THESIS TITLE

Assessment of cataract blindness prevalence and factors associated with surgical coverage in Rwanda

BY

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DECLARATION

I, Michael Owusu Kyei, hereby declare that the work on which this dissertation/thesis is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

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DEDICATION

I would like to dedicate this thesis to my family and friends for their love and support.

ABSTRACT

Background:

The Rapid Assessment of Avoidable Blindness (RAAB) survey methodology is a cost-effective tool for assessing the burden of blindness and cataract surgical services in a population. This study analyses the 2015 Rwanda National RAAB data to ascertain whether there are gender differences in access to cataract surgical services and also assess whether there is an association between measured distances travelled to access cataract surgical services and the cataract surgical coverage (CSC) in the country.

Methods:

Secondary data non automated analysis was performed on the 2015 Rwanda RAAB data, which had a sample of 5,275 persons who underwent ophthalmic examinations as per RAAB protocols to elicit the prevalence and causes of blindness and answered a standard questionnaire on barriers to cataract surgery. Cataract blindness prevalence and cataract surgical coverage were estimated for males and females and assessed for significant differences. Distances from clustered patients' locations to the nearest eye surgical facility were calculated using Google Maps and analyses performed to identify if a relationship exists between distances travelled and the CSC for the area.

Results:

The prevalence of bilateral cataract blindness for males was 0.4% (n=8; 95% CI=0.1-0.7) and females 0.5% (n=17; 95% CI=0.3-0.8) and the CSC for males and females were 69.2% and 68.5%

respectively. The difference in CSC was not statistically significant. Females aged ≥70 years reported more barriers to cataract surgical services compared to men.

At a VA <3/60 in the better eye, 1km increase in the distance to the nearest eye surgical centre was associated with a reduction in the CSC for the area of 4.8% (Linear regression: F (1,95) = 16.06, p = 0.0001, R-Squared = 0.1446, Adjusted R-Squared = 0.1356).

Conclusions:

Older women (≥70 years) were the most vulnerable to untreated cataract blindness in Rwanda and therefore special programs need to target them for cataract surgical services. Distance to surgical facilities with ophthalmologists is related to the cataract surgical coverage even in a small country like Rwanda.

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ORGANISATION OF THE MINI DISSERTATION

PART A - Protocol outlining the background and process of the research submitted to the Human Research Ethics Committee of the University for approval

PART B - Literature review on the topic of research

PART C - Summary of Part A, Part B and results of the research in the format suitable for publication in a chosen journal

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PART A: PROTOCOL

1.0 Background

According to the World Health Organization (WHO), blindness is defined as a presenting best corrected distant visual acuity of less than 3/60, or a visual field loss of less than 10° from the point of fixation in the better eye (WHO, 2007). Visual acuity (VA) is defined as “the relative ability of the visual organ to resolve detail” (Merriam Webster Dictionary). In the latest classification of diseases, vision impairments are grouped as distance or near presenting vision impairment (ICD 11, 2018; WHO, 2018). (Table 1.0)

Table 1.0 Categorization of visual function (ICD 11)

Vision category	**Presenting visual acuity in the better eye**
No vision impairment	6/6 – 6/12
Mild vision impairment	<6/12 - 6/18
Moderate vision impairment	<6/18 - 6/60
Severe vision impairment	<6/60 - 3/60
Blindness	<3/60
Near vision impairment	<N6 or <N8 at 40cm with existing correction

In 1999, WHO launched the ‘Vision 2020 The Right to Sight Initiative' which aimed to eliminate all causes of avoidable blindness worldwide by the year 2020 (WHO, 1999). This was subsequently updated to “Universal Eye Health: A global action plan 2014 – 2019” by the World Health Assembly in 2013 with the aim of reducing the “prevalence of avoidable visual impairment by 25% by 2019”from the baseline data of 2010 (WHO, 2013). Consequently, many countries have rolled out national and regional plans using these global initiatives as the blue prints to guide the development and implementation of blindness prevention activities.

The burden of people living with vision impairment worldwide were estimated to be 253 million as of 2017; of which 36 million were blind and 217 million had moderate to severe vision impairment (WHO, 2017; Bourne et al., 2017). The trend in estimates between the year 1990 and 2017 showed that the number of blind people increased by 17.9% from 30.6 million in 1990 (Bourne et al., 2017), whilst the number of people living with moderate to severe vision impairment also increased by 73.7% from 160 million in 1990 (Bourne et al., 2017). However, the age-standardised prevalence rates of blindness for all ages worldwide decreased from 0.75% in 1990 to 0.48% in 2015 (Bourne et al., 2017). The age-standardised prevalence rates of moderate to severe vision impairment for all ages worldwide also decreased from 3.83% in 1990 to 2.90% in 2015 (Bourne et al., 2017). It is estimated that 81% of people living with blindness are aged 50 and above (WHO, 2017) and the increase in absolute numbers of people with vision impairment from 1990 to 2017 were attributed to population growth, increase in life expectancy and a more ageing population (Bourne et al., 2017). The vast majority of people living with vision impairment live in low-income settings (WHO, 2017).

Globally, the main cause of moderate and severe vision impairment is uncorrected refractive errors and the main cause of blindness is cataract especially in low-and-middle income countries (WHO, 2017). It is estimated that 80% of all vision impairment can be prevented or cured (WHO, 2017).

Cataract is an opacity of the lens of the eye which impedes the passage of light thereby reducing vision. Causes of cataract can be grouped as congenital or acquired (Kanski & Bowling, 2012 pp. 269-270). Acquired cataracts are related to the ageing process, and may also develop from a traumatic injury or inflammation of the eye and from diseases such as diabetes mellitus (WHO, 2010). Other risk factors for acquired cataracts include prolonged exposure to sunlight, smoking and alcohol drinking (WHO, 2010). Congenital cataract refers to children born with the condition, however the majority of cases of cataract blindness are due to ageing (WHO, 2017). In a systematic review and meta-analysis, Wu et. al (2016) found a very low prevalence of congenital cataract globally. The pooled prevalence was 4.24 per 10,000. Cataract surgery is the main treatment for sight restoration for people living with cataract blindness (WHO, 2010). Barriers such as access to surgical facilities and affordability prevent people from accessing cataract surgical services in many countries (Lewallen & Courtright, 2000; WHO, 2010; Aboobaker & Courtright, 2016).

Population based eye surveys to assess the prevalence and causes of blindness and vision impairment had been a challenge in many low income countries (Kuper, Polack & Limburg, 2006; Mathenge et al., 2007). Baseline data on the prevalence of blindness and vision impairment are however needed in other to compare with future data and assess the progress and effectiveness of blindness prevention programs. This is especially needed in countries who have a higher burden of preventable blinding eye diseases but have limited resources to tackle them (Mathenge et al., 2007; Mathenge et al., 2007). The Rapid Assessment of Avoidable Blindness (RAAB) was introduced as a quick and efficient population-based eye survey methodology. The focus is on the population aged 50 years and older. This age group was selected because people aged 50 and above have a higher prevalence of vision impairment and account for over 80% of blindness in the population (Kuper, Polack & Limburg, 2006). This age group also represents a smaller proportion of the general population and therefore a smaller sample size required, which thereby contribute to reduce costs significantly (Kuper, Polack & Limburg, 2006). “RAAB has been described as giving good estimates of the prevalence and causes of visual impairment and blindness in the general population because the proportion of blindness and visual impairment due to different causes is the same in those over 50 years as in the total population” (Mathenge et al., 2007). RAAB also assesses the cataract surgical coverage (CSC), the main barriers to the uptake of cataract surgery, as well as visual outcomes after cataract surgery in a population (Kuper, Polack & Limburg, 2006). These indicators allow the assessment of the effectiveness of eye care services. RAAB has successfully been conducted in several countries in Africa, Asia, the Middle East and Latin America. An online database known as the RAAB repository contains data of over 268 successfully conducted RAAB studies (www.http://raabdata.info/; Nemeth et al., 2017).

Cataract Surgical Coverage (CSC), one of the indicators in RAAB, is an important “indicator that assesses the extent to which cataract surgical services are meeting the needs of the population” (Limburg & Foster, 1998; IAPB, 2015). CSC is defined as the ratio of the number of individuals who have had cataract surgery to the total number of individuals who have or have ever had cataract in the population.

Ideally, the CSC is expected to be as close to 100% as possible for any country, but in reality this is often not the case (Lewallen et al., 2015). A CSC of 80% however has been discussed as ideal to achieve the aims of universal health coverage (UHC) (IAPB, 2015). The CSC is one of the indicators required of countries in monitoring the progress of achieving “Universal Eye Health: Global Action Plan 2014-2019” (WHO, 2013). Since cataract is the leading cause of blindness in low-and-middle countries (WHO, 2017), a higher CSC and a lower cataract blindness prevalence in such countries indicates a significant reduction in the number of blind people. However according to the International Agency for the Prevention of Blindness (IAPB), a country with a higher CSC may still have people living with cataracts in underserved areas, among the poor and among people living with disabilities as they often lack cataract surgical services (IAPB, 2015). A recent study of CSC data from 27 countries with available national RAAB data (10 Latin American, 8 Asian, 6 African, 2 Eastern Mediterranean and 1 European countries) by the IAPB showed that majority of these countries have not been able to achieve adequate CSC for their populations (IAPB, 2015). The IAPB study also stated that “the CSC data showed significant inequities in respect of gender, literacy and location” (IAPB, 2015). In terms of gender, women have been found to consistently have a lower cataract surgical rate than men. Aboobaker and Courtright (2016) in a systematic review of barriers to cataract surgery in Africa from 1999 to 2014 reported that the CSC was lower in females in 88.2% of the studies. This was due to the unequal access to cataract surgical services between men and women. Other studies (Dean et al., 2011; Lewallen & Courtright, 2009; Nkomazana, 2009; Lewallen, Mousa & Courtright, 2008;

Geneau et al., 2008; WHO, 2007) gave specific reasons for this unequal access, such as better socioeconomic status of men in most cases and mens' domination in decision making processes related to healthcare. Lewallen and Courtright (2009) in a systematic review estimated that blindness and severe visual impairment from cataract could be reduced by around 11% in low and middle income countries if women were to receive cataract surgery at the same rate as men. In this regard, gender sensitive analyses of barriers to the uptake of cataract surgical services are a key component of blindness reduction strategies.

RAAB surveys and other studies using qualitative approaches have also reported that distance to surgical services is a common mentioned barrier to access cataract surgical services and therefore impacts on cataract surgical coverage (Courtright et al., 2010; Mehari et al., 2013; Olusanya et al., 2016). However, qualitative interviews in eye surveys do have challenges. According to Aboobaker and Courtright (2016), "people who have not had cataract surgery sometimes do not give the truthful reasons for not accessing the surgical services in order to avoid embarrassment". In view of this, other forms of data acquisition to establish barriers to uptake of cataract surgical services can complement qualitative interviews. In respect of distance as a barrier, one objective method is to determine whether measured distances to eye surgical centres are related to cataract surgery uptake. Geographic Information System (GIS) and spatial accessibility methods have widely been used to assess how distances and the time patients travel to health facilities may have an effect on the uptake of health care services (McLafferty, 2003; Gabrysch et al., 2011). Whilst distance is a known barrier to the uptake of cataract surgery, there has been no research to date using calculated distances between patients' locations and the nearest eye surgical centre to investigate this relationship. This study seeks to fill this gap.

1.0.1 Study setting - Rwanda

Rwanda is a small landlocked country in Central East Africa with a total surface area of 26.3 square kilometres. It is bordered in the north by Uganda, in the on the south by Burundi, in the west by the Democratic Republic of Congo and in the east by Tanzania (RDHS, 2015). The country's relief is generally mountainous with an average altitude of 1700 metres (RDHS, 2015). Almost 84 percent of the country's residents live in rural settings (RDHS, 2015) and access to health services is often difficult because of the terrain (Muller et al., 2010; MOH, 2013). The country is densely populated at 483 people per square kilometre as of 2016 (World Bank, 2018) and has a current population of 11 million of which an estimated 43.4 percent are under the age of 15 years (RDHS, 2015). Rwanda is a low-income country with a Gross Domestic Product of $8.48 billion as of 2016 (World Bank, 2018). According to the United Nations Human Development Index Report, Rwanda ranked 159 out of 188 countries studied (UNDP, 2016). According to the same report about 60 percent of the population lived below the poverty line of $1.90 a day (UNDP, 2016). The economy of Rwanda is largely agriculture-based with an estimated 72 percent of the population employed in it (FAO, 2018). Administratively, the country is subdivided into 5 provinces and 30 districts. Each district is divided into sectors which are further divided into cells and villages. A village typically accommodates 50 to 150 households (RDHS, 2015).

Rwanda went through an ethnic war and genocide in 1994, of which an estimated 800,000 to 1,000,000 people were killed. Rwanda's social services including health services were severely affected; hospitals and health centres were destroyed and an estimated two-thirds of the professional health workforce were either killed or exiled (Vickery, 1994; Kumar et al., 1996). According to Grundman (2016); only 198 health professionals were reported to have remained immediately after the genocide to serve thousands of people and Rwanda continually struggled with the severe shortage of skilled health professionals years after the genocide (MOH, 2005; MOH, 2015). To address the acute shortage of skilled health professionals, the country in 1995 introduced a task shifting initiative; the Community Health Programme (CHP) which were a cadre of community health workers (CHWs) trained and tasked to provide basic health services to communities (MOH, 2013; Ndahiro et al., 2015). In 1995, there were approximately 12,000 CHWs and by the year 2005 they were increased to 45,000 (MOH, 2013). Health training institutions which had lost a significant number of their staff in the genocide and therefore closed were reopened in 1995 and the training of skilled health workforce recommenced gradually to fill in the gap of shortage (Flinkenflogel et al., 2015). However, traditional Rwandan medical education trained more general physicians than specialists. Most specialists were trained abroad or in sandwich programs (Flinkenflogel et al., 2015) and this made the country lack this human resource (MOH, 2005; MOH, 2011; MOH, 2015; Flinkenflogel et al., 2015). The Rwandan Human Resource for Health programme, which was launched in 2012, aims to partner with International training institutions to improve the skills of the health workforce in the country (MOH, 2011; Binagwaho et al., 2013). As is the case with other fields with specialised health services, the country lacked eye care services for several years (Mathenge et al., 2007).

In 2007, there were only 10 ophthalmologists in Rwanda half of whom worked in the capital city (Mathenge et al., 2007). This number was unchanged in 2011 (MOH, 2011). The number increased to 18 ophthalmologists in 2014, still with "most working in the capital city leaving rural areas underserved" (Binagwaho et al., 2015). Due to the low number of ophthalmologists, alternative cadres of health workers are trained to provide eye care services at the peripheral areas to increase access to the population. The training of 1,855 Community Health Workers (CHWs) in eye care and blindness prevention started in 2007 and refresher courses in primary eye care given to general nurses in 502 health centres commenced in 2012. These primary eye care nurses are able to examine and dispense medications and spectacles at the health centres across the entire country (Binagwaho et al., 2015). Ophthalmic Technicians who provide mid-level eye care services at the district level were also trained since 2010 and as of 2018 Rwanda had 65 ophthalmic technicians (Bright et al., 2018). Through partnership with key Non-governmental organisations (NGOs)', the Rwandan eye health system receives support in human resource development, infrastructure development and eye health research (Binagwaho et al., 2015). Currently the Rwanda eye health system is delivered at the primary level by a network of 45,000 CHWs and 1,250 health centre nurses in 502 health centres spread across the country (Binagwaho et al., 2015). At the secondary level, district hospitals provide eye care services which may include surgical services (MOH, 2018). In 2015 it was reported that Rwanda has 8 referral hospitals, 4 provincial hospitals and 34 district hospitals (Binagwaho et al., 2015).

Table 2.0 Administrative structures and related health facilities in Rwanda

No.	Administrative level/structures	Number	Health system structures	Number
1	Villages/Imidugudu	14,837	Community Health Worker (CHW)	45,516
2	Cells/Akagari	2,148	Health Posts	476
3	Sectors/Imirenge	416	Health Centres	499
4	Districts/Uturere	30	District Hospitals	34
5	Provinces (Including City of Kigali)	5	Provincial Hospitals	4
6	National		National Referral and Teaching Hospitals	8
7	Referral systems		Ambulances	225
8	Registered private health facilities	250		

Source: MOH, 2018 pp. 9 [Health Information Management Systems (HMIS) 2016 - 2017]

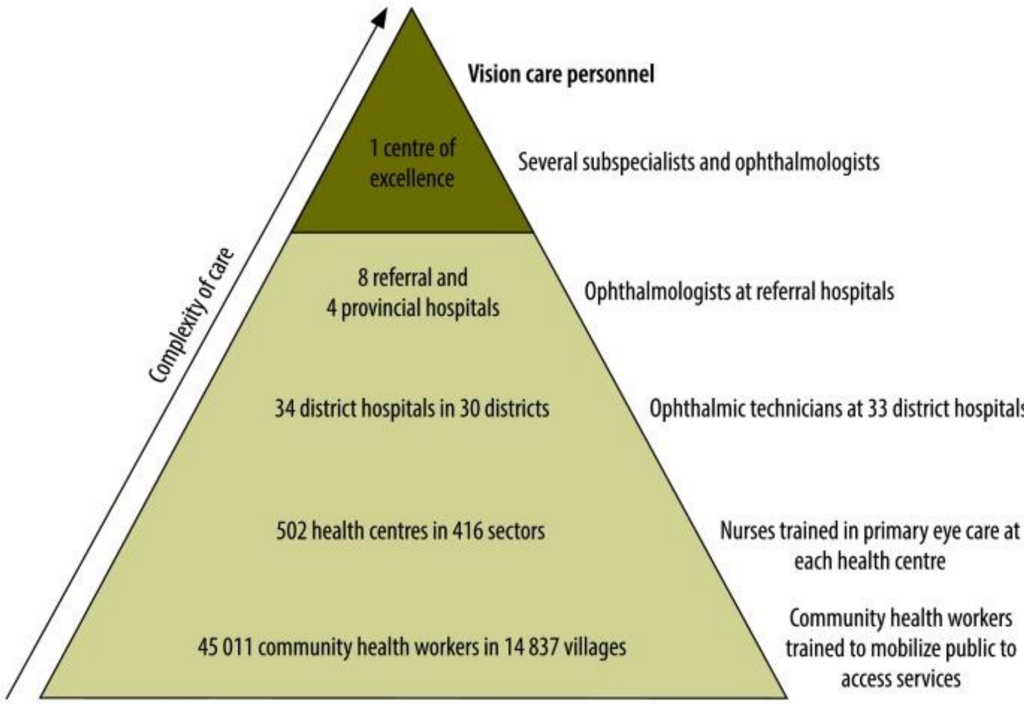

Figure 1.0 Structure of the health sector and organization of current vision care personnel in Rwanda (Binagwaho et al., 2015)

Because a significant number of the population lived below the poverty line (Binagwaho et al., 2015; UNDP, 2016), the Rwandan government implemented measures to make health care services affordable to the people by supporting the creation of community based mutual health insurance schemes (CBHI) which has a national coverage (MOH, 2010). The government also made the payment of insurance premiums to the CBHI very affordable to all segments of the population and even free for the very poor (Kalisa et al., 2015). The government also coordinates funds from both the national coffers and its development partners to support mutual health insurance schemes cover health costs of subscribers (MOH, 2010; Kalisa et al., 2015. The Rwandan mutual health insurance comprises of the following; the Minimum Package of Activities (MPA), which covers all services provided at the health centres, and the

Complementary Package of Activities (CPA) which covers medical and surgical care including cataract surgery at the district and the national referral hospitals (MOH, 2011; IAPB, 2013). Insurance coverage as at 2018 was estimated to be 90% (MOH, 2018).

Improved access to primary eye care using primary health workers and increased affordability by the utilisation of health insurance increased demand for services at secondary and tertiary levels (Binagwaho et al., 2015). The 2015 RAAB was conducted to assess progress in delivery of eye care since the 2007 RAAB blindness survey.

Considering that almost 84 percent of the Rwanda's residents live in rural settings (RDHS, 2015) and that the country's terrain presents a challenge in accessing health services (Muller et al., 2010), this study explores if there is a relationship between distance to access cataract services and the cataract surgical coverage in different parts of the country.

2.0 Study Aim

To determine the prevalence of cataract blindness and assess whether gender and distance are barriers to uptake of cataract surgical services in Rwanda.

2.0.1 Study Objectives

1) To determine the prevalence of cataract blindness in Rwanda without using the automatic RAAB software.

2) To assess the cataract surgical coverage in men and women and determine whether they are significantly different.

3) To assess whether cataract surgical coverage is related to the distance between the nearest surgical centre and patients' locations.

3.0 Methodology

3.0.1 Methods, study design and analysis

This is a descriptive study using secondary data from a population-based, cross-sectional survey - the 2015 Rwandan national RAAB. Even though this dataset has the advantage of coming from a study that was properly powered and used a validated methodology, it did not offer all the information needed to answer all the questions in this research. In view of this, the data for the third objective of this research were generated from Google maps. The RAAB software automatically calculates prevalence and cataract surgical coverage. However for this study raw data was exported into Excel and analyses were done using Stata.

Authority to use the 2015 Rwandan RAAB data was granted by the principal investigator.

Methods

Sample Size Calculation for primary study

The population of persons aged ≥ 50 years in Rwanda was found to be 1,091,370 from the latest population census. Conservatively estimating the prevalence of blindness in this age group to be 3%, with a worst acceptable result of 2.4% (precision of 20%), 95% confidence level, design effect (DEFF) of 1.5, and a non-response rate of 10%, a minimum sample size of 5,161 persons aged ≥50 years was required, which would require 104 clusters of 50 people aged ≥ 50 years.

Sampling for primary study

In the first stage, 104 clusters of persons aged ≥ 50 years were selected through probability proportionate to size sampling using updated data from the 2012 national census as the sampling frame. A list was produced of 416 enumeration areas or sectors and their respective population sizes of people aged ≥ 50 years, based on the population distribution from the census. A column was created with the cumulative population across the enumeration areas/sectors. The total population aged ≥50 years of 1,091,370 was divided by the 104 expected clusters required to derive the sampling interval. The first cluster was selected by multiplying the sampling interval with a random number between 0 and 1, the resulting number was traced in the cumulative population column, and the first cluster was selected from the corresponding enumeration area/sector. The next clusters were selected by adding the sampling interval to the previous number.

In the second stage, households within clusters were selected through compact segment sampling. From the census data, the proportion of the population ≥ 50 years was estimated for each of the 104 clusters/sectors. If this population exceeded 50 people, then the actual number of people was divided such that the cluster/sector contained segmented groups of households that contained 50 individuals aged ≥ 50 years per group of households. If for instance, the cluster population was 300 people aged ≥ 50 years, the cluster area will be divided into 6 segments such that each segment will have total households that contain 50 people aged ≥ 50 years. In such an instance, only 1 segment out of the 6 was needed. The segments were labelled appropriately and numbered on sheets of paper. Lots were drawn and 1 of the segments was be picked randomly. Finally, all individuals aged ≥ 50 years in the households within the chosen segment who had lived in the household for at least 3 months was taken through ophthalmic examination and then interviewed using a structured questionnaire (Appendix 7).

Generation of data for third objective

Google Maps will be used to calculate all distances between patients' locations in the RAAB data and the nearest eye surgical centre. In Google Maps distance calculator, patients' locations will be entered in the form of cluster locations as point A whilst point B will be 7 eye surgical centres in Rwanda. The 7 eye surgical centres were selected because they had undertaken cataract eye surgeries for the past 5 years. In this way seven estimated distances in kilometres will be obtained from Google Maps and the shortest distance in kilometres by road between the two points A and B will be selected to represent the nearest eye surgical centre.

Data analysis

The outcome variables will be collected from the existing survey (2015, Rwanda RAAB). The RAAB data will be prepared out from the RAAB data capture software as excel file with coded information of survey participants for further analysis.

Cataract surgical coverage will be calculated at three different levels of vision impairment; <6/18, <6/60 or <3/60 in the better eye. Cataract surgical coverage (CSC) will be calculated for eyes using the formula a/(a + b), where 'a' is the number of eyes with previous operation (regardless of VA) and 'b' is the number of eyes with VA of <6/18, <6/60 or <3/60 due to cataract. CSC for persons will be calculated using the formula (x + y)/(x + y + z), where x is the number of people who had unilateral aphakia/pseudophakia and VA <6/18, <6/60 or <3/60 in the contralateral eye; y is the number of people with bilateral operated eyes (regardless of VA) and z is the number of people with VA of <6/18, <6/60 or <3/60 in their best eye (at least one of which had reduced vision owing to cataract). Prevalence estimates with 95% confidence intervals will be calculated for the three vision impairment categories. Differences in blindness prevalence associated with gender will be calculated with test of proportions and the association of cataract surgical coverage and distance will be explored using correlation and linear regression. The data will be coded and analysed using statistical methods including t-tests, correlation, linear and multiple regressions. Results will be reported as statistically significant if $p < 0.05$ (two-tailed). Data analysis will be performed using STATA version 14.0 (STATA Corp, College Station, Texas, USA).

4.0 Ethical considerations

4.0.1 Ethical Approval for primary and secondary studies

Ethical approval for the primary study was granted by the National Institute of Statistics of Rwanda (NISR) (Appendix 2). Informed verbal consent was obtained from the patients after explanation of the nature and possible consequences of the study. All people with operable cataract or other treatable conditions were referred for treatment. Ethical approval for the secondary study was granted by the Human Research Ethics Committee of the University of Cape Town (HREC) (Appendix 1).

4.0.2 Description of risks and benefits

No risks of any kind were anticipated from this study as only secondary data was used for analysis. There was no contact or communication with participants.

4.0.3 Potential risks and discomforts

No potential risks and discomfort as only secondary data was used for this study.

4.0.4 Potential benefits

The results from this study will inform planners and implementers of the eye care programme in Rwanda on how gender and distance affect the utilisation of existing cataract services and on how the consideration of these factors can help achieve the goal of reducing cataract blindness in the country. This will help inform how the national government allocate resources to reduce blindness from cataract.

4.0.5 Informed consent process

National ethical committees provided approval prior for the primary survey work. No informed consent was needed for the secondary analysis data to be undertaken.

4.0.6 Withholding information

No information will be withheld from the National Institute of Statistics of Rwanda regarding the results of the study.

4.0.7 Privacy and confidentiality

Only electronic data was used and this was only be accessed by the author. The data was anonymised by using unique identifiers instead of names. This data was kept in a personal computer which had a password only known by the researcher.

4.0.8 Emergency care and insurance for research-related injury

Research related injury was not anticipated as this is a secondary data analysis.

5.0 Justification of the study

Cataract blindness is an easily correctable eye condition and people need not be blind from it. The main focus of this study is to analyse some aspects of the 2015 Rwandan RAAB with a focus on cataract blindness in the population and to determine whether gender and distance are significant barriers to uptake of cataract surgical services. The Global Action Plan (GAP 2014 - 2019) Objective 1.2 asks Member states to report on whether access to services is universal and to report on quality and inequity of services. This analyses of Barriers and CSC will provide useful information for Rwanda including information that is not generated by the RAAB automated reports. The results of this study will contribute information in the planning of eye care services.

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PART B: STRUCTURED LITERATURE REVIEW

1.0 Objectives of the literature review

A review of existing literature was conducted in order to provide the context for this mini-dissertation entitled; "Assessment of cataract blindness prevalence and factors associated with surgical coverage in Rwanda". The scope of the literature review included examination of;

1) Studies on the prevalence of blindness and cataract surgical coverage in various countries using the Rapid Assessment of Avoidable Blindness (RAAB) methodology

2) Studies on the barriers to uptake of cataract surgical services and the factors affecting cataract surgical coverage

3) It also aimed to identify the potential gaps in literature on these topics

1.0.1 Literature search strategy

The search strategy for the literature review focussed on papers addressing topics related to the RAAB methodology and outcome results in lower and middle-income countries. It also looked at factors affecting health care services utilisation. The terms were searched within online databases such as PubMed, MEDLINE and Google Scholar. The official RAAB data website (RAAB Repository) which contains up to date data on RAAB studies both published and unpublished was accessed. Grey literature such as policy documents and official reports on health services in Rwanda were found utilizing Google search. Search terms used to access papers in PubMed Central is found in table 1.0

Table 2.0 Search Items utilized in PubMed Central

Concept	**Search Items**	**Papers Found**	**Criteria of Selection**	**Date of Search**
Rapid Assessment of Avoidable Blindness (RAAB)	Rapid Assessment of Avoidable Blindness	394	1)English Language 2)Low income settings	August 2016
Cataract Surgical Coverage and Gender	(Cataract Surgical Coverage) AND gender AND sex AND males AND females	352	1)English Language 2)Low income settings	August 2016
Cataract Surgical Coverage and Distance	(Cataract Surgical Coverage) AND distance	378	1)English Language 2)Low income settings	August 2016
Distance and Health Services Utilization	Distance AND health care service utilization AND Google Map and GIS	86	English Language	September 2016
Access to cataract surgery	(Access and cataract surgery) AND (Barriers and cataract surgery) AND (Lack of cataract surgery) AND Low income	373	English Language	January, 2019

2.0 Summary of literature review

2.0.1 Blindness and visual impairment

Visual acuity (VA) is defined as "the relative ability of the visual organ to resolve detail" (Merriam Webster Dictionary). In the latest classification of diseases, vision impairment is categorised into two groups; distance and near (ICD 11, 2018; WHO, 2018). Blindness is defined as a presenting best corrected distant visual acuity of less than 3/60 or a visual field loss of less than 10^{o} from the point of fixation in the better eye (WHO, 2007).

Table 2.0 Categorization of visual function by (ICD 11)

Vision category	**Presenting visual acuity in the better eye**
No vision impairment	6/6 – 6/12
Mild vision impairment	<6/12 - 6/18
Moderate vision impairment	<6/18 - 6/60
Severe vision impairment	<6/60 - 3/60
Category 1 Blindness	<3/60 - 1/60
Category 2 Blindness	<1/60 - Perception of Light (PL)
Category 3 Blindness	No Perception of Light (NPL)
Near vision impairment	<N6 or <N8 at 40cm with existing correction

It is estimated that 1.3 billion people worldwide live with some form of distance or near vision impairment (WHO, 2018). As at the year 2017, 253 million people were estimated to be living with distant vision impairment worldwide of which 36 million were blind and 217 million had moderate to severe vision impairment (WHO, 2018; Bourne et al., 2017). About 90% of people with vision impairment worldwide live in low-income settings (Pascolini & Mariotti, 2011; WHO, 2017). There is an association between ageing and blindness with 81% of people living with blindness aged 50 and above (WHO, 2017). 53% of the burden of moderate to severe vision impairment worldwide are attributed to uncorrected refractive errors whilst cataracts are the major cause of blindness representing 35% of the burden (WHO, 2017). 80% of all vision impairment can be prevented or cured (WHO, 2017).

2.0.2 Cataract

Cataract is an opacification of the crystalline lens of the eye which obstructs the passage of light thereby causing reduced vision. The majority of cataracts develop as a result of the ageing process. Other risk factors for the development of cataract include diabetes mellitus, prolonged exposure to ultraviolet rays from the sun, smoking, drinking, trauma to the eye and inflammatory eye diseases (WHO, 2010). Children can also be born with cataract known as congenital cataract. The prevalence of congenital cataract has been found to be low; Wu et. al (2016) estimated 4.24 per 10,000 in a systematic review. Age-related cataract is therefore the major cause of vision impairment worldwide (WHO, 2017). In people with vision impairment caused by cataract, vision can be restored by surgically removing the cataract lens, and replacing it with an artificial one (WHO, 2010). However in many low and middle income countries, barriers such as access to surgical services and the cost of services exist that prevent people to benefit from cataract surgery (WHO, 2010).

2.0.3 Measuring blindness and cataract in the population

Prevalence of blindness in the population is measured by means of surveys. Previous methods of surveys were resource intensive so only few countries were able to conduct population-based surveys. Rapid Assessment of Avoidable Blindness (RAAB) was introduced in 2006 and has since been the main methodology to estimate blindness in populations in several countries (Kuper, Polack & Limburg, 2006). Estimates show that 82% of people living with blindness are aged 50 and above (WHO, 2014) making the prevalence of blindness in this age group much higher than the general population. RAAB focusses on this age group of 50 years and older utilizing a smaller sample size than what would have been required to survey all age groups in the population. From the RAAB methodology, a sample size of between 2500 and 5000 of people aged 50 years and above has been proven to provide accurate estimate on vision impairment for the entire population (Limburg et al., 2007). The proportion of blindness due to different causes is the same in those over 50 years as in the total population, making RAAB provide a realistic estimate of blindness prevalence as compared to a full survey (Mathenge et al., 2007). A comparative study to assess the validity of RAAB methodology in estimating the prevalence and causes of blindness and visual impairment in Gambia confirmed similar results gotten with the total population study (Dineen, Foster &Faal, 2006). Therefore, RAAB has been shown to be cost efficient and a more rapid methodology whilst being effective (Kuper, Polack & Limburg, 2006; Mathenge et al., 2007).

The standard RAAB methodology involves the following:

Sampling size determination:

Adequate sample size is obtained by factoring in the expected prevalence of blindness in the survey area, the precision of estimates required, the confidence interval and the design effect (DEFF) from the cluster random sampling procedure (Limburg et al., 2007). RAAB typically samples clusters of 40 to 60 people aged 50 years and above living together in census units other than individual simple random sampling. Clusters of people living together have common characteristics and lesser variances amongst each other therefore the design effect (DEFF) is a correctional factor to account for the loss in variations caused by the cluster random sampling (Limburg et al., 2007).

Sampling:

Multistage cluster random sampling is used to select study units: In the first stage, the sampling frame is produced from enumeration areas (usually referring to a defined settlement in the survey area) and their respective population sizes of people aged ≥ 50 years based on the population distribution from the areas' recent census (Limburg et al., 2007). A column is made of enumerated areas or settlements and their cumulative populations. The total population aged ≥ 50 years in the survey area is divided by the number of clusters of 50 people required to meet the sample size. The quotient number becomes the sampling interval. The sampling interval is then multiplied by a random number between 0 and 1. The resulting number is then traced in the population column to identify the corresponding enumeration area to be selected as the first cluster. The second cluster is selected by adding the sampling interval to the previous number used to select the first cluster and then traced in the cumulative population column accordingly. This process is continued until all clusters of 50 people aged ≥ 50 years are selected that meets the sample size (Mathenge et al., 2007).

In the second stage households within the clusters are selected through compact segment sampling. From the census data, the proportion of the population ≥ 50 years can be estimated for the cluster. If this population exceeds 50 people, then the actual number of people is divided such that the cluster area contains segmented groups of households that contains 50 individuals aged ≥ 50 years per group of households. If for instance, the cluster population is 300 people aged ≥ 50 years, the cluster area will be divided into 6 segments such that each segment will have total households that contain 50 people aged ≥ 50 years. In such an instance, only 1 segment out of the 6 is needed. The segments are labelled appropriately and numbered 1 to 6 on sheets of paper. Lots will be drawn and 1 of the 6 segments will be picked randomly. Finally, all individuals aged ≥ 50 years in the households within the chosen segment will be taken through ophthalmic examination and then interviewed using a standardised structured questionnaire (Mathenge et al., 2007).

Data analysis:

Survey data is entered into a developed RAAB software for Windows (Visual FoxPro 7.0) and analysed automatically thereby not requiring a statistician. The RAAB software produce estimates of the following: age and sex adjusted prevalence of blindness, severe visual impairment (SVI), visual impairment (VI); causes of blindness, SVI, and VI; cataract surgical coverage; outcome after cataract surgery; causes of poor surgery outcome; satisfaction with cataract surgery and barriers to uptake of cataract surgery (Kuper, Polack & Limburg, 2006, (Limburg et al., 2007)).

2.0.4 Determinants of blindness and cataract in the population

The prevalence of blindness differs from country to country. Research has shown that higher income countries have the lowest prevalence and lower income countries often have the highest prevalence (Resnikoff et al., 2002). There is also an association between the gross domestic product (GDP) of a country and its prevalence of blindness (Ho & Schwabb, 2001). Countries with better economies usually have better health care systems to deal with the burden of blindness, largely in terms of infrastructure and human resources (Sommer et al., 2014).

Research by Lewallen et al. (2013) showed that the epidemiology of cataract also varies substantially across low income countries such as in sub-saharan Africa. They found that "the age-adjusted incidence is two to four times higher in Sahel populations (roughly corresponding to the Nilo-Saharan and Afro-Asiatic language groups) than in Bantu language group populations and this may be related to genetic variations or to environmental or cultural factors."

The prevalence of blindness of a country is also related to the proportion of aged in the population, this is because blindness prevalence increases with aging, especially in regards to cataract. 82% of all blind people are aged 50 years and above (WHO, 2014) and confirms that the more aged a population is the higher the prevalence of cataract. However this is truer for low and middle income countries because of inadequate resources to tackle the burden of cataract. Conversely, higher income countries who have longer life expectancy with corresponding older populations have been found to have lower prevalence of cataract because of their better eye health systems (Sommer et al., 2014).

On an individual level, higher levels of education and income have been shown to be associated with lower levels of visual impairment. Individuals with higher levels of education were likely to have more knowledge of their health condition and the corresponding financial means to seek appropriate health services (Ploubidis et al., 2013; Ulldemolins et al., 2012; Cockburn et al., 2012).

2.0.5 Indicators in monitoring cataract services

With the launch of the Global Action Plan for the prevention of blindness (GAP) 2014 - 2019; many countries are accelerating blindness prevention activities in order to achieve set targets. The indicators that are used to measure cataract services in the population fall into two main categories: those that measure the quantity of services and those that measure the quality of services. Those that measure the quantity are the cataract surgical rate (CSR) and the cataract surgical coverage (CSC). Those that measure the quality are the cataract surgery success rate or outcomes (Limburg et al., 2005; Limburg & Ramke, 2017). Cataract surgical rate is the number of cataract surgeries that an eye care system performs per million population per year. A target of at least 2000 surgeries per million per year was considered ideal for low-income countries in order to meet the demands of their population to reduce blindness (Foster, 2000). This target is however proposed to tackle blinding cataract and not all cataract.

Cataract surgical coverage is defined as the proportion of people with bilateral cataract eligible for cataract surgery who have received cataract surgery in one or both eyes from a visual acuity levels of 3/60, 6/60 and 6/18. Of the indicators mentioned above; the indicators that are used to measure the impact of cataract services in the population are changes in the prevalence of cataract blindness, cataract surgical coverage and cataract surgical rate (Limburg & Foster, 1998). Cataract Surgical Coverage (CSC) is an “indicator that assesses the extent to which cataract surgical services are meeting the need of the population” (Limburg & Foster, 1998; IAPB, 2015). The lower the percentage of cataract surgical coverage in a population, the likelihood that the demand for cataract surgical services has not been adequately met. According to IAPB, an 80% CSC threshold has been used in discussions as ideal to meet the demand of cataract surgical services. However according to an IAPB report, “even in countries with a good CSC coverage of 80%, it is still likely that people from the poorest or more excluded sections of society, such as persons with disabilities, minority groups and people living in remote areas may not get access to the services they need” (IAPB, 2015). CSC is also one of the proxy indicators used to monitor the achievement of universal health coverage (UHC) (IAPB, 2015).

2.0.6 Factors affecting cataract surgical coverage

Factors that affect CSR and CSC seem to cut across the eye health systems in many countries. There are factors mainly on the hospital’s side and factors on the patient side. The factors related to the health system such as "insufficient surgeons, or auxiliary ophthalmic staff, inadequate facilities in which to operate, insufficient equipment, supplies or other resources necessary for surgery, inefficient diagnostic or referral services to identify people with cataracts" have been discussed extensively by Lewallen et al.(2015). The factors on the patient side that are often mentioned as barriers to achieving a higher CSC have been reported in several eye health surveys. The main ones include; fear of surgery, costs of surgery, distance to travel for surgery, and knowledge of eye care services (Mathenge et al.,2007; Chandrashekar et al.,2007; Athanasiov et al.,2008; Mitsuhiro et al.,2009; Kagmeni et al.,2015; Okoye et al.,2015).

2.0.7 Differences in cataract blindness prevalence and cataract surgical coverage in males and females

In terms of gender differences in blindness prevalence, most research has shown that women consistently do have a higher prevalence than men. A meta-analysis by Abou-Gareeb et al. (2000), concluded that globally women bear excess blindness compared to men. After age adjustment, the overall odds ratio (OR) of women living with blindness to men were 1.39 for Africa, 1.41 for Asia, and 1.63 for industrialized countries.

The terms 'gender' and 'sex' are often used interchangeably in some literature to refer to differences in males and females. However according to WHO, 'sex' refers to the biological characteristics that differentiates males from females whilst 'gender' refers to the socially constructed roles and behaviours that are considered appropriate for males and females. Using these two descriptions, biological and social reasons are distinctly identified for the differences in blindness prevalence in males and females. 'Sex'/biological reasons include reduced oestrogen levels in menopausal women which have been cited to play some role in cataract formation (Hales et al., 1997; Zetterberg & Celojevic, 2015). Increased life expectancy of women than men in many countries has also been mentioned as a possible factor for women having excess blindness than men. In Rwanda for example; life expectancy for women in 2012 was 66.2 years compared to 62.6 years for men (RHDS, 2015). 'Gender'/social reasons for the varied blindness prevalence in males and females is often reported in low and middle income countries to include differences in access and affordability of eye care services in settings where societal and cultural expectations make men dominate over women in terms of financial ability and decision making process. The implication is that often males (husbands and sons) are given priority to eye care services than females (wives and daughters) (Geneau et al., 2005; Geneau et al., 2008; Courtright & Lewallen, 2009). Consequently, many studies report higher cataract surgical coverage for males than females;

Abubakar et al. (2012) from the Nigeria National Blindness and Visual Impairment Survey also reported a difference of CSC 1.7 times higher among males than females. Dean et al. (2011) also reported in their study that CSC was lower in females compared to males (73.3% vs. 100.0%, $P < 0.001$). Odugbo and Mpyet (2012) in a survey from the Plateau state of Nigeria found the prevalence of bilateral blindness due to cataract to be 1.8% in males (95% CI: 1.2-2.4%) and 2.4% in females (95% CI: 1.8-3.8%). The cataract surgical coverage was 60.5% for males and 48% for females. Nkomazana (2009) in a survey in Botswana found that the prevalence of bilateral cataract blindness was 1.0% (95% CI: 0.001%–2.1%) in men compared with 1.6% (95% CI:0.6%–2.7%) in women, 76.9% of men, bilaterally blind from cataract had cataract surgery in one or both eyes compared with 59.4% of women. Unequal access to cataract surgery between men and women in Botswana had contributed to the higher prevalence of cataract-related blindness in women. Mathenge et al. (2007) in the survey done in the Western Province of Rwanda from a sample size of 2,250 people aged ≥ 50 years showed that the unadjusted prevalence of blindness in the population was 1.8% (95% CI: 1.2%–2.4%), which was similar in men and women but the CSC was consistently higher for men than for women; 64.3% vs. 36.4% at a VA<3/60; 55.6% vs. 34.5% at a VA<6/60 and 24.4% vs. 19.4% at a VA <6/18. Aboobaker and Courtright (2016) in a systematic review of barriers to cataract surgery in Africa from 1999 to 2014 reported that CSC was lower in females in 88.2% of the studies. Lewallen and Courtright (2009) in a systematic review estimated that blindness and severe visual impairment from cataract could be reduced by around 11% in low- and middle-income countries if women were to receive cataract surgery at the same rate as men.

2.0.8 Distance and health services utilization

Several studies show that distance shows an inverse relationship with health services utilization in both low and high resource settings (Raknes, Hansen & Hunskaar, 2013; Awoyemi, Obayelu, &Opaluwa, 2011; Girma, Jira, & Girma, 2011; Venkatesh, Siddharthan & Metri, 2011; Buor, 2002; Muller et al., 1998). This relationship is more prevalent regarding maternal health services utilization such as antenatal care visits and institutional birth deliveries. Studies have shown that pregnant women mostly tend to choose the closest health facility for delivery and if it is not available or they do not have the means to access a farther one, they simply deliver at home (Kebede, Hassen & Nigussie et al., 2016; Zegeye, 2014; Nai-Peng & Siow-li, 2013; Kyei, Campbell & Gabrysch, 2012; Manzi et al., 2010). However, other studies have proven that distance alone does not predict utilization of health services. Buor (2002) listed six factors that combine with distance in order to predict health services utilization, namely; size of health facility, range of services offered, quality of services offered, cost of services offered, transport availability and the need or nature of the health problem. This is concurred by Oladipo (2014) who even elaborated to eleven factors. Girma, Jira, & Girma, (2011) found in their research in South West Ethiopia that the major predictors of utilization of health care services were: marital status, socioeconomic status, presence of disabling health problem, presence of an illness episode, perceived transport cost and distance to the nearest health centre or hospital. Buor (2002) also mentioned confounding variables that relate to distance itself; such as travel time and transport cost. This is to mean that, a longer distance could involve greater cost which has the potential of discouraging utilization in a poverty-endemic region however in settings with good road networks and affordability for transport, longer distances may actually take a shorter travel time. Conversely, in settings with poor road network and unmotorable terrains, shorter distances may take longer time to travel (Munoz & Kallestal, 2012).

2.0.9 Distance as a barrier to the uptake of cataract surgical services

The predictors of general health services utilization also come into play in eye care services utilization. Logically, people who stay farther away from eye care facilities may have to travel long distances to access them. A significant proportion of people living with cataract blindness are aged who are often weak and have co-morbidities. This situation coupled with transportation costs and its availability may be a huge barrier to uptake of cataract surgical services. Razafinimpanana et al. (2012) reported in their study in Madagascar that proximity to the eye surgical centre was an important predictor to the uptake of cataract surgery. They found that people who were closer to the eye surgical centre were twice more likely to present themselves for surgery than people who were distant. Distance is also a known barrier to the uptake of cataract surgical services that is reported in many RAAB studies (Courtright et al., 2001; Sapkota et al., 2003; Razafinimpanana et al., 2012; Mehari et al., 2013; Olusanya et al., 2016). However, Courtright et al. (2010) found that reducing the distance between patients and eye care services alone do not increase utilization and that patients consider the costs of surgery and quality of services before they present themselves to surgical centres. Lewallen et al. (2015) in a systematic review also outlined factors that encourage the uptake of cataract surgical services in a population which were; having a fixed eye surgical centre with an eye surgeon and getting good outcomes from the cataract surgery. Indeed distance is only one of the barriers that may reduce the uptake of cataract surgical services.

2.0.10 Other barriers that affect the uptake of cataract surgical services

Typical RAAB studies have structured interviews that elicit interviewees' responses to specific possible barriers that may have delayed their cataract surgery. These barriers include: 'surgery need not felt', 'fear of surgery or loss of vision', 'inability to afford surgery costs', 'surgery denied by the surgical centre', 'unaware of surgery availability' and 'distance to travel to surgical centre'. Depending on the survey area, some barriers are frequently reported than others and this reflects the area's specific challenges in accessing cataract surgical services. Chandrashekar et al. (2007), Athanasiov et al. (2008) and Okoye et al. (2015) reported affordability of surgery as the main barrier to cataract surgery in south India, Myanmar and Nigeria respectively. Lindfield et al. (2012) reported 'unaware of surgery availability' as the main barrier in Zambia and Kalua et al. (2011) reported "no need felt" as the main barrier in Malawi. However, "fear of surgery" is the most common reported barrier to cataract surgery uptake in many studies (Chandrashekar et al., 2007; Athanasiov et al., 2008; Mitsuhiro et al., 2009; Kagmeni et al., 2015). Beyond the aforementioned barriers, Courtright et al. (2010) and Geneau et al. (2008) reported that for a person to undergo surgery, complex decision making processes are involved and these are often not apparent to health care providers.

2.0.11 Measuring distance as a barrier to cataract surgical services utilization

Most studies that have reported distance as a barrier to uptake of cataract surgical services have used interviews to obtain information from study participants. Whilst patients reported barriers to accessing health care services are better captured in qualitative methods, it has been reported that people who have not had cataract surgery sometimes do not give the truthful reasons for not accessing the surgical services in order to avoid embarrassment or to provide responses that enable them avoid surgery because they are not interested (Kessy & Lewallen, 2007; Courtright et al., 2010; Aboobaker & Courtright, 2016). Other objective forms of assessing patients barriers can provide public health planners added information to qualitative reports. An attempt was made by Randrianaivo et al. (2014) to objectively determine whether distance has an effect on uptake of cataract surgical services. In a RAAB survey in Madagascar, they used hospital records of patients cataract surgery and their places of residence to calculate the cataract surgical rate and the proportion of patients who lived closer to the hospital and found a strong positive correlation between cataract surgical rate by district and the proportion of people living within 2 hours of the access road to the surgical centre (r^2 = 0.89, P = 0.002). Razafinimpanana et al. (2012) also reported in their study in Madagascar that people who were closer to the eye surgical centre were twice more likely to present themselves for surgery.

Geographic Information System (GIS) and spatial accessibility methods have widely been used to assess the distances and time patients travel to health facilities and its effect on uptake of health care services (McLafferty, 2003; Gabrysch et al., 2011). There has been some critique of this method that it does not mimic the real challenges people may go through in travelling to access health services such the terrain and nature of the road (Shahid et al., 2009; Guagliardo, 2004). However, a paper by Nesbitt et al. (2014) which compared six different methods utilised in geographic access measurements in public health found all of them robust and comparable in effectiveness. However, two techniques commonly utilised in accessibility studies in public health research are Euclidean and Network distance measurements (Mizen et al., 2015). Euclidean distance techniques utilise straight-line distances measured between locations or points whilst Network distance techniques use actual road distances measured between two locations (Dos Anjos Luis & Cabral, 2016). The critique of the Euclidean technique is that it does not take into account real life challenges such as the terrain in travelling to access of health care services (Cubukcu et al., 2016). Google Maps function like Network distance technique and calculates the real road distance between two locations within the map. Google Map is able to capture the real distances travelled and the time needed for patients to get to health facilities by road (McGuire, 2015 pp. 112-113). Google Maps is a free desktop and mobile application which offers worldwide satellite images, street maps and panoramic views of some places on two-dimensional map. Vuori, Kylanen and Tritter (2010) in a study investigating the effect of distance on policy makers' decision making to transfer patients between health care centres and special care services in three Nordic countries utilised Google Maps. Raknes, Hansen and Hunskaar (2013) in a study by to assess the relationship between distance and utilisation of out-of-hours services in a Norwegian urban/rural district used Google Maps to calculate the travel distance and travel time between postcode coordinates of patient locations and a casualty clinic. They found that increasing distance was associated with lower utilisation of out-of-hours services. Similar studies utilising this methodology include; Lin, Gray and Qu (2010); Raknes and Hunskaar (2014); and Dunivan et al. (2014). Whilst distance is a known barrier to uptake of cataract surgery, there has been no research using calculated distances between patients' locations and the nearest eye surgical centre to assess this relationship.

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PART C: JOURNAL"READY"MANUSCRIPT

TITLE PAGE

Assessment of cataract blindness prevalence and factors associated with surgical coverage in Rwanda

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ABSTRACT

Purpose:

Rapid Assessment of Avoidable Blindness (RAAB) is a cost-effective method of assessing the burden of blindness and cataract surgical services in a population. This study analyses the 2015 Rwanda RAAB data to ascertain whether gender and distance affects cataract surgical coverage (CSC).

Methods:

Secondary non automated data analysis was performed on the 2015 Rwanda RAAB. Cataract blindness prevalence and CSC were estimated for the sexes and assessed for significant differences. Distances from clustered patients' locations to the nearest eye surgical facility were calculated using Google Maps and assessed if it had any relationship with the CSC for the area.

Results:

The prevalence of bilateral cataract blindness for males was 0.4% (n=8; 95% CI=0.1-0.7) and females 0.5% (n=17; 95% CI=0.3-0.8). The CSC for males and females were 69.2% and 68.5% respectively but the difference in CSC was not statistically significant. Females aged ≥70 years reported the highest number of barriers to cataract surgical services. At a VA <3/60 in the better eye, 1km increase in the distance to the nearest eye surgical centre was associated with a reduction in the CSC for the area of 4.8% (Linear regression: $F(1,95) = 16.06$, $p = 0.0001$, R-Squared = 0.1446, Adjusted R-Squared = 0.1356).

Conclusions:

Older women (≥70 years) were the most vulnerable to untreated cataract blindness in Rwanda and therefore special programs need to target them for cataract surgical services. Distance to surgical

facilities with ophthalmologists is related to the cataract surgical coverage even in a small country like Rwanda.

Key words:

RAAB, Blindness, Cataract, Cataract Surgical Coverage, Utilization, Barrier, Distance

List of Abbreviations:

RAAB - Rapid Assessment of Avoidable Blindness

VA - Visual Acuity

IOL - Intraocular Lens

CSC - Cataract Surgical Coverage

CSR - Cataract Surgical Rate

DTNSC - Distance to Nearest Eye Surgical Centre

RDHS - Rwanda Demographic and Health Survey

MOH - Ministry of Health

WHO - World Health Organisation

1.0 INTRODUCTION

The WHO, World Health Assembly launched "Universal Eye Health: A global action plan 2014 – 2019" (GAP 2014 – 2019) in 2013 to call for global support in reducing the prevalence of avoidable visual impairment from the baseline data in 2010 by 25% by 2019[1]. GAP 2014 – 2019 supersedes "Vision 2020", the original global initiative to eliminate all causes of avoidable blindness by 2020[2]. In 2010, it was estimated worldwide that 285 million people were living with visual impairment of which 39 million were blind[3, 4]. In 2017, estimates showed that the people living visual impairment had reduced to 253 million of which 36 million were blind and the rest had moderate to severe visual impairment[5, 6]. Cataract; defined as an opacification of the crystalline lens of the eye which reduces visual acuity currently accounts for 35% of global burden of vision impairment and 50% of the burden of blindness in many low income countries[5]. Cataract has received a lot attention in blindness prevention programs because of its simple treatment by surgery to restore vision. Cataract surgical coverage (CSC) is an indicator used to assess the extent to which a population's burden of cataract blindness has been reduced[7, 8]. CSC is defined as the proportion of people with operable cataract in the population who have received cataract surgery. CSC is a key indicator in the Universal Eye Health Global Action Plan (2014-2019). Some studies have assessed possible factors that influence CSC in a population. These border on barriers to the uptake of cataract surgery and the quality of eye health systems[9, 10]. A report by IAPB in 2015 from a study of CSC data from 27 countries (10 Latin American, 8 Asian, 6 African, 2 Eastern Mediterranean and 1 European countries) showed that CSC was influenced by gender, literacy and location of the population[8] and specific strategies were needed by countries to deal with inequities of such segments of the population in accessing cataract surgical services to achieve adequate CSC.

Prevalence data on vision impairment is needed by health planners to properly allocate scarce resources in blindness prevention and intervention programs[11]. Conducting population-based blindness surveys had been costly and challenging and fewer countries were able to undertake[11, 12]. The Rapid

Assessment of Avoidable Blindness (RAAB) was introduced as an alternative quicker and less costly population-based eye survey methodology with a focus on the population aged 50 years[12, 13]. This age group was selected because they have a high prevalence of blindness and account for 85% of visual impairment in the population and thus a smaller sample size is adequate for surveys[12, 13]. RAAB survey analyses are automated and the results are standardised for all surveys using a RAAB software[12]. The RAAB methodology has been assessed for its validity in estimating the prevalence and causes of blindness and visual impairment in Gambia and Kenya and confirmed to produce similar results gotten with the total population survey[14, 15].

Rwanda is a small landlocked country in Central East Africa with a population of 11 million[16]. Administratively, the country is subdivided into 5 provinces and 30 districts. The country's relief is mountainous which presents transportation challenges[17-19]. Rwanda is classified as a low income country with a GDP of $8.48 billion as at 2016[20]. The country went through a devastating civil war in 1994 in which almost a million of its population perished and its health services infrastructure and workforce were severely affected[21, 22]. Rwanda continued to struggle with shortages of skilled professionals[23-25] and lack of specialised health care services after the war including eye care[26]. In 2007, the entire country had 10 ophthalmologists[26] which increased to 18 in 2014[27] but most of whom worked in the national capital[26, 27]. To increase access to eye care services especially in underserved areas and improve referrals to ophthalmologists, the NGOs; Christoffel Blinden Mission (CBM) and Vision for a Nation (VFAN) supported the training of nurses in the provision of primary eye care services across the country in 2007 and 2012 respectively[27] . Additionally, a cadre known as ophthalmic technicians are currently being trained to provide mid-level eye care services[27]. The Rwandan eye health system is delivered at the primary level by 45,000 community health workers and 1,250 health centre nurses in 502 health centres spread across the entire country[27]. District hospitals provide eye care services at the secondary level and may include surgical services. Rwanda has 8 referral hospitals, 4 provincial hospitals and a tertiary hospital[27]. Currently, the cost of healthcare services is borne through mutual health insurance schemes which is supported by the government and has a national coverage[28, 29].

In 2007, the first RAAB was conducted in the Western Province of Rwanda[26] and in 2015 the second RAAB was conducted for the whole country. This study analyses the 2015 Rwanda RAAB with a focus on cataract blindness and cataract surgical coverage. In 2014, a report by USAID on gender analysis in Rwanda mentioned that older women were traumatised from the country's civil war because they lost their husbands and sons and had been vulnerable[30]. Rwanda's terrain being mountainous is also said to present challenges in assessing health care services[17, 19]. This study assesses whether the two factors stated; 'gender' and 'distance to travel to access eye care services' have impact on the uptake of cataract surgery and the achievement of adequate cataract surgical coverage for the country.

2.0 METHODS

2.0.1 Data acquisition

This is a descriptive study using secondary data from a population-based, cross-sectional survey; the Rwanda Rapid Assessment of Avoidable Blindness (RAAB) conducted in 2015. This data was obtained with permission from the principal investigator.

Ethical clearance for the study was given by the Human Research Ethics Committee of the University of Cape Town.

A minimum sample size of 5,161 was required for the primary study. This was obtained by factoring in the expected prevalence in the age group ≥ 50 years in Rwanda to be 3% with 20% precision, 95% confidence level, design effect (DEFF) of 1.5 and a non-response rate of 10%.

The standard RAAB methodology was followed for the primary study. In brief, it involved 104 clusters of 50 people aged ≥ 50 years selected by probability proportionate to size sampling. The clusters were obtained using the updated data of the 2012 Rwanda population and housing census as the sampling frame. A list was produced of 416 sectors in Rwanda and their respective population sizes of people aged ≥ 50 years, based on the population distribution from the census. A column was created with the cumulative population across the enumeration areas/sectors and clusters selected by probability proportionate to size. Households within clusters were selected through compact segment sampling.

Variables in the data from the primary study were obtained through study participants undergoing standard clinical ophthalmic examination by an eye care team as well as being interviewed using a structured questionnaire. The secondary data was originally captured in the RAAB software package but was prepared out into an excel document by the principal investigator before handing over for all analysis. The secondary data used contained 39 variables: appendix 6 (list of variables in RAAB data).

For the purposes of the third objective in this study; being the assessment of the association between distance of patients' locations to the nearest eye surgical facility, an additional data was generated by calculating the cataract surgical coverage for all the clusters included in the study. Google Maps was used to calculate all distances between patients' locations and the nearest eye surgical facility. In Google Maps, patients' locations were entered in the form of cluster location as point A and seven eye surgical facility locations in Rwanda were entered as point B in the Google Map distances calculator. The eye surgical facilities were: Rwamagana Hospital located in Rwamagana town for the Eastern Province, Kabgaye Hospital located in Muhanga district for the Southern Province, Gisenyi District Hospital located in Gisenyi town for the Western Province, Ruhengeri District Hospital located in Musanze (Ruhengeri) for the Northern Province and Central Hospital, Military Hospital and Dr Agarwals Hospital all located at Kigali, the capital. In this way seven estimated distances in kilometres were obtained from Google Map and then recorded into an Excel sheet. A column was then created that contained the shortest distance in kilometres by road between the two points A and B. This shortest distance was chosen to represent the nearest eye surgical facility. The final data was given to the principal investigator for comments and validation.

2.0.2 Data definition

Eye surgical centre: This is defined as an eye unit that is manned by an ophthalmologist who has performed cataract surgery within the last five (5) years.

Nearest eye surgical centre: The nearest eye surgical facility by virtue of having the shortest distance from a patient cluster location.

Patients' locations: This is defined as clustered locations where group of patients may reside or converge. In the distance calculations, examples of locations used include markets, sector offices, schools and health centres.

Pseudophakia: An eye that has undergone a type of cataract surgery whereby an artificial lens has been implanted in situ.

Aphakia: An eye that has undergone a type of cataract surgery whereby no artificial lens has been implanted.

2.0.3 Data analysis

RAAB data was exported to Excel and then to Stata version 14.0 for analyses (STATA Corp, College Station, Texas, USA).The prevalence estimates of bilateral and unilateral cataract blindness with 95% confidence intervals were calculated and stratified by gender. Cataract surgical coverage (CSC) was calculated for eyes using the formula $a/(a + b)$, where 'a' is the number of eyes with previous operation (regardless of VA) and 'b' is the number of eyes with VA of <6/18, <6/60 or <3/60 due to cataract. CSC for persons was calculated using the formula $(x + y)/(x + y + z)$, where x is the number of people who had unilateral aphakia/pseudophakia and VA <6/18, <6/60 or <3/60 in the contralateral eye; y is the number of people with bilateral operated eyes (regardless of VA) and z is the number of people with VA of <6/18, <6/60 or <3/60 in their better eye (at least one of which had reduced vision owing to cataract). Cataract surgical coverage was calculated at three different levels of visual acuity: <6/18, <6/60 or <3/60. Estimate results gotten with Stata analyses were compared with automated results from the RAAB software and found to be similar. Differences in cataract surgical coverage associated with gender was assessed using significance test of proportions in Stata. Data on the distances between clusters of various patients’ locations and the nearest surgical eye centre was obtained using Google Maps. Cataract surgical coverage for all 104 clusters (patients' locations) was calculated using Stata. The association between CSC and the distance to the nearest surgical centre (DTNSC) was explored using correlation and linear regression. Results were reported as statistically significant if (two-tailed) $P < 0.05$.

3.0 RESULTS

3.0.1 Description of data

The RAAB data included observations from 5,275 people examined and recorded into 39 variables. Of the 5,275 persons aged 50 and above included in the sample; 5,146 (97.6%) were examined, 91 (1.7%) were not available for examination, 12 (0.2%) declined to be examined and 26 (0.5%) were not examined due to inability to communicate. Among the examined; 2,011 (39%) were males and 3,135 (61%) were females. The mean age of persons in the sample was 63 years, youngest 50 years and oldest 99 years and was similar for males and females. The age and sex distribution in the sample is found in table 1.0

Table 1.0 Age and sex distribution of people examined in the sample

	Males		Females		Total	
	n	%	n	%	n	%
50 - 59 yrs	911	45.3	1,381	44.1	2,292	44.5
60 - 69 yrs	637	31.7	952	30.4	1,589	30.9
70 - 79 yrs	287	14.3	493	15.7	780	15.2
80 - 89 yrs	145	7.2	245	7.8	390	7.6
90 - 99 yrs	31	1.5	64	2.0	95	1.8
Total	2,011	100.0	3,135	100.0	5,146	100.0

3.0.2 The prevalence of blindness in Rwanda

The overall unadjusted prevalence of blindness from all causes in the examined adults aged 50 and above was 1.2% (95% CI 0.9–1.5). The overall prevalence of blindness in males was 1.4% (95% CI 0.9–2.0) and females was 1.1% (95% CI 0.7–1.4). The prevalence of unilateral blindness from all causes was 4.9% (95% CI 4.3–5.5) which was similar for both sexes. The extrapolated age and sex adjusted magnitude of blindness in the Rwandan population aged 50 and above was 1.1% (95% CI 0.7-1.4).

Table 2.0 shows the prevalence of blindness in the sample disaggregated by sex.

Table 2.0 Prevalence of blindness in the sample

	Males		Females		Total	
	n	% (95% CI)	n	% (95% CI)	n	% (95% CI)
Bilateral Blindness VA<3/60	29	1.4% (0.9 - 2.0)	33	1.1% (0.7 - 1.4)	62	1.2% (0.9 - 1.5)
Bilateral Cataract Blindness VA<3/60	8	0.4% (0.1 - 0.7)	17	0.5% (0.3 - 0.8)	25	0.5% (0.3 - 0.7)
Unilateral Cataract Blindness VA<3/60	29	1.4% (1.0 - 1.9)	66	2.1% (1.6 - 2.7)	94	1.9% (1.5 - 2.3)

There were 62 people in the sample with bilateral blindness (presenting VA <3/60 in the better eye) representing a prevalence of 1.2% (95% CI 0.9 – 1.5). Further disaggregation by age and sex showed this prevalence increased with aging and was similar for males and females. Those older than 70 years had the greatest prevalence of blindness. Table 3.0 shows the prevalence of blindness in the sample according to age groupings and sex.

Table 3.0 Blindness prevalence (Presenting VA <3/60 in the better eye) by age group and sex

	Males		Females		Total	
	n	% (95% CI)	n	% (95% CI)	n	% (95% CI)
50 - 59 yrs	4	0.5 (0.0-0.9)	0	0.0 (0.0-0.0)	4	0.2 (0.0-0.3)
60 - 69 yrs	6	1.0 (0.2-1.7)	5	0.5 (0.1-1.0)	11	0.7 (0.3-1.1)
70 - 79 yrs	6	2.1 (0.8-4.4)	10	2.1 (1.0-3.7)	16	2.1 (1.0-3.2)
80 - 89 yrs	7	4.8 (2.0-9.7)	11	4.5 (2.3-7.9)	18	4.6 (2.8-7.2)
90 - 99 yrs	6	19.4 (7.5-37.5)	7	10.9 (4.5-21.2)	13	13.7 (7.5-22.3)
All 50+ years	29	1.4 (0.9-2.0)	33	1.1 (0.7-1.4)	62	1.2 (0.9-1.5)

3.0.3 The prevalence of cataract blindness in Rwanda

It was found that 25 people were bilaterally blind from cataract in the sample giving a prevalence of 0.5% (95% CI 0.3–0.7) and 94 people also had unilateral cataract blindness giving a prevalence of 1.9% (95% CI 1.5–2.3). 8 males and 17 females had bilateral cataract blindness in the sample giving a prevalence of 0.4% (95% CI 0.2–0.8) and 0.6% (95% CI 0.3–0.9) respectively. Extrapolating this to the Rwandan population aged 50 and years and older; It can be estimated that approximately 6,002 people in Rwanda aged 50 years and above are bilaterally blind from cataract, of which 2,401 are males and 3,601 are females.

The prevalence of cataract blindness showed a similar trend of increasing with aging as observed with the trend of prevalence for general blindness. Table 4.0 shows the prevalence of bilateral cataract blindness according to age group and sex.

Table 4.0 Bilateral cataract blindness prevalence (Corrected VA<3/60 in the better eye) by age group and sex

	Males		Females		Total	
	n	%	n	%	n	%
50 - 59 yrs	1	0.1	0	0.0	1	0.0
60 - 69 yrs	0	0.0	1	0.1	1	0.1
70 - 79 yrs	0	0.0	7	1.4	7	0.9
80 - 89 yrs	3	2.1	5	2.0	8	2.1
90 - 99 yrs	4	13.0	4	6.3	8	8.4
All 50+ years	8	0.4	17	0.6	25	0.5

For unilateral cataract blindness, females aged 60 years and above consistently had a higher prevalence than their male counterparts. Table 5.0 shows the prevalence of unilateral cataract blindness by age group and sex.

Table 5.0 Unilateral cataract blindness prevalence (Corrected VA<3/60) by age group and sex

	Males		Females		Total	
	n	%	n	%	n	%
50 - 59 yrs	8	0.9	6	0.4	14	0.6
60 - 69 yrs	5	0.8	12	1.3	17	1.1
70 - 79 yrs	6	2.1	15	3.0	21	2.7
80 - 89 yrs	7	4.8	19	7.8	26	6.7
90 - 99 yrs	3	9.7	14	21.9	17	17.9
All 50+ years	29	1.4	66	2.1	95	1.9

3.0.4 Cataract surgical coverage in men and women and differences

The cataract surgical coverage (CSC) for people with VA <3/60 in the better eye was 68.8% (69.2% for males and 68.5% for females), for people with VA<6/60 in the better eye it was 62.0% (56.3% males, 65.0% females) and for those with VA<6/18 it was 44.0% (46.3% males, 43.0% females). Even though the CSC for males with VA<3/60 in the better eye was slightly higher than females, the difference was not statistically significant (P = 0.95, 95% CI: -0.22; 0.21). Table 6.0 describes the cataract surgical coverage in the sample.

Table 6.0 Cataract surgical coverage disaggregated by sex

	Males (%)	Females (%)	Total (%)
CSC (eyes) VA<3/60	52.1	47.9	49.3
CSC (eyes) VA<6/60	46.2	43.4	44.3
CSC (eyes) VA<6/18	39.5	31.8	34.1
CSC (persons) VA<3/60	69.2	68.5	68.8
CSC (persons) VA<6/60	56.3	65.0	62.0
CSC (persons) VA<6/18	46.3	43.0	44.0

3.0.5 The relationship between cataract surgical coverage and the distance between the nearest surgical centre to the patient location

The median distance to the nearest eye surgical centre (DTNSC) was 44.1km, whilst the shortest distance was 2.7km and the longest distance was 220km. The interquartile range was 53.2km

The Spearman rank correlation coefficient for the relation between CSC Eyes at 3/60 and DTNSC was -0.35, p = 0.004; for correlation of CSC Eyes at 6/60 and DTNSC, it was -0.35, p = 0.003; and for correlation of CSC Eyes at 6/18 and DTNSC, it was -0.36, p = 0.003. These findings showed a moderate negative correlation between CSC and DTNSC.

Linear regression established that the distance of patients' location from the nearest surgical centre (DTNSC) could statistically predict the areas' cataract surgical coverage (CSC): $F(1, 95) = 16.06$, $p = 0.0001$ and the distance of patients' location from the nearest surgical centre accounted for 14.5% of the variability in the cataract surgical coverage in the sample (R-squared = 0.1446) and 13.6% in the population (Adjusted R-squared = 0.1356). The regression equation was: Predicted CSC at 3/60 = 69.15 - 4.8 DTNSC. As the coefficient of the regression equation is negative, it indicates that larger distances of patients' location from the nearest surgical centre may be associated with lower cataract surgical coverage for that area. From the regression equation, for every 1 km increase in DTNSC we expect 4.8% decrease in CSC eyes at 3/60.

Linear regression of CSC eyes at 6/60 and DTNSC yielded similar results; $F(1, 95) = 15.20$, $p = 0.0002$; R-squared = 0.1380 and Adjusted R-squared = 0.1289. The regression equation was: Predicted CSC at 6/60 = 59.25 - 4.3 DTNSC. From this regression equation, for every 1 km increase in DTNSC we expect 4.3% decrease in CSC eyes at 6/60.

The regression between CSC eyes at 6/18 and DTNSC was also similar to earlier results; $F(1, 95) = 16.13$, $p = 0.0001$, R-squared = 0.1452 and Adjusted R-squared = 0.1356. The regression equation was: Predicted CSC at 6/18 = 60.88 - 4.4 DTNSC. From this regression equation, for every 1 km increase in DTNSC we expect 4.4% decrease in CSC eyes at 6/18.

3.0.6 Barriers to cataract surgery in sample for persons with bilateral VA less than 6/60 due to cataract

In this study, 96% of those who reported barriers to cataract surgery were aged 70 years and above. The most reported barriers found in this study were: "unaware that treatment is possible" and "cannot reach the hospital" and were most reported by females aged 70 years and above. (Table 7.0)

Table 7.0 Barriers to cataract surgery in sample for persons with bilateral VA less than 6/60 due to cataract by age group and sex

Barrier	50 - 59 years		60 - 69 years		70 -79 years		80 - 89 years		90 - 99 years		All ages Total Male n(%)	All ages Total Female n(%)	Total n(%)
	M (n)	F (n)	M (n)	F (n)	M (n)	F (n)	M (n)	F (n)	M (n)	F (n)			
Need not felt									1		0(0.0)	1(100.0)	1(100)
Fear of surgery or loss of vision							1	1	1		1(33.3)	2(66.7)	3(100)
Cannot afford operation - has mutual insurance						1	1	1	1	1	3(60.0)	2(40.0)	5(100)
Went to hospital but was denied operation	1			1			1				1(33.3)	2(66.7)	3(100)
Unaware that treatment is possible					1	5	4	1	1	4	6(37.5)	10(62.5)	16(100)
Cannot reach the hospital						6	2	5	2	2	4(23.5)	13(76.5)	17(100)
Cannot afford operation - has no mutual insurance						1		2	2	1	2(33.3)	4(66.7)	6(100)
Total	1	0	0	1	1	13	9	10	8	8	17(33.3)	34(66.7)	51(100)

4.0 DISCUSSIONS

4.0.1 Non Automated analyses

Results obtained using non automated analyses by Stata was similar to the output produced from the RAAB software. This shows that the RAAB automated software was helpful in calculating survey results without the need of a statistician. The Stata analyses however was needed to produce extra outputs needed for this research. Specifically this is in regards to the disaggregated age group information on the barriers to cataract surgery and the cataract surgical coverage for all the 104 clustered patients' locations.

4.0.2 Cataract blindness prevalence

The prevalence of blindness in Western Province of Rwanda in 2007 was 1.8% of which 65% was due to cataract which was similar to the prevalence of blindness estimated in the national census at that time[26]. Comparing these figures with the current prevalence of blindness for the whole country being 1.1% and 50% due to cataract; this shows that blindness prevention activities were yielding results.

The influencing factors may include the increased eye health human resources from 10 ophthalmologists in Rwanda in 2007[26] to 18 as at 2015[27] and the introduction of mid-level eye care personnel known as Ophthalmic Technicians at the district level across the country[27, 31] as well as the training of primary eye health nurses which have increased access to eye care services across the country[27].

This integration of primary eye care into existing primary health services has also boosted more eye screenings and referrals[27, 32]. Even though very few district hospitals in Rwanda have ophthalmologists, well-coordinated outreach activities have been introduced by the Ministry of Health and the Ministry of Defence to ensure surgeons from referral hospitals can provide surgery regularly in district hospitals moving services closer to the people[33].

There has been infrastructural improvements in terms of eye clinics set up at the district hospitals and increase in surgical centres in existing eye clinics[27]. The introduction of health insurance to cover eye surgeries since 2011 reduces the cost of surgeries to patients and makes it more affordable[34].

The prevalence of blindness in Rwanda is similar to that of Burundi 1.1% but slightly better than that of DR Congo 2.1%, Tanzania 2.7% and Kenya 2.5% which are neighbouring countries[35].

4.0.3 Cataract surgical coverage in males and females

The CSC for persons living with blindness was slightly higher in males 69.2% than females 67.9%. The data from barriers to cataract surgery shows that of those who mentioned that they could not reach the hospital; 76% were females aged 70 years and above as compared to 24% of males in the same age group (Table 7.0). This may be a contributing factor to the slight disparity in CSC of males to females.

Research has shown that in countries where societal and cultural expectations make men dominate over women in terms of financial ability and decision making process, there are differences in access and affordability of eye care services by the two sexes[36-38]. According to a report by USAID in 2014 on gender analysis in Rwanda, traditional and cultural norms ensure that men are the decision makers in the home[30]. The 2014-2015 demographic and health survey (RDHS) in Rwanda also reported that 69% of households were headed by men compared to 31% by women[16]. Since cataract surgery requires some decision making, it is possible that for households headed by men, women may need permission to access such services.

Higher levels of education and income have also been shown to be associated with lower risk of visual impairment[39-41].The 2014-2015 demographic and health survey in Rwanda reported that 19% of women had never attended school compared to 13% of men. Similarly, 75% of women aged 65 years and older had never attended school compared with 41% of men of similar age group[16].The national survey also found a positive association between education attainment and household wealth[16].This shows that older women may be at a disadvantage in accessing cataract surgical services compared to older men. Further probe into the reported barriers to cataract surgery in this study shows the second most frequent reported barrier to not having cataract surgery was "unaware that treatment is possible". And of those who reported this barrier; 63% of them were females aged 70 years and above compared to 37% of males of same age (Table 7.0). According to the RDHS (2015), older women were less exposed to mass media of information than their younger counterparts. This meant that older illiterate women may lack information or education on blindness issues.

The most reported barrier to not accessing cataract surgery in this study was “cannot reach the hospital” and was reported by 41% females compared to 21% of males and 76% females aged 70 years and above compared to 24% males of same age (Table 7.0). A report by USAID in 2014 on gender analysis in Rwanda stated that most older women were traumatised during the Rwanda genocide in 1994[30]. Most of these women had lost their husbands and sons during the war and were vulnerable. These women living with vision impairment may therefore require escorts to take them through the challenging terrain in Rwanda to a surgical facility and no one may be available.

4.0.4 Relationship between cataract surgical coverage and distance

A significant association was found between the cataract surgical coverage (CSC) of an area and the distance for patients in the area to travel to the nearest eye surgical centre (DTNSC). The CSC for people living with blindness dropped by 4.8% for every 1 km increase in distance to the surgical centre. However, DTNSC accounted for 14.5% of the variability of the predicted value of CSC in the sample suggesting other contributing factors on the accurate prediction of CSC in an area. Achieving a high cataract surgical coverage is a function of complex interactions between service supply and patient demand[9]. Distance as a factor affecting CSC could be seen as a demand-side factor along with other factors such as fear of surgery and cost or affordability of surgery. On the providers' side, "insufficient surgeons, or auxiliary ophthalmic staff; inadequate facilities in which to operate; insufficient equipment, supplies or other resources necessary for surgery, inefficient diagnostic or referral services to identify people with cataracts" all affect cataract surgical rate and coverage[9].

The terrain in Rwanda is said to pose a big challenge to access health services[17, 19]. The terrain is mountainous especially in the western and north-central parts of the country[16]. Rural or feeder roads account for 50% of the road network in the country which are not easily motorable. There is therefore limited road network through which public transportation vehicles can operate on[18]. Eighty-four percent of the population are in rural areas[16] and the major means of transportation is by walking or using bicycle[18]. It is also possible that the physical barriers of geographical access and the poor road network will make even seemingly shorter distances to travel a challenge.

If a small country like Rwanda has challenges with distance as a barrier to access health care services then it is likely that African countries with larger land size and poor road networks will have even bigger challenges with health care services accessibility. Democratic Republic of Congo which is the second largest country in Africa have only twenty-percent of its population able to access to health care services because of its difficult terrain to travel and widespread poverty[42].

Poor road network is a general problem in African countries limiting access to health care services including eye care services[43]. The significant effect of distance suggests that increasing the density of health facilities with ophthalmologists in rural areas would help increase cataract surgical services and therefore cataract surgical coverage. In this study in Rwanda, the average distance to the nearest district hospital was 23km. The average distance to the nearest eye surgical facility was double as far.

Therefore, if more districts hospitals were manned by ophthalmologists to perform cataract surgeries, the cataract surgical rate and cataract surgical coverage would increase. However, notwithstanding the low number of ophthalmologists in Rwanda which makes it impossible for all the district hospitals to have these specialists; if frequent outreach surgical services are conducted by ophthalmologists, distance as a barrier will be greatly reduced. However, merely increasing the number of cataract surgical facilities may not be sufficient to promote eye service utilization unless the quality of care is also trusted by the population as poor quality by poorly skilled personnel can also inhibit the uptake of the services.

5.0 LIMITATIONS OF THE STUDY

The strength of this study is that the national RAAB data used was properly sampled and validated. Another strength is that the prevalence estimates found using Stata corresponded accurately with the automated analyses figures. But there are some limitations to the study; a challenge to this study is that the questionnaire used in RAAB is not the most sensitive way to study barriers to surgery in a population. Secondly, the distances used in the study were calculated from Google maps which may not be totally accurate as only the main roads as captured in the Google maps could be utilized. The challenge of using feeder roads or farm roads by walking or cycling was not captured. Travel times were also not accessed. A future study using Geographic Information Systems (GIS) embedded with the country's geographic accessibility to calculate the distances of patients' locations to the nearest eye surgical centre may be more accurate. Additionally, distances were based on cluster locations and not the individual locations of patient's homes. Finally, another limitation is that the choice of eye surgical centre used by a patient may not be necessarily distance based. For example elderly patients may not have their surgery from where they usually live but in the area where their children live.

6.0 CONCLUSIONS

In conclusion, the prevalence of blindness in the country is 1.1% and the proportion from cataract is 50%. This prevalence has reduced when compared to 1.8% in 2007. The difference in cataract surgical coverage for men and women were not statistically significant but older women aged $\geq$ 70 years had more challenges accessing cataract surgical services. This study found that the distance to surgical facilities with ophthalmologists is related to the cataract surgical coverage even in a small country like Rwanda.

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Appendix 1: UCT ethical approval letter

UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
Human Research Ethics Committee

Room E53-46 Old Main Building
Groote Schuur Hospital
Observatory 7925
Telephone [021] 406 6626
Email: shuretta.thomas@uct.ac.za
Website: www.health.uct.ac.za/fhs/research/humanethics/forms

7 November 2016

HREC REF: 779/2016

Prof W Mathenge
Division of Ophthalmology

Dear Prof Mathenge

PROJECT TITLE: ASSESSMENT OF CATARACT BLINDNESS PREVALENCE AND FACTORS ASSOCIATED WITH SURGICAL COVERAGE IN RWANDA (MpH-candidate Dr M Kyei)

Thank you for submitting your study to the Faculty of Health Sciences Human Research Ethics Committee.

It is a pleasure to inform you that the HREC has **formally approved** the above-mentioned study subject to providing the local Ministerial and IRB approval from Rwanda.

Approval is granted for one year until the 30th November 2017.

Please submit a progress form, using the standardised Annual Report Form if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period. (Forms can be found on our website: www.health.uct.ac.za/fhs/research/humanethics/forms)

Please quote the HREC REF in all your correspondence.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please note that for all studies approved by the HREC, the principal investigator **must** obtain appropriate institutional approval before the research may occur.

The HREC acknowledge that the student Dr Michael Owusu Kyei will also be involved in this study.

Yours sincerely

pp T.Burgess
PROFESSOR M BLOCKMAN
CHAIRPERSON, FHS HUMAN RESEARCH ETHICS COMMITTEE
Federal Wide Assurance Number: FWA00001637.
Institutional Review Board (IRB) number: IRB00001938

HREC 779/2016

REPUBLIC OF RWANDA

Kigali, 21 SEP 2015

N°.0624./2015/10/NISR

NATIONAL INSTITUTE OF STATISTICS OF RWANDA
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Dr. John NKURIKIYE
Consultant Ophtalmologist
Director and Principal Investigator
RIIO
KIGALI

Dear Sir,

RE: Visa Approval

Reference is made to your letter dated September 3rd, 2015 requesting for authorization to conduct the "*Rapid Assessment of Avoidable Blindness in Rwanda*".

After examining your request and according to the law N° 45/2013 of 16/06/2013, stating on statistical activities organization in Rwanda, we have the pleasure to inform you that the visa has been granted, with the conditions that the data and final report will be submitted to NISR before the publication. In addition, the customised international standard classification manuals (ISIC Rev 4, ISCO 08, ISCED 97) that NISR has published must be used during the data processing stage to improve the quality of data.

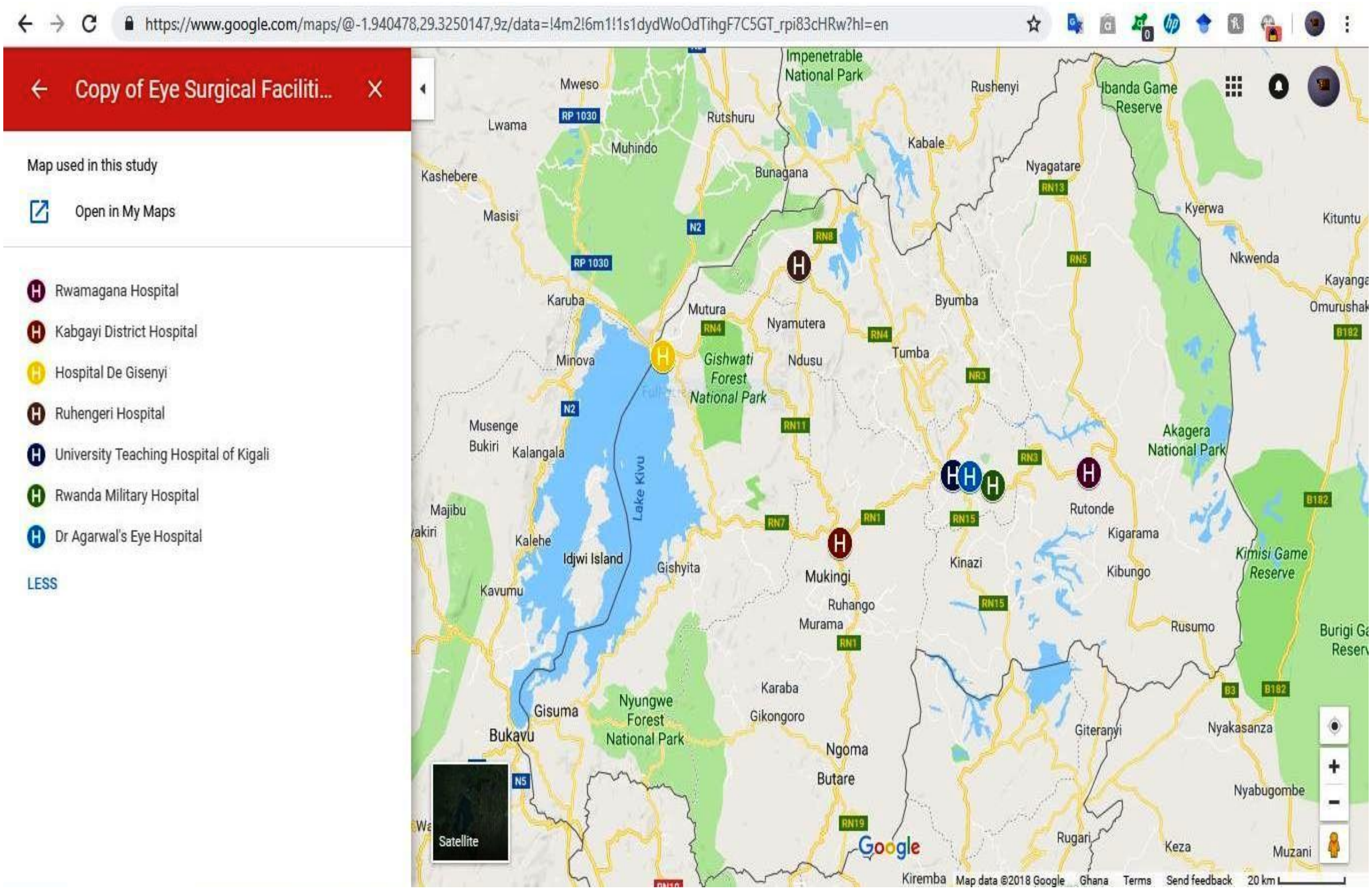
Thank you for your collaboration.

Yusuf MURANGWA
Director General

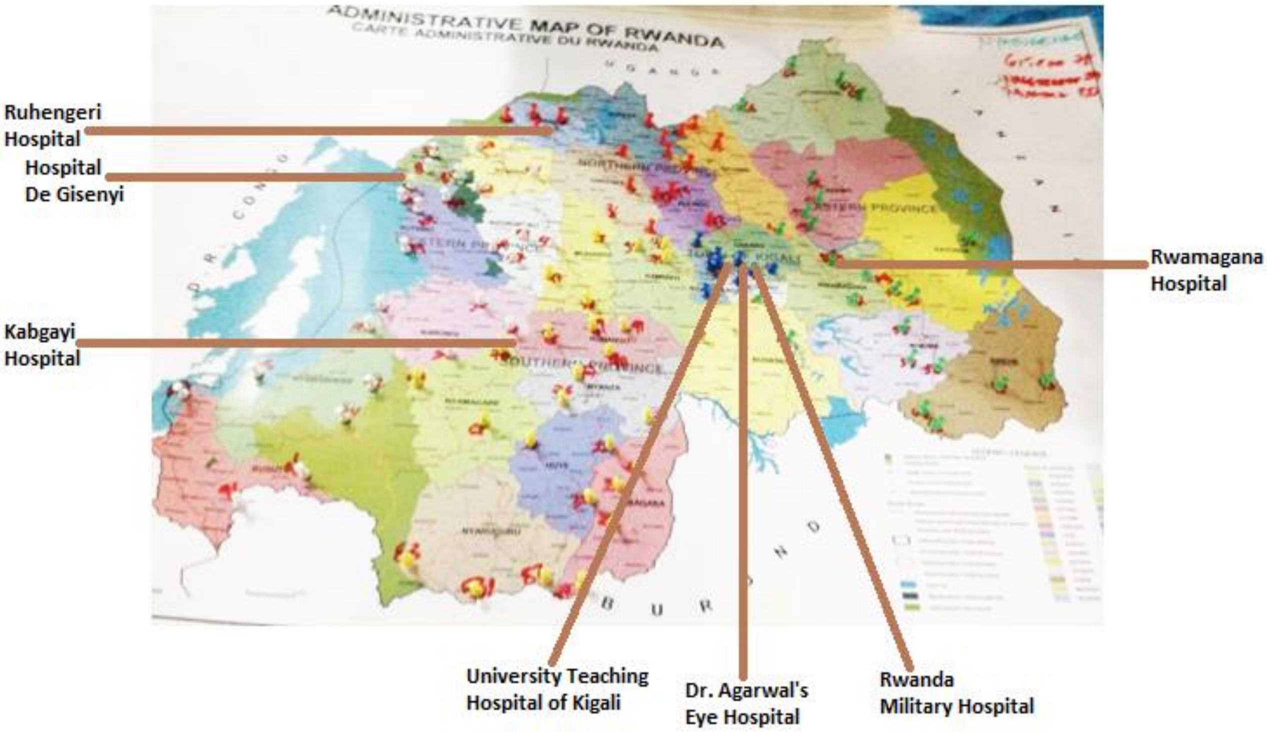
Website : http://www.statistics.gov.rw

Appendix 3: Rwandan map showing roads

Appendix 4: Rwandan eye surgical facilities in the study



Appendix 5: Rwandan map showing cluster locations and eye surgical facilities in this study



Appendix 6: List of variables in RAAB data

No.	Variable List	Representation
1	Year	Year of RAAB survey
2	Month	Month of RAAB survey
3	Areaname	Area/cluster name
4	Areacode	Area code
5	Cluster	Cluster identification number
6	Individual	Individual identification number
7	Sex	Sex of individual
8	Age	Age of individual
9	Option 1	Presence/absence of night blindness
10	Option 2	Awareness of eye check up
11	Status	Eye examination status
12	Glasses	Status using distance glasses
13	Glassesn	Status using reading glasses
14	Pvare	Presenting right eye VA
15	Pvale	Presenting left eye VA

16	Bvare	Pinhole VA right eye
17	Bvale	Pinhole VA left eye
18	Lere	Right eye lens examination
19	Lele	Left eye lens examination
20	Causere	cause of VA less than 6/18 in right eye
21	Causele	cause of VA less than 6/18 in left eye
22	Prcause	principal cause of VA less than 6/18 in the person
23	Histre	history of right eye if not examined
24	Histle	history of left eye if not examined
25	Bar1	First reason for barrier to cataract surgery
26	Bar2	Second reason for barrier to cataract surgery
27	Agere	Age at cataract surgery in right eye
29	Agele	Age at cataract surgery in left eye
30	Plre	Place of cataract operation for right eye
31	Plle	Place of cataract operation for left eye
32	Surgre	Type of cataract surgery for right eye
33	Surgle	Type of cataract surgery for left eye

34	Costre	Cost of cataract surgery for right eye
35	Costle	Cost of cataract surgery for left eye
36	Outlowre	cause of vision less than 6/18 after surgery in right eye
37	Outlowle	cause of vision less than 6/18 after surgery in left eye
38	Satisre	satisfaction after surgery of right eye
39	Satisle	satisfaction after surgery of left eye

Appendix 7: RAAB questionnaire used in primary study

RAPID ASSESSMENT FOR AVOIDABLE BLINDNESS RWANDA 2015

A. GENERAL INFORMATION

Year - month: ____ - __

Survey area: ______________ Cluster: ___ Individual no.: __

Name: ______________ Sex: Male: O (1) Female: O (2) Age (years): __

Night Blindness: Yes O (1) No O (2)

Examination status: Examined: O (1) (go to B) Not available: O (2) (go to E) Refused: O (3) (go to E) Not able to communicate: O (4) (go to E)

Aware of HC eye check? Yes O (1) No O (2)

Always ask: "Have you ever had any problems with your eyes?"

B. VISION - presenting vision

Using distance glasses: No: O (1) Yes: O (2)

Using reading glasses: No: O (1) Yes: O (2)

	Right eye	Left eye
Can see 6/18	O (1)	O (1)
Cannot see 6/18 but can see 6/60	O (2)	O (2)
Cannot see 6/60 but can see 3/60	O (3)	O (3)
Cannot see 3/60 but can see 1/60	O (4)	O (4)
Light perception (PL+)	O (5)	O (5)
No light perception (PL-)	O (6)	O (6)

VISION - with pinhole

	Right eye	Left eye
Can see 6/18	O (1)	O (1)
Cannot see 6/18 but can see 6/60	O (2)	O (2)
Cannot see 6/60 but can see 3/60	O (3)	O (3)
Cannot see 3/60 but can see 1/60	O (4)	O (4)
Light perception (PL+)	O (5)	O (5)
No light perception (PL-)	O (6)	O (6)

C. LENS EXAMINATION

	Right eye	Left eye
Normal lens / minimal lens opacity:	O (1)	O (1)
Obvious lens opacity:	O (2)	O (2)
Lens absent (aphakia):	O (3)	O (3)
Pseudophakia without PCO:	O (4)	O (4)
Pseudophakia with PCO:	O (5)	O (5)
No view of lens:	O (6)	O (6)

D. MAIN CAUSE OF PRESENTING VA<6/18

(Mark only one cause for each eye)

	Right eye	Left eye	Principal cause in person
Refractive error:	O (1)	O (1)	O (1)
Aphakia uncorrected,	O (2)	O (2)	O (2)
Cataract, untreated:	O (3)	O (3)	O (3) (F)
Cata Surg complications:	O (4)	O (4)	O (4)
Trachoma corneal opacity:	O (5)	O (5)	O (5)
Other corneal scar	O (6)	O (6)	O (6)
Phthisis:	O (7)	O (7)	O (7)
Onchocerciases	O (8)	O (8)	O (8)
Glaucoma:	O (9)	O (9)	O (9)
Diabetic retinopathy:	O (10)	O (10)	O (10)
ARMD:	O (11)	O (11)	O (11)
Other post. segment / CNS:	O (12)	O (12)	O (12)
All globe/CNS abnormalities	O (13)	O (13)	O (13)
Not examined (can see 6/18)	O (14)	O (14)	O (14)

E. HISTORY, IF NOT EXAMINED

(From relative or neighbour)

Believed	Right eye	Left eye
not blind	O (1)	O (1)
blind due to cataract	O (2)	O (2)
blind due to other causes	O (3)	O (3)
operated for cataract	O (4)	O (4)

F. WHY CATARACT OPERATION WAS NOT DONE

(Mark up to 2 responses, if VA<6/18, not improving pinhole, with visually impairing lens opacity in one or both eyes)

Need not felt	O (1)
Fear of surgery or loss of vision	O (2)
Cannot afford operation-has mutuel	O (3)
Went to hospital but was denied operation	O (4)
Unaware that treatment is possible	O (5)
Cannot reach the hospital	O (6)
Cannot afford operation-no mutuel	O (7)

G. DETAILS ABOUT CATARACT OPERATION

	Right eye	Left eye
Age at operation (years)	__	__
Place of operation		
District hospital	O (1)	O (1)
Referral hos.(KFH, KEU, CHUK, KMH)	O (2)	O (2)
Private hospital	O (3)	O (3)
Eye camp / foreign surgeons	O (4)	O (4)
Traditional setting(Couching)	O (5)	O (5)
Type of surgery		
Non IOL	O (1)	O (1)
IOL implant	O (2)	O (2)
Couching	O (3)	O (3)
Cost of surgery		
Totally free	O (1)	O (1)
Partially free	O (2)	O (2)
Fully paid	O (3)	O (3)
Cause of VA<6/18 after cataract surgery		
Ocular comorbidity (Selection)	O (1)	O (1)
Operative complications (Surgery)	O (2)	O (2)
Refractive error (Spectacles)	O (3)	O (3)
Longterm complications (Sequelae)	O (4)	O (4)
Does not apply - can see 6/18	O (5)	O (5)

DILATE ALL EYES WITH VA<6/18

Appendix 8: Instructions for author from journal whose format has been used

OPHTHALMIC EPIDEMIOLOGY

Accessed at:

www.tandfonline.com/action/authorSubmission?journalCode=iope20&page=instructions

Taylor & Francis is a member of the Committee of Publications Ethics (COPE). COPE aims to provide a forum for publishers and editors of scientific journals to discuss issues relating to the integrity of their work, including conflicts of interest, falsification and fabrication of data, plagiarism, unethical experimentation, inadequate subject consent, and authorship disputes. For more information on COPE please visit http://publicationethics.org.

Instructions for Authors

All submissions should be submitted at http://mc.manuscriptcentral.com/nope

All submissions should be double spaced, with consecutively numbered pages.

All abbreviations/acronyms must be defined at first use in the abstract, again at first use in the text and in each and every table or figure, regardless of seeming redundancy.

The following are the files needed to make your online submission complete:

I. MANUSCRIPT FILE

1. Cover page –

a) list the title of your submission – no abbreviations or acronyms (acronyms may be considered if important for recognition of a prominent study, and in that case they should be used only after defining the acronym in the title)

b) supply a running head - a shortened version of title, not to exceed 50 characters. If the full title is 50 characters or less, they can be the same.

c) list all authors in publication order and their related affiliations,

d) indicate who is the corresponding author and the corresponding contact information (especially email),

e) financial support – list all financial support

f) list any proprietary interests or conflicts of interest for any and all authors related to this submission. "If none, please state: None of the following authors have any proprietary interests or conflicts of interest related to this submission:"; then list all the authors with no such interests. "None of the authors" suffices if no one has any such interests. Please err on the side of disclosure if it is unclear whether something is an interest or not, and please include relationships that may be perceived by others as a conflict of interest.

g) statement that this submission has not been published anywhere previously and that it is not simultaneously being considered for any other publication. Note: if the paper previously has been reviewed and rejected by another journal, please indicate so, and please indicate what criticisms were given and what changes have been made in response (as if you were revising and resubmitting to the original journal). We are open to accepting such papers if they have merit, and there is no need to hide this information.

2. Abstract – start on new page – not to exceed 250 words, define all abbreviations or acronyms used at first use, formatted into the following four sections:

a) Purpose

b) Methods

c) Results

d) Conclusion

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