Causes of Childhood Blindness in North Ghana: Results From a School for the Blind in Wa, Upper West Region

by

Grace Jeakyung Huh

Duke Global Health Institute
Duke University

Date:_____
Approved:

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Sasapin Grace Prakalapakorn, Co-supervisor

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Christopher Woods, Co-supervisor

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Joanna Asia Maselko

Thesis submitted in partial fulfillment of
the requirements for the degree of
Master of Science in the Duke Global Health Institute
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ABSTRACT

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Abstract

Background: Because most developing countries lack sufficient resources and infrastructure to conduct population-based studies on childhood blindness, it can be difficult to obtain epidemiologically reliable data available for planning public health strategies to effectively address the major determinants of childhood blindness. The major etiologies of blindness can differ regionally and intra-regionally. The objective of this retrospective study was to determine (1) the major causes of childhood blindness (BL) and severe visual impairment (SVI) in students who attend Wa Methodist School for the Blind in Upper West Region, North Ghana, and (2) any potential temporal trends in the causes of blindness for this region.

Methods: In this retrospective study, demographic data and clinical information from an eye screening at Wa Methodist School for the Blind were coded according to the World Health Organization/Prevention of Blindness standardized reporting methodology. Causes of BL and SVI were categorized anatomically and etiologically. We determined the major causes of BL/SVI over time using information provided about the age at onset of visual loss for each student.

Results: The major anatomical causes of BL/SVI among the 190 students screened were corneal opacity and phthisis bulbi (n=28, 15%), optic atrophy (n=23, 13%), glaucoma (n=18, 9%), microphthalmos (n=18, 9%), and cataract (n=18, 9%). Within the

first year of life, students became blind mainly due to whole globe causes (n=23, 26%), cataract (n=15, 17%), and optic atrophy (n=11, 13%). Those who became blind after age one year had whole globe causes (n=26, 26%), corneal opacity (n=24, 24%), and optic atrophy (n=13, 13%).

Conclusion: At the Wa Methodist School for the Blind, the major anatomical causes of BL/SVI were corneal opacity and phthisis bulbi. About half of all students became blind within the first year of life, and were disproportionately affected by cataract and retinal causes in comparison to the other students who became blind after age one year. While research in blind schools has a number of implicit disadvantages and limitations, considering the temporal trends and other epidemiological factors of blindness may increase the usefulness and/or implications of the data that come from blind school studies in order to improve screening methods for newborns in hospitals and primary care centers, and to help tailor preventative and treatment programs to reduce avoidable childhood blindness in neonates and schoolchildren.

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1. Introduction

In 2010, an estimated 285 million people were visually impaired worldwide, of whom 39 million were blind (Pascolini & Mariotti, 2011; World Health Organization, 2014). According to the World Health Organization's (WHO) categories of visual impairment, severe visual impairment is characterized by a visual acuity (VA) of less than 6/60 to 3/60, while blindness is defined as a VA of less than 3/60 to no perception of light (NPL) (Table 1) (World Health Organization, 1977). VA is a measure of one's ability to discern letters or symbols at a given distance and is scored in comparison to a "normal" vision. Having 6/6 VA indicates the ability to see clearly at six meters of what should be normally seen at that distance, while 6/18 indicates that the person can see at six meters what should normally be seen at eighteen meters (Stevens, 2007).

Table 1. WHO categories of visual impairment.

Normal vision	6/18 or better
Visual impairment	Less than 6/18 to 6/60
Severe visual impairment	Less than 6/60 to 3/60
Blind	Less than 3/60 to NPL

NPL, no perception of light
Note. Adapted from "Manual of the International Statistical Classification of Disease, Injuries, and Causes of Death," by World Health Organization, 1977, Geneva: World Health Organization.

Low-income settings in developing countries bear about 90% of the global burden of all blindness (World Health Organization, 2014). Epidemiological patterns of

blindness and low vision vary across regions by socioeconomic development, but overall global prevalence of blindness is projected to reach 76 million by 2020 if no significant intervention is implemented (Pizzarello et al., 2004).

Blindness is considered "avoidable" if the condition can be treated or is preventable by known and cost-effective means (International Agency for the Prevention of Blindness, 2016). In low-income countries, avoidable blindness can be categorized into three different groups: the primary level includes diseases for which there are successful, affordable treatments such as cataract and refractive error; the secondary level includes conditions that afflict specific populations and are prevented by cheap medicines such as vitamin A deficiency, trachoma, and onchocerciasis; the third level of avoidable blindness include diseases like glaucoma and diabetic retinopathy, for which screening and treatment are cost-ineffective and typically unavailable to poor people (Lewallen & Courtright, 2001).

To date, about 80% of global blindness is deemed avoidable and is attributable to cataract, glaucoma, corneal opacities, trachoma, childhood blindness, and onchocerciasis (Figure 1) (Pascolini & Mariotti, 2011; World Health Organization, 2016a).

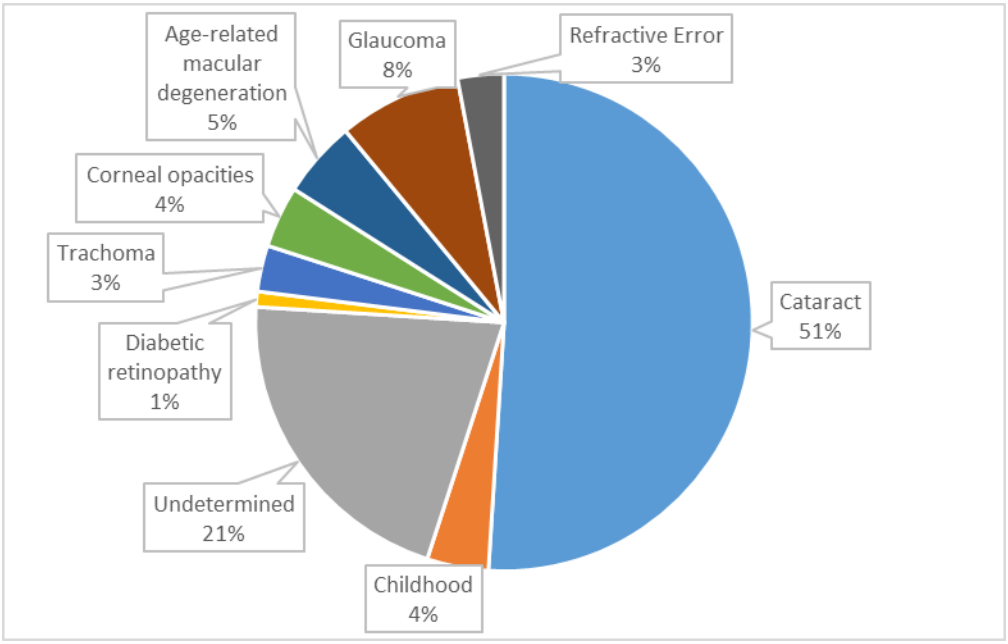


Figure 1. Causes of global blindness in 2010. Adapted from "Global estimates of visual impairment: 2010," by D. Pascolini & S. P. Mariotti, 2011, *British Journal of Ophthalmology, 96*(5), 614-618. doi: 10.1136/bjophthalmol-2011-300539

1.1 Childhood visual impairment

In 2010, an estimated 19 million children of ages 0 to 15 years were visually impaired, and over 1.4 million children were irreversibly blind (Pascolini & Mariotti, 2011; World Health Organization, 2014). Of the 1.4 million blind children globally, 1 million are in Asia and 300,000 are in Africa (Programme for the Prevention of Blindness and Deafness & International Agency for the Prevention of Blindness, 2000). The sparsity of reliable data and surveillance systems makes it difficult to estimate incidence, but an estimated 500,000 children become blind every year (Kocur, 2007).

A systematic review on the data for global pediatric blindness and United States blind schools concluded that 7 to 31% of childhood blindness is avoidable, 10 to 58% is considered treatable, and 3 to 28% is preventable in developing countries (Kong, Fry, Al-Samarraie, Gilbert, & Steinkuller, 2012). The primary causes of childhood blindness differ from region to region, and is mostly based on socioeconomic development (Gogate & Gilbert, 2007). In middle- and high-income countries, the primary causes are cataract, retinal diseases, lesions of the optic nerve and higher visual pathways (C. E. Gilbert & Foster, 2001; Gogate, Kalua, & Courtright, 2009). In low economic settings with poor public health infrastructure and health care service delivery, the primary causes of blindness in children are corneal opacity as a result of measles; vitamin A deficiency; ophthalmia neonatorum, which is a neonatal conjunctivitis that can be potentially blinding if the infection is gonococcal; deleterious traditional eye remedies; and cataract secondary to rubella (Foster & Klauss, 1995; C. E. Gilbert & Foster, 2001; World Health Organization, 2016b). Most blind children are blind since birth or become blind before their fifth birthday (Kocur, 2007).

1.2 The VISION2020 Initiative for combatting childhood blindness

In 1999 the VISION2020: The Right to Sight plan was initiated, which was a joint program organized by WHO and the International Agency for the Prevention of Blindness (IAPB), whose mission was to eliminate avoidable blindness by year 2020 through the intensification and acceleration of preventative activities worldwide.

Specifically, the three key strategies of this program were to (1) expand cost-effective interventions for disease control; (2) provide technical support and motivation for human resource development; and (3) expand service accessibility through infrastructural development of facilities and treatment technologies (Solomon, 2005; Thylefors, 1998).

Childhood blindness in particular was deemed a priority for VISION2020, as there are heightened risks for mortality and disability that are associated with blind years. Blindness is closely linked to child survival - for instance, up to 60% of children in developing countries die within one year of becoming blind, especially those who became blind from measles, meningitis, rubella, prematurity, genetic diseases, and head injuries (C. E. Gilbert & Foster, 2001). Amblyopia, which is visual loss in one or both eyes due to abnormal development of vision during infancy or early childhood, is another time-sensitive risk factor that necessitates prompt treatment and monitoring of avoidable causes of blindness. For blind children who survive childhood, the irreversibility of amblyopia in adulthood heightens the urgency of treating childhood eye pathologies early on (C. E. Gilbert & Foster, 2001; Kocur, 2007; Kong et al., 2012).

1.2.1 The impact of VISION2020 on global childhood blindness

The collaborative efforts of partners in the VISION2020 program have led to significant progress over the past 20 years, particularly in public health, that has reduced the prevalence of avoidable childhood blindness. For instance, measles vaccination

campaigns became a large-scale public health intervention to combat child mortality and morbidity attributed to measles epidemics. In 2004, there were 454,000 deaths caused by measles, which is 48% lower than the global mortality rate in 1999 (Kocur, 2007; Measles & Rubella Initiative, 2014). However, there are still communities in poor socioeconomic settings, particularly in sub-Saharan Africa, that are still susceptible to measles outbreaks and related deaths and morbidity. An estimated 98% of measles-associated deaths are still in sub-Saharan Africa (Kocur, 2007; Measles & Rubella Initiative, 2014). The Measles Initiative, which is a joint program between multiple organizations including the United Nations International Children's Emergency Fund (UNICEF) and WHO, have focused on this region with the goal to reduce mortality by 90% by 2010 (Kocur, 2007). In turn, combating measles has also reduced avoidable childhood blindness due to corneal perforation and scarring that occurs secondary to measles.

Vitamin A deficiency (VAD) has been another significant cause of avoidable childhood blindness, especially since VAD is commonly observed concomitantly with measles and can lead to xerophthalmia. Xerophthalmia is the spectrum of ocular changes that results from severe VAD and includes night blindness, conjunctival and corneal dryness, corneal ulceration, and corneal softening and necrosis (International Vitamin A Consultative Group, UNICEF, & World Health Organization, 1997). Its associated morbidity and mortality in children worldwide has decreased concomitantly with VAD due to the supplementation campaigns in developing countries (C. E. Gilbert

& Muhit, 2008). While distributions of vitamin A supplementation coincide with mass measles vaccination campaigns in many developing countries, 190 million children under age 5 still have VAD, the majority of whom are in Africa and Southeast Asia (International Agency for the Prevention of Blindness, 2016; Kocur, 2007). However, significant progress has been made due to the increase of vitamin A supplementation coverage globally from 50% to 66% for children under age 5, thereby reducing VAD-associated deaths by 1 million children from 1998 to 2000 (Kocur, 2007).

Other major causes of avoidable childhood blindness, such as ophthalmia neonatorum, rubella, and retinopathy of prematurity, are all issues that necessitate a stronger awareness among mothers and local primary health care centers about effective treatment and preventative measures. For instance, ophthalmia neonatorum is an infection of the conjunctiva that can be contracted from the mother's birth canal during delivery, and is caused by chemical, bacterial, or viral agents. *Neisseria gonorrhoeae* and *Chlamydia trachomatis* are the most commonly seen types of bacterial infection (Fransen & Klauss, 1988). Ocular prophylaxis is recommended as a highly effective preventative strategy for certain strains of bacterial infections, while systemic antibiotics or other drugs are available for treating infants. Ophthalmia neonatorum is a significant cause of childhood blindness in regions with high prevalence of maternal gonococcal infection, a strain that rapidly leads to blindness in the infant (Fransen & Klauss, 1988; Laga, Meheus, & Piot, 1989). VISION2020's strategy of effective disease control in low-income

economic settings includes an education component for the community and primary health care centers to use ocular prophylaxis, avoid harmful traditional remedies, and increase awareness in mothers about the prevention and treatment of sexually transmitted infections or other infectious diseases that can lead to childhood blindness (Kocur, 2007).

Since 2006, the VISION2020 Global Initiative has paved the way for a series of complemental action plans that have built upon VISION2020. The Global Initiative for Elimination of Avoidable Blindness Action Plan for 2006 to 2011 represented a notable revision of VISION2020's mission to not only eliminate avoidable blindness, but also to eliminate avoidable visual impairment such as uncorrected refractive error (International Agency for the Prevention of Blindness, 2016; Kocur, 2007). The Universal Eye Health: A global action plan for 2014 to 2019 is the most recent action plan that was adopted in 2013. It reiterates the main mission of VISION2020 to eliminate avoidable blindness and visual impairment, while further expanding its goals to promote universal access to comprehensive eye care services (International Agency for the Prevention of Blindness, 2016).

1.3 Research in blind schools

One of the mains strategies of the VISION2020 global initiative is to monitor the epidemiological patterns of childhood blindness in order to coordinate the most appropriate control measures and programs to prevent childhood visual loss (Solomon,

2005). However, one limitation is the lack of adequate population-based epidemiological data on the prevalence and major causes of blindness in children (C. E. Gilbert & Foster, 2001; Kocur, 2007). Also because most low- and middle-income countries lack the infrastructure and resources to conduct population-wide surveys and national blind registers, the vast majority of available literature on childhood blindness is based on research that has been conducted in blind schools.

Research conducted in blind schools has several implicit biases that limit its external validity for overall childhood blind populations: (1) there is a high potential for bias that would exclude certain populations, as one estimate suggested that only 10% of blind children are in special disabilities schools across the globe, and children with multiple disabilities do not meet enrollment criteria of some blind schools (C. E. Gilbert & Foster, 2001); (2) pre-school children are underrepresented in blind schools (C. E. Gilbert, Canovas, Hagan, Rao, & Foster, 1993); and (3) the high mortality rate associated with certain causes of blindness would result in a skewed representation in the blind school of the distribution of causes of blindness in the region. For example, a higher infant mortality associated with rubella with associated cataract would lead to an underestimation of the prevalence of childhood blindness caused by rubella cataract, as represented a group of students in a blind school who survived early childhood.

Despite the implicit limitations of research in blind schools, blind school surveys have become accepted methods for collecting epidemiological data to determine

regional prevalence and main causes of childhood visual impairment. Researchers are able to examine a large number of blind children during a single screening, which would be unlikely for population-based studies, and there is greater conformity in reporting data by a single team of researchers (C. E. Gilbert et al., 1993). Research in blind schools can be used to help tailor community-based active case finding programs for identification and referral of child patients to tertiary care, and also to improve screening programs in hospitals and primary care centers for early identification of visually impaired newborns and infants (Steinkuller et al., 1999).

1.4 Ghana

1.4.1 Country profile

Ghana is located in West Africa, neighboring Burkina Faso to the north, Cote d'Ivoire to the west, and Togo to the east. The country has an area of 238,533 square kilometers, which is the relative size or Oregon in the United States. In 2015, the estimated population was 26,237,649, with a positive growth rate of 2.18% (Central Intelligence Agency, 2016). Ghana has ten administrative regions, three of which comprise the northern part of the county – Northern, Upper East, and Upper West regions.

Ghana is currently experiencing a youth bulge, with children of ages 0 to 14 comprising almost 40% of the population (Figure 2). The youth dependency ratio, which is a ratio of the number of dependents aged 0 to 14 to the total population, is 67.2%

(Central Intelligence Agency, 2016). In 2015, 54% of the total population lived in urban areas, with an urbanization rate of 3.4% annual increase between 2010 and 2015 (Central Intelligence Agency, 2016). However, the urbanization rates differ drastically between northern and southern regions of Ghana – for instance, the Greater Accra Region in the south was most urbanized at 87.4% in 2000, with the other southern regions having urbanization rates ranging from 26.6% to 53.2%. The three northern regions had urbanization rates of 27%, 17.5%, and 15.1% in the Northern, Upper West, and Upper East regions, respectively (Songsore, 2010).

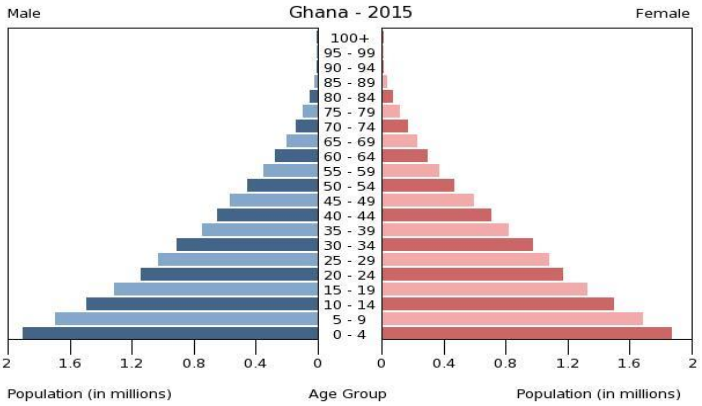


Figure 2. The population pyramid of Ghana in 2015. Reprinted from *Ghana. In the World Factbook*, by Central Intelligence Agency, 2016. Retrieved from https://www.cia.gov/library/publications/resources/the-world-factbook/geos/gh.html.

Despite the notable progress made in the reduction of communicable diseases in the past 25 years, the top 10 causes of years of life lost (YLL) in 2013 were communicable, maternal, neonatal and nutritional diseases (Institute for Health Metrics and Evaluation, 2015). In 2010, the three main causes of premature death in Ghana, as

quantified by the number of YLLs, were malaria, HIV/AIDS, and lower respiratory infections. Diarrheal diseases, which used to be the third leading cause of YLLs in 1990, decreased by 65% by 2010. Ghana also saw a drastic decrease in the prevalence of malaria by 94.7% from 1990 to 2013 (Institute for Health Metrics and Evaluation, 2015).

1.4.2 Disparate economic development between North and South Ghana and its implications on health

Ghana experienced rapid economic growth over the past thirty years since its adoption of the Structural Adjustment Program (SAP), which was a set of neoliberal economic policies that conditioned the nation to rely heavily on an export-based economy and reduce state intervention on foreign trade and production. This resulted in rapid but unstable economic growth (Kraus, 1991). Between 1983 and 2000, the average economic growth rate was 4.7%, and 7.2% between 2000 and 2013. Poverty reduction was also a large economic achievement, from 7.9 million to 6.3 million people between 1990 and 2006 (Osei-Assibey, 2014). Despite this, there is a distinct north-south divide in which the northern regions are significantly less-developed and still have relative high poverty rates (Figure 3) (Ghana Statistical Service, 2015). For instance, in the South the poverty rate decreased from 48% to 20% between 1992 and 2006, while the North only experienced a marginal decrease from 69% to 63%. The Gini coefficient, an index used to represent inequality of income distribution, increased from 0.37 to 0.42 from 1992 to 2006 (Osei-Assibey, 2014). The Upper West region in North Ghana has the highest poverty incidence of 70.7% in the country (Ghana Statistical Service, 2015).

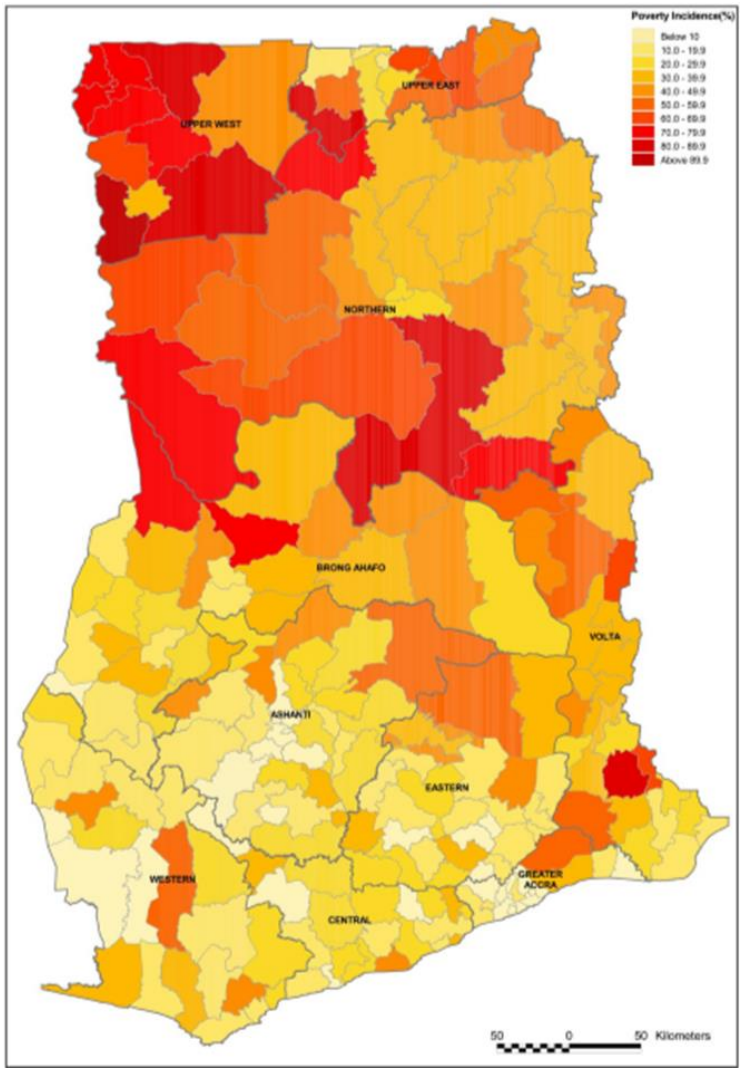


Figure 3. Incidence of poverty in Ghana in 2015. Reprinted from "Ghana Poverty Mapping Report," by Ghana Statistical Service, 2015, Retrieved from http://www.statsghana.gov.gh/docfiles/publications/POVERTY%20MAP%20FOR%20GHANA-05102015.pdf.

The stark economic regional inequality has important implications on health and education. For example, the under-five mortality rate is 75 per 1000 live births in the Greater Accra region in the South, while the rate in the Upper West Region of North

Ghana is 208 per 1000 live births (Shepherd, Gyimah-Boadi, Gariba, Plagerson, & Musa, 2006). The disparate child malnutrition prevalence is another indicator of regional inequality, as the three northern regions have underweight levels above the national average as well as the highest levels of stunted growth in the country (Shepherd et al., 2006). Regarding education, the adult literacy rates ranged from 44.6% to 76.6% for the southern regions in 2003, while those of the northern regions ranged from 22.6% to 24.4% (Shepherd et al., 2006).

1.4.3 Eye health in Ghana

Overall, cataract is the leading cause of blindness in Ghana and accounts for about 50% of the cases, followed by glaucoma (8.5%), for which Ghana has the second highest prevalence in the world (Bowen, 2011; Gyasi, 2006). Estimated childhood blindness is 5 to 10% of the national burden of blindness, affecting an estimated 0.9 per 1000 children (Essuman, 2013; Potter, Debrah, Ashun, & Blanchet, 2013.). To date, there are only three blind school studies that were conducted on childhood blindness in Ghana, all three of which were based on the Akropong School for the Blind in the south, with one also including data from Wa Methodist School for the Blind in the North and Wenchi Secondary School, which is an integrated school of both visually impaired students and sighted students (Akafo & Hagan, 1990; C. E. Gilbert et al., 1993; Ntim-amponsah & Amoaku, 2008). The most recent study in 2008 showed that the main cause of childhood blindness at the Akropong blind school was corneal opacity due to

measles, bacterial and fungal infectious agents, and harmful traditional remedies (Ntim-amponsah & Amoaku, 2008).

Other studies on childhood visual impairment have been conducted in Ghana. A randomized cross-sectional study on 24 primary and secondary sighted schools in the Greater Accra Region of south Ghana concluded that the estimated prevalence of refractive error in this region was 7.0% and was the major cause of visual impairment observed in the students, while amblyopia, squint, and macular scars were also observed as causes of unilateral visual impairment (Ntim-Amponsah & Ofosu-Amaah, 2007). A retrospective case series study on the prevalence of congenital eye anomalies that was conducted at the pediatric eye clinic of Korle-Bu Teaching Hospital concluded that of all admissions to the clinic over a period of six years, 54% of the cases had congenital eye anomalies. Congenital cataract and glaucoma were the major causes of childhood blindness in this sample, while retinoblastoma accounted for 8.0% of the cases (Ilechie, Essuman, & Enyionam, 2013).

Since the 1990s, more attention has been focused on the inequities between the urban and rural areas and between the south and the north, which have prompted initiatives to bridge the gap. The implementation of Ghana's National Health Insurance Scheme in 2003 was a monumental shift towards universal eye health care, as it now covers the majority of ocular causes of visual impairment (K. Blanchet & James, 2013). Despite the fact that this scheme was vastly expanded to include the poorest, there is

still a significant disparity in eye care provision between North and South Ghana. For instance, there are 52 ophthalmologists, 75% of whom work in the more economically robust South region where only 25% of the population live. There are only five ophthalmologists who serve the four northernmost regions of the country (K. Blanchet, Gordon, Gilbert, Wormald, & Awan, 2012; Gyasi, 2006). A study on optometrists in Ghana showed that 71% of the surveyed practitioners were also disproportionately located in urban centers (Boadi-Kusi, Ntodie, Mashige, Owusu-Ansah, & Antwi Osei, 2015).

Currently, national initiatives are being implemented in order to expand access to eye care to regions where service is limited or nonexistent. For example, in 1996 the Swiss Red Cross and the Ghana Red Cross collaborated to implement an eye care program in the Brong Ahafo region of Central Ghana, where eye care services were previously unavailable. Through this program, an ophthalmologist was able to provide services in the regional hospital and also in district hospitals for outreach surgeries. Ophthalmic nurses were also deployed to provide outreach consultations to local villages and communities, including schools for student eye screenings (K. Blanchet & James, 2014). The 2013 Ghana Country Report for Eye Health Systems Assessment (EHSA) reported that the private sector, national and international donors and health organizations were also contributing to the expansion and quality of eye care access in partnership with the National Eye Care Unit of Ghana (Potter et al., 2013.).

In 2003, WHO implemented a five-year childhood blindness prevention project, in which a center for comprehensive pediatric eye care was established at the Korle Bu Teaching Hospital in the Greater Accra Region of southeastern Ghana. The objectives of the program included training of health workers in primary eye care, increased service delivery for cataract and other treatable causes, improve low vision services, and continue research and evaluation of eye care services in this region (Essuman, 2013). In North Ghana, a similar program called Action Against Childhood Blindness (AACHIB) for expanding comprehensive primary eye care was initiated by the Swiss Red Cross, Ghana Red Cross, the national health service, and its international nonprofit partners (Essuman, 2013). AACHIB included a training program for volunteers to conduct community outreaches in order to identify visually impaired children who could be treated at local hospitals (Ghana News Agency, 2015).

1.4.4 Educational institutions for the visually impaired in Ghana

Currently, there are only two blind schools in Ghana. Wa Methodist School for the Blind is located in the Upper West Region of North Ghana, and Akropong School for the Blind is located close to the country capital of Accra in Eastern Region, south Ghana. There are also integrated primary and secondary schools that educate both sighted and visually impaired students: Wenchi Secondary School in the Brong Ahafo Region in central Ghana, De Youngsters in Accra, Achimota Primary School in Accra, Wa Secondary School, and Okuapeman Secondary School in Akropong, Eastern Region.

Institutions for higher education also offer education services for the visually impaired including Presbyterian Training College in Akropong, N.J. Ahmadiyya Training College in Upper West Region, University of Ghana, Legon in the Greater Accra Region, Kwame Nkrumah University of Science & Technology in the Ashanti Region, Centre for the Blind at the University of Ghana in Accra, and Winneba and Resource Centre at the University of Cape Coast in Central Region ("Chapter One: Overview of Education in Ghana," n.d.).

Founded in 1958 by a group of missionaries, Wa Methodist School for the Blind serves Northern, Upper West, and Upper East regions of North Ghana ("History: Wa Methodist School for the Blind," n.d.). Referral of potential students to this school is done by local missionaries in the region and community-based rehabilitation workers in the area who identify visually impaired students ("Chapter One: Overview of Education in Ghana," n.d.). The school is comprised of six departments: Kindergarten, Primary Education, Functional Education, Junior High School, Vocational Training, and Braille. All students are taught how to read Braille beginning in Kindergarten. The Primary program offers a basic curriculum that includes all subjects that are taught in sighted schools. Junior High is designed to prepare students for the Basic Education Certificate Examination (BECE), which is devised by the Ghana Ministry of Education as one of the criteria for student admission into secondary or vocational schools ("History: Wa Methodist School for the Blind," n.d.). Past students who successfully completed the

BECE pursued higher education in senior high schools and universities of their choices. The Vocational Training program is designed for students who complete Junior High School but are not eligible to continue to Senior High School. Instead, the program aims to prepare the students for future careers in one of the following specialized areas: bed weaving, door mat production, soap production, or pomade production ("History: Wa Methodist School for the Blind," n.d.).

1.5 Research aims

In light of AACHIB and other national initiatives to combat avoidable childhood blindness in North Ghana, more epidemiological data is needed to design and implement effective primary eye care and service delivery programs.

The objective of this retrospective study was to determine (1) the major causes of childhood blindness (BL) and severe visual impairment (SVI) in students who attend Wa Methodist School for the Blind in Upper West Region, North Ghana, and (2) any potential temporal trends in the causes of blindness for this region.

2. Methods

2.1 Setting

This study is based on the data of an eye screening that took place at the Wa Methodist School for the Blind in Upper West Region, North Ghana. Only children who have a vision disability are eligible to enroll in the Wa Methodist School for the Blind, while other students with multiple disabilities are referred to other specialized intuitions in the country. The programs offer specialized education for both blind and visually impaired students as a boarding school. There are currently 190 students enrolled in the school, ranging from ages 6 to 24 years.

2.2 Participants

This study was a retrospective analysis of data previously collected on students enrolled in the Wa Methodist School for the Blind. These students were eligible for inclusion in this study if they had participated in a school-wide eye screening performed in February 2014. The screening team was comprised of one ophthalmologist (JS) and two optometrists from Tamale Teaching Hospital in Tamale, Ghana. Over a two-day period, the screening team conducted a basic eye screening on each student, recording demographic and clinical data on paper forms (Appendix A). The paper forms were later transcribed into an Excel database by the screening ophthalmologist (JS). All 190 students were recruited for the eye screening and all 190 students completed the eye exams.

2.3 Procedures

This was a retrospective study carried out on previously collected data. This study was approved by the International Review Board at Duke University in Durham, North Carolina, U.S.A and the Ethical Review Committee at Tamale Teaching Hospital, in Tamale, Ghana.

2.4 Measures

2.4.1 Demographic variables

The age and gender of each student were self-reported by the student and recorded during the screening.

2.4.2 Self-reported past medical history variables

The self-reported variables on the past medical history of blindness were the onset of blindness and family history of blindness.

The exam sheet that was used during the eye screening denoted the "onset of blindness" variable as "blind since ____" (Appendix A). Because of this notation, there were variations in the way that this data was reported by the student and recorded on the form by the screening team. For instance, some students reported the exact year during which he/she became blind; some reported the age at which he/she became blind; while other students reported the onset of blindness as "since birth," "not at birth," or "late blindness."

For family history, students reported any known immediate or extended family members who were blind or had visual impairment.

2.4.2.1 Transformation of the variable "onset of blindness"

For the purpose of transforming this variable, "not at birth" was assumed to indicate onset of blindness between ages 1 and 15, while "late blindness" was assumed to indicate onset between ages 6 and 15. All students were assumed to have been enrolled at the school for at least one year before the screening, which occurred in February 2014.

The "onset of blindness" variable was then transformed into two new variables: "Age category at onset of blindness" ("age-onset"), and "the year at onset of blindness" ("year-onset").

"Age-onset" had four categories: blind at birth or less than 12 months of age, ages 1 through 5 years inclusive, ages 6 through 15 years inclusive, and over 15 years of age. "Age-onset" was determined using the age of each student and the information provided for the onset of blindness. For instance, a 15-year old student who became blind in 2010 was assumed to have become blind at age 11, and thus was categorized into the "6-15 years old, inclusive" level. There was a number of students who reported ambiguous information for onset of blindness (e.g. "not at birth," "late blindness") and thus could not be categorized into a single age-onset group. Because of this uncertainty in the proper categorizations of these students, two subsequent variables were created

for "age-onset": the lower imputations of the age category at the onset of blindness ("age-onset-lower") and the upper imputations ("age-onset-upper"). "Age-onset-lower" represented the youngest age category that could have been inferred from the available data on the student's age and onset of blindness, while "age-onset-upper" represented the oldest age category that could have been possible for the student's onset of blindness. For example, a student aged 14 years old reported the onset of blindness as "not at birth," which indicates that the onset of blindness could have occurred between the ages of 1 and 13. Because this falls within the "1 through 5 years old" and the "6-15 years old" category for age-onset, the "age-onset-lower" would be the former category, and "age-onset-upper" would be the latter.

"Year-onset" is the second main variable created based on the student's age at the time of the screening and his/her age at onset of blindness, and is a discrete quantitative variable. The year during which the onset of blindness occurred was calculated for each student if the onset was not reported as an exact year. For instance, given that the screening examination was performed in the year 2014, a student of age 13 years who was reported to be blind since birth was assumed to have become blind in the year 2001 and thus was assigned a "year-onset" value of 2001. A 10-year old student who became blind at birth had "year-onset" value of 2004. There was a number of students for which "year-onset" could not be specifically determined – for example, an 11-year old had "late" onset of blindness. In this case, the range of years during which

the student could possibly have become blind was calculated, and the median was used as the imputation for year-onset. In this example, the student could have become blind between ages 6 and 10, which corresponds with years 2009 and 2013. The median of these years is 2011, which was recorded as the "year-onset" impute. A 16-year old who had "late blindness" could have become blind between ages 6 and 15, which correspond to years 2004 and 2013, so the median of year 2008 was used.

Two separate binary variables were created that indicated whether "age-onset" and "year-onset" were imputed ("onset-impute" and "year-impute"). For instance, a student whose "year-onset" was imputed had "year-impute" = 1, while a student whose exact year of onset of blindness was reported had a "year-impute" = 0.

2.4.2.2 Transformation of the variable "family history"

Family history was transformed into a binary variable, with 0 indicating "no family history of blindness" and 1 indicating "positive family history of blindness."

2.4.3 Clinical variables

The clinical variables recorded during the eye exam were visual acuity, intraocular pressure, ocular alignment, pupil reactivity, and nystagmus.

2.4.3.1 Visual acuity (VA)

The screening team and the school staff were trained to assess VA. A Snellen distance VA chart was used to record best uncorrected, meaning without optical correction (e.g. glasses or contact lenses), VA at 6 meters for each eye independently, of

every student. VA was recorded in meter notation (e.g. 6/60), counting finger at X meters (CF @ Xm), hand motion (HM), perception of light (PL), or no perception of light (NPL). No student owned corrective lenses. The students with aphakia were provided corrective lenses by the screening team during the eye exam and their best VA was tested with and without correction.

VA was later categorized according to the WHO categories of visual impairment (Table 1, above). The categories were: < 6/18 to 6/60, < 6/60 to 3/60, < 3/60 to 1/60, < 1/60 to LP, and NPL.

2.4.3.2 Intraocular pressure (IOP)

An Icare® rebound tonometer was used to determine the IOP of each eye of each student, and was recorded as discrete integers. The IOP is the pressure inside the eye and is used to help the screener ascertain whether patients are at risk for or have glaucoma (Tsai, 2016).

2.4.3.3 Ocular alignment

Ocular alignment was noted by the ophthalmologist or optometrist using a pen light. There are four categories: normal alignment, esotropia (ET) meaning that one or both eyes turn inwards, exotropia (XT) or the outward turning of one or both eyes, and other. This measure is used to evaluate whether a patient has strabismus, or ocular misalignment in which both eyes are not simultaneously aimed at the same fixation point (Wright, Spiegel, & Thompson, 2006).

2.4.3.4 Pupil reactivity

The pupil reactivity of each eye of each student was assessed by the ophthalmologist or optometrist using a penlight. This assessment of pupillomotor function and reaction to light has clinical significance that can inform the screener of neurogenic or non-neurogenic etiologies of visual loss (Carlson, Kurtz, Heath, Hines, & Flom, 2004). Reactivity was described as normal, slow reaction to light stimulus, irregular reaction to light stimulus, nonreactive to light stimulus, or indeterminable.

2.4.3.5 Nystagmus

Presence of nystagmus, a repetitive and uncontrolled eye movement, was noted by the ophthalmologist or optometrist as "yes" or "no."

2.4.3.6. Primary and secondary diagnoses

A clinical eye examination was performed for each eye of each student using a portable slit lamp, a direct ophthalmoscope, and indirect ophthalmoscope by the ophthalmologist or optometrist. Each student's eye was pharmacologically dilated. The clinical findings were then used to make primary and any secondary diagnoses of cause of visual loss for each eye of each student. The etiological cause of blindness in each student was also noted by the screener according to the WHO/PBL Eye Examination Record For Children with Blindness and Low Vision, which lists categories of etiological causes of visual loss (Appendix B) (C. Gilbert, Foster, Négrel, & Thylefors, 1993).

2.4.3.6.1. Transformation of the variables, primary diagnosis and etiological cause

The WHO/PBL Form for reporting childhood blindness was used as a template to design the coding of the primary and secondary diagnoses as the major and minor anatomical abnormalities, respectively, leading to visual loss in each eye (Appendix B). The WHO/PBL form includes anatomical causes of blindness, which are further categorized by anatomical site of abnormality leading to visual loss, and etiological causes of blindness. Thirty-four separate binary variables were created for each anatomical cause of blindness listed in the WHO/PBL form – for example, the variable "phthisis" has two levels, 0 for no and 1 for yes, to denote whether this was a major cause of blindness for the student.

The WHO/PBL form was also used to categorize the etiological causes of blindness. Twenty-six separate binary variables were created for each etiological cause of blindness listed in the WHO/PBL form, in the same format as mentioned above for anatomical causes. For example, the variable "measles" has two levels, 0 and 1, to indicate whether this was the student's etiological cause of blindness.

The primary diagnosis of each eye of each student and the VA of each eye were used to determine the major site of anatomical abnormality leading to visual loss for the student ("major-site-child"). The major-site-child variable was created using the WHO/PBL Eye Examination Record coding instructions for Section F.124 (Appendix C) (C. Gilbert et al., 1993). The levels within this categorical variable are the anatomical sites of the eye: normal globe, whole globe, cornea, lens, uvea, retina, optic nerve, other, and

unknown, and the diagnoses were classified according to the WHO/PBL Form Section F. For example, one student had the same primary diagnosis of end-stage primary open-angle glaucoma for both the right eye and left eye, meaning that the major-site-child of this student is whole globe. Another student had a retinal scar in the right eye and a corneal scar in the left eye. According to the instructions, the most treatable cause of visual loss should first be selected – because corneal scars may potentially be treatable with a corneal transplant or preventable but retinal scars are irreversible, the major-site-child in this case is cornea. The major-site-child was determined by the researcher and was verified by a fellowship-trained pediatric ophthalmologist (SGP).

2.5 Literature Search

We performed a literature search on PubMed (MEDLINE) for English-language only articles for the period 1946 to 2016, using combinations of the following search terms: *Ghana blind schools AND/OR childhood visual impairment AND/OR blindness AND/OR visual loss*.

2.6 Analysis

For this study, a de-identified version of the Excel database, created and sent electronically by the screening ophthalmologist (JS) via a secure Duke Box account to the researcher. For this study, we constructed a second Excel spreadsheet database that included the original de-identified data and the transformed variables that were manually entered by the researcher. Data entry verification was completed by the

researcher in multiple iterations over several days following the completion of data entry. Stata 13.1 (StataCorp LP, College City, TX, USA) was used for all data analysis. All tables and figures were adapted from the Stata analyses and were formatted in Microsoft® Excel® 2013.

Missing data for the variable "age category at onset of blindness" were resolved by creating lower and upper imputations for each missing case, and the lower and upper imputations were used for separate analyses for statistical comparison. However, the lower-bound imputations were used in the full analysis, as one study showed that most children become blind within the first five years of life, which corresponds with the lower levels of the variable (Kocur, 2007). The variable "year of onset of blindness" were resolved as described above (Section 2.4.2.1).

2.6.1 Statistical tests for Aim #1

2.6.1.1. Distribution of the major causes of blindness

The major anatomical site of abnormality leading to overall visual loss for the student (major-site-child) was used to describe the distribution of the major causes of blindness in the sample. All students were included in the general summaries for the anatomical causes and the etiological causes of blindness. Next, we compared our findings of the prevalence and causes of blindness found at Wa Methodist School for the Blind with the results from a study conducted in 2008 at Akropong School for the Blind, which was found during the literature search (Ntim-amponsah & Amoaku, 2008).

2.6.1.2. Distribution of the major causes of blindness, categorized by age at onset of blindness

The major-site-child variable was used to describe the distribution of major causes of blindness, which was categorized by the age category at onset of blindness. Students who became blind after 15 years of age were excluded from this part of the analysis for two reasons: 1) they do not fit the definition of having childhood blindness, which occurs during the first 15 years of life; and 2) the sub-sample size of this group was too small to be compared to the other three categories in this variable in the statistical analysis. For students with missing data on the age at onset of blindness, the lower-bound imputations as described in Section 2.4.2.1 were used for this analysis. However, a separate analysis using the upper-bound imputations for age category at onset of blindness was also conducted (Appendix B).

The number of students who became blind from each category within the major-site-child variable (e.g. whole globe, cornea, lens) was tabulated with the age categories at onset of blindness in order to form a 2x3 table. Fisher's Exact Tests were conducted for each major-site-child variable, with a Cronbach alpha of 0.05 used to determine statistical significance of any differences in the proportion of cases of blindness between age categories. This addresses the aim of whether a certain cause of blindness was observed disproportionally in one or more age categories at onset of blindness.

2.6.2 Statistical tests for Aim #2

In order to assess for temporal trends in the anatomical and etiological causes of blindness, a linear regression was constructed with year of onset of blindness as the dependent variable, and the causes of blindness and age at onset of blindness as the independent variables. Two different regressions were conducted, one for the anatomical causes of blindness, and one for the etiological causes of blindness. The imputed variables for the age at onset and the year of onset variables were also included in the regression as covariates to adjust for the imputations. Students who became blind after age 15 years were excluded from this portion of the analysis for the reasons stated above (Section 2.5.2). Cronbach alpha coefficient of 0.05 was used to determine statistical significance of the coefficients of the independent variables.

By setting the year of onset of blindness as the independent variable, the regression makes it possible to compare the mean year of onset of blindness for the groups of students who had different anatomical causes and etiological causes of blindness. Assuming that the function of incidence of blindness due to each cause does not contain multiple relative extrema, the coefficients from this regression should be able to yield reasonable estimates of years during which prevalent causes of blindness occurred. However, no statistical tests are available to compare the magnitudes of the coefficients of the regressions, so the coefficients of the regressions will be discussed within a practical context/significance.

Scatter plots were also constructed for anatomical and etiological causes of blindness across time to identify any clusters of cases within time frames.

3. Results

3.1 Description of the sample

Of the 190 students who were enrolled at the school during the time of the screening, 190 (100%) were screened. Students' ages ranged from 6 to 24 years (mean age = 15 years). Of the total sample, 41 (22%) of the students reported a family history of blindness, and 86 (45%) of the students were noted to have some degree of residual vision, which was subjectively determined by the blind school staff and was considered present if the visual acuity was better than no light perception (Table 2). The majority of students were blind (n=188, 99%), and 2 (1%) had visual impairment (Table 3). The summary of the clinical data for IOP, pupil reaction, nystagmus, and ocular alignment are shown in Table 4.

Table 2. Summary of demographic and self-reported history variables of the students examined during the Wa Methodist School for the Blind eye screening.

Age in years, M (SD)	15.2 (4.3)
Gender, n (%)	
Female	81 (43)
Male	109 (57)
Family History of blindness, n (%)	
No	149 (78)
Yes	41 (22)
Residual Vision*, n (%)	
No	104 (55)
Yes	86 (45)
*residual vision was subjectively determined by the blind school staff and was considered present if the visual acuity was better than no light perception.	

Table 3. Results of visual acuity measurement of the better-seeing eye for the students in Wa Blind School, using WHO categories of visual loss.

Category of visual loss	N (%)
Normal Vision (6/18 or better)	0 (0)
Visual Impairment (Less than 6/18 to 6/60)	2 (1.1)
Severe Visual Impairment (Less than 6/60 to 3/60)	0 (0)
Blind	
Less than 1/60 to light perception	125 (65.8)
No light perception	63 (33.2)

Table 4. Summary of the clinical variables of the students examined during Wa Methodist School for the Blind eye screening.

Intraocular Pressure (mmHg)	Mean (SD)	Minimum	Maximum
Right eye	20.7 (10.9)	2	64
Left eye	21.2 (12.0)	4	62
Pupil Reaction	n (%)		
Right eye			
Normal	61 (32)		
Slow	6 (3)		
Irregular	1 (1)		
Non-reactive	44 (23)		
Indeterminable	79 (41)		
Left eye			
Normal	62 (32)		
Slow	6 (3)		
Irregular	2 (1)		
Non-reactive	42 (22)		
Indeterminable	79 (41)		
Ocular Alignment			
Normal	125 (65)		
Esotropia	19 (10)		
Exotropia	36 (19)		
Indeterminable	11 (6)		
Nystagmus			
No	89 (47)		
Yes	96 (50)		
Indeterminable	6 (3)		

Of the 190 students who were screened, 83 (44%) were blind since birth, while 60 (32%) became blind between ages 6 and 15. In our review of the literature, a study conducted at the Akropong School for the Blind in South Ghana reported that of the 244 students who were enrolled in the school at the time of the screening, 96 (40%) were

blind since birth and 53 (22%) became blind between ages 6 and 15 (Ntim-amponsah & Amoaku, 2008). Table 5 provides a side-by-side comparison of the distributions of the ages at onset of blindness of the students at Wa Methodist School for the Blind in the North and the Akropong School for the Blind in the South.

Table 5. Comparison of the distributions of the students' ages at onset of blindness between Wa Methodist School for the Blind and Akropong School for the Blind using imputed* age at onset of blindness.

Age at onset of blindness	**Wa Methodist School for the Blind** (this study)	**Akropong School for the Blind****
Total Number of Students	N=190	N=244***
	n (%)	n (%)
<1 year	83 (44)	96 (40)
1 to 5 years, inclusive	11(6)	33 (14)
6 to 15 years, inclusive	60(32)	53 (22)
>15 years	7 (4)	43 (18)
Missing	29 (15)	17 (7)

*Lower imputations of age category at onset of blindness determined by using the lower level of the range of possible levels for the age at onset of blindness.
**Note: Adapted from "Causes of childhood visual impairment and unmet low-vision care in blind school students in Ghana," by C. T. Ntim-Amponsah & W. M. Amoaku, 2008, *International Ophthalmology, 28*(5), 317-323.
***244 students were enrolled at Akropong School for the Blind at the time of the study.

3.2 Distribution of the causes of blindness

The main anatomical sites of abnormality that lead to visual loss for the students were whole globe (n=17, 26%), cornea (n=38, 20%), and lens (n=28, 15%). Corneal opacity/phthisis bulbi was the most common cause of blindness (n=28, 15%), followed by optic atrophy (n=23, 13%), glaucoma (n=18, 9%), microphthalmos (n=18, 9%), and cataract (n=18, 9%) (Table 6).

The main etiological causes of blindness are summarized in Table 7. The majority of students (n=114, 60%) had unknown etiologies, including cataract (n=25, 13%) and glaucoma (n=13, 7%). Unspecified hereditary disease was seen in 28 students (15%), while 35 (18%) were blind due to childhood factor. Measles caused 19 cases of blindness (10%), while rubella and toxoplasmosis together only accounted for 6 of the cases (3%).

Table 6. Anatomical causes of blindness in students at Wa Methodist School for the Blind.

Anatomical cause of blindness	N (%)
Normal Globe	**17 (9)**
Cortical blindness	13 (7)
Refractive error	3 (2)
Whole Globe	**49 (26)**
Microphthalmos	18 (9)
Glaucoma	18 (9)
Phthisis bulbi	8 (4)
Anophthalmos	2 (1)
Enophthalmos	2 (1)
Removed	1 (0.1)
Cornea	**38 (20)**
Scar/opacity	20 (11)
Corneal dystrophy	9 (5)
Sclerocornea	5 (3)
Staphyloma	2 (1)
Pannus	2 (1)
Lens	**28 (15)**
Cataract	18 (9)
Aphakia	4 (2)
Haze/Opacity	2 (1)
Uvea	**8 (4)**
Uveitis	8 (4)
Retina	**17 (9)**
Scar	8 (4)
Retinitis pigmentosa (RP)	4 (2)
Albinism	4 (2)
Unknown	1 (0.1)
Optic Nerve	**24 (13)**
Atrophy	23 (13)
Hypoplasia	1 (0.1)
Other	**9 (5)**
Vitreous opacity	3 (2)
Unknown	6 (3)

Table 7. Etiological causes of blindness in students at Wa Methodist School for the Blind.

Etiological cause of blindness	N (%)
Hereditary Disease	**28 (15)**
Intrauterine factor	**6 (3)**
Rubella	4 (2)
Toxoplasmosis	2(1)
Perinatal/Neonatal factor	**7 (3)**
Postnatal/Infancy/Childhood Factor	**35 (18)**
Measles	19 (10)
Trauma	3 (2)
Other	13 (7)
Cannot determine (unknown etiology)	**114 (60)**
Cataract	25 (13)
Glaucoma/Buphthalmos	13 (7)
Abnormality since birth	33 (17)
Other	42 (22)

3.3 Main causes of blindness, by age at onset of visual loss

Of the anatomical causes, lens (p = 0.036), uvea (p = 0.017), and retina (p = 0.004) has statistically different proportions of cases between the age categories <1 year, 1 to 5 years, 6 to 15 years (Table 8). One-hundred percent of lens pathology caused blindness that had an onset of blindness during the first year of life and in late childhood. Eighty-two percent of retinal causes of blindness occurred during the first year of life.

Table 8. Causes of blindness in students at Wa Methodist School for the Blind, by age at onset of blindness.

		Age at onset of blindness		
Anatomical causes of blindness	**p-value**	**< 1 year**	**1 to 5 years**	**6 to 15 years**
		n (%)	**n (%)**	**n (%)**
Normal globe	0.344	5 (6)	3 (12)	8 (12)
Whole globe	0.919	23 (26)	6 (23)	16 (24)
Cornea	0.320	14 (16)	6 (23)	17 (25)
Lens	0.036*	15 (17)	0 (0)	11 (16)
Uvea	0.017*	1 (1)	4 (15)	3 (4)
Retina	0.004**	14 (16)	2 (8)	1 (1)
Optic nerve	0.568	11 (13)	5 (19)	7 (10)
Other	0.278	2 (2)	0 (0)	0 (0)
Unknown	0.792	3 (3)	0 (0)	5 (7)
Total		88 (100)	26 (100)	68 (100)
Etiological causes of blindness				
Unspecified hereditary disease	0.001**	21 (24)	2 (7)	3 (4)
Intrauterine factor				
Rubella	0.813	3 (3)	0 (0)	1 (1)
Toxoplasmosis	0.416	1 (1)	1 (4)	0 (0)
Perinatal factor, other	0.025*	7 (8)	0 (0)	0 (0)
Postnatal/Infancy/Childhood factor				
Measles	0.000**	1 (1)	4 (14)	12 (18)
Trauma	0.109	0 (0)	0 (0)	3 (4)
Other	0.004**	1 (1)	3 (11)	9 (13)
Unknown				
Cataract	0.184	12 (14)	1 (4)	12 (18)
Glaucoma	0.334	6 (7)	0 (0)	6 (9)
Abnormal since birth	0.000**	32 (36)	0 (0)	0 (0)
Other	0.000**	4 (5)	17 (61)	22 (32)
Total		88 (100)	28 (100)	68 (100)

3.4 Trends: Anatomical causes of blindness across time

Figures 4 and 5 display the distributions of the anatomical and etiological causes of blindness across time. The linear regressions showed that the anatomical causes of blindness had statistically significant p values for all of the anatomical categories leading to visual loss except lens, uvea, and other (Table 9).

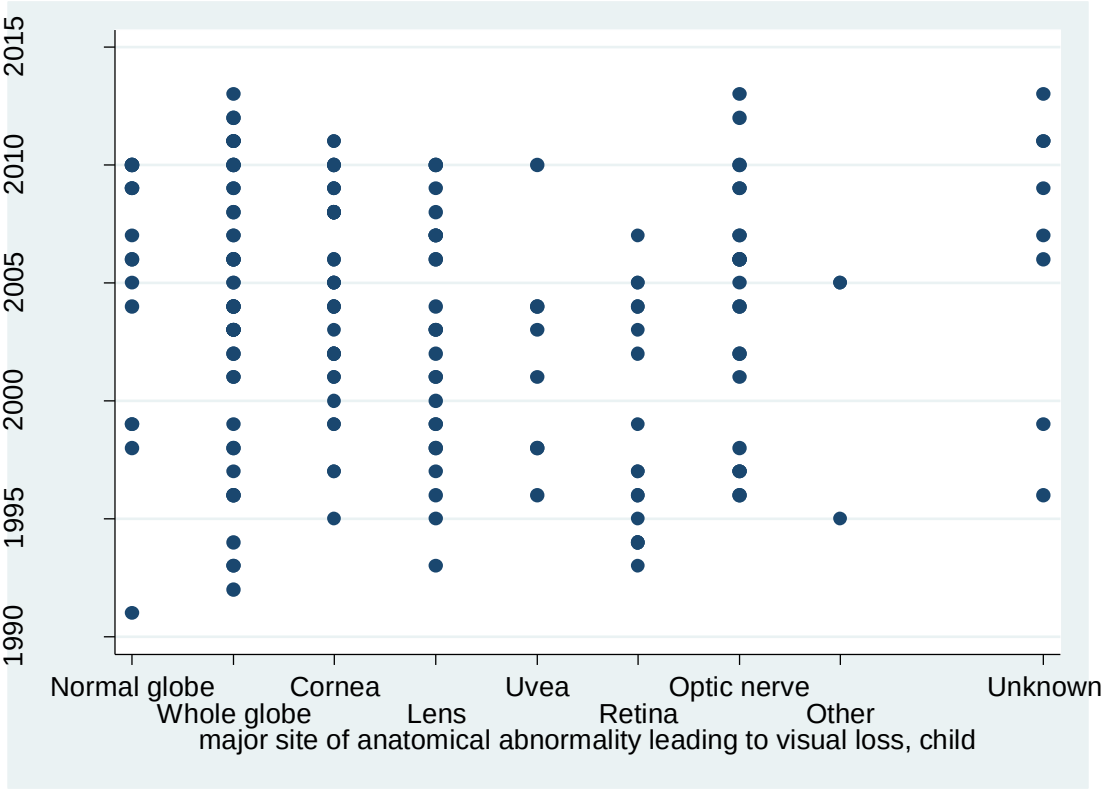


Figure 4. Anatomical causes of blindness in students at Wa Methodist School for the Blind whose onset of visual loss was before 15 years of age, across time.

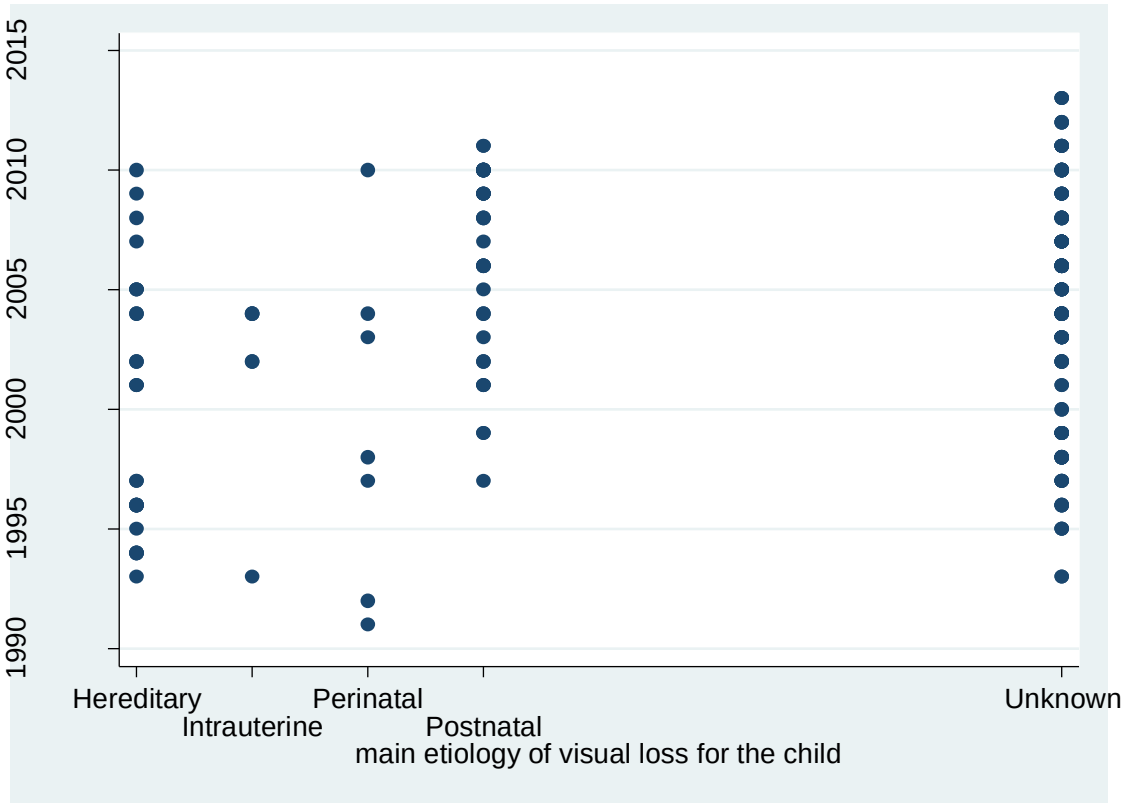


Figure 5. Etiological causes of blindness in students at Wa Methodist School for the Blind whose onset of visual loss was before 15 years of age, across time.

Table 9. Linear regression models of causes of blindness and age category at onset of blindness on year of onset of blindness in students at Wa Methodist School for the Blind.

Year of Onset of Blindness	β-coefficient	Standard Error	p-value
ANATOMICAL CAUSES			
Globe appears normal	2.83	1.37	0.04*
Whole globe	2.42	1.11	0.03*
Cornea	2.82	1.16	0.016*
Lens	1.38	1.22	0.261
Uvea	-0.40	1.71	0.815
Optic nerve	2.46	1.24	0.049*
Other	2.19	2.40	0.36
Unknown	4.07	1.67	0.016*
Age at onset of blindness (referent group (<1 year)			
1 to 5 years	0.61	1.05	0.562
6 to 15 years	5.41	0.81	<0.001**
Onset-Impute	0.45	1.14	0.69
Year-Impute	2.83	0.98	0.004**
Constant (Retina)	1998.18	0.94	<0.001**
ETIOLOGICAL CAUSES			
Hereditary	-0.60	1.62	0.71
Intrauterine	0.76	2.12	0.72
Postnatal	1.99	1.72	0.25
Unknown	2.24	1.52	0.14
Age at onset of blindness (referent group: <1 year)			
1 to 5 years	0.17	1.07	0.88
6 to 15 years	4.99	0.85	<0.001**
Onset-impute	0.01	1.12	0.99
Year-Impute	3.09	0.95	0.001**
Constant (Perinatal)	1998.84	1.44	<0.001**

*p<0.05; **p<0.01

When cases caused by measles for all age groups is plotted across time, the vast majority of cases fell between years 2000 and 2010, with mean year of onset at 2006 (Figure 6).

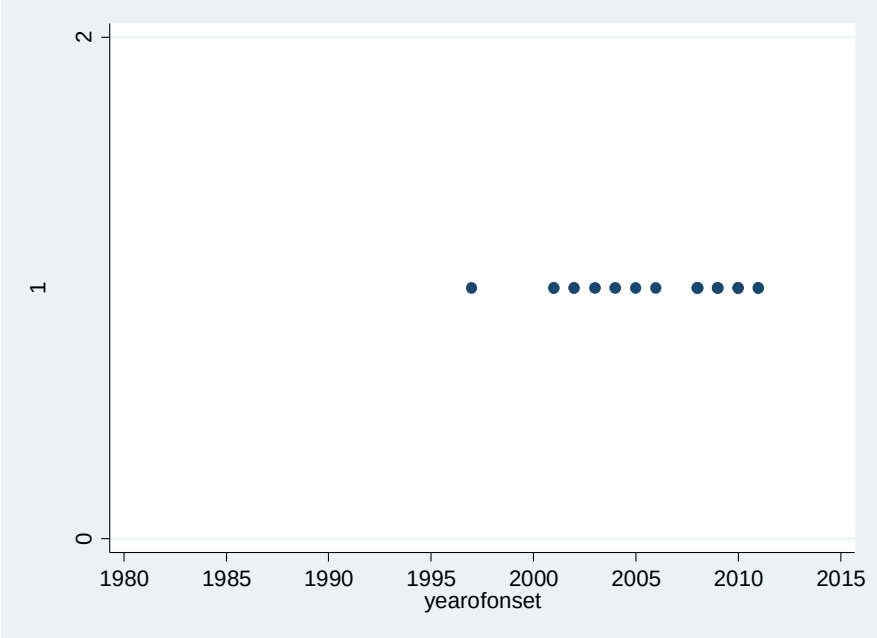


Figure 6. Visual loss caused by measles in students at Wa Methodist School for the Blind whose onset of visual loss was before 15 years of age, across time.

4. Discussion

The purpose of this study was to identify the major causes of blindness in students who were enrolled in Wa Methodist School for the Blind, while considering the socioeconomic context of Upper West Region in North Ghana. We found that the major avoidable cause of blindness in the students was corneal opacity/phthisis bulbi. Corneal pathology is primarily seen in low economic settings with poor public health infrastructure that cannot effectively combat known preventable causes of corneal pathology such as measles, vitamin A deficiency, and ophthalmia neonatorum. However, almost one-fourth of the students in the study had blindness due to cataract, retinal causes, optic nerve pathology, and causes affecting higher visual pathways, which are primary causes of blindness for middle- and high-income countries. While no discernable trends were noted for each of the anatomical causes of blindness, the significant proportion of blind students affected by lesions of the central nervous system might hint at the progress that has been made in North Ghana through the public health campaigns to reduce avoidable corneal blindness, thus possibly reducing the relative proportion of corneal causes of blindness in this group of students at Wa Methodist School for the Blind.

Using data collected on students at Wa Methodist School for the Blind, we determined the major causes of blindness in this region and compared these findings to a 2008 study on Akropong School for the Blind in the South of Ghana. Corneal

opacities/phthisis bulbi was the most common cause of blindness for both groups at the Wa and Akropong schools. Despite not being able to ascertain the etiologies of these cases for certain, the high prevalence of corneal pathologies in both schools alludes to the importance of continuing to manage risk factors such as measles, vitamin A deficiency, and harmful traditional practices, which are suggested to be the major causes of corneal scarring in Africa (Foster & Sommer, 1987; C. E. Gilbert et al., 1993) .

A greater percentage of cases caused by measles was seen in the Akropong students (27%) as opposed to the Wa students (10%). It is difficult to infer the reasons for this difference due to confounding factors, such as biased childhood blind population sampling due to higher urbanization rates and consequently higher school attendance in the South compared to the North, and the fact that complications from unmanaged measles cases lead to multiple disabilities in addition to blindness that would exclude children with multiple disabilities from enrolling in either blind school. However, we note that the biggest challenges that faced Ghana's immunization program during the late 1990s included limited access to services in hard-to-reach areas but especially in the Volta Lake basin and other central/southern regions with significant geographic barriers (World Health Organization, n.d.). This is demonstrated by the fact that of the 30 districts in Ghana that had measles immunization rates below 80% in 2003, 26 of them were in central and southern Ghana (World Health Organization, n.d.). Of the identified measles cases in the Wa group, 18 out of 19 of the cases had years of onset between 2001

and 2011, while the remaining one case occurred in 1997. According to World Bank database of measles immunization rates in Ghana, coverage fell drastically from 90% in 2000 to 78% by 2001, with a gradual increase during the next 10 years to 93% in 2010 (The World Bank, 2016). The negative correlation between measles vaccination in the southern region of Ghana and the prevalence of visual loss caused by measles is apparent in these findings, suggesting the importance of considering the temporal component of the onset of blindness in blind school studies instead of just the causes.

In both groups of students at the two schools, the distributions of the age at onset of blindness were roughly similar – almost half became blind within the first year of life, and roughly a third to a fourth of the students became blind during late childhood. This is consistent with the previous finding in other blind schools that most blind children are blind since birth or become blind before their fifth birthday (Kocur, 2007). In the group of students at the Wa School, there were statistically significant differences in the distribution of anatomical causes of blindness between age categories for the onset of blindness. Cataract disproportionately caused blindness in students who were blind since birth and between ages 6 to 15 years, and retinal causes disproportionately affected students who were blind since birth. Some cases of congenital cataract may be a treatable cause of childhood blindness, but must be identified, monitored, and treated early on, as delayed treatment results in the abnormal development of vision (i.e. deprivation amblyopia). Retinal pathologies in neonates, such as albinism and retinal

dystrophy, are genetically inherited and can cause visual loss since birth. Peri/neonatal causes of blindness such as rubella, toxoplasmosis, ophthalmia neonatorum, and congenital glaucoma, are avoidable through prevention and/or prompt treatment. The high prevalence of cases of blindness within the first year of life in both groups at Wa and Akropong schools for the blind suggests the need for stronger training programs for community health workers, traditional birth attendants, and physicians to perform or refer at-risk children for neonatal eye examinations, and as well as for the timely management of identified cases. For genetically inherited causes, there is a need for more programs in genetic counseling and public awareness about consanguineous marriage as a negative risk factor for genetically inherited childhood blindness causes.

We did not find a discernable temporal trend for broader anatomical and etiological causes of blindness. For the linear regression of the anatomical causes of visual loss, the categories "Globe appears normal," "Whole globe," "Cornea," "Optic nerve," and "Unknown" all had statistically significant beta-coefficients; however, the magnitudes of the coefficient for each category were close to each other. For instance the mean year of onset of visual loss for the group of students who were blind since birth due to whole globe causes was year 2000, which is the same mean year of onset of visual loss for the students who were blind since birth due to optic nerve causes. The similar values of the statistically significant beta-coefficients for these anatomical causes means that there are no distinct periods in time during which a single anatomical cause of

visual loss predominated. Despite this inconclusive finding on broader anatomical and etiological categories, the finding on the clustered cases of measles in the 2000s points to the potential usefulness of considering temporal trends in future blind school studies.

4.1 Implications for policy and practice

Decreased immunization rates during the 2000s in Ghana, as possibly evidenced by the group of students at Wa School for the Blind who became blind likely due to measles, underscores the broader importance of maintaining high immunization coverage for disease control. As measles, vitamin A deficiency, and other infectious agents are still major causes of blindness in both North and South Ghana, national policy regarding eye health care must continue to diligently implement public health strategies for combatting avoidable blindness.

There is also a need for vast improvement in childhood visual impairment screenings in hospitals, primary care centers, within communities and in schools so that children who could be helped can be identified early and referred for treatment. The District Health Management Team (DHMT) of district hospitals in Ghana tasks ophthalmic nurses to conduct outreaches in their respective districts, but funding and support are not always made available (Potter et al., 2013.). Other players in the field, such as international eye health organizations, private clinics, and the Ghana Red Cross and Swiss Red Cross, also provide community screenings – this fragmentation and uncertainty regarding the coordination of school and community screening outreaches

should be addressed regionally. One suggestion for policymakers would be to centralize the coordinating and organizing of screening efforts in education facilities and communities so that expanding these services becomes more strategic and efficient.

4.2 Implications for further research

The finding on the temporal trend of measles cases in this blind school suggests the need for further research on blind schools with the objective of determining potential epidemiological trends and factors on a timely and recurrent basis, so that current major problems contributing to childhood blindness may be promptly addressed. Evidence gathered from these types of studies could serve to inform policymakers on the need to create, expand, and improve new and existing programs on combatting avoidable blindness. While blind school studies inherently have a number of important biases and pitfalls, analyzing their data for more epidemiological factors such as time may potentially yield useful information on the epidemiology of childhood blindness and visual impairment in order to advise programs and policy.

Future blind school studies of this type would require standardized reporting on patient history of blindness (i.e. age at onset of blindness). A study conducted by Elder and de Cock, in which they sent students to the base hospital nearest to the blind school for additional examination (e.g. ultrasound, visual field tests, electrodiagnostic testing), demonstrates the possibility for more thorough screening procedures that could yield more reliable diagnoses and other useful information for epidemiological data (Elder &

De Cock, 1993). In addition, blind schools could implement a policy for all admitted students to have a baseline exam prior to matriculation in order to compile a regional blind school registrar that could be made available to researchers for analysis for potential epidemiological trends.

4.3 Study strengths and limitations

This study had many strengths and weaknesses. The study had 100% participation rate of the students at this school, so there was no selection/participation bias. There was one screening ophthalmologist who examined and diagnosed each student, which allowed for conformity in the reporting of the data and minimized the variability of the clinical data collected.

This was a retrospective study, thus the screening team did not collect data for the purposes of a study, but collected data for the purposes of an eye screening. Thus, the collection of data was not standardized. This created challenges because there was non-standard reporting of certain variables such as the onset of blindness. Also, the screening team was not introduced to the WHO/PBL Eye Examination Record, and so did not measure or record all variables listed in the standardized WHO/PBL form during the screening. Some of the collected data had to be interpreted and recoded into the retrospective study electronic database, which could have increased opportunities for error in interpreting the data and managing missing/ambiguous data. However, a strength of this study was that for the variables of interest with missing values, we

conducted analyses using both the upper bound and lower bound imputations and compared the output of both sets of data, allowing us to see how much or little of an effect the imputations had on the outcomes.

5. Conclusion

This study on the Wa Methodist School for the Blind is the first to describe the causes of childhood blindness in northern Ghana, while considering potential epidemiological trends within the socioeconomic and public health contexts of Ghana. While research in blind schools are not truly representative of the populations of visually impaired and blind children, it still confers the significant advantage of examining a large sample of low vision/blind children to determine the causes of blindness for that region. While predicting the trajectory of childhood blindness may not be feasible based solely on blind school studies, considering other factors such as past temporal trends and age at onset may yield important findings for bolstering preventative strategies and helping to shape future strategies for combatting avoidable childhood blindness.

Appendix A

Wa Methodist School for the Blind eye screening examination form

Exam sheet blind school

Name …… …… Age ……..Sex…….. blind since…….

Vision R Vision L alignment EX=0 ET XT Else

Pupils R L APD Nystagmus Y N RR OD OS

OD OS FH……..

Cornea ……

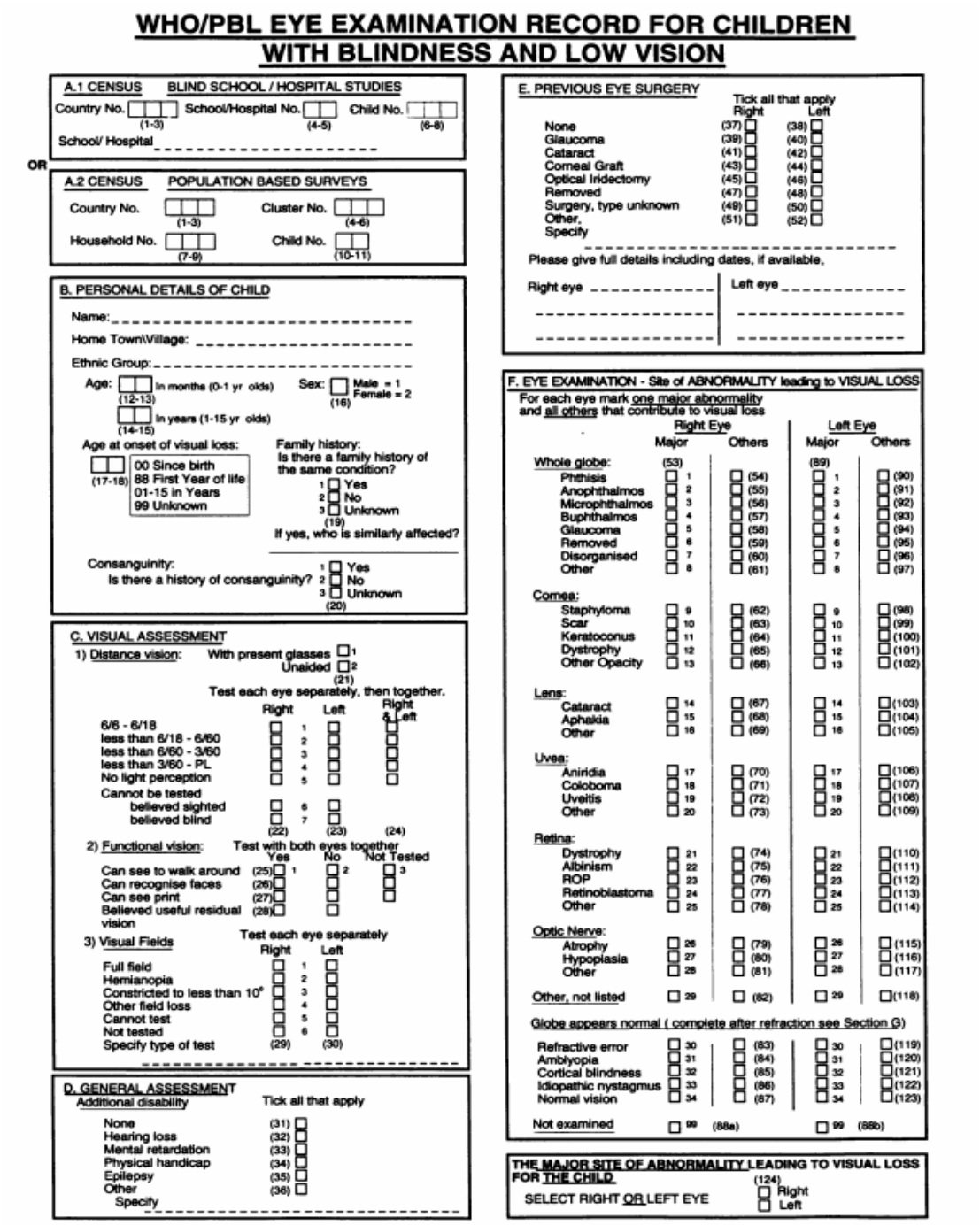
Lens Other problems: ……

Retina ……

DG……..

Appendix B

WHO/PBL Eye Examination Record for Children with Blindness and Low Vision



WHO/PBL EYE EXAMINATION RECORD FOR CHILDREN WITH BLINDNESS AND LOW VISION

A.1 CENSUS BLIND SCHOOL / HOSPITAL STUDIES
Country No. (1-3) School/Hospital No. (4-5) Child No. (6-8)
School/ Hospital

OR

A.2 CENSUS POPULATION BASED SURVEYS
Country No. (1-3) Cluster No. (4-6)
Household No. (7-9) Child No. (10-11)

B. PERSONAL DETAILS OF CHILD
Name:
Home Town\Village:
Ethnic Group:
Age: (12-13) In months (0-1 yr olds) (14-15) In years (1-15 yr olds)
Sex: (16) Male = 1 Female = 2
Age at onset of visual loss: (17-18) 00 Since birth; 88 First Year of life; 01-15 in Years; 99 Unknown
Family history: Is there a family history of the same condition? (19) 1 Yes 2 No 3 Unknown
If yes, who is similarly affected?
Consanguinity: Is there a history of consanguinity? (20) 1 Yes 2 No 3 Unknown

C. VISUAL ASSESSMENT
1) Distance vision: With present glasses (21) 1 Unaided 2
Test each eye separately, then together.

	Right	Left	Right & Left
6/6 - 6/18	1	1	
less than 6/18 - 6/60	2	2	
less than 6/60 - 3/60	3	3	
less than 3/60 - PL	4	4	
No light perception	5	5	
Cannot be tested			
believed sighted	6	6	
believed blind	7	7	
	(22)	(23)	(24)

2) Functional vision: Test with both eyes together

	Yes	No	Not Tested
Can see to walk around	(25) 1	2	3
Can recognise faces	(26)		
Can see print	(27)		
Believed useful residual vision	(28)		

3) Visual Fields: Test each eye separately

	Right	Left
Full field	1	1
Hemianopia	2	2
Constricted to less than 10°	3	3
Other field loss	4	4
Cannot test	5	5
Not tested	6	6
Specify type of test	(29)	(30)

D. GENERAL ASSESSMENT
Additional disability — Tick all that apply

None	(31)
Hearing loss	(32)
Mental retardation	(33)
Physical handicap	(34)
Epilepsy	(35)
Other	(36)
Specify	

E. PREVIOUS EYE SURGERY — Tick all that apply

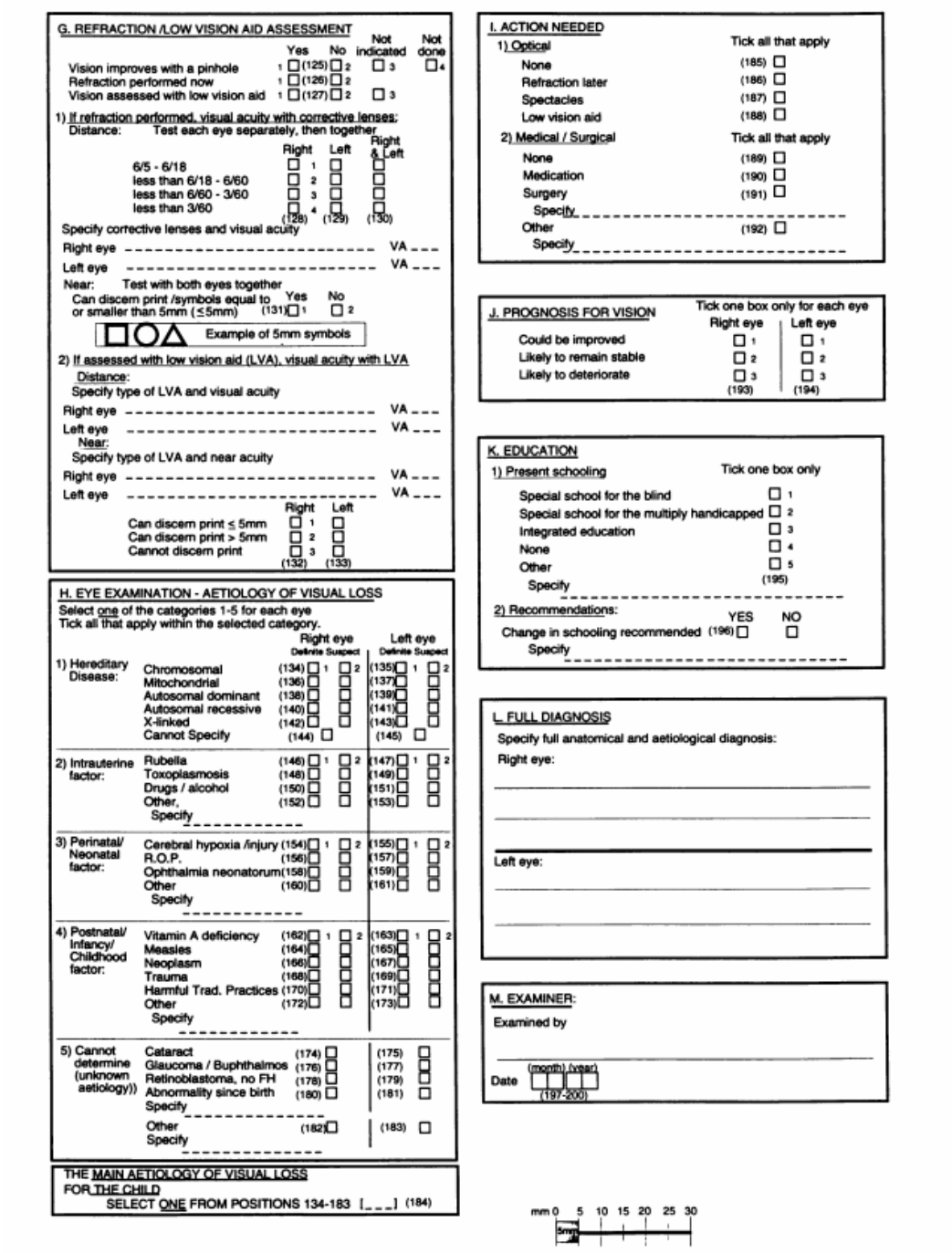
	Right	Left
None	(37)	(38)
Glaucoma	(39)	(40)
Cataract	(41)	(42)
Corneal Graft	(43)	(44)
Optical Iridectomy	(45)	(46)
Removed	(47)	(48)
Surgery, type unknown	(49)	(50)
Other, Specify	(51)	(52)

Please give full details including dates, if available.
Right eye | Left eye

F. EYE EXAMINATION - Site of ABNORMALITY leading to VISUAL LOSS
For each eye mark one major abnormality and all others that contribute to visual loss

	Right Eye Major	Right Eye Others	Left Eye Major	Left Eye Others
Whole globe:	(53)		(89)	
Phthisis	1	(54)	1	(90)
Anophthalmos	2	(55)	2	(91)
Microphthalmos	3	(56)	3	(92)
Buphthalmos	4	(57)	4	(93)
Glaucoma	5	(58)	5	(94)
Removed	6	(59)	6	(95)
Disorganised	7	(60)	7	(96)
Other	8	(61)	8	(97)
Cornea:				
Staphyloma	9	(62)	9	(98)
Scar	10	(63)	10	(99)
Keratoconus	11	(64)	11	(100)
Dystrophy	12	(65)	12	(101)
Other Opacity	13	(66)	13	(102)
Lens:				
Cataract	14	(67)	14	(103)
Aphakia	15	(68)	15	(104)
Other	16	(69)	16	(105)
Uvea:				
Aniridia	17	(70)	17	(106)
Coloboma	18	(71)	18	(107)
Uveitis	19	(72)	19	(108)
Other	20	(73)	20	(109)
Retina:				
Dystrophy	21	(74)	21	(110)
Albinism	22	(75)	22	(111)
ROP	23	(76)	23	(112)
Retinoblastoma	24	(77)	24	(113)
Other	25	(78)	25	(114)
Optic Nerve:				
Atrophy	26	(79)	26	(115)
Hypoplasia	27	(80)	27	(116)
Other	28	(81)	28	(117)
Other, not listed	29	(82)	29	(118)
Globe appears normal (complete after refraction see Section G)				
Refractive error	30	(83)	30	(119)
Amblyopia	31	(84)	31	(120)
Cortical blindness	32	(85)	32	(121)
Idiopathic nystagmus	33	(86)	33	(122)
Normal vision	34	(87)	34	(123)
Not examined	99 (88a)		99 (88b)	

THE MAJOR SITE OF ABNORMALITY LEADING TO VISUAL LOSS FOR THE CHILD (124)
SELECT RIGHT OR LEFT EYE — Right / Left



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Appendix C

WHO/PBL Eye Examination Record for Children with Blindness and Low Vision: Coding Instructions

2) Site of abnormality leading to visual loss for the child:

One major site of abnormality leading to visual loss i.e. that for the right eye or the left eye should be selected as the major *site for the child*. When the sites of abnormality are different for the two eyes the major site for the child should be selected using the following criteria:

First: Select the most *treatable* abnormality:

For example: right eye, cataract left eye, optic atrophy Select cataract, as this cause is treatable

If neither eye has treatable abnormalities

Second: Select the most preventable abnormality:

For example: right eye, corneal scarring from measles left eye, optic atrophy Select corneal scarring, as this cause is preventable

Third: If neither eye has a preventable or treatable cause, select the abnormality that *occurred most recently*:

For example: right eye, macular scar since the age of 2 years left eye, optic atrophy since the age of 5 years Select optic atrophy, as this occurred more recently.

Fourth: If it is not known which abnormality occurred more recently select the eye with the *better vision*:

For example: right eye, NPL from optic atrophy left eye, PL from macula scar Select macula scar, as this eye has the better acuity

Site of abnormality leading to visual loss for the child:

Position	Instructions
(124)	Choose whether the major site of abnormality leading to visual loss for the child is in the right eye or the left eye.

Reprinted from International Centre for Eye Health and World Health Organization (2005). "WHO/PBL Examination Record for Children with Blindness and Low Vision: Coding Instructions and Manual for Data Entry in Epi-Info," page 17. Copyright World Health Organization (2005). http://www.cehjournal.org/wp-content/uploads/who-childhood-blindness/Coding-Instructions-June-23-2008.pdf. Accessed 19 April 2016.

Appendix D

Fisher Exact Tests for the anatomical and etiological causes of visual loss across age categories at onset of visual loss, using upper-bound imputations

		Age at onset of blindness		
Anatomical causes of blindness	**p-value**	**< 1 year n (%)**	**1 to 5 years n (%)**	**6 to 15 years n (%)**
Normal globe	0.081	4 (5)	2 (22)	9 (12)
Whole globe	0.911	22 (27)	2 (22)	17 (23)
Cornea	0.117	13 (16)	2 (22)	21 (29)
Lens	0.119	15 (18)	0 (0)	6 (8)
Uvea	0.200	1 (1)	0 (0)	5 (7)
Retina	0.002**	13 (16)	2 (22)	1 (1)
Optic nerve	1.000	10 (12)	1 (11)	9 (12)
Other	0.552	2 (2)	0 (0)	0 (0)
Unknown	0.668	3 (4)	0 (0)	5 (7)
Total	-	83 (100)	9 (100)	73 (100)
Etiological causes of blindness				
Unspecified hereditary disease	0.001**	21 (24)	2 (7)	3 (4)
Intrauterine factor				
Rubella	0.813	3 (3)	0 (0)	1 (1)
Toxoplasmosis	0.416	1 (1)	1 (4)	0 (0)
Perinatal factor, other	0.025*	7 (8)	0 (0)	0 (0)
Postnatal/Infancy/Childhood factor				
Measles	0.000**	1 (1)	4 (14)	12 (18)
Trauma	0.109	0 (0)	0 (0)	3 (4)
Other	0.004**	1 (1)	3 (11)	9 (13)
Unknown				
Cataract	0.184	12 (14)	1 (4)	12 (18)
Glaucoma	0.334	6 (7)	0 (0)	6 (9)
Abnormal since birth	0.000**	32 (36)	0 (0)	0 (0)
Other	0.000**	4 (5)	17 (61)	22 (32)
Total	-	88 (100)	28 (100)	68 (100)

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