluster from which a minimum of 6 schools (stratified into public and private schools) were selected at random from all the public and private schools identified within the circuit. A total of 19 primary schools, 10 public and 9 private (n= 6,050 children) were randomly selected. The total number of children enrolled in the 19 selected schools was 6050 children. All pupils of the selected schools within a cluster, aged between 5 and 15 years were enumerated to participate in the study. An eye screening was conducted on all enumerated children who were present at each selected school to identify those who met the eligibility criteria for enrolment into the study (uncorrected visual acuity ≤ 6/12 in at least one eye).

Inclusion criteria

Male and female children aged 5 to 15 years, attending one of the selected schools in the study area and provided parental consent were the criteria for inclusion into the study. Each child's age was confirmed by the school authorities by consulting school records. Because they were minors, their assent was not sought thus the parents and teachers acted as locus parentis. All children at the 19 selected schools who satisfied the inclusion criteria were eligible for inclusion in the main study. Only participants found to have defective vision underwent cycloplegic refraction.

Data Collection Instruments

To achieve the specific objectives of the study, the instruments used for collecting data are described as follows:

RESC eye examination form (Appendix A): The RESC survey instrument was developed by the WHO in collaboration with the National Eye Institutes of Health, Bethesda, United States of America, to provide a standard protocol for studying refractive errors and its related visual impairment in school children. The RESC eye examination form has been utilized in refractive error studies in children in Nepal (Pokharel et al., 2000), China (Zhao et al., 2000), Chile (Maul et al., 2000), Indian (Dandona et al., 2002), South Africa (Naidoo et al., 2003) and Ghana (Kumah et al., 2013). The protocol serves as a harmonized survey methodology that provides valid, core information for comparison across studies (Negrel et al., 2000). It was used in this study because it has direct relevance to the study area.

Questionnaire (Appendix B): A structured questionnaire was used to obtain information on near-work activities of each child after school. It also sought information on parental refractive status. It probed the time spent on near work activities, and parental history of spectacle wear. It also asked about the occupation and educational level of parents which was used as a proxy for classifying socioeconomic status. The questionnaire items on near-work activities, as well as parental refractive status were adopted from previous studies on refractive error (Ip et al., 2008; Mutti & Zadnik, 2009; Saw et al., 2002). The Cronbach's alpha coefficient for each item was 0.75.

Tumbling "E" Snellen chart: Measurement of visual acuity was performed using the "Tumbling E Snellen's" chart (Precision Vision, La Salle, IL) at 6 meters. The Tumbling E eye chart is a chart made of different orientations of E. It was used for testing the visual acuity of the children because majority of them do not know letters of the alphabet used in letter charts. It can also be used to test the distance acuity of children or adults who cannot communicate verbally due to physical or mental disability.

Pinhole occluder: This is an opaque disk with one small hole at the center, used to test visual acuity. It was used to distinguish visual defects caused by refractive error. Visual defects caused by refractive error can be easily detected with a pinhole occluder. It improves when a pinhole occluder is used to test visual acuity in defects caused by refractive error. Other conditions due to pathology in the eye do not improve with a pinhole occluder

Hand held slit lamp biomicroscope (BX 900, Haag-Streit USA): The hand-held slit-lamp biomicroscope was used for examination of the anterior segment of the eye including the eyelids, conjunctiva, cornea, anterior chamber, iris, pupil, lens and anterior vitreous. The slit lamp is an instrument consisting of a high-intensity light source that can be focused to shine a thin sheet of light in the form of a slit, into the eye. The slit lamp facilitates an examination of the anterior segment of the human eye. This technique is the gold standard for detailed examination of the anterior segment of the eye.

Direct and indirect ophthalmoscope (Keeler, Halma UK): The ophthalmoscopes were used for comprehensive examination of the interior eye including the posterior vitreous and the retina. The direct ophthalmoscope is about the size of a small flashlight (torch) with several lenses that can magnify up to about 15 times. The device consists of a concave mirror and a battery-powered light contained within the handle. The operator looks through a single monocular eye piece into the patient's eye to view the fundus. An indirect ophthalmoscope, on the other hand, constitutes a light attached to a headband, in addition to a small handheld lens. It provides a wider view of the eye including the periphery of the retina. These instruments are the gold standard techniques for examining the posterior segments of the eye.

A streak retinoscope (Keeler, Halma UK): The streak retinoscope was used for objective refraction in order to determine the refractive error of the child's eye. This device is also about the size of a small flashlight. It projects an oblong streak of light into the patient's eye which can be adjusted in width and rotated in various meridians to determine and measure refractive error. This technique is the gold standard technique for objective determination of refractive error.

Hand-held Occluder: The hand-held occluder was used for the cover-test procedure: This is an opaque translucent disk made of plastic material, held before the eye as a cover to obscure vision. It has a handle about 197mm long which the examiner holds to cover the eye.

Pen-torch: An energized pen torch was used for pen-light examination of the ocular adnexa. The pen-torch is a small flash light having the size and shape of a fountain pen. It is the standard technique for gross examination of the ocular adnexa.

1% Cyclopentolate eye drop (Cyclogyl, FDC Limited): Cylopentolate 1% was used as the cycloplegic drug for paralyzing the eye's accommodative facilities prior to refraction. This medication belongs to a class of drugs known as anticholinergic. Anticholinergic drugs work by temporarily widening (dilating) the pupil of the eye and relaxing the muscles of the eye. This process is referred to as cycloplegic refraction. 1% Cyclopentolate eye drop is the standard eye drop used for cycloplegic refraction in children.

Wall-mounted measuring scales: The wall-mounted measuring scale was used for measuring the height of children. It has a measuring range of 3.5 – 230 cm. The wall plate is mounted on the wall. The rod itself is compact at only 1.5 meters tall. This ensures stability. The scale is printed on a separate strip which slides into the rod. This device has long been the choice for accurate height measurement.

The Digital Bathroom Scale: The Arlyn EatSmart Precision Digital Bathroom Scale is a type of electronic weighing machine, which is used for measurement of muscle mass. It was used for measuring the weight of the children and is a standard scale for measuring weight of children.

Reliability and validity of instruments

A pilot study was conducted in a separate school in Elmina which was not part of the study area. The aim was to pretest all the instruments used in the study. The pilot exercise was conducted on a sample of 50 primary school children drawn from five schools in a nearby fishing community. The ages of the children fit the inclusion criteria for the main study.

To test reliability of the questionnaire, the questionnaire was administered to the children on two separate occasions (a test-retest interval of 2 weeks) to establish whether or not they would give similar answers. The overall intra-class correlation was 0.75 with a Cronbach's alpha coefficient for each item of 0.70.

To test the reliability of the digital bathroom scale used in measuring weight, the bathroom scale was first zero scaled when no weight was on it.

Then the weighing scale was used to measure weight of the children on two different occasions separated by an interval of 2 weeks. The reliability coefficient was found to be 0.92. This result was similar to that ($r = 0.91$) obtained by Teslim, Olainka, Michael, Adesoji and Oluwole, (2013) among Nigerian children.

To assess the accuracy of visual acuity, retinoscopy and subjective refraction measurements, 50 children with uncorrected visual acuity and 50 children with normal vision were subjected to quality assurance by independent re-evaluation. The procedure for evaluating accuracy of instruments was modeled on previous research (Kumah et al., 2013; Naidoo et al., 2003). Results showed that only 5 children differed in visual acuity by one line in the right eyes. The left eyes visual acuity showed that 4 children differed by one line, and three differed by two lines. Over 95% of the children had line-by-line agreement in visual acuity in both eyes. To assess reliability of cycloplegic retinosocopy and subjective refraction, each procedure was conducted on the children on two separate occasions by the optometrist (repeatability) and on one occasion by the two optometrists (inter-observer agreement). The inter-observer agreement for retinoscopy and subjective refraction between the two optometrists was satisfactory (kappa (k) > 0.82). To evaluate repeatability (reliability), the difference between measures on two different occasions was calculated by subtracting the second measurements from the first and then using the one sample t-test to compare the mean retest differences relative to zero. Mean ± SD test-retest differences for cycloplegic retinoscopy were -0.02 ± 0.013D in the right eyes and -0.022 ± 0.025 in the left eyes. Neither differences from zero was statistically significant (one sample t-test, p>.05), thus indicating that repeated measurements for cycloplegic retinoscopy were comparable. The 95% limits of agreement between the first and repeated retinoscopy measurements were -0.011 to + 0.02D and -0.012 ± +0.02D for right and left eyes, respectively. Similarly, repeatability for subjective refraction was comparable, with mean ± SD test-retest differences of -0.015 ± +0.14D and -0.02 ± +0.15D for right and left eyes, respectively. Also, neither of these differences was significantly different from zero (p>.05). The 95% limits of agreement for subjective refraction were -0.021 to +0.03D and -0.025 to +0.03. Weaknesses identified for each of the study components were addressed prior to implementation of the main study.

To further minimize inter-observer variations, 50 children from the main study with uncorrected visual acuity of 6/12 or worse were randomly selected from 10 schools for re-testing of visual acuity by a second experienced optometrist who was masked to the first results. The inter-rater agreement for visual acuity measurements was also good (k = 0.76).

Training and quality assurance

Prior to commencement of field-work, the study research team comprising of two optometrists, ten final year optometry students, all the class teachers of enumerated children, and one coordinator underwent a four-day rigorous training to familiarize them with the study protocol, equipment use, measurement methods, and data collection and data entry procedures. This was also necessary in order to identify weaknesses in the examination process.

Data Collection Procedures

The study took place from 6th June, 2017 to 25th July, 2017. Human subject approval for the study was obtained from the Institutional Review

Board (IRB) of the University of Cape Coast, Ghana (Appendix F). In addition, permission to conduct the study was sought from the Regional Directorates of Health and of Education, both at district and regional levels in Cape Coast. Informed written consent was also obtained from the principals/school authorities of the respective schools and from the parents. An informational session for the parents and or guardians of children in the selected classes was arranged. Parents were informed about the objectives of the study and the details regarding the eye examination of the child. The parents were encouraged to ask questions before they signed the consent form. If the child's parent is illiterate, provision was made to include the signature of a literate witness, preferably selected by the illiterate parent. Informed Consent Form (Appendix C) for the parents who could not attend the sessions was sent home with each eligible child. Participation was free and voluntary. Only children whose parents approved the consent forms were examined.

After the clinical examinations, children identified with uncorrected refractive errors were given corrective spectacles. Medical treatment for minor ophthalmic problems were also provided free of charge at the time of examination. Children requiring further diagnostic assessment or treatment were provided with an explanation and referred to the hospital/clinic nearest their home. When necessary, children were referred for further management to a tertiary eye care facility and followed-up.

Recruitment

Before the scheduled examination date, the research team comprising of three optometrists and twelve level 600 optometry students, individually visited the schools selected for the screening, according to a predetermined schedule. The aim of the visit was to explain the purpose of the study to the school administration. During the visit, data on the school population and class sizes were obtained, and a date was scheduled for enumeration of the study participants.

Enumeration procedures

Each school was re-visited by the research team to identify by name, age, and gender all children aged 5 to 15 years. Parents/guardian's name and contact information was also collected for each enumerated child. Inform consent forms were given to the child to take to their parents or guardians for approval. After the enumeration process, a convenient examination date was scheduled at each school by the school authorities and the research team. Teachers of enumerated children were given copies of the RESC Eye Examination Form to fill in the child's identification section (child name, school #, grade #, class #, age, and gender) before the scheduled examination date.

Ophthalmic examination procedure

Enumerated children were examined in their respective classes according to the predetermined schedule. A single survey team conducted the eye examinations in each school. The ophthalmic examination was carried out in the following sequence:

Child identification: The research assistants retrieved the appropriate RESC Eye Examination Form to verify the name, age and gender of the child.

Vision assessment: Distance visual acuity was measured at 6m using Tumbling "E" Snellen chart securely fixed on the wall. Prior to distance acuity testing, the classroom was controlled for required distance between the child and the chart (6m), appropriate light conditions and no light reflection from the chart. The lowest line read successfully with one or no errors was assigned as the visual acuity for the eye undergoing the testing. The right eye was tested first, and then the left eye, each time occluding the other eye. Care was taken to ensure that the occluded eye was not pressed. Also, the tested eye was observed to prevent squeezing/squinting (pinhole effect) while reading the optotypes. Acuity was measured unaided (uncorrected visual acuity), and then with child's spectacles if the child wears them (presenting visual acuity). If the presenting visual acuity is less than 6/12 in either eye, a pinhole vision was also measured. This was done to ascertain whether the reduced vision was caused by refractive error or pathological conditions (Kanski, 2003). Viewing the acuity chart through a pinhole increases the child's depth of focus and decreases the retinal blur. Thus, the retina and visual pathway will be free of abnormalities and the visual acuity of the child will improve.

If uncorrected vision was worse than or equal to 6/12 in either eye, the child was diagnosed to have defective vision. Children with visual acuity of 6/6 in both eyes and with subjective refraction results that confirmed the absence of a refractive error were excluded from further procedures. All the participants diagnosed with defective vision underwent the following examinations in the indicated order:

Binocular motor function: The Hischberg test was used to determine the presence of strabismus. A cover-uncover test was then performed at 0.5 and 4 meters to confirm the diagnosis. Heterotropias, if any, were categorized as exotropia, esotropia and vertical tropia.

External and anterior segment examination: Eyelids, conjunctiva, cornea, iris, and pupil were examined with a magnifying loupe and torch light and any abnormalities detected were recorded.

Cycloplegic dilation: In children with unaided visual acuity 6/12 or worse in either eye, pupillary dilation and cycloplegia (in both eyes) were attained using the following: two drops of 1% cyclopentolate eye drops were administered 5 minutes apart into each eye. Twenty minutes after instillation of the eye drops, if a pupillary light reflex was still present when observed with a bright torch light without magnification, then a third drop was administered as required. After a further 15 - 20 minute interval, the light reflex and pupil dilation were checked. Cycloplegia was considered complete if the pupil dilated to 6mm or greater and a light reflex was absent (Negrel et al., 2000).

Cycloplegic refraction: In eyes with successful cycloplegia, refraction was performed with a retinoscope. Retinoscopy was carried out using a streak retinoscope in a semi-darkened room, with the examiner at a working distance of 67cm and a +1.50 diopter lens in the trial frame. The additional spherical, cylindrical power and axis necessary to neutralize the shadow movement were noted.

Best corrected visual acuity (subjective refraction): Using the retinoscope measurement as the starting point (when available), subjective refraction was carried out to determine best corrected visual acuity.

Media and fundus examination: Examination of the lens, vitreous and fundus was performed with direct/indirect ophthalmoscope in children with defective vision. After the examinations, refractive error was assigned as the cause if visual acuity improves by ≥ 2 lines with subjective refraction correction.

Children with presenting visual acuity worse than 6/12 in the better eye improving with refraction were provided with spectacles, free of charge and enrolled in the questionnaire survey. Medical treatment for minor ophthalmic problems was also provided free of charge at the time of examination. Children requiring further management were provided with an explanation and referred to the hospital/clinic nearest their home.

Questionnaire survey of near work and parental refractive error

All eligible children participated in the questionnaire survey. The questionnaire (Appendix B) was adapted from an already tested questionnaire on role of near work in myopia among Australian children (Ip et al., 2008). Participating children completed the questionnaire. It probed the amount of time each child spent on near work activity after school by asking how many hours each child spent daily (individually for every day of the week from Monday to Sunday) on each of the following activities: personal study at home, watching television (TV), playing video games and computer use, participating in extra tuition classes, and participating in outdoor activities of all kinds. The questionnaire was interviewer-administered in class by asking in Ghanaian language translations the details from the child, and by telephone or in-home interview of the parents. During the telephone or in-home interview of the parents, the teachers explained the questionnaire to the parents who then helped to confirm the child's answers or choose the appropriate answers.

***Assessment of child's academic* performance:** Teacher-assessed academic performance of child was categorized as "Poor", "Average" and "Good".

Children percentile scores for the local promotion examination in all subjects were averaged and used as the outcome measure for school academic performance. The academic performance of each child was graded qualitatively as poor (< 40 marks, average 40-60 marks, or good > 60 marks).

Assessment of parental refractive status: Questions on family history include questions on family refractive status. This was assessed with the history of spectacle usage among family members (whether parents or siblings had refractive error or not), and occupation of parents (which was used as a proxy for classifying socioeconomic status into low, middle, high). Parents underwent an interview, which obtained information on their socio-demographic data including level of education and occupation. To determine parent's refractive status, the questions were phrased as follows: Do child's parents wear glasses? For what purpose do they wear the glasses (for distance viewing only or near work only or for both distance viewing and near work)? Can they read without glasses? And at what age were the glasses first prescribed? A parent was classified as myopic if he or she wore glasses only for distance viewing or if glasses were worn to view distance and near objects as long as the glasses were prescribed before age 16. This method has been shown to classify parents' refractive error correctly (Wallne, Zadnik & Mutti, 1996). The flow chart summarizing recruitment and examination process is shown in Figure 5.

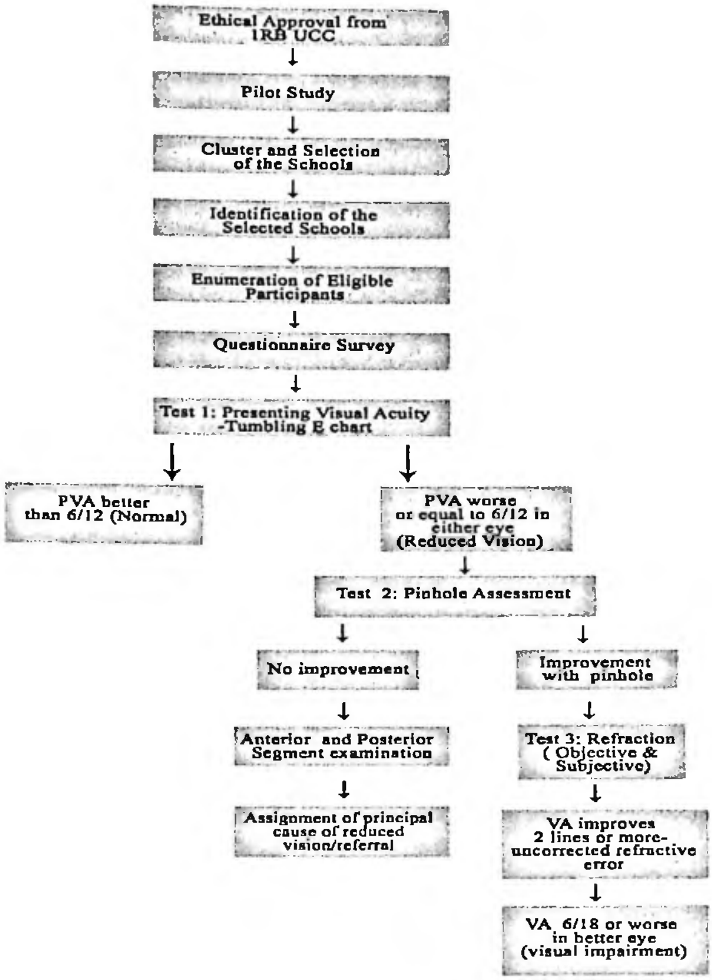

Figure 5: Flowchart summarizing recruitment and examination process

Anthropometric measurements

Each participant in whom the risk factor questionnaire was filled underwent anthropometric measurements of height and weight. Height and weight were measured using a wall-mounted measuring scale and digital bathroom scale (Arlyn EatSmart Precision Digital Bathroom Scale), respectively. To measure weight the scale was first calibrated to zero, then each child was instructed to remove any footwear and school uniform before the measurement and stand on the scale with minimal or no movement while they placed their hands by their sides. Out of respect for children's privacy, the anthropometric measurements were conducted in an enclosed room within the school premises. The weight readings were recorded for each participant in units of Kilograms (Kg). The heights of the participants were measured whiles the participants were standing erect. The participants removed their shoes and hair ornaments and anything that could increase their height. They stood against a wall facing outward and looking straight ahead. Their heads, shoulders, rear and heels were also made to touch the wall. Whiles standing against the wall, the distance from the floor to a mark on the top of their head was measured in centimeters (cm) and represented the height of the participant.

Measurement of BMI

Data of height and weight measurements were used to determine each child's BMI. The universally recognized formula: BMI= weight (kg) /height (m^2) was used. It was classified as underweight, normal, or overweight according to the proposed criteria of the WHO, underweight < 18.5 Kg/m^2, normal 18.5 – 24.5 Kg/m^2, and overweight ≥ 25 Kg/m^2.

Data Processing and Analyses

Clinical examination data forms were reviewed for accuracy and completeness before computer data entry. Then data was transferred for statistical analysis with standard routines available in Statistical Package for Social Sciences for Windows (version 16.0; SPSS Inc, Chicago, Illinois, USA) with confidence intervals (CIs) set at 95% and statistical significance drawn at an alpha level of 0.05 (2-tailed).

Clinical examination data were explored for missing values, outliers and normal distribution. There were no outliers in the numerical data, as assessed by inspection of boxplot. The numerical data follow the normal probability distribution, as assessed by inspection of quartile-quartile plots (Q-Q plots) and histograms. Descriptive statistics were carried out to generate frequencies, percentages and their 95% CI. The near-work activities were analyzed as a composite variable called "amount of near work" which was categorized as heavy (> 4hr daily) or light (< 1hr daily) based on the sum of the daily duration of all near work activities.

The following primary analyses were conducted for the research questions and hypotheses:

Research Question 1: What is the Prevalence of Visual impairment with Uncorrected, Presenting, and Best Corrected Visual Acuity among the Children Attending Primary Schools in the Coastline of Cape Coast, Ghana?

Prevalence of visual impairment with uncorrected, presenting, and best corrected visual acuity was calculated. Children with visual acuity of 6/18 or worse in the better eye were regarded as having visual impairment. Visual acuity threshold of 6/18, 6/24 to 6/60 and worse than 6/60 were used to establish mild, moderate and severe visual impairment.

Research Question 2: What is the Prevalence and Distribution of Uncorrected Refractive Error among the Children Attending Primary Schools in the Coastline of Cape Coast, Ghana?

Uncorrected refractive error was defined as presenting VA of 6/12 and worse in at least one eye that could be improved by 2 or more lines with optical correction. Prevalence of uncorrected refractive error was calculated as the ratio of the number of children with uncorrected refractive error to the total number of children examined.

Research Question 3: What is the Prevalence and Distribution of Visual Impairment Caused by Uncorrected Refractive Error among the Children Attending Primary Schools in the Coastline of Cape Coast, Ghana?

Visual impairment due to uncorrected refractive error was calculated as the ratio of the number of children that are visually impaired from uncorrected refractive error to the total number of children evaluated. Uncorrected refractive error was stratified by visual impairment categories of mild, moderate and severe visual impairment and the proportion in each category was calculated.

Main Hypotheses: There is a significant association between visual impairment caused by uncorrected refractive error and the following factors: child's age, gender, socio-economic status, school type, BMI, school academic performance, parent refractive status, and amount of near work activity?

In the first step of the statistical analyses to assess the determinants of visual impairment caused by uncorrected refractive error, the distribution of visual impairment due to uncorrected refractive error across the socio-demographic variables were examined in a univariate manner. To determine the presence of an association, significance of group differences was explored using the Pearson chi square test for categorical variables.

In the second step of the analysis, the binary logistic regression was performed (Hair, Black, Babin & Anderson, 2010), with the presence or absence of visual impairment due to uncorrected refractive error as categorical dependent variables and the factors significantly associated with visual impairment due to uncorrected refractive error, in univariate analysis, as independent variables. The independent variables used for the multivariate logistic regression analysis included age group (younger children 6-9 years and older children 10-12 years old), grade level (lower 1-3, upper 4-6), SES (low, middle and high), school type (private and public) school academic performance (poor, average, good), parental history of glasses (yes and no), and BMI (underweight, normal and overweight). Overweight and obese categories were combined into overweight/obese because of the small number of participants (n= 48). Strengths of associations using crude odds ratio (OR) and their corresponding significant levels was used to identify the determinants of visual impairment due to uncorrected refractive error.

CHAPTER FOUR

RESULTS AND DISCUSSION

The purpose of this study was to assess the prevalence, distribution, and determinants of visual impairment due to uncorrected refractive error in children attending primary schools in the Coastal communities of Cape Coast, Central Region of Ghana, and to provide corrected spectacles to the affected children. This chapter describes a detailed account of the results of the data analysis which are presented with respect to the research questions. The results are presented in narrative formats. Numerical results generated from the data are presented with appropriate tables and figures.

Research Question 1: What is the Prevalence of Visual impairment with Uncorrected, Presenting, and Best Corrected Visual Acuity among the Children Attending Primary Schools in the Coastline of Cape Coast, Ghana?

Visual acuity of 3,088 children was measured. Out of this number, 2,771 (89.7%) children had uncorrected (unaided) visual acuity of 6/9 or better (normal vision). Uncorrected visual acuity of 6/12 or worse in the better eye was recorded in 10.3% (n=317) children. Presenting visual acuity of 6/12 or worse in at least one eye was found in 9.9% (n=306) children. Only 0.71% (n=22) children had corrective glasses at the time of this examination. The prevalence of visual impairment with uncorrected, presenting and best corrected visual acuity among the study population are shown in Table 2.

Table 2: Distribution of Uncorrected, Presenting, and Best Corrected Visual Acuity in the Study population

VA Category	Uncorrected VA n (%)	Wearing glasses n (%)	Presenting VA n (%)	BCVA n (%)
6/9 or better in the worse eye	2771 (89.7)	11(0.35)	2782 (90.1)	3023 (97.8)
6/12 or worse in one eye only (Unilateral VI)	234 (7.5)	-	234 (7.6)	52 (1.68)
6/12 to 6/18 or better in the better eye (Mild VI)	45 (1.5)	5(0.16)	40 (1.3)	6 (0.19)
6/24 to 6/60 or better in the better eye (Moderate VI)	31 (10)	4 (0.13)	27 (0.87)	4 (0.13)
6/60 to 3/60 in the better eye (Severe VI)	7 (0.22)	2 (.065)	5 (0.16)	3 (0.10)
Total	3088 (100)	22(0.71)	3088 (100)	3088(100)

VA means Visual acuity; BCVA means Best Corrected Visual Acuity

Cycloplegic dilation and refractive error

Cycloplegic dilation and refraction was performed in 485 eyes of the 317 children with reduced visual acuity (76.5%). Pupillary dilation of at least 6 mm was achieved in all the eyes except one right eye without full dilation and absence of light reflex. After subjective refraction, refractive error was found to be the cause of reduced visual acuity in 435 eyes of 267 children (89.7%), 168 (63%) was bilateral and 99 (37%) unilateral. With the optical correction from subjective refraction, presenting visual acuity decreased to 2.1% (n=65) children (Table 2).

Ocular abnormalities and causes of visual impairment

A total of 485 eyes of 317 children with reduced vision have undergone media and fundus examinations and ocular motility examinations, and 3.7% (18 eyes) were found to have amblyopia. Amblyogenic factors were strabismus in 12 eyes and anisometropia of >2.00D in 6 eyes. The major cause of visual impairment was refractive error in 84.2% (267/317) of children with reduced vision. Other causes of reduced vision included 20 eyes with retinal diseases (macular toxoplasma scar), 6 eyes with lens opacities, 4 eyes with absolute glaucoma, and 2eye- s with corneal opacities. Causes of reduced vision of 6/12 and worse among the study participants are outlined in Table 3.

Table 3: Causes of reduced vision of 6/12 or worse in 485 eyes

Cause of VI	Frequency (n)	Percentage (%)
RE	435	89.7
Retinal disorder	20	4.1
Amblyopia	18	3.7
Glaucoma	4	0.8
Cornea opacity	2	0.4
Lens opacity	6	1.3
Total	485	100

Research Question 2: What is the Prevalence and Distribution of Uncorrected Refractive Error among the Children Attending Primary Schools in the Coastline of Cape Coast, Ghana?

The prevalence of uncorrected refractive error defined as presenting vision of 6/12 or worse in one or both eyes and achieving 2 or more lines of improvement with optical correction after subjective refraction, was 8.6% (n=267). Prevalence of uncorrected refractive error differed significantly by age, type of schooling, grade level, SES and parental refractive status. Prevalence of uncorrected refractive error was higher in older (10-15 years olds) children compared to younger (5-9 years olds) children (χ^2 (1, N = 267) = 6.436, p=.011), in private schools compared to public schools (χ^2 (1, N = 267) =12.113, p=.002), in upper (4-6) grade compared to lower (1-3) grade (p<.0001). Prevalence of uncorrected refractive error was highest in children belonging to middle SES compared to low and high SES (χ^2 (2, N = 267) = 22.101, p<.0001) and among children whose parents have refractive error (p<.0001) compared to those without refractive error. Though the difference in the prevalence of uncorrected refractive error was not statistically significant for gender (p=.689) and amount of near-work (p=.405), higher prevalence was recorded in females (9.0%) compared to males (8.1%) and children who did light near work (9.0) compared to children who did heavy near work (8.2%).

In the present sample of 3,088 children aged between 5 and 15 years, drawn from both public and private schools in Ghana, approximately 90% of children presented with normal vision (Table 2). This finding confirms Van Alphen (1961) theory of emmetropisation which theorized that there is a higher prevalence of emmetropia than ametropia in the general population. It is this excess of normal vision in the population that led to the proposition by Van Alphen (1961) that a mechanism exists for regulating eye growth during infancy to bring refraction to emmetropia. Data from several RESC studies showed similar distributions of an excess of emmetropes compared to ametropes in the sample (Kumah et al., 2013; Naidoo et al., 2003; Murthy et al., 2002; Zhao et al., 2000). Opubiri and Pedro-Egbe (2013) screening for refractive error among primary school children in Bayelsa State, Nigeria, obtained similar result (97.7%) for eyes with normal vision in their sample. Several RESC studies reported lower prevalence of uncorrected visual acuity (VA of 6/12 or worse in the better eye) compared to the findings in this study (10.3%). The previous RESC study in Ghana mentioned 3.7% although that study result is not directly comparable with the current study, as it was carried out on older children (12 to 15 years) recruited from private schools only (Kumah et al., 2013). In a comparable age range, the RESC study in South Africa reported a prevalence of 1.4% (Naidoo et al., 2003). The corresponding rates in Asia were 6.4% in New Delhi, India (Murthy et al., 2002), 2.7% in southern India (Dandona et al., 2002) and 2.9% in Nepal (Pokharel et al., 2000). However, studies in North East of China [12.8%] (Zhao et al., 2000), Santago, Chile [15.8%] (Maul et al., 2000) and Kathmandu, Asia [18.6%](Sakpota et al., 2006) found higher rates to that in the present study.

Table 4 shows the prevalence and distribution of uncorrected refractive error among the study population. In some studies, as that in Guangzhou in China [22.3%] (He et al., 2004) and Yangxi county in southern China [27%] (He et al., 2004), the rates are significantly higher, by some measures, than what we found in the present study. This observation confirms the high proportion of school children with suboptimum vision in rural Ghana. Again, the large variation in the prevalence rates between Kumah et al. (2013) survey conducted among private school children in urban Kumasi and the present one in rural Cape Coast, may be attributed to rural - urban differences in access to and quality of eye care services in Ghana. Nevertheless the prevalence of uncorrected visual acuity in this study decreased to 2.1% with best optical correction

Table 4: Distribution of uncorrected refractive error by socio-demographic characteristics among the study population

Variables (n)	Prevalence of uncorrected refractive error			
	Frequency	(%)	χ^2	p
Gender			.372	.689
Male (1344)	110	8.1		
Female (1744)	157	9.0		
Age group			6.44	.011
5-9 (1674)	125	7.5		
10-15 (n=1414)	142	10.0		
Type of school			12.11	.002
Private (n=1046)	116	11.1		
Public (n=2042)	151	7.4		
Grade			18.30	.002
1-3 (1676)	116	6.9		
4-6 (1412)	151	10.7		
SES			22.10	<.0001
Low (n=1738)	171	9.8		
Middle (n=571)	61	10.7		
High (n= 779)	35	4.5		
BMI			3.27	.072
Underweight (n= 786)	65	8.3		
Normal (n= 1888)	154	8.2		
Overweight (n= 414)	48	11.6		
Academic Performance			1.66	.286
Poor (n= 847)	80	9.4		
Average (n=1338)	103	7.7		
Good (n= 903)	84	9.3		
Parent refractive error			15.43	<.0001
Yes (226)	41	18.1		
No (2862)	226	7.9		
Amount of near work			.385	.405
Light (1683)	152	9.0%		
Heavy (1405)	115	8.2%		

RESC studies have consistently reported comparable rate of best vision acuities with optical correction of 0.32% in South Africa (Naidoo et al., 2003), 0.4% in Ghana (Kumah et al., 2013), 0.81% in New Delhi, Indian (Murthy et al., 2002), and 1.8% in North East of Beijing, China (Zhao et al., 2000). These findings illustrate the potential benefit of spectacles among children presenting with uncorrected refractive error.

Uncorrected refractive error was responsible for approximately 9 out of every 10 cases of reduced vision in the current study population. This observation confirms that the problem is of public health concern among children in Ghana. A similar finding was observed in the RESC study of older children (12-15 years) in private schools in Ghana (Kumah et al., 2013) where uncorrected refractive error accounted for 71.7% of reduced vision. Aside from this study, there were no comparable published studies in this age group previously carried out in Ghana. In Africa also, published literature in this age group is sparse, but the RESC study in South Africa (Naidoo et al., 2003) showed a lower prevalence of visual impairment than the present study, with uncorrected refractive error accounting for 63.6% of the cases. In studies that are comparable in other parts of the world, uncorrected refractive error was the cause of reduced vision in 56.3% in Chile (Maul et al., 2000), 61% in Southern Indian State of Andhra Pradesh (Dandona et al., 2002), 81.7% in New Delhi, India (Murthy et al., 2002), 94.9% in urban China (He et al., 2004) and 97.1% in rural Southern China (He et al., 2005). In general, the contribution of refractive error as a cause of reduced vision in this study is much higher than that of South Africa, Chile and southern India but comparable to that of New-Delhi, and lower than rates reported in China. The differences in these studies in the contribution of uncorrected refractive error to visual impairment may be due to methodological differences across studies as some were population based whereas others were school-based and while some studies, like the present study, reported data for persons, others reported only for eyes.

Although the prevalence rate of uncorrected refractive error of 8.6% in this study population falls within the WHO's prevalence of 2-10% worldwide (Wedner, Ross, Balira, Kaji & Foster, 2000), it is higher than the rates of 4.4% in a recent study in North West Nigeria (Balarabe, Adamu & Abubakar, 2015), 2.7% in a more recent comparative study in Eastern Nigeria (Atowa, Munsamy & Wajuihian, 2016), 2.1% in Maharashtra, India (Padhye & Maharashtra, 2009), and 1.3% .in Australia (Robaei, Rose & Ojaima, 2005). However, the observed prevalence value for uncorrected refractive error in this study is comparable to the 7.03% in Banglore (Pavithra, Maheshwaron & Rami, 2013), 7.7% in a sub-urban area of Malaysia (Hashim, Tan, Wan-Hazabbah & Mohtar, 2006) and 9.5% in Ethopia (Sewunet, Aredo & Gedefew, 2014). The variations in the prevalence of uncorrected refractive error across studies may be related to ethnic differences, study area (urban versus rural) and difference in level of access to eye care services (Resnikoff et al., 2008).

A secondary cause of reduced vision in this study was amblyopia in 3.7% children. Comparable findings were observed in the previous RESC studies including that in Ghana and South Africa. Amblyopia was the cause of reduced vision in 5% children in China (Zhao et al., 2000), 6.5% children in Chile (Maul et al., 2000), 4.4% children in New Delhi, India (Murthy et al., 2002), 1.9% in Southern China (He et al., 2004), 7.3% children in South Africa (Naidoo et al., 2003) and 9.9% children in Ghana (Kumah et al., 2013). Although the rate of amblyopia in the present study is higher than the corresponding rates in previous RESC studies, measures should be taken to include amblyopia screening in in-school health services in Ghana as delay in treatment can lead to irreversible blindness. These data suggest that intervention to improve delivery of refractive services and provision of optical corrections in areas where there is a high level of need, limited resources and low access to refractive services is crucial as it could significantly decrease the burden of visual loss among children.

Research Question 3: What is the Prevalence and Distribution of Visual Impairment Caused by Uncorrected Refractive Error among the Children Attending Primary Schools in the Coastline of Cape Coast, Ghana?

Of the 3,088 children examined, the prevalence of visual impairment caused by uncorrected refractive error (presenting vision of 6/18 or worse in the better eye and achieving 2 lines or more improvement with subjective refraction) was 2.7% (n = 83). When stratified by visual acuity categories, the prevalence of mild, moderate and severe visual impairment caused by uncorrected refractive error were calculated as 1.5% (n=46), 1% (n=31) and 0.2% (n=7). Prevalence of visual impairment due to uncorrected refractive error differed significantly by age, grade level, BMI and academic performance ($p < .05$) but not by gender, schooling type, SES, parent refractive error and amount of near work ($p > .05$). The prevalence of visual impairment caused by uncorrected refractive error increased with increasing age, from 1.4% in the 5-9 year age group to 4.2% in the 10-15 year old group ($p < .0001$), and increasing grade level from 1.4% in children of grade 1-3 to 4.2% in children of grade 4-6 ($p < .0001$). The observed higher prevalence in the older children may have resulted from increasing axial length as the child gets older according to Steiger's biological theory (Steiger, 1913) or from eye strain due to educational demand in higher grades according to the use-abuse or near work hypothesis (Van-Alphen, 1961). This assertion was further confirmed by the observation of higher prevalence in the higher grades. Overweight children had the highest prevalence of visual impairment due to uncorrected refractive error when compared to normal and underweight children (p=.020). Children with poor academic performance had the highest prevalence of visual impairment due to uncorrected refractive error compared to the children who performed averagely and those with good academic performance.

There have been several RESC surveys of school-aged children in this age group in different locations worldwide. The major difference between the other RESC surveys and the present study is that the previous surveys did not take into account the determinants of visual impairment due to uncorrected refractive error, which contributes a major proportion of causes of visual impairment globally. The 2.7% prevalence of visual impairment due to uncorrected refractive error recorded in the present study was substantially higher than the 0.26% estimate by the WHO (Resnikoff et al., 2008), for the number of children in the WHO Africa who are visually impaired due to uncorrected refractive error. The reason for the large difference may be because the WHO estimate was not derived from the population of the individual WHO region. As a result, extrapolations were made based on other regions with available data. The distribution of visual impairment caused by uncorrected refractive error across socio-demographic variables is presented in Table 5.

Table 5: Proportion of children with visual impairment due to uncorrected refractive error across demographic factors

Variables (n)	Prevalence of visual impairment due to uncorrected refractive error			
	Frequency	(%)	χ^2	p
Gender			0.389	.641
Male (1344)	32	2.4		
Female (1744)	51	2.9		
Age group			18.103	<.0001
5-9 (1674)	23	1.4		
10-15 (n=1414)	60	4.2		
Type of school			2.155	.110
Private (n=1046)	37	3.5		
Public (n=2042)	46	2.3		
Grade			22.101	<.0001
1-3 (1676)	24	1.4		
4-6 (1412)	59	4.2		
SES			1.465	.410
Low (n=1738)	49	2.8		
Middle (n=571)	18	3.2		
High (n= 779)	16	2.1		
BMI			7.824	.020
Underweight (n= 786)	23	2.9		
Normal (n= 1888)	41	2.2		
Overweight (n= 414)	19	4.6		
Academic Performance			9.110	.011
Poor (n= 847)	33	3.9		
Average (n=1338)	24	1.8		
Good (n= 903)	25	2.7		
Parent refractive error			2.158	.108
Yes (226)	11	4.9		
No (2862)	72	2.5		
Amount of near work			.291	.864
Light (1683)	46	2.7		
Heavy (1405)	37	2.6		

The WHO estimates for prevalence of visual impairment due to uncorrected refractive error for other developing countries for which epidemiological data were available were 0.20% in Australia, 0.20% in South America, 0.55% in Europe, 0.63% in India, 1.00% in America, and 2.66% in China. Baring the estimate for China which is comparable with the present study, these estimates are considerably lower than that obtained in the present study. Comparatively, results of most of the RESC studies conducted in recent times indicated that the WHO rates were generally under-estimated (Kumah et al., 2013; Naidoo et al., 2003). The differences across studies may also be related to the cut-offs used in identifying participants with visual impairment, although, cut-off did not influence spectacle wear compliance rates in a study among school-aged children in South Africa (Congdon et al, 2008). However, the influence of cut-off points is quite apparent in the WHO estimates, which used stricter criteria of visual acuity worse than 6/18 leading to fewer qualifying subjects.

In the present study, visual impairment due to uncorrected refractive error was defined as uncorrected visual acuity of worse than 6/12 in the better eye, on the observation that the children with this level of acuity had severe functional consequences including limiting the ability to read off distance prints in the classroom. There are even other broad but widely acceptable criteria used for visual impairment derived from other WHO funded studies in low-income settings which include visual acuity of 6/12 or worse (Kumah et al., 2013; Naidoo et al., 2003) and visual acuity worse than 6/12 (Abdul et al., 2009; Nangia et al., 2013). Despite the different cut-offs which represents a problem to compare studies, uncorrected refractive error was responsible for the majority of the presenting visual impairment in the study population, but over 90% of those affected attained normal vision with optical correction. Again, these data suggest that intervention with a simple pair of glasses could significantly decrease the burden of needless visual loss among children in the study population. This finding is significant in the sense that it underscores the urgency and intensification of refractive programmes aimed at delivery of refractive services and spectacle correction in the study population as well as in Ghana.

Majority of the children in the present study had moderate visual impairment (visual acuity in the better eye worse than 6/18 but not worse than 6/60); only 7 were severely visually impaired (visual acuity in the better eye worse than 6/60 but not worse than 3/60) out of which 2 children were blind (visual acuity worse than 3/60). A remarkable finding in this study was the high proportion (97%) of children with severe visual impairment who attained normal vision with optical correction. This observation confirms the results of several studies in developing countries wherein a high proportion of the general population of children in the developing world with needless visual impairment benefitted from optical correction after subjective refraction (Dandona et al., 2002; Maul et al., 2000; Murthy et al., 2002; Naidoo et al., 2003; Zhao et al., 2001). Resnikoff (2008) contend that ignorance and inability to afford refractive services are mainly responsible for refractive error remaining uncorrected, which is in accordance with opinions of several researchers in investigations carried out in most developing countries (Dandona et al., 2002; Pokharel et al., 2000). In a study in Asia, the main reasons for unwillingness to use eye glasses were appearance and embarrassment (Jacqueline, Reene, du-Toit, Palagyi, 2007). In most developing countries, it is reported that those in rural poor areas believe that wearing eye glasses causes the eyeball to sink inside or the eye to deteriorate faster while some assume that poor vision is inevitable or treatable only in ways they cannot afford (Karnani, 2011). These reports suggest the need for intensification of education and health promotion programs in rural areas.

Main Hypothesis: There is significant association between visual impairment caused by uncorrected refractive error and the following factors: child's age, gender, socio-economic status, school type, BMI, school academic performance, parent refractive status, and amount of near work activity?

The multivariate logistic regression models for predicting visual impairment due to uncorrected refractive error included age group, type of school, BMI, academic performance, SES and parent refractive error as covariates. The presence or absence of visual impairment due to uncorrected refractive error was the dependent variable.

The statistically significant predictor variables for being visually impaired due to uncorrected refractive error were older age (OR, 3.379, $p < .0001$, 95% CI, 2.064 to 5.529), attending public school (OR, .332, $p < .0001$, 95% CI, .191 to .577), being of middle SES (OR, 2.931, $p = .003$, 95% CI, 1.430 to 6.008), and high SES (OR, 2.230, $p = .030$, 95% CI, 1.081 to 4.597) and being overweight (OR, 2.211, $p = .006$, 95% CI, 1.255 to 2.956). Table 6 presents the binary logistic regression for determinants of visual impairment due to uncorrected refractive errors. The model was not statistically significant according to the Hosmer and Lemeshow goodness-of-fit test (χ^2 (8, $N = 267$) = 14.840, $p = .062$). The model explained 8.8% (Nagelkerke R^2) of the variance in visual impairment caused by uncorrected refractive error and correctly classified 97.3% of cases.

Sub-Hypothesis 1: There is a significant association between visual impairment caused by uncorrected refractive error and the child's age.

The evidence in this school-based sample of 5-15 year-old children confirms the hypothesis that increasing age is associated with increase prevalence of visual impairment caused by uncorrected refractive error (H1).

Table 6: Binary logistic regression predicting visual impairment caused by uncorrected refractive error

	Category	Multivariate Logistic Regression	
		OR (95% CI)	p-value
Gender	Male	REF	
	Female	.693	.307
Age group	5-9	REF	
	10-15	3.379 (2.064-5.529)	<.0001
Type of school	Private	REF	
	Public	.332 (.191-.557)	<.0001
SES	Low	REF	
	Middle	2.931 (1.430-6.01)	.003
	High	2.230 (1.081-4.597)	.030
BMI	Underweight	REF	
	Normal	1.570 (.834–2.96)	.162
	Overweight	2.211 (1.255-3.896)	.006
Academic Performance	Poor	REF	
	Average	0.892 (0.40-1.98)	.778
	Good	2.053 (0.93-4.50)	.073
Parental refractive error	Yes	REF	
	No	1.954 (0.79-4.83)	.147

REF=Reference, Hosmer and Lemeshow goodness-of-fit test, χ^2 (8) = 14.840, p=.062; Classification table = 97.3; -2 log likelihood = 712.518; Cox & Snell R square=.019; Nagelkerke R square =.088

Increasing age was the strongest predictor of visual impairment caused by uncorrected refractive error in the study population in that the odds were the highest (3.379) among the other factors. This observation is in accordance with the bulk of epidemiological evidence in literature including the RESC studies in Africa (Kumah et al., 2013; Naidoo et al., 2003) and Asia (Murthy et al., 2002; Zhao et al., 2000). In the study by Fan et al. (2004) who carried out a longitudinal survey of myopia in Chinese school children of comparable age range (5-16 years) in HongKong, the older children were 15 times more likely to have myopia than the younger children. The observation of increasing age correlating with increased incidence of refractive error is conceptualized on the three theories. First, the biological theory of Steiger (1913) which proposed that with increasing age, the natural increase in eye growth and axial length results in progression of myopia in potentially myopic eyes. Thus, preventive approaches need to concentrate on controlling eye growth and excessive elongation of the axial length because slowing the progression of myopia will likely afford a great benefit to a large number of people, especially children in economically deprived areas, where the emphasis on cost of spectacles and poor spectacle-wear compliance have led to a high prevalence of uncorrected refractive error in the population. Second, the existence of a mechanism called emmetropisation that actively regulates eye growth of young children so as to bring refraction towards normal (Young, 1963) but the tendency to develop myopia during later childhood because emmetropisation is largely complete by age 6 years. Accordingly, lower prevalence of refractive error in younger age children compared to the older age group was shown in several RESC studies (Kumah et al., 2013; Murthy et al., 2002; Naidoo et al., 2003; Zhao et al., 2000). The third arises from the proposed theory of use and abuse of the eye that results in myopia progression. The fact that the older children are faced with increased academic workload from formal education which entails excessive use of the eyes for reading and other education related activities might have led to the higher prevalence of uncorrected refractive error and its associated visual impairment compared to the younger children, who do less intensive reading. The similarities in findings pertaining to older age being a risk indicator of uncorrected refractive error across racial ethnic groups and in Africa and Asia (Fan et al., 2004; Kumah et al., 2013; Murthy et al., 2002; Naidoo et al., 2003; Zhao et al., 2000) underscores the importance of public education and increased access to refractive services in the population.

Sub-Hypothesis 2: There is a significant association between visual impairment caused by uncorrected refractive error and the child's gender.

Given the controversy regarding the association between gender and refractive error among children, the non-significant association between gender and visual impairment caused by uncorrected refractive error in this study (Table 6) is not surprising. The link between gender and refractive error is borne out of the speculation that puberty and earlier maturation typically found in girls seems to influence development of refractive error and its associated visual impairment (Sewunet et al., 2014; You et al., 2012). This trend has also been linked to the introverted personality of females which limits them to indoor activities such as near-work activities and reading of novels, as explained by the near-work theory (Sewunet et al., 2014). In contrast however, this study found no evidence in support of an association between gender and uncorrected refractive error or visual impairment caused by uncorrected refractive error (H2). Kumah et al. (2013) and Naidoo et al. (2007) reported similar findings among children in Ghana and South Africa, respectively. The findings of this current study are also similar to results obtained by Padhye et al. (2009) and Ruiz-Alcocer et al. (2011) who studied the magnitude and determinants of uncorrected refractive error among school children in India and Mozambique, respectively. A recent study among tertiary students aged 16-39 years in Ghana found no significant association between uncorrected visual impairment and gender (Abokyi et al., 2016). Result of this study is not in agreement with other studies in this age range which performed similar analysis and found significant higher prevalence of uncorrected refractive error among female children (Dandona et al., 2002; Kingo & Ndawi, 2009; Murthy et al., 2002; Sakpota et al., 2006; Zhao et al., 2001).

Sub-Hypothesis 3: There is a significant association between visual impairment caused by uncorrected refractive error and the child's socio-economic status (SES).

Findings in this study indicate that children belonging to middle and high SES were more likely to be visually impaired from uncorrected refractive error compared to children of low SES (Table 6). This finding confirms the hypothesis that uncorrected refractive error is highly prevalent in high SES children than low SES children. This hypothesis is grounded on the association between near work and myopia which is conceptualized on the use and abuse theory. Children of high SES are considerably more exposed to high-tech technology such as intense use of the computer and other close work machines that they spend most of their time using electronic devices for doing their homework. Accordingly, some RESC studies have confirmed higher prevalence of uncorrected refractive error and its associated visual impairment among children in urban areas who are more likely to have access to computer, video games and television compared to children in rural areas who are less likely to have these high-tech technology, due to the influence of near-work induced myopia (He et al., 2004; Hashim et al., 2006). These findings seem to underscore the strong influence of near-work in myopia pathogenesis as proposed by Young (1962). However, the association between refractive errors and high SES has not been consistently observed. For instance, Robaei et al. (2005) reported a higher prevalence of uncorrected visual impairment among Australian children of low SES. A range of factors including difference in study design, children's ethnicity, definitions of myopia and near work, accuracy of the self-reported SES and differences in the age of children studied. For example, Robaei et al. (2005) studied only 6 year-olds whereas the present study included children aged between 5 and 15 years. This discrepancies indicate that more than the environmental factors, other factors such as the genetic factors are more likely to promote the development of uncorrected refractive error.

Sub-Hypothesis 4: There is a significant association between visual impairment caused by uncorrected refractive error and type of school child attends.

This study found evidence in support of an association between type of school child attends and prevalence of visual impairment caused by uncorrected refractive error among children (Table 6). Type of school is often used as a surrogate measure for near-work given that private schools are noted for more hectic educational schedules compared to public schools. The hypothesis for this association was conceptualized on the near work (use and abuse) theory wherein refractive error could be highly prevalent in private schools compared to public schools because of more intense educational activities. Children in private schools could be considerably more exposed to high-tech technology such as intense use of computer and other close work machines that they spend most of their time using electronic devices for doing their homework and this could lead to development of refractive error. Further, it is common knowledge that parents of children who attend private schools may pay more attention to the academic performance of their children and encourage more time spent on studying books and other near work activities unlike parents of children who attend public schools. Findings in this study suggest that children in public schools were at lesser odds than children in private schools of being visually impaired from uncorrected refractive error. The RESC study carried out in rural Southern China observed a similar finding (He et al., 2004). In Eastern China Lian-Hong et al. (2010) reported that children in private schools had a higher risk of occurrence of refractive error. The intensive close work activities, such as reading, writing, computer use and attending extracurricular classes after school hours that the children are subjected to might be a factor contributing to the high prevalence of visual impairment caused by uncorrected refractive error according to the near work theory.

Sub-Hypothesis 5: There is a significant association between visual impairment caused by uncorrected refractive error and the child's BMI.

This study found an association between BMI and visual impairment caused uncorrected refractive error among the children (Table 6). In general, the prevalence of visual impairment from uncorrected refractive error was significantly highest in the overweight children compared to underweight and normal children. The findings in the present study indicate that overweight children were about twice more likely to have visual impairing uncorrected refractive error than underweight and normal children. This finding is consistent with that of a recent study by Yang et al. (2016) in Central China. Yang et al. (2016) found that a high level of BMI ($\geq$ 19.81 kg/m^2 was associated with a higher prevalence of visual impairment among 3,771 Chinese students aged 6-21 years. They (Yang et al., 2016) indicated that obese children were 1.5 times more likely to have visual impairment than normal children.

The conceptual basis of the association between BMI and refractive error is grounded on the Steigers biological theory (Steiger, 1913) relating axial length growth and development of refractive error. In extension of Steiger's biological theory, Hirsch and Weymouth (1991) pointed out that since BMI also affects the eye size then eye size growth in overweight children may result in the development of myopia. The mechanism for this association is still not known but Yang et al. (2016) attributed the association to unhealthy lifestyles due to insufficient outdoor physical activities, such as overuse of the eyes for television watching and computer games. The authors (Yang et al., 2016) posit that the mechanism underlying the relationship might be that visual impairment in the student was actually caused by overweight or obesity considering that children with visual impairment rarely engage in sports activities and spend more time in front of the screen or doing other near work activities, which are known risk factors for refractive error.

Body stature's contribution to myopia has been assessed in several population-based studies especially in Asian children (Hammond et al., 2001; Sharma et al., 2009; Wang et al., 2015). The Twin eyes study of Chinese children showed a significant association between height and axial length (Hammond et al., 2001). Sharma et al. (2009) reported that height was inversely associated with refractive error among Chinese boys, although no such association was observed among girls. However, this relationship was not consistent across studies. For instance, no relationship between body stature and myopia shift was found in a study with school children aged 7 to 9 years in Taiwan (Huang et al., 2014). The inconsistency of these studies may be derived in part from ethnic and demographic differences. Nonetheless, overweight and obesity are currently major public health concerns in both developing and developed countries. Therefore, school children should be encouraged to do more outdoor activities and spend less time on watching television and using computers.

Sub-Hypothesis 6: There is a significant association between visual impairment caused by uncorrected refractive error and the child's school academic performance.

The influence of visual impairing uncorrected refractive error on school academic achievement has been the topic of much debate in the literature. In the present study, the proportion of children with visual impairing uncorrected refractive error was significantly higher in children who performed poorly in their respective classes than in those who had average and those who had high scores (Table 5). Although possible environmental confounders, including school system, SES, intelligent quotient (IQ), and developmental delay cannot be excluded, this finding underscores the negative impact of visual impairing uncorrected refractive error on vision-related functions. However, there was no evidence in multivariate analysis (Table 6) to confirm such an association in the present study. In other words, school academic performance did not play a significant role in predicting visual impairment caused by uncorrected refractive error. The existence of such an association is conceptualized on the near-work theory that there is a possibility of better reading ability and excessive near work in myopic children which culminates in better school performance. In other words, children who score higher grades spend more time doing near-work activities such as reading of books, which is a known risk factor for the development of myopia. Consistent with this theory, some studies reported a positive association between school academic achievement and visual impairing myopia (Mutti et al., 2002; Saw et al., 2007; Saw et al., 2004). Among Singaporean children, Saw et al. (2007) found that children with higher exam scores were 2.5 times more likely to be myopic than children with lower exam scores. In contrast, other authors (Dirani et al., 2010) did not find an association between academic performance and uncorrected refractive error. Dirani et al (2010) showed that distance visual acuity does not play a significant role in predicting academic performance among a sample of Singaporean children aged 9 to 10 years.

The impact of visual impairing uncorrected refractive error on school academic performance may be biased in the present study because the local percentile score rather than a national percentile score as used in other studies, was used for this assessment, although the potential impact of these differences has not been established. In Ghana, primary education lasts for 6 years and no national examination is sat by pupils during the primary school phase. The complexity of the relationship between academic performance and uncorrected refractive error warrant analytical and longitudinal studies to clarify any cause-effect relationship. As a necessity though, school children must be screened for every potential refractive error that might be detrimental to high academic achievement.

As mentioned earlier, the significant difference in prevalence of uncorrected refractive error across categories of academic performance (Poor 3.9%, average 1.8%, good 2.7%) found in chi-square analysis indicates that in fact, visual impairing uncorrected refractive error has a negative impact on vision-related functions. This association could be interpreted as evidence that visual impairment causes poor vision resulting in poor grades. In general, there is a potential for major improvement in visual function in this population with interventions primarily focused on providing efficient refractive services.

Sub-Hypothesis 7: There is a significant association between visual impairment caused by uncorrected refractive error and the child's parent refractive status.

A positive relationship between parental refractive error and childhood visual impairment caused by uncorrected refractive error has been reported (Dirani et al., 2006; Liang et al., 2004). However, in the present study, there was no association between visual impairment caused by uncorrected refractive error and parental refractive error in both chi square (Table 5) and binary logistic regression analysis (Table 6). The bulk of epidemiologic evidence on this relationship (Dirani et al., 2006; Liang et al., 2004; Mutti et al., 2002) showed that parents who have myopia tend to have children with myopia, in support of a strong hereditary impact in the development of refractive errors (Steigers, 1913). Correlations as detailed as increase in prevalence of childhood refractive errors associated with a greater number of myopic parents have been reported by Mutti et al. (2002). In the current study, although parents with refractive error tend to have children with uncorrected refractive error in univariate analysis ($p < .0001$) as shown in Table 4, parental refractive error did not play a significant role in predicting visual impairment caused by uncorrected refractive error in the final multivariate model. It is possible that the failure to find an association of visual impairing refractive error with parent refractive error was because there were very few participants (11) in the parents with visual impairment due to uncorrected refractive error category which could have prevented accurate statistical analyses of this relationship. Further studies involving a larger proportion of parents with refractive error are warranted to properly explore this association. Another explanation for the result of the present study is that perhaps the self-assessment of parental refractive status especially among the illiterate parents was inaccurate given that the parents were instructed to report past events. To determine parental refractive status, parents were asked if they wear or have ever worn glasses and at what age were the glasses first prescribed. It is likely that recall bias have affected the accuracy of the self-report. However, the questionnaire survey method used for assessing parental refractive status was adopted from previous studies (Morgan & Rose, 2013; Mutti et al., 1995; Zadnik et al., 1994). It is also possible that the associations might have been confound by other unmeasured environmental factors. Because of the cross-sectional design of this study, the role of unmeasured environmental confounders in determining the pattern of association in these children could not be assessed. Further analysis of the impact of possible environmental confounders is required and longitudinal studies involving children of different Ghanaian ethnicities are warranted. Nevertheless similar results were reported by children in a previous study examining such association. That study was a longitudinal study carried out on a sample of Hongkong children aged between 7 to 12 years. The study reported no difference in prevalence rates of refractive error of children irrespective of whether one or both parents had refractive error (Edwards, 1998).

Sub-Hypothesis 8: There is a significant association between visual impairment caused by uncorrected refractive error and child's amount of near work activity.

Despite substantial evidence in literature in support of environmental influences in the development of refractive errors (Mutti et al., 2002; Morgan

& Rose, 2013; Saw et al., 2006; Young, 2009), this study found no evidence in both chi-square (Table 5) and logistic regression analysis (Table 6) to confirm an association of near work with uncorrected refractive error in the study population. There was no significant overall association between time spent doing extracurricular classes after school hours, watching TV for long hours, or using computers at home and being visually impaired due to uncorrected refractive error (Table 6), a finding consistent with that of several previous studies (Lin et al., 2014; Lu et al., 2009; Rose et al., 2008; Wu et al., 2010). Lu et al. (2009) surveyed 1,892 children of mean age 14.6 years in rural China and found that none of the near work activities, including homework were associated with myopia. Among 4,118 children aged 6 and 12 years, the same view was given by Rose et al. (2008) when she and her team demonstrated that prevalence of myopia did not vary with the amount of time the children spent on near work activities. In similar study, Lin et al. (2014) studied 386 Chinese children aged 6 to 12 years and found that level of near work time was not related to myopia development after adjusting for the children's age, gender, and parental refractive error. In contrast, several cross-sectional studies examining this association found that more near work activities increased the prevalence of myopia in children between 6 to 18 years of age (Deng, Gwazala & Thorn 2010; Ip et al., 2008; Mavracana et al., 2000; Mutti et al., 2002; Saw et al., 2002; Saw et al., 2001). Saw et al. (2002) undertook a study of 1,005 children aged 7 to 9 years from the Singapore Cohort Study of the Risk factors for myopia. The study revealed that children who read more than two books per week were 3 times more likely to have myopia than those who read fewer than two books. The study by Ip et al. (2008), based on the records of 2,353 children aged 12 to 13 years in Sydney, showed that close reading distance (<30cm) and continuous reading (>30mm) increased the risk of myopia by 2.5-fold and 1.5-fold, respectively. In a more recent study in the United States of America, Deng et al. (2010) reported that myopic white children aged 6-18 years old watched more TV (12.78 ± 9.28 hours/week) than non-myopes (8.91± 5.95 hours/week) (p=0.02) during the school year. The multivariate odds ratio for the association between myopia and TV viewing was significantly higher than 1.0 in that study. A survey by Mavracanas (2000) of 1,378 children aged 15 to 18 years from Greece, showed that 43.1% of the myopic children studied more than 5 hours per day compared with 28.6% of the non-myopic children ($\chi^2 = 37.36$, $p < 0.001$). Among 377 children aged 6 to 12 year from Thailand, the multivariate odds ratio of myopia for each diopter-hour per week of near activities was 1.019 (Yinyong, 2010). Correlations as detailed as faster rates of progression of myopia following periods of intense study and slower rates during school holidays have also been reported (Ip et al., 2008; Saw et al., 2002). Differences in population characteristics, educational and physical environments, examination protocols and statistical methods across studies may account for these variations.

It is possible that the failure to find an association between amount of near work and visual impairment due to uncorrected refractive error in both univariate and multivariate data was due to inaccuracy in the assessment of time spent on near work especially with the young children who were not mature enough to respond independently. The near-work data was obtained from questionnaire survey rather than direct measurement, and this could have led to recall bias. Although the questionnaire measures showed high test-retest agreement, but given that the children were instructed to report near-work on daily basis in the previous week, recall bias might still affect accuracy of the associations. The reliability of children's data from of near work questionnaire survey has not been established (Ip et al., 2008; Mutti and Zadnik, 2009; Saw et al., 2001), although the method adopted for estimate of near-work in this study was rated as correlating well with the objective method (Ip et al., 2008; Mutti and Zadnik, 2009; Saw et al., 2001) which is more intensive and of limited usefulness in large population studies like the present study. In the objective method of assessment of amount of near work activities, research assistants documented the number of hours children spend reading during school hours (Saw et al., 2002). Further studies should consider using the objective methods for logging near work. The concept of diopter hours was suggested by Zadnik et al. (1994) as a weighted measure of near work. In the present study it was calculated by the number of hours spent reading plus the number of hours spent playing video-type games plus the number of hours spent watching television. The same quantification was done in this study except that a binary categorization was used for near work activity levels such that spending more than 4hr daily on near work activities represents heavy amount of near work and spending less than 1hr daily represents light amount of near work. This method of classifying near work showed high validity and reliability in the pilot study. Further prospective studies are necessary to further understand the role of near work in the pathogenesis of refractive error.

This study found evidence in support of an association between type of school child attends and prevalence of visual impairment caused by uncorrected refractive error among the children (Table 6). Type of school is often used as a surrogate measure for near-work given that the private schools are notable for more hectic educational schedules compared to the public schools hence this hypothesis was conceptualized on the near work (use and abuse) theory that refractive error will be highly prevalent in private schools compared to public schools. Children in private schools are considerably more exposed to high-tech technology such as intense use of computer and other close work machines that they spend most of their time using electronic devices for doing their homework and this might lead to development of refractive error. Further, parents of children who attend private schools seem to pay more attention to the academic performance of their children and encourage more time spent on studying books and other near work activities unlike the parents of children who attend public schools. Findings in this study suggest that children in private schools were about 3 times more likely to become visually impaired due to uncorrected refractive error than children in private schools. The RESC study carried out in rural Southern China observed a similar finding (He et al., 2004). In Eastern China, Lian-Hong et al. (2010) reported that children in academically challenging school had a higher risk of occurrence of refractive error. In the past decades schooling system in private primary school in Ghana has become rigorous and highly competitive, operating stringent academic programs with hectic educational schedules and long hours of studying, to achieve impressive net national entrance scores that will attract parents to enroll their children in the schools (GES, 2018). The intensive close work activities, such as reading, writing, computer use and attending extracurricular classes after school hours that the children are subjected to might be a factor contributing to the high prevalence of visual impairment caused by uncorrected refractive error according to the near work theory (Cohn, 1886). Studies from Singapore (Seet et al., 2001) and Japan (Verkichara, Matsai & Saw, 2015) also found an increase in the prevalence of myopia over the past decades.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The main purpose of this study was to assess the prevalence, distribution, and determinants of visual impairment due to uncorrected refractive error in children attending primary schools in the Coastal areas of Cape Coast, Central Region of Ghana. Findings from the study could help to provide information from which the scope and priorities for preventive- and cost- effective refractive programmes can be planned. Children found with uncorrected refractive error were provided with corrective spectacles free of charge. This chapter presents an overview of the entire thesis.

Summary

In spite of its importance, previous RESC studies did not take into account participants with visual impairing uncorrected refractive error, which contributes significantly to the causes of visual impairment globally. The present study examined the prevalence of visual impairment caused by uncorrected refractive error and its determinants such as age, gender, BMI, SES, parental refractive status and amount of near-work, using a survey of public and private primary school children in a rural population in Cape Coast. Random selection of geographically defined school-based clusters was used to identify a representative sample of 3420 eligible school children (aged 5 to 15 years) from 19 schools. Out of the 3420 enumerated, 3088 (90.3%) underwent a standard ophthalmic examination comprising of cycloplegic refraction and examination of the external and posterior segments of the eye. Independent replicate measurement of visual acuity in 50 children with reduced vision was carried out for quality assurance monitoring from ten schools enrolled in the main study. The prevalence of uncorrected, presenting and best visual acuity in at least one eye was 10.3%, 9.9% and 2.1%, respectively. Uncorrected refractive error was the cause in approximately 85% of reduced vision, and amblyopia in 3.7%. The prevalence of uncorrected refractive error was 8.6%. The prevalence varied significantly with age, type of schooling, grade level, socio-economic status and parental refractive status. The prevalence of visual impairment due to uncorrected refractive error was 2.7%, which was significantly higher in the older children, children in upper grades, overweight children and in children who performed poorly in school. The prevalence of mild, moderate and severe visual impairment was 1.5%, 1% and 0.2%, respectively. In multivariate analysis, visual impairment due to uncorrected refractive error was associated with older age, schooling in private school, middle and high SES and being overweight. Ninety-Seven percent (97%) of children with visual impairment at baseline examination were all given free spectacles. To the best knowledge of this researcher, this is the first study examining these outcomes in children anywhere in Ghana. Findings in this study revealed that uncorrected refractive error is the major cause of visual impairment among children in Coastal areas of Cape Coast, Ghana.

Main Findings

1. A high prevalence of uncorrected refractive error of 8.6% was found among school going children in the coastal community of Cape Coast.

2. A high prevalence of visual impairment caused by uncorrected refractive error of 2.7% was found among school going children in the coastal community of Cape Coast.
3. Older age, schooling in private schools, belonging to middle and high socioeconomic status and being overweight were the determinants of visual impairment due to uncorrected refractive error among the study population.

Conclusions

Although studies on visual impairment attributable to refractive error have been conducted in Ghana, most were performed in settings of unknown representativeness with different measurement methods and non-uniform definitions which made comparison with other RESC studies difficult. Findings in this study performed using the RESC protocol revealed a prevalence of 8.8% of uncorrected refractive error among school going children in coastal areas of Cape Coast, Ghana. The prevalence of visual impairment caused by uncorrected refractive was 2.7%. Prevalence of visual impairment caused by uncorrected refractive error was higher the older age group (10-15 years) compared to the younger age group (5- 9 years). Prevalence of visual impairment caused by uncorrected refractive error was higher among children in higher grades (4-6) compared to children in lower grades (1-3). Prevalence of visual impairment caused by uncorrected refractive error was higher among overweight children compared to underweight and normal children. Children who had poor academic performance had a higher prevalence of visual impairment caused by uncorrected refractive error compared to children who had average and good academic performance. The determinants of visual impairment caused by uncorrected refractive error were older age, schooling in private schools, belonging to middle and high SES and being overweight. Older age was the strongest determinant. The results showed that factors such as type of school and overweight that were associated with visual impairment due to uncorrected refractive errors were modifiable suggesting that the burden of the disease can be reduced. The need for spectacle correction in this population is high with more than three-quarters of the children with refractive error needing corrective spectacles. Routine eye examinations are essential to identify persons visually impaired from uncorrected refractive error, in whom a simple pair of glasses can prevent visual impairment. This study provides previously unavailable data on determinants of visual impairment caused by uncorrected refractive error in Ghana.

Recommendations

Based on the findings of the study, three areas of action as set out in 1986 in the Ottawa Charter (WHO, 1986), namely health education, reorientation, and advocacy, are recommended as follows:

1. Based on the high prevalence of uncorrected refractive error and its associated visual impairment among children assessed in the schools, health education to address and promote the adoption of eye health promoting behaviors and increase uptake of eye care services should be pursued by public health authorities in Cape Coast. One approach is for teams of health educators to visit schools and run health education sessions, and train teachers and staff in screening for refractive errors. In addition, school health programmes should be augmented to incorporate

regular in-school eye screening that will help in early identification of children at risk of amblyopia

2. In the area of reorientation, strategies to improve access to quality refractive services in the communities, detect children in need of refractive corrections, and make low-cost glasses available to affected children should be pursued by the Ghana Health Service, to decrease the burden of avoidable visual impairment due to refractive error.
3. Based on the finding that being overweight is associated with the development of visual impairment caused by uncorrected refractive error, the Ghana's Ministry of Health should focus on addressing lifestyle factors that lead to overweight and obesity in children.

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APPENDIX A

RESC EYE EXAMINATION FORM

RESC EYE EXAMINATION

Examination Station

School Name: ______________________________

Exam Date _____/_____/_____

SECTION A: CHILD IDENTIFICATION

Child Name: ____________________________________

Child ID:

School Grade Class

Child Age Sex (1: Male; 2: Female)

SECTION B: VISION ASSESSMENT

VA Examiner ID

B1. Child is wearing corrective lenses?0: NO; Go to B3 1: YES

B2. Visual Acuity with corrective lenses:

VA

OD /

OS /

Visual Acuity cannot be determined (reason):

B3. Uncorrected Visual Acuity (UCVA):

UCVA

OD/OS /

Visual Acuity cannot be determined (reason):

SECTION C: EXTERNAL/ANTERIOR SEGMENT EXAMINATION

0: Normal 1: Abnormal 9: Undetermined

C1. Eyelids?

OD If abnormal:

OS If abnormal:

C2. Conjunctiva?

OD If abnormal:

OS If abnormal:

C3. Cornea?

OD If abnormal:

OS If abnormal:

C4. Pupil?

OD If abnormal:

OS If abnormal:

C5. Other anterior segment?

OD If abnormal:

OS If abnormal:

SECTION D: REFRACTION WITH CYCLOPEGIA

D0. Is Uncorrected VA □ 6/9 in both eyes?

0: NO; continue 1: YES; Go to G

9: Undetermined; continue

D1.Pupil dilated □ 6mm AND light reflex absent?

0: NO; Go to E5 1: YES; continue

2: Light reflex absent, but < 6 mm; continue

8: □ 6mm, but light reflex present; Go to E5

9: Undetermined; Go to E5

OD If 0 or 9comments:

OS If 0 or 9, comment:

D3. Autorefraction (staple printout & record results)or Retinoscopy

Examiner ID

Sphere Cyl. Axis

OD

OS

Cannot be examined (reason)________________________

D5. Subjective refraction (with BCVA)

Examiner ID...

GRADE/CLASS ENUMERATION FORM

CLASS (CLUSTER) ENUMERATION

Name of School: ______________________________

School #: _________

Address: ____________________________________

Grade #: _________

Principal's Name: _______________________________

Class #: _________

Number of Children: ______

Enumerator ID: ______

Date: ____/____/_____

Child # ___

Child Name

Age

Sex

Parent/Guardian Name __

Home Address _ _ _ Tel #__

Scheduled Examination Date: ____/____/____

APPENDIX B

QUESTIONNAIRE SURVEY FORM

i. **Childs age...**

ii. **Sex..**

iii. **School..**

iv. **Class..**

Questions on near-work activities

ITEMS	AMOUNT OF TIME CHILD SPENT ON EACH ITEM	
1) doing homework	_______time/week	_____hours _____minutes for each time
2) reading books for pleasure	_______time/week	_____hours _____minutes for each time
3) watching TV/ video	_______time/week	_____hours _____minutes for each time
4) playing computer games	_______time/week	_____hours _____minutes for each time

5) drawing, painting, writing	______time/week	_____hours _____minutes for each time
6) extra tuition classes	______time/week	_____hours _____minutes for each time
7) outdoor activities/games	______time/week	_____hours _____minutes for each time
8) playing football/ampe	______time/week	_____hours _____minutes for each time
9) playing cards	______time/week	_____hours _____minutes for each time
10) Others, please describe____	______time/week	_____hours _____minutes for each time

Supplementary questions on near work activities

1. Please evaluate the distance between book and child's face when your child read or write

   ☐ 0-10 cm ☐ 10-20 cm ☐ 20-30 cm ☐ >30 cm ☐ Not sure

2. Please evaluate the distance between TV and child when he/she watches TV

   ☐ <1 m ☐ 1-2 m ☐ 2-3 m ☐ > 3m ☐ Not sure

3. Usually, how long will your child continuously read or doing nearwork before he/she has a rest?

☐ 0-15 minutes

☐ 16-30 minutes

☐ 31-45 minutes

☐ 46-60 minutes

☐ 61-90 minutes

☐ 91-120 minutes

☐ >120 minutes

Questions on parental refractive status

1. Relationship of parent to child

☐ Father

☐ Mother

☐ Guardian

☐ others

2. Occupation of parent

....

3. Level of education of parent

☐ primary/basic

☐ secondary

☐ tertiary

☐ no education

☐ others

4. Do you wear glasses?

☐ No

☐ Yes

☐ Not sure

5. For what purpose do you wear glasses?

☐ distance vewing

☐ near viewing

☐ both distance and near viewing

☐ not sure

6. At what age were the first glasses prescribed

....

7. Can you read without glasses?

☐ No ☐ Yes ☐ Not sure

APPENDIX C

INFORMED CONSENT FORM

Child Name: ____________________ School #: ____ Grade #: ____

Class #: ____

Researchers Name: _DR ALEX ILECHIE_______

I am Dr Ilechie Azuka Alex of the University of Cape Coast, Central Region of Ghana. I am studying the determinants of visual impairment due to uncorrected refractive error among school children in Cape Coast.

Purpose: In children it is quite common that a number of them may have impaired or low vision and may not be able to see the blackboard clearly in a class room. Such child may not be able to perform well in studies because of this impaired vision. Impairment because of myopia, or short sightedness, can easily be corrected by wearing appropriate devices such as glasses. Many children or parents may not know about the presence of such problems. In Ghana we do not have reliable data on the magnitude of this problem. After examining a large number of school children we will know the extent of the problem. This will help in planning adequate eye service for school children by government or school authorities. To obtain such important information I invite your child to have his/her eye examined. Your child will receive a free complete eye examination that includes routine tests of the eyes and vision. If your child participates in the examination he/she may require the instillation of eye drops (Cyclopentolate 1%), which may cause temporary glare and difficulty in reading printed materials for up to one day. The examination may last ten minutes to one hour. This is a routine procedure performed for eye examination by optometrists in their daily clinical practice.

Benefits: The examination will detect if your child has any abnormalities. If your child has defective vision which can be corrected by glasses he/she will be given free glasses. If medical/surgical treatment for your child's eyes is necessary, you will be given an explanation and your child will be referred to an appropriate hospital/clinic.

Confidentiality: The examination information will be kept confidential and will not be given to anyone outside the study. Your name and your child's name will never be used in any reports.

Right to refuse or withdraw: Your child's participation is voluntary and he/she can withdraw from the study after having agreed to participate. Your child is free to refuse any aspect of the examination.

This study has been approved by the University of Cape Coast Institutional Review Board. This committee's task is to make sure that research participants are protected from harm.

If you have any questions you may ask now or later. If you wish to ask question later, you may contact the address below.

Dr Alex Azuka Ilechie

Department of Optometry

University of Cape Coast

Mobile: 0244170148

APPENDIX D

CERTIFICATE OF CONSENT

My child has been invited to take part in the research on visual impairment among school children in Cape Coast. I have read the foregoing information, or it has been read to me. I have had opportunity to ask questions about it and any questions that I have asked have been answered to my satisfaction. I consent voluntarily for my child's participation as a subject in this study and understand that my child has right to withdraw from the study at any time without any way affecting his medical care.

Name:______________________________

Signature: ____________________________

Date:___________________

If illiterate:

Name of independent literate witness:

____

Signature:____________________________

Date:____________________

(If possible, the witness should be selected by the illiterate participant and have no connection to the research team)

Name of Researcher:_________________

Signature:___________________________

Date: ____________________

APPENDIX E

LIST OF ACTIONS TAKEN/EQUIPMENT USED

0: None indicated

1: Glasses prescribed & to be provided

2: Glasses prescribed only

3: On-site medical treatment given

4: Prescribed medical treatment

5: Referred to Eye Center

6: Other/Multiple actions

If other/multiple actions specify:

EQUIPMENT (per clinical team)

Retro illuminated LogMAR Vision Charts (2)

Magnifying loupe (1)

Torch Lights (4)

Streak Retinoscope (4)

Trial frame (paediatric and adult size) and trial lens set (4)

Hand held Slit Lamp (1)

Direct ophthalmoscope (4)

Computer and software (SPSS software)

MEDICAL SUPPLIES

Cyclopentolate 1% eye drop (1 ml per child)

Other medications –Common antibiotics drops and anti-inflammatory drops for allergic conjunctivitis