Magnitude and Determinants of the Ratio between Prevalences of Low vision and Blindness in Rapid Assessment of Avoidable Blindness Surveys

by

DINESH KAPHLE
KPHDIN001

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University of Cape Town

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Supervisor: Prof Susan Lewallen
Division of Ophthalmology, University of Cape Town

DECLARATION

I, DINESH KAPHLE, 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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Date: 15 March 2016

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Magnitude and Determinants of the Ratio between Prevalences of Low vision and Blindness in Rapid Assessment of Avoidable Blindness Surveys

ABSTRACT

Part A of the dissertation includes the protocol of the study, which was approved by Faculty of Health Sciences Human Research Ethics Committee, University of Cape Town. The study was observational analytical, aiming to determine the magnitude and determinants of the ratio between prevalence of low vision and prevalence of blindness using Rapid Assessment of Avoidable Blindness (RAAB) surveys across World Bank regions. The surveys included in the study were available in the RAAB repository and obtained through permission from the primary investigators. A univariate and multivariate analysis were performed across the regions using the ratio as an outcome variable and potential explanatory variables as follows: prevalence of Uncorrected Refractive Error (URE), Cataract Surgical Coverage (CSC) at visual acuity 3/60, 6/60 and 6/18 for persons, logarithm of Gross Domestic Product (GDP) per capita and health expenditure per capita.

Part B contains the structured literature review. PubMed, Scopus, EBSCOHOST (Africa wide and MEDLINE) and Web of Science databases were used to search for literature using the following key words: *rapid assessment, blindness, age-related cataract, uncorrected refractive error, low vision, visual impairment, avoidable OR curable OR preventable OR treatable.* The summary of the literature review in addition to the gap in the literature is presented in the section.

Part C includes a journal manuscript, which includes methodology and results of the study. The main findings showed that the ratio between prevalence of low vison and prevalence of blindness ranged from 1.35 in Mozambique to 11.03 in India with a median value of 3.90. There was a statistically significant variation of the ratio across the regions: approximately 7.0 in South Asia and approximately 3.0 in Sub-Saharan Africa (χ^2=28.23, p<0.001). The variables: prevalence of URE, CSC at visual acuity 3/60, 6/60 and 6/18 for persons, logarithm of GDP per capita and logarithm of health expenditure per capita were found to be statistically significantly associated with the ratio with univariate analysis. However, only prevalence of URE and CSC at 3/60 for persons across the regions were found statistically significant in multivariate analysis.

Part D comprised of appendices used in the mini-dissertation.

Part A: Protocol

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LIST OF ABBREVIATIONS

CSC: Cataract Surgical Coverage

CSR: Cataract Surgical Rate

EPI: Expanded Program on Immunization

GDP: Gross Domestic Product

IAPB: International Agency for the Prevention of Blindness

RA: Rapid Assessment

RAAB: Rapid Assessment of Avoidable Blindness

RACSS: Rapid Assessment of Cataract Surgical Services

URE: Uncorrected Refractive Error

WB: World Bank

WHO: World Health Organization

PROTOCOL SYNOPSIS

Title of the study

Magnitude and Determinants of the Ratio between Prevalences of Low vision and Blindness in Rapid Assessment of Avoidable Blindness Surveys

Background

A recent systematic review estimated that there were 285 million visually impaired people in the world: 39 million blind and 246 million low vision in 2010. People aged 50 years and above contributed 65% and 82% of the total visual impairment and blindness respectively. Uncorrected refractive error (URE) (43%) and cataracts (33%) were the major causes of visual impairment whereas cataracts (51%) and glaucoma (8%) were the major causes of blindness. Cataracts are a cause of visual impairment as well as blindness because immature cataracts cause visual impairment whereas mature cataracts cause blindness. In addition, more than a billion people have poor vision because of lack of eye glasses and more than 100 million of them are visually impaired because of URE globally. It is estimated that 10% of the total URE ultimately causes visual impairment.

The prevalence of blindness and low vision vary considerably in different surveys. For instance the prevalence of blindness was as little as 0.7% in Bagmati, Nepal to 7% in Al Amaran, Yemen. Similarly, the prevalence of low vision varied from 2.5% in Ngozi and Kayanza, Burundi to 22.2% in Binh Dinh, Vietnam.

Hypothesis

Our hypothesis is that there is a positive correlation between the ratio of prevalence of low vision to prevalence of blindness and the prevalence of Uncorrected Refractive Error in Rapid Assessment of Avoidable Blindness (RAAB) surveys. Prevalence of URE, which is a major cause of low vision but not of blindness, differs widely in the world. Therefore we expect that the variation in the ratio of low vision to blindness might be explained by the difference in prevalence of URE.

Methodology

Design: Observational analytical

Population: Rapid Assessment of Avoidable Blindness Surveys

Sites: Worldwide

Study duration: October 2015 to March 2016

Instrument and methods: The ratio between prevalences of low vision and blindness is considered as outcome variable. Data on outcome variable along with other explanatory variables will be extracted from the reports which are available from RAAB repository website. For RAAB surveys, whose reports are not available in the repository, a request to send the report will be sent to the Principal Investigator of the survey. Univariate and Multivariate regression models will be fitted to identify the determinants of the variation in the ratio.

Aim and Objectives

Aim

The aim of the study is to determine the magnitude of the ratio of prevalences of low vision to blindness and the determinants of the ratio in the RAAB surveys.

Specific objectives

i. To describe the variation in ratios of prevalence of low vision to blindness in RAAB surveys across different geographical regions.

ii. To measure the relationship between the outcome variable and other potential explanatory variables including the prevalence of Uncorrected Refractive Error, Cataract Surgical Coverage as a proxy for service delivery, Gross Domestic Product per capita and total health expenditure in the RAAB surveys.

iii. To measure the correlation between the outcome variable and the prevalence of URE in RAAB surveys.

STUDY PROTOCOL

1. PURPOSE OF THE STUDY

The hypothesis of the study is that there is a positive correlation between the ratio of the prevalences of low vision to blindness and the prevalence of Uncorrected Refractive Error (URE) in Rapid Assessment of Avoidable Blindness (RAAB) surveys. The reason for this assumption is that any variation in the ratio might be due to difference in the prevalence of URE among populations. This is because of the fact that URE is more likely to cause low vision than to cause blindness.

1.1 Aim and Objectives

Aim

The aim of the study is to determine the magnitude of the ratio of prevalences of low vision to blindness and the determinants of the ratio in the RAAB surveys.

Specific Objectives

i. To describe the variation in ratios of prevalence of low vision to blindness in RAAB surveys across different geographical regions. The ratio will be considered as the outcome variable.

ii. To measure the relationship between the outcome variable and other potential explanatory variables including the prevalence of Uncorrected Refractive Errors, Cataract Surgical Coverage (CSC) as a proxy for service delivery, Gross Domestic Product (GDP) per capita and total health expenditure per capita in the RAAB surveys.

iii. To measure the correlation between the outcome variable and the prevalence of URE in RAAB surveys.

2. BACKGROUND

A systematic review estimated that there were 285 million visually impaired people in the world in 2010, of which 39 million were blind and 246 million were low vision.[1] In addition, more than a billion people have poor vision because of lack of eye glasses and more than 100 million of them are visually impaired because of Uncorrected Refractive Error globally.[2] It is estimated that there are 1 to 2 billion people with URE in the world. The figure on URE was projected from the findings of the Blue Mountain Eye Study (BMES) in Australia which showed that prevalence of URE is 10 times larger than the prevalence of visual impairment caused by URE.[3] It is important to note that the BMES study defined URE as any amount of refractive error which could be corrected with spectacles but had not been. However, blindness surveys such as RAAB surveys defined URE as refractive error which improves from visual acuity of less than 6/60 to at least 6/18 with the pinhole test.

According to the International Classification of Diseases (ICD)-10th revision[4], blindness is defined as visual acuity of less than 3/60. Moderate Visual Impairment (MVI) is defined as visual acuity of less than 6/18 but equal to or better than 6/60 and Severe Visual Impairment (SVI) is defined as visual acuity of less than 6/60 but equal to or better than 3/60. All acuities are of the available correction in the better eye. In addition, MVI and SVI are jointly called low vision. It is essential to note that in the field of vision rehabilitation, the term “low vision” refers to people who have had medical, spectacle, and surgical corrections and still have vision less than 6/18 but better than light perception. In this study, low vision will be used as the ICD-10 definition. Furthermore, it is worth noting that none of the definitions mentioned above account for visual acuity for near visual tasks.

Globally, cataracts (51%) and glaucoma (8%) are the major causes of blindness whereas Uncorrected Refractive Error (43%) and cataracts (33%) are the major causes of visual impairment.[1] Cataracts are a cause of visual impairment as well as blindness because immature cataracts cause visual impairment whereas mature cataracts cause blindness. It was found that people aged 50 years and above contributed 65% and 82% of the total populations of visual impaired and blind people respectively in the world.

Until 2005, Rapid Assessment of Cataract Surgical Services (RACSS) survey was used to assess blindness and visual impairment in Asia, Africa and Latin America.[5, 6] RACSS surveys use multistage cluster sampling to select the participants. Within a cluster, the households are selected by the “random walk” method in which households are chosen based on the orientation of the neck of a spun bottle at every crossing of the streets. People of age 50 years and above living in the house are interviewed with the questionnaire as well as examined for vision loss. However, there are mainly two limitations of the RACSS survey method.[7] Firstly, as the selection of households for the eye examination is done using the random walk method, which involves an individual’s subjective decision to choose the house to be included in the survey, it is likely to yield selection bias particularly in larger populations. Secondly the RACSS survey does not account for other causes of vision loss besides cataracts.

Rapid Assessment of Avoidable Blindness (RAAB) methodology was developed after a national blindness survey conducted in the Gambia in 1996. The national eye survey was performed to estimate the prevalence and distribution of visual impairment and blindness.[8] The results of the countrywide survey were compared with another survey which was conducted among people of age 50 years and above.[9] The comparison showed that the causes of blindness and visual impairment among the 50 years and above group was a good indicator of the causes in the total population. Furthermore, the distribution of causes of severe visual impairment and moderate visual impairment was similar in both groups except for refractive error, which was proportionally more important in the total population than in the 50 years and above.[9]

Essentially, RAAB is an upgraded and revised version of the RACSS.[5] RAAB provides more standardised methodology and training for examiners so the results are easily comparable across different surveys.[9] Unlike RACSS, RAAB uses the "compact segment" sampling method which is a random selection of a segment of the population as a cluster and includes all the households of that segment. The people of age 50 years and above in the households undergo visual acuity measurement, pinhole acuity assessment if the visual acuity is less than 6/18 and ocular examination with torchlight and direct ophthalmoscope. The improvement of visual acuity with pinhole is considered as a proxy for the presence of refractive error.[7] The primary focus of RAAB is on the prevalence of major causes of avoidable blindness, which are: blindness due to cataracts, refractive errors, trachoma, onchocerciasis, corneal scarring and posterior segment diseases such as glaucoma. This is in line with the aim of "VISION 2020: The Right to Sight", which aims to eliminate avoidable blindness by the year

2020.[10] Furthermore, RAAB surveys are helpful in assessing CSC, identifying the main barriers to the uptake of cataract surgery and measuring the outcome after cataract surgery.[10]

Despite many advantages, RAAB surveys have some limitations. Because the eye examination is conducted door-to-door, the diagnostic facilities are limited. Therefore the exact cause of loss of vision may not be identified for posterior segment diseases such as glaucoma or diabetic retinopathy. Moreover, RAAB only includes people aged 50 years and above, therefore the prevalence of blindness in people under 50 years cannot be estimated. In addition, RAAB measures only blindness or visual impairment and does not assess other non-vision impairing conditions such as active trachoma, trichiasis and onchocerciasis.[10] It also does not assess early signs of serious eye diseases such as glaucoma which may be present but not yet have caused severe vision loss in an individual.

The results of the RAAB surveys along with RACSS surveys are available freely in the RAAB repository website (http://www.raabdata.info/repository/). The purpose of the repository is to bring the survey findings in to public access so that interested researchers can utilise them easily. The RAAB repository displays summary tables which provide data on sample size, coverage of the survey, proportion of total blindness and low vision and proportion of blindness related to cataract, refractive error and diabetic retinopathy. Similarly, CSC, outcome of cataract surgeries and proportion of intraocular lens insertion are available in the summary. Furthermore, some of the full reports of the surveys are available in the RAAB repository website while others can be requested from the principal investigators through a built-in request form within the website. The links to the relevant publications of the surveys are also available in the website.

Comparison of the survey results show that there is a big variation of prevalence of blindness and low vision across the regions. A recent systematic review found that prevalence of blindness varies from 0.1% in Uganda to 9% in Eritrea among Sub-Saharan African countries.[11] The variation of prevalence of blindness was narrower in Latin American countries which ranged from 1.3% in Argentina to 4% in Peru.[7] Similarly, prevalence of low vision varied from 1.6% in Gambia and Uganda to 17.1% in Ghana in Sub-Saharan Africa whereas the variation was 5.9% in Argentina to 12.5% in Peru in Latin America.[7, 11]

There is a broad agreement that cataracts and refractive errors are the leading causes of blindness and visual impairment, hence they should be the priority diseases for VISION 2020 programs. The simplest way to reduce blindness and visual impairment related to cataracts is by performing as many cataract surgeries as possible with good visual outcomes. If Cataract Surgery Rate (CSR), which is the number of cataract operations performed in a year per one million of the population, is high, we can assume that the CSC will be high too. Cataract Surgical Coverage, which is defined as the proportion of people who received surgery among those who required it, is the indicator used to measure the extent of the cataract surgical need.[12] However, the CSR is dependent upon many factors such as age structure of the population particularly the proportion of people over 50 years of age, visual acuity threshold at which cataract operation is set to be performed and accessibility and affordability of the cataract surgery.[13]

Uncorrected Refractive Error is not only the leading cause of visual impairment, but also a major cause of disability globally which hugely reduces economic productivity and educational opportunities as well as overall quality of life.[2, 14] Even though provision of eye glasses is a simple, effective and largely affordable remedy for URE, the majority of people do not benefit from spectacles in low resource settings. The main barriers identified are awareness about the services, accessibility of the services and affordability of the spectacles.[2] This shows that there is some relationship between visual impairment and the economic status of the country.

In addition, it is found that the prevalence of blindness is associated with the economy of the country. For instance, the estimated prevalence of blindness is 0.25% in high income countries, whereas the prevalences are 0.50%, 0.75% and more than 1.0% in middle, low and very low income countries respectively.[15]

The World Health Organization (WHO) estimated the prevalence of low vision based on the prevalence of blindness for the VISION 2020 programs. For adults, the prevalence of low vision is estimated to be three to four times the prevalence of blindness. However, a study of 27 RAAB surveys in 19 Sub-Saharan African countries found that the ratio between the prevalences of low vision and blindness varied from 1.3 to 6.3.[16] The study recommended further research to explore the determinants of the wide variation.

To the best of our knowledge, there is no evidence on the distribution of the ratio of prevalences of low vision to blindness in other geographical regions. Therefore, this study is proposed to find the magnitude and the determinants of the ratio between prevalence of low vision and prevalence of blindness in all the RAAB surveys. Describing the variation among a larger number of surveys from a wider geographical area and examining whether it is correlated with the prevalence of URE would enhance understanding of the epidemiology of visual impairment and blindness globally and possibly provide a useful indicator for where URE needs to be targeted.

3. METHODOLOGY

3.1 Study Design

The study design will be observational analytical. A retrospective secondary analysis of cross-sectional survey data will be performed from the previously performed population based RAAB studies. A pilot study will be conducted including 10 RAAB surveys to validate the data collection tools.

3.2 Sample Size

In order to calculate a sample size we considered the question of whether the correlation coefficient between the outcome variable (ratio) and the prevalence of URE in the populations differs from zero. We wanted to show a correlation coefficient (r) of 0.3 and we used the formula below.[17]

$N= [(Z_\alpha + Z_\beta) \div C]^2 + 3$

where

r= expected correlation coefficient

$C=0.5 \times \ln [(1+r) / (1-r)]$

N=Total number of subjects required

For a β of 0.2 and a two sided α of 0.01, the sample size we need would be 67 studies.

Out of a total of 156 RAAB surveys available in the repository website (as of 10 February, 2016), the reports for 66 surveys are downloadable. The request to send the reports will be sent to 90 remaining surveys using the request report link of the repository. The surveys which meet the inclusion criteria and have accessible full reports will be included in the study.

3.3 Inclusion Criteria

RAAB survey will be included in the study if;

- The coverage of the primary survey was at least 80% of the sample size selected.
- The standard RAAB reports are available in the website or the reports are received through a built in “Request Report” feature of the website.

3.4 Exclusion Criteria

- If there is more than one survey conducted for the same region, the latest survey will be used for the analysis.
- Surveys which have missing data for the study variables.

3.5 Research Procedures and Data Collection Methods

All RAAB surveys follow the standard RAAB examination methodology. Each participant undergoes eye examination in each eye with visual acuity graded into 6 categorises (≥6/18 to no light perception). Visual acuity is measured using a Snellen tumbling ’E’ chart with an optotype of size 6/18 and 6/36 on either side at 6 metres (or 3 metres distance if required) in daylight with best available correction. When presenting visual acuity is less than 6/18 in either eye, visual acuity is measured with a pinhole. Primary cause of visual impairment is recorded as refractive error if the visual acuity improved to at least 6/18 with a pinhole. In cases in which visual acuity does not improve with a pin-hole, further examination is performed by an ophthalmologist or ophthalmic clinical officer.

Whenever multiple causes of visual impairment are observed, the most treatable or preventable condition is recorded as the primary cause of vision loss. For example if a person has refractive error and cataract, refractive error is recorded as the primary cause. Similarly if a person has cataract and glaucoma, cataract is recorded as the primary cause. The RAAB data are initially recorded on standard forms before being transferred into RAAB software (version 4.02 software, 2007, International Centre for Eye Health, UK). Crude, age-adjusted prevalences and causes of blindness and visual impairment are calculated using the RAAB software. All completed RAAB survey results are made available on the RAAB repository website; http://www.raabdata.info/repository/.

The Principal Investigator (PI) will assess the eligibility criteria of 156 RAAB surveys. The surveys which meet the inclusion criteria will be identified using the inclusion criteria checklist (Appendix 1). The full reports of the identified surveys will be downloaded, if available from the website. For reports which are not available online, a request for the report will be sent to the PI of the survey via the built in link of the website. A second reminder request will be sent if the report is not received within a month. If the report is not received within two weeks of the reminder the study will be excluded from the analysis.

The relevant data such as prevalence of low vision and blindness, prevalence of URE and CSC for persons at 3/60, 6/60 and 6/18 will be extracted from the RAAB reports before entering them in the data capture sheet. The data on GDP per capita and health expenditure per capita of the countries will be obtained from the World Bank website for the year the survey was conducted or the closest year available.[18, 19] Additional data to be extracted from the standard RAAB reports are shown in the data capture sheet (Appendix 2).The regions for the data analysis will be classified based on the World Bank classification; Sub-Saharan Africa, South Asia, Latin America and Caribbean, East Asia and Pacific, Middle East and North Africa, Europe and Central Asia and North America.[20]

3.6 Data Analysis

The data will be initially entered in a Microsoft Excel 2013 data sheet, then it will be transferred to data analysis statistical software STATA 11 (Stata Corp. College Station, Texas) for analysis. The ratio of the prevalences of low vision to blindness will be calculated for each survey, then it will be described as either mean (with confidence intervals) or median (with interquartile range) based on the normality test. The relationship between the ratios and the prevalence of URE in the population will be calculated by using Pearson's or Spearman's correlation test, based on the normality of the ratio. The distribution of the ratios across the geographical regions will be assessed by using the Analysis of Variance (ANOVA) test. The effect of other explanatory variables (such as CSC at different visual acuity levels for persons, GDP per capita and total health expenditure per capita) on the magnitude of ratios will be explored by using univariate regression analysis. The explanatory variables which were found to have *p* value below 0.2 in univariate analysis will be included for multivariate analysis. The significance level will be considered at 5% for two tailed tests. The description and source of the variables is presented in Table 1.

3.7 Ethical Approval

The ethical approval of the study protocol will be obtained from the University of Cape Town Departmental Research Committee and the Faculty of Human Research Ethics Committee. As a part of the standard methodology of RAAB surveys, all RAAB surveys obtained ethical approval from the relevant ethics committee of the respective region or province. Participants who were enrolled in the surveys provided verbal consent for the study. Each individual survey was conducted in accordance with the tenants of the Declaration of Helsinki. In addition, this study will also adhere to the ethical principles of the Declaration of Helsinki.

3.8 Risks

The primary RAAB surveys pose minimal risk to the participants. This research will utilise the data from the previously conducted surveys, therefore it will not have any harmful effects on the human subjects.

3.9 Potential Benefits

The major benefit of the primary RAAB surveys was to measure the prevalence and the causes of blindness and visual impairment in different surveyed regions. This could benefit the population by targeting resources towards the more prevalent conditions. The current study will identify the magnitude and the determinants of the ratio between visual impairment and blindness in different regions which will be useful to prioritise the activities of VISION 2020 programs.

Table 1. Description and source of the variables.

Variables	Description and source
Prevalence of unadjusted LV	Continuous variable, obtained from Sample report (Table 2)
Prevalence of unadjusted BL	Continuous variable, obtained from Sample report (Table 2)
Ratio	Ratio of the prevalence of unadjusted LV to the prevalence of unadjusted BL
Prevalence of URE	Continuous variable, calculated as the number of people Blind, SVI and MVI due to URE divided by the total number of people examined in the survey: obtained from Sample report (Tables 1, 4, 6 & 8)
CSC 3/60 (Persons)	Continuous variable, obtained from Sample report (Table 12)
CSC 6/60 (Persons)	Continuous variable, obtained from Sample report (Table 12)
CSC 6/18 (Persons)	Continuous variable, obtained from Sample report (Table 12)
WB region	Polytomous variable: 6 regions based on World Bank classification[20]
GDP per capita	GDP per capita in US dollars by country for closest year of survey, obtained from WB report[18]
Health expenditure per capita	Health expenditure per capita in US dollars by country for closest year of survey, obtained from WB report[19]

LV, Low Vision; BL, Blindness; URE, Uncorrected Refractive Error; MVI, Moderate Visual Impairment; SVI, Severe Visual Impairment; CSC, Cataract Surgical Coverage; WB, World Bank; GDP, Gross Domestic Product.

3.10 Informed Consent

The participants of the primary RAAB surveys provided verbal informed consent. As this study utilises the data from the previous surveys, there will not be any informed consent process.

3.11 Privacy and Confidentiality

The extracted data for the study will be kept in a password protected computer file of the primary investigator to maintain privacy and confidentiality. The data will be destroyed after 5 years of the completion of the study.

3.12 Dissemination of the Results

This study is a part of the mini-dissertation for the Masters of Public Health, Community Eye Health track at University of Cape Town. A copy of the dissertation will be made available at the Health Sciences library. In addition, as a part of the dissertation, a manuscript describing the study and the findings of the study will be prepared for a peer reviewed journal and will be submitted for publication.

3.13 Logistics

Timeline

The timeline for the dissertation work is shown in Table 2.

Budget and Costs

There was no major cost involved for the dissertation as the secondary data was collected from online sources.

Table 2. Timeline of dissertation.

Task	Oct-Nov'15	Dec'15	Jan'16	Feb'16	Mar'16
Protocol development	X				
DRC Application		X			
Structured literature review			X		
HREC application				X	
Manuscript preparation				X	X
Submission of dissertation					X

DRC, Departmental Research Committee; HREC, Human Research Ethics Committee

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Part B:
Structured Literature Review

TABLE OF CONTENTS

1. SUMMARY

There are 32.4 million blind and 191 million moderate and severe visually impaired people in the world. These data come from a systematic review which included the results of Rapid Assessment of Avoidable Blindness (RAAB) surveys and Rapid Assessment of Cataract Surgical Services (RACSS) in addition to unpublished population based surveys.

The prevalence of blindness and low vision (low vision includes moderate and severe visual impairment) is found to vary greatly among the surveys. For “VISION 2020: The Right to Sight initiative”, it is generally estimated that the prevalence of low vision is 3 to 4 times that of blindness. However this estimate is not applicable for all regions. For instance, it was found that the ratio between the proportion of low vision and the proportion of blindness in the population varies from 1.30 to 6.30 in Sub-Saharan Africa. Moreover, there is no evidence for the magnitude of the ratio in other continents or for the determining factors for the ratio. Therefore we proposed a study to describe the magnitude of the ratio in different regions as well as to identify the contributing factors determining the ratio. Our assumption is that prevalence of Uncorrected Refractive Error (URE) could possibly explain the variation in the ratio since this is the main cause of severe and moderate visual impairment but not of blindness. Understanding the factors contributing to the variation would help to prioritise the ophthalmic services since the provision of spectacles to the people with URE is considered to be one of the indicators of ophthalmic service delivery in a region.

2. AIM OF THE LITERATURE REVIEW

The aim of the literature review was to identify indexed articles which could provide the magnitude of the prevalences of low vision and of blindness in RAAB surveys and potentially explore the variation of ratio of prevalences of low vision and of blindness in RAAB surveys across different regions.

3. STUDY QUESTION

What is the variation of the ratio between prevalence of low vision and prevalence of blindness in the RAAB surveys?

What are the determining factors for the variation of the ratio between prevalence of low vision and prevalence of blindness?

4. LITERATURE SEARCH STRATEGY

4.1 Inclusion and Exclusion Criteria

Inclusion Criteria

Studies which used population based Rapid Assessment of Avoidable Blindness survey methodology.

Studies which provided the data on prevalence of low vision and prevalence of blindness.

Studies which had at least 80% of coverage of the sample size.

Exclusion Criteria

Surveys which used methodology of RACSS and custom surveys.

4.2 Quality of Literature

Population based cross-sectional surveys which used multistage cluster sampling, which is one of the proportional probability sampling techniques for data collection were included in the study.

4.3 Databases

The literature was searched using the following databases; MEDLINE (through PubMed), Embase (through Scopus), EBSCO-host (selecting Africa-Wide Information and MEDLINE) and Web of Science for the articles listed before 8 February 2016 in the database. For PubMed, articles were filtered using only “Human species”. English language was used for all the databases to filter the publications. There was no filter on the article type, text availability and publication dates.

4.4 Keywords

The following keywords were used for the literature search; *rapid assessment, blindness, age-related cataract, uncorrected refractive error, low vision, visual impairment, avoidable, preventable, curable, treatable.*

Out of 192 articles identified using the PubMed search, 7 articles were found relevant to our study and were selected for this literature review. We also searched the reference list of the included articles using the “snow ball technique”. The keywords and number of studies found in PubMed is shown in Table 1.

The same keywords were used with minor modification for the other databases according to the requirements of the databases. Three more articles were found through EBSCO-host and one more article was found through Web of Science which had not been found through PubMed. There were no more articles found through Scopus than through PubMed.

Table 1. Keywords and number of studies found in PubMed.

	Keywords	Studies found
1	Rapid assessment	15,981
2	Blindness	25,599
3	Age-related cataract	1806
4	Uncorrected refractive error	2688
5	Low vision	10468
6	Visual impairment	61406
7	#2 OR #3 OR #4 OR #5 OR #6	77,403
8	Avoidable OR curable OR preventable OR treatable	33,571
9	#1 AND #7 AND #8	192

5. LITERATURE REVIEW

5.1 Definition of Blindness and Low Vision

Many ophthalmic surveys, including RAAB surveys, use the World Health Organization (WHO) International Classification of Diseases 10th edition definition of blindness and low vision but with some small modification. This is to include people with uncorrected aphakia and Uncorrected Refractive Error in the definition.[1] Blindness is defined as Presenting Visual Acuity (PVA) of less than 3/60 in the better eye whereas low vision is defined as PVA of less than 6/18 but not less than 3/60 in the better eye. Recently the WHO replaced the term low vision with Moderate Visual Impairment (Category 1: PVA worse than 6/18 and equal to or better than 6/60) and Severe Visual Impairment (Category 2: PVA worse than 6/60 and equal to or better than 3/60).[1]

5.2 Epidemiology of Blindness and Visual Impairment

Globally, there are 32.4 million blind and 191 million moderate and severe visually impaired people.[2] It is important to note that these figures are lower than in the global estimates of visual impairment study.[3] Since the estimates of the global burden of disease study came from more recent and larger published, as well as unpublished, studies we preferred to use them consistently for the remaining sections of the study. Worldwide, cataracts (33%) are the leading cause of blindness followed by URE (21%) and macular degeneration (7%). There are some variations in the causes of blindness across different regions. Cataracts are the main (>40%) cause of blindness in South and Southeast Asia, Oceania and Sub-Saharan Africa whereas macular degeneration is the leading (>15%) cause of blindness in high income regions, Southern Latin America and Central and Eastern Europe.

Uncorrected Refractive Error (53%) is the leading cause of Moderate and Severe Visual Impairment (MSVI) followed by cataracts (18%) and macular degeneration (2%) globally.[2] In 2010, people affected by blindness and MSVI caused by URE were 6.8 (95% Confidence Intervals, CI 4.7-8.8) million and 101.2 (95% CI 87.88; 125.5) million respectively. Furthermore, the age-adjusted combined prevalence of URE causing blindness and MSVI in adults was 5.7% (95% CI 5.0-6.9%). Similarly, the proportion of MSVI related to cataracts is smallest in the highest-income regions (Range 13.0 to 13.8%) and largest in South Asia (21.4%, 95% CI 16.1-24.2) and Southeast Asia (22.7%, 95% CI 17.9; 27.4).

It is important to note that nearly two-thirds (65%, 95% CI, 61-68) of blindness and just over three-quarters (76%, 95% CI 73-79) of MSVI is preventable or treatable. These data come from a systematic review which included 48 population-based unpublished studies, 4 government reports and 44 rapid assessment surveys particularly; Rapid Assessment of Cataract Surgical Services surveys and Rapid Assessment of Avoidable Blindness surveys.

5.3 Rapid Assessment Methods in Eye Care

Studies from various parts of the world have shown that visual impairment affects the quality of life of individuals.[4-6] Quality of life can be improved greatly if avoidable blindness is eliminated. The WHO along with International Agency for the Prevention of Blindness (IAPB) introduced an initiative, "VISION 2020: The Right to Sight", with the goal to eliminate avoidable blindness by the year 2020.[7] The VISION 2020 initiative initially prioritises five areas based on the magnitude of the problem and cost-effective treatment options. The priority areas are cataract, trachoma, onchocerciasis, childhood blindness and refractive errors and low vision.

In order to find out the prevalence of low vision and blindness in the populations of different countries surveys had to be conducted. Traditional epidemiological surveys provide accurate information however they are heavily constrained by money and time particularly in resources limited settings. To overcome this challenge, Rapid Assessment (RA) methods have been developed. RA methods were used in the 1990s in eye care for cataract, onchocerciasis and trachoma and more recently in avoidable blindness and visual impairment.[8] The main advantageous features of RA methods are: use of local resources, simplified sampling methodology and simple examination and data collection protocol which can be conducted by locally available human resources.[9] The survey is relatively inexpensive so it can be repeated every 5 to 10 years to assess the change of disease burden or to evaluate the impact of an interventional program.

Rapid Assessment methods have been used to provide global information on blindness and its causes for populations aged 50 years and above in order to plan for VISION 2020 programmes and to monitor progress towards the VISION 2020 goal.[9] The information obtained from samples of people ≥ 50 years of age can be used to estimate the prevalence in the total population since we expect that at least 80% of blindness is found in the population ≥ 50 years.[10, 11] Rapid Assessment of Cataract Surgical Services and Rapid Assessment of Avoidable Blindness are the two widely used RA methods in eye care.

5.3.1 Rapid Assessment of Cataract Surgical Services

Rapid Assessment of Cataract Surgical Services (RACSS) was one of the earliest RA methods. It was used to find out information about the age group 50 years and above on the prevalence of blindness due to cataracts, Cataract Surgical Coverage, visual outcomes after cataract surgery and barriers for uptake of cataract surgery.[12] It was the first standardised method proposed to measure vision loss and was used until

2005. RACSS uses Expanded Programme on Immunization (EPI) random walk cluster sampling method.

Expanded Programme on Immunization random walk sampling method divides the study area into clusters with a comparable number of households and average number of people in each household based on the recent census data. The clusters to sample, usually of 40 to 50 households, are then randomly selected.[13, 14] The second stage of the sampling is selection of individual households within the cluster. It is recommended to start the selection process at the centre of the area, which is identified as a cluster. One direction is randomly selected at the centre of the cluster, usually by spinning a bottle and starting with the first household where the neck of the bottle faces. The adjacent household with the closest door is selected as the second household and so on. This process carries on until the last household to be sampled from that cluster is visited.

Despite wide use of the EPI random walk sampling method it has several limitations. Firstly, clusters are divided based on the population proportion to size which comes from the census. Unfortunately, census data may not be accurate and updated in many low and middle income countries. In addition a census conducted every ten years may not reflect the true population changes and growth rates. Secondly, the first household within the cluster is selected based on the spun bottle which is a subjective method, the EPI sampling method is likely to have selection bias. Moreover, the centrally located households may be systematically different from peripherally located households, potentially creating selection bias. For example, households with common features such as higher family income are likely to be adjacently located. Taking into account design effect is expected to minimise these biases but cannot eliminate them completely.

The RACSS eye examination protocol comprises of visual acuity measurement using the modified Snellen tumbling E chart with 6/60 and 6/18 optotype on either side. The crystalline lens is examined using a torchlight and direct ophthalmoscope and the fundus is examined by direct ophthalmoscopy. Participants with visual acuity below 6/18 in either eye are referred to the nearest eye care facility for further investigation or treatment.

RACSS software is available to assist at all stages of the survey: sample selection, data entry and automated data analysis. The software is designed to perform the survey easily without the need of experts such as statisticians.

5.3.2 Rapid Assessment of Avoidable Blindness

Rapid Assessment of Avoidable Blindness is essentially a modified, and improved version of RACSS, commonly used from 2005 onwards.[12] RAAB provides information on the prevalence of visual impairment due to avoidable and correctable causes such as cataracts, URE, glaucoma, trachoma, onchocerciasis and corneal scarring. Like RACSS, it also provides data on CSC, barriers to the uptake of cataract surgery and visual outcome after surgery. RAAB uses compact segment sampling methods to recruit 2000 to 5000 participants of age 50 years and above, typically at district level.[15]

Compact segment sampling method is the improved version of cluster sampling method introduced to overcome the limitations of the EPI method.[16] The first stage of the sampling is the determination of sample size followed by selection of cluster based on the population proportion to size method. In the second stage sampling a map of the study clusters is divided into segments with an equal number of individuals in each segment, usually 50 people of ≥50 years of age. A segment is randomly selected from each cluster and all the households of the segment included for the survey. All eligible people in that segment are examined similar to in RACSS methodology except that the fundus is examined by direct ophthalmoscopy through the pupil which may be dilated at the discretion of the examiner.

Unlike in EPI random walk method, compact segment sampling method eliminates the subjectivity while selecting the first household thus minimising possible bias from household selection. Moreover, this sampling method recommends to revisit the households when there is no response.[16] There is a standardised training package for RAAB surveys, which can be conducted only under the supervision of certified RAAB trainers. Inter-observer variation is measured among the teams to maintain the uniformity before the survey. A kappa score of 0.6, which is considered to be a moderate strength of inter-observer agreement, is required for a RAAB survey to be valid.[17]

Even though RAAB overcomes some of the limitations of RACSS, it still has some drawbacks. Diagnosis of posterior segment diseases using the direct ophthalmoscope may not be very accurate and the procedure is difficult to do properly in the field situation. Moreover, leaving dilation of the pupil to the discretion of the examiner means that some examinations are performed more thoroughly than others. Similarly, URE is defined as inability to see 6/60 but can see 6/18 when pinhole is used. This diagnosis guideline provides a gross estimate of refractive error but cannot provide information on the severity of the refractive error.

One problem with both RACSS and RAAB surveys is that only the most easily preventable or curable cause of blindness or visual impairment is reported while in reality there are often multiple causes contributing equally to the vision loss. For example this potentially underestimates the impact of diabetic retinopathy, glaucoma and other diseases when a patient presents with cataract.[18] Recently, examination to detect Diabetic Retinopathy (DR) has been added to the RAAB methodology, which is also referred to as RAAB+DR.

The major strength of the RAAB is its standardised methodology. Although it is not perfect, it allows the best possible opportunity to make comparisons of the prevalence of vision loss and the causes of the vision loss across different settings.

5.4 Rapid Assessment of Avoidable Blindness Repository

The RAAB repository provides safe storage of the results of RACSS and RAAB surveys conducted worldwide (http://www.raabdata.info/repository/). The freely available RAAB software assists in sample selection, data entry and data analysis. All results are presented in a standardised format using the RAAB software. Full reports of the surveys are either available from the repository or may be requested from the Principal Investigator (PI). The main aim of freely sharing the information to the public is that researchers can have easy access to the data for study purposes. However, the PI or the donor agency determines what information to put in the repository and what information to provide on request.[19] This makes it difficult to generalise the findings locally or globally merely based on the repository results. If more survey results were available in the repository then accessing a proper representation of results would be easier.

5.5 Variation of the Prevalences of Blindness and Visual Impairment

The prevalences of blindness and low vision vary greatly among the RAAB surveys. For instance a recent systematic review in Sub-Saharan Africa (SSA), which included 17 surveys of 15 counties, found that the prevalence of blindness ranged from 0.1% in Uganda to 9% in Eritrea.[20] In addition, the prevalence of low vision varied from 1.6% in Gambia and Uganda to 17.1% in Ghana. Similarly a recent review study conducted using RACSS and RAAB surveys of 12 Latin American countries found that the prevalence of blindness was between 1.3% in Argentina and 4.2% (PVA <6/60 in the better eye) in Venezuela.[21] A previous review of 9 surveys from Latin America found the prevalence of blindness similar to that found in the recent review (1.3% in Argentina and 4% in Peru) whereas the prevalence of low vision was found to be between 5.9% (in Argentina) and 12.5% (in Guatemala).[10] The wide variation in the prevalences of low vision and blindness in different countries has to be considered in order to allocate resources appropriately.

5.6 Potential Determining Factors of the Ratio

In order to achieve the goal of VISION 2020, priority has to be given to cataracts and URE which are the leading causes of blindness and visual impairment respectively. The simplest way to reduce the visual impairment and blindness related to cataracts is to perform as many cataract surgeries as possible. By increasing the Cataract Surgical Rate (CSR), which is the number of cataract surgeries per million population, we can increase CSC. Cataract Surgical Coverage, which is the proportion of people who had the surgery among those who needed it, is considered an indicator to measure what extent of the cataract surgical need is met for a community.[22] However, CSR is dependent upon many other factors such as population structure, particularly elderly population, visual acuity threshold for the surgery and accessibility and affordability of the cataract surgical services.[23]

One of the most important potential determining factors for the ratio of low vision to blindness is URE. The simplest way to reduce visual impairment and blindness caused by URE is to identify the refractive errors and provide the appropriate refractive correction, commonly spectacles. When refractive errors are not corrected, as with other disabilities, they reduce economic productivity and educational opportunities as well as quality of life.[24, 25] Even though provision of spectacles is a simple, effective, and largely affordable management for URE, the majority of people do not get spectacles in low resource settings. The main barriers identified for this are awareness about the services, accessibility of the services and affordability of the spectacles.[24] Since accessibility and affordability of ophthalmic services are the barriers to spectacle provision, it is likely that there is some relationship between URE and the economic status of a country.

It is interesting to note that the prevalence of blindness varies with the country's economy. For instance it is estimated that the prevalence of blindness is more than 1% in very low income countries whereas it is 0.75%, 0.50% and 0.25% in low, middle and high income countries respectively.[26]

Since the data on low vision prevalence is not available for many regions, prevalence of low vision is estimated based on the prevalence of blindness: it is estimated to be 3 to 4 times the prevalence of blindness in adults.[26] However, there is a wide variation in the ratio of prevalence of low vision to prevalence of blindness worldwide. For example the ratio of the prevalence of low vision to blindness was found to be between 1.3 and 6.3 in 27 RAAB surveys of 19 Sub-Saharan African countries.[27] To understand the variation better, Lewallen et al. recommended further research which identifies the determining factors of the ratio.[27]

5.7 Identification of the Gap

To the best of our knowledge, there is no description of the variation of ratio of prevalence of low vision to blindness in countries other than in Sub-Saharan Africa, nor is there any exploration into the reasons for the variation. It was found from the previous review that URE is the most common cause of low vision but is not a common cause of blindness.[28] Since the prevalence of refractive errors vary tremendously in various parts of the world [24, 25, 28] it is possible that variation in URE would explain the variation in the ratio of prevalence of low vision to prevalence of blindness. Describing the variation across a large number of surveys from a wide geographical region and examining whether it is associated with prevalence of URE would enhance understanding of epidemiology of visual impairment and blindness globally and possibly provide useful information for predicting the impact of targeting URE needs. Therefore this study was proposed to determine the magnitude and the determinants of the ratio between prevalence of low vision and prevalence of blindness globally, using data from RAAB surveys.

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Part C: Journal Manuscript

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ORIGINAL ARTICLE

Magnitude and Determinants of the Ratio between Prevalences of Low vision and Blindness in Rapid Assessment of Avoidable Blindness Surveys

Dinesh Kaphle*

Faculty of Health Sciences, University of Cape Town

ABSTRACT

Purpose: To determine the magnitude and determinants of the ratio between prevalence of low vision and prevalence of blindness in Rapid Assessment of Avoidable Blindness (RAAB) surveys globally.
Methods: Standard RAAB reports were downloaded from the repository or requested from principal investigators. Potential predictor variables included Cataract Surgical Coverage (CSC) and prevalence of Uncorrected Refractive Errors (URE), extracted from the reports, as well as Gross Domestic Product (GDP) per capita, health expenditure per capita of the country across World Bank regions. Univariate and multivariate linear regression were used to investigate the correlation between potential predictor variables and the ratio.
Results: The results of 94 surveys from 43 counties showed that the ratio ranged from 1.35 in Mozambique to 11.03 in India with a median value of 3.90. There was a significant regional variation of the ratio: approximately 7.0 in South Asia and approximately 3.0 in Sub-Saharan Africa (p<0.001). Univariate regression analysis showed that prevalence of URE, CSC (at 3/60, 6/60 and 6/18) for persons, logarithm of GDP per capita and logarithm of health expenditure per capita were significantly associated with the ratio. However, only prevalence of URE and CSC at 3/60 for persons were found to be statistically significant in multivariate regression analysis.
Conclusion: There is a wide variation in the ratio of the prevalence of low vision to the prevalence of blindness. Eye service indicators such as the prevalence of URE and CSC explain some of the variation across the regions.

Keywords: rapid assessment of avoidable blindness, low vision, blindness, uncorrected refractive errors, cataract surgical coverage

*Under supervision of Prof Susan Lewallen, Department of Ophthalmology, University of Cape Town

INTRODUCTION

There are 32.4 million blind and 191 million moderate and severe visually impaired people in the world.[1] Worldwide, cataracts (33%) are the leading cause of blindness (Presenting Visual Acuity (PVA) of less than 3/60 in the better eye) followed by Uncorrected Refractive Error (URE) (21%) and macular degeneration (7%). Uncorrected Refractive Error (53%) is the leading cause of Moderate and Severe Visual Impairment (MSVI) (PVA of less than 6/18 but not less than 3/60 in the better eye) followed by cataracts (18%) and macular degeneration (2%). Moderate and Severe Visual Impairment combined is known as low vision. These data come from a systematic review which included 48 population-based unpublished studies, 4 government reports and 44 Rapid Assessment of Cataract Surgical Services (RACSS) and Rapid Assessment of Avoidable Blindness (RAAB) surveys.

Until 2005, Rapid Assessment of Cataract Surgical Services surveys were conducted to provide information on prevalence of blindness due to cataracts, cataract surgical coverage, visual outcomes after cataract surgery and barriers for uptake of cataract surgery in the age group 50 years and above.[2] The RACSS uses a modified Expanded Programme on Immunization (EPI) random walk sampling method which divides the study area into clusters with equal numbers of households and people in each household based on recent census data. Then the clusters are randomly selected.[3, 4] The second stage of the sampling is the selection of individual households within the cluster by spinning a bottle at the street crossing. All the eligible participants of the selected households go through the standard eye examination.

Selection of households using a spun bottle was considered to lead to potential selection bias (favoring households nearest the centre of the village). To avoid this compact segment sampling was introduced with the RAAB methodology. The RAAB methodology provides information on prevalence of visual impairment due to cataracts but also includes causes of vision loss such as URE, glaucoma, trachoma, onchocerciasis, and corneal scarring. RAAB uses a compact segment sampling method whereby the study area is divided into clusters of, usually, 50 people. The clusters to be sampled are randomly selected then divided into many segments with equal numbers of households and people in each segment. A segment is randomly selected from each cluster and all the households of the segment are included for the survey. The standard RAAB protocol is used to examine all eligible people in that segment.

The RAAB repository website provides a safe storage of RACSS and RAAB survey data conducted worldwide so that researchers, in theory, have access to the data.[5] This is to try to increase use of the data. Full reports of the surveys are either available from the repository or may be requested from the Principal Investigator (PI). The PI or the donor agency determines what information to put in the repository and what information to provide on request. This makes it difficult to generalise the findings globally merely based on the repository results.

When the RAAB survey results are compared for different countries it can be seen that the prevalences of blindness and low vision vary widely. For instance a recent systematic review in Sub-Saharan Africa (SSA), which included 17 surveys of 15 countries, found that the prevalence of blindness was between 0.1% in Uganda and 9% in Eritea.[6] In addition, the prevalence of low vision varied from 1.6% in Gambia and Uganda to 17.1% in Ghana. Similarly a review study conducted using RACSS and RAAB surveys of 12 Latin American countries found that the prevalence of blindness (PVA<3/60 in the better eye) was between 1.3% in Buenos Aires, Argentina and 4.2% (PVA <6/60 in the better eye) in Venezuela.[7]

Since the data on prevalence of low vision is not available for many regions, it is estimated based on the prevalence of blindness. Prevalence of low vision is estimated to be 3 to 4 times the prevalence of blindness in adults.[8] But there is a wide variation in the ratio of prevalence of low vision to prevalence of blindness across geographical regions worldwide. For example the ratio of prevalences of low vision to blindness was found between 1.3 and 6.3 in 27 RAAB surveys of 19 Sub-Saharan African countries.[9]

To the best of our knowledge, there is no description of the variation of the proportion of low vision to blindness in countries other than Sub-Saharan Africa, nor is there any exploration into the reasons for the variation. URE is the most common cause of low vision but is not a common cause of blindness.[10] Since the prevalence of refractive error varies tremendously in various parts of the world,[10-12] it is possible that variation in URE would explain the variation in the ratio of prevalence of low vision to prevalence of blindness. It is also known that the prevalence of blindness differs with the country's economy. For instance it is estimated that the prevalence of blindness is more than 1% in very low income countries whereas it is 0.75%, 0.50% and 0.25% in low, middle and high income countries respectively.[8] Therefore it might be that either or both of these factors correlates with the ratio of the prevalence of low vision to blindness and helps explain the variation.

Describing the variation in the ratio of low vision to blindness across a large number of surveys from a wide geographical region and examining whether it is associated with prevalence of URE and indicators of a country's economy would enhance understanding of epidemiology of visual impairment and blindness globally. Furthermore it could possibly provide useful information for predicting the impact of targeting URE needs. Therefore this study aimed to determine the magnitude and the determinants of the ratio between prevalences of low vision to blindness globally, using data from RAAB surveys.

MATERIALS AND METHODS

Study Design

The study design was observational analytical. A retrospective secondary analysis was performed of 94 RAAB surveys, covering 257,757 people of 50 years and above from 43 counties between 2003 and 2015.

Examination and Data Collection

The detailed methodology for the RAAB survey was previously published, a brief description of the methodology is mentioned in this paper.[13] Visual Acuity (VA) of eligible participants is measured using a Snellen tumbling E chart, which has optotype of size 6/18 and 6/60 on either side. Pinhole vision is assessed if the person cannot see 6/18 in either eye. If the VA improves to at least 6/18 with pinhole, the eye is recorded to have refractive error. The crystalline lens is examined using both torch and distant direct ophthalmoscopy in a shaded or dark room. All eyes with VA less than 6/18 with the available correction are examined with a direct ophthalmoscope to assess the cause of vision loss. Portable slit lamp may be used to assess the vision loss if it is available. Only the primary cause of blindness or visual impairment is recorded as the diagnosis for each eye. If the two eyes have different diagnoses, then the cause of vision loss for the person is recorded as the diagnosis considered most easily treated.

All the 217 RAAB surveys listed in the RAAB repository (as of 10 February 2016) were assessed using the inclusion criteria checklist guidelines (Appendix 1). Those surveys which had the reports in the repository and met the criteria were identified and selected for the study. Reports of surveys which were eligible for the study but missing in the repository were requested from the PIs through the request link in the repository. Finally, surveys which were not listed in the repository but were known from previous publications using RAAB methodology[14] and for which data were available (KwaZulu-Natal, South Africa-2009 and White Nile, Sennar, Northen, Kodorfan of Sudan-2010) were also included in the study.

Inclusion and Exclusion Criteria

The inclusion criteria for the study were: the survey should have used the standard RAAB methodology, the coverage of the survey had to be at least 80% of the sample size calculated and the survey should have a downloadable standard RAAB report in the repository OR the report obtained through the request procedure with permission from the PIs. The exclusion criteria for the study were: the surveys conducted using RACSS or custom methodology and the surveys with missing data on prevalence of low vision and blindness AND/OR probable explanatory variables. In addition, the surveys for which the permission to use the data could not be obtained from the PIs were excluded from the study.

Statistical Analysis

Data analysis was performed using the statistical software STATA 11 (Stata Corp. College Station, Texas). The ratio of unadjusted prevalence of low vision to unadjusted prevalence of blindness was considered as the outcome variable. Continuous variables were described using mean (standard deviation) or median (inter-quartile range) based on the normality. Normality of the variables was checked using the histogram and Shapiro-Wilk test. The associations between the ratio and the potential explanatory variables were assessed using Spearman's rank correlation coefficient. The variation of the ratio in different regions was assessed using analysis of variances (ANOVA). When the variances were significantly different to one another (checked using Bartlett's test), Kruskal-Wallis test was used. Univariate regression analysis was performed keeping ratio as an outcome variable and the other variables individually as explanatory variables. Multiple linear regression was fitted using the ratio as the outcome variable, and the explanatory variables which had *p* value of below 0.2 in the univariate analysis. Explanatory variables which had high collinearity were excluded from the multivariate analysis. Logarithm transformation (base 10) was performed for the highly skewed variables and the not-normally distributed outcome variable. The description and source of the variables is shown in Table 1. Probability (*p*) value below 0.05 was considered statistically significant for two-sided tests.

Table 1. Description and source of the variables.

Variables	Description and source
Prevalence of unadjusted LV	Continuous variable, obtained from Sample report (Table 2)
Prevalence of unadjusted BL	Continuous variable, obtained from Sample report (Table 2)
Ratio	Ratio of the prevalence of unadjusted LV to the prevalence of unadjusted BL
Prevalence of URE	Continuous variable, calculated as the number of people Blind, SVI and MVI due to URE divided by the total number of people examined in the survey; obtained from Sample report (Tables 1, 4, 6 & 8)
CSC 3/60 (Persons)	Continuous variable, obtained from Sample report (Table 12)
CSC 6/60 (Persons)	Continuous variable, obtained from Sample report (Table 12)
CSC 6/18 (Persons)	Continuous variable, obtained from Sample report (Table 12)
WB region	Polytomous variable; 6 regions based on WB classification[15]
GDP per capita	Gross domestic product per capita in US dollars by country for closest year of survey, obtained from World Bank report[16]
Health expenditure per capita	Health expenditure per capita in US dollars by country for closest year of survey, obtained from World Bank report[17]

LV, Low Vision; BL, Blindness; URE, Uncorrected Refractive Error; MVI, Moderate Visual Impairment; SVI, Severe Visual Impairment; CSC, Cataract Surgical Coverage; WB, World Bank; GDP, Gross Domestic Product; USD, United States Dollars.

Ethical Considerations

All the RAAB surveys, which were included in the study, obtained verbal consent from the participants before enrolling them in the survey. Each individual survey was conducted in accordance with the tenants of the Declaration of Helsinki. The ethical approval of the study protocol was obtained from the Human Research Ethics Committee, University of Cape Town (Approval number 069/2016).

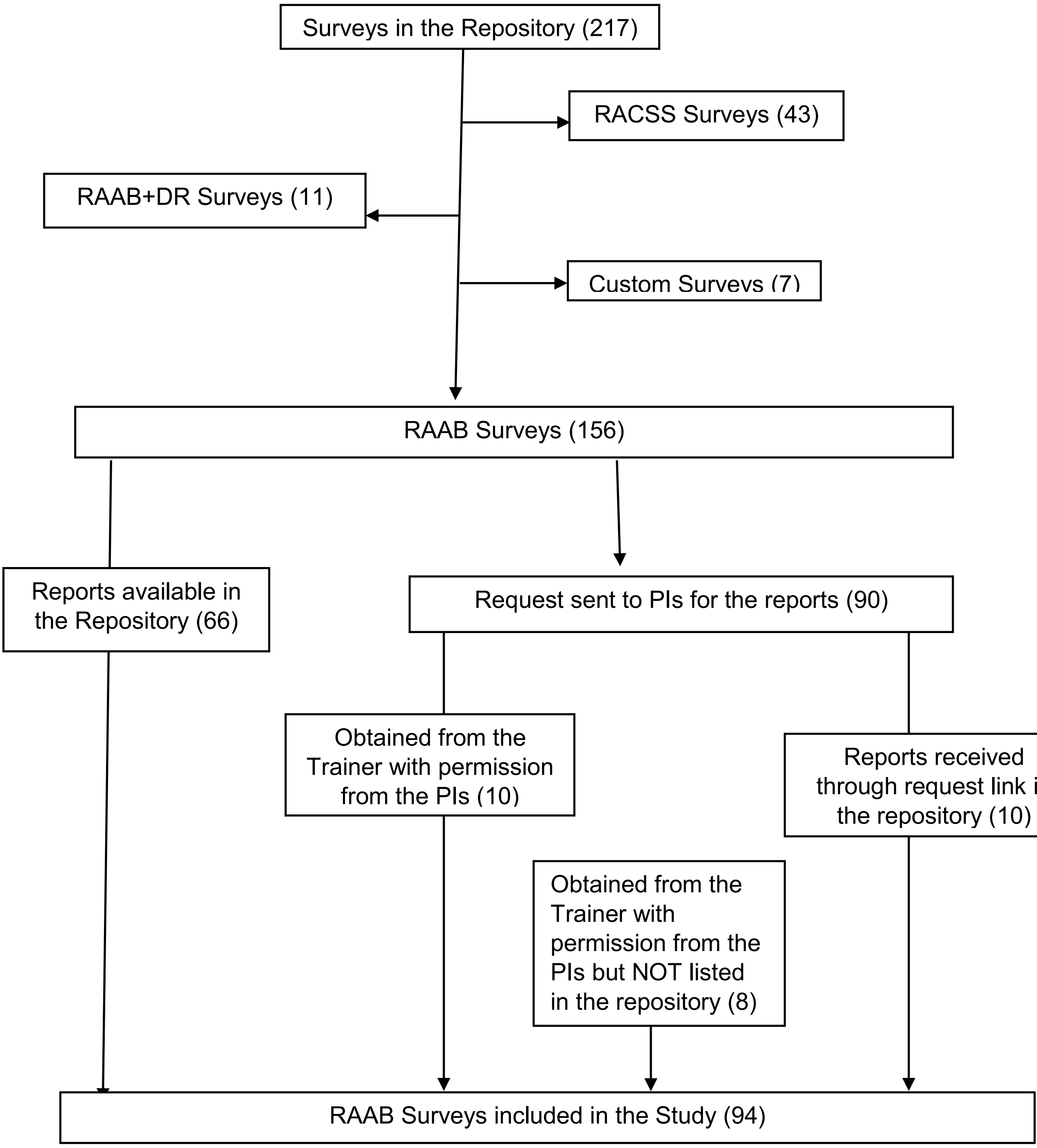
RESULTS

Surveys included in the Study

Out of 217 surveys in the repository, 156 were RAAB surveys. The sources of 94 surveys, which were included in the study, are presented in Table 2. A survey from Negros, Philippines (2005) was excluded from the study because of low coverage (76%). The largest number of surveys were from Vietnam (16) followed by China (10) and Nepal (10). Figure 1 presents the sources of the 94 surveys. The description of the 94 surveys is shown in Tables 7, 8, 9, 10 and 11 of Appendix 6.

Description of the Variables

The ratio of the prevalences of low vision to blindness was the lowest in Nampula, Mozambique (1.35 times) and it was the highest in Gujarat, India (11.03 times). The mean (standard deviation), range, median and interquartile range of the ratio and potential explanatory variables are shown in Table 2.



RAAB, Rapid Assessment of Avoidable Blindness; DR, Diabetic Retinopathy,

RACSS, Rapid Assessment of Cataract Surgical Services; PI, Principal Investigator

Figure 1. Sources of the included surveys.

Table 2. Description of the variables.

Variables	Survey, N	Mean (SD)	Range	Median (IQR)
Prevalence of unadjusted low vision [a]	94	11.85 (4.82)	2.30; 26.10	11.90 (7.90; 14.80)
Prevalence of unadjusted Blindness [a]	94	3.33 (2.27)	0.70; 10.84	2.65 (1.70; 4.0)
Ratio [a]	94	4.51 (2.32)	1.35;11.03	3.90 (3.06;5.38)
Prevalence of URE (%)[a]	86	4.50 (2.25)	1.38;14.66	4.03 (3.03;5.14)
CSC 3/60 (Persons) (%)	94	64.58 (19.09)	10.10;100	64 (52.10;80.60)
CSC 6/60 (Persons) (%)	94	55.40 (19.77)	8.20;98	55.25 (39.60;69.60)
CSC 6/18 (Persons) (%)[a]	94	37.77 (17.78)	6.40;96.70	36.1 (25.50;48.80)
GDP per capita (USD) [a]	94	2925.86 (3478.107)	244.20; 14166.60	998.10 (629.30;4255.60)
Health expenditure per capita (USD) [a]	93	157.29 (190.32)	9;1138	58 (35;237)

[a] Data not normally distributed (Shapiro Wilk test *p*<0.05).

SD, Standard Deviation; IQR, Interquartile Range; URE, Uncorrected Refractive Error; CSC, Cataract Surgical Coverage; GDP, Gross Domestic Product; USD, US Dollars.

Association between the Ratio and Other Variables

The association between the ratio and other potential explanatory variables is shown in Table 3. There was a statistically significant association between the ratio and the prevalence of URE (r_s=0.26, *p*=0.01).

Table 3. Correlation between the ratio and the explanatory variables.

	Survey, N	Spearman's coefficient (r_s)	*p* value
Prevalence of URE	86	0.26	0.01
CSC 3/60	94	0.52	<0.001
CSC 6/60	94	0.41	<0.001
CSC 6/18	94	0.28	<0.01
GDP per capita	94	0.21	0.03
Health expenditure per capita	93	0.19	0.05

URE, Uncorrected Refractive Error; LV, Low Vision; CSC, Cataract Surgical Coverage; GDP, Gross Domestic Product.

Distribution of the Ratio across the Regions

The distribution of the ratio across the regions is shown in Table 4. The mean (standard deviation) ratio was found to be the highest in South Asia, 6.96 (2.86) followed by Latin America and Caribbean, 6.22 (2.63). There was a statistically significant difference in variation of ratio across the regions (Kruskal-Wallis test, $\chi^2=31.15$, $p<0.001$).

Table 4. Distribution of the ratio across the WB regions.

Region	Frequency (Percent)	Mean (SD)	Range	Median (IQR)
East Asia and Pacific	34 (36.17)	4.37 (1.15)	1.60;8.70	4.18 (3.32;5.21)
Sub-Saharan Africa [a]	28 (29.79)	2.95 (1.30)	1.35;6.16	2.71 (1.76;3.69)
Latin America and Caribbean [a]	16 (17.02)	6.02 (2.55)	3.41;10.85	5.28 (4.07;6.87)
South Asia	12 (12.77)	6.96 (2.86)	3.37;11.03	7.75 (3.89;9.11)
Middle East and North Africa	4 (4.26)	3.33 (1.73)	1.91;5.53	2.93 (1.94;4.72)
Total	94 (100)			

[a] Data not normally distributed (Shapiro Wilk test $p<0.05$).

WB, World Bank; SD, Standard Deviation; IQR, Interquartile Range.

Univariate Regression Analysis

The results of the univariate regression analysis are presented in Table 5.

Table 5. Univariate analysis of the logarithm of the ratio with other variables.

Log10 of Ratio	Survey, N	Univariate regression coefficients (95% CI)	R^2 adj. (%)	*p* value	RMSE
Prevalence of URE (%)	86	0.047 (0.0006; 0.094)	3.47	0.04	0.49
Log10 CSC 3/60	94	0.70 (0.45;0.95)	25.11	<0.001	0.43
Log10 CSC 6/60	94	1.18 (0.67;1.69)	17.98	<0.001	0.45
Log10 CSC 6/18	94	0.67 (0.22;1.13)	7.73	0.004	0.48
Log10 GDP per capita	94	0.25 (0.045;0.47)	4.93	0.01	0.49
Log10 Health expenditure per capita	93	0.23 (0.20;0.45)	3.89	0.03	0.49

CI, Confidence Intervals; URE, Uncorrected Refractive Error; R^2 adj, Adjusted coefficient of determination; RMSE: Root Mean Square Error; CSC, Cataract Surgical Coverage; GDP, Gross Domestic Product.

Multivariate Regression Analysis

Logarithm of CSC at 6/60 and logarithm of CSC at 6/18 were found to be statistically significantly correlated with logarithm of CSC at 3/60 (Pearson's coefficient=0.97, p<0.001 and spearman's coefficient=0.91 and p<0.001 respectively). Hence only CSC at 3/60 was included in the multivariate model. Similarly logarithm of GDP per capita was found to be statistically significantly correlated with logarithm of health expenditure per capita (spearman's coefficient=0.94, $p<0.001$). Hence, logarithm of GDP per capita was excluded from the model.

East Asia and Pacific was used as the reference region because it had the largest number of surveys contributing to the study. In addition, the average mean ratio of East Asia and Pacific region was the closest to the overall mean ratio of all the surveys. The coefficients with *p* values of the multivariate regression model are presented in Table 6.

Interpretation of the Multivariate Regression Model

Prevalence of URE and CSC at 3/60 explained the variability of the ratio of prevalence of low vision to prevalence of blindness. The effect was statistically significant (p=0.03 and 0.002 respectively). The effect of health expenditure per capita on the ratio was not statistically significant (p=0.60). On average, keeping prevalence of URE and CSC at 3/60 constant, South Asia and Latin America and Caribbean had higher logarithms of the ratio between prevalences of low vision and blindness compared to East Asia and Pacific. However the effect was not statistically significant (p=0.07 for each). Sub-Saharan Africa and Middle East and North Africa had lower logarithms of the ratio compared to East Asia and Pacific. The effect for Sub-Saharan Africa was statistically significant (p=0.002) but was not statistically significant for Middle East and North Africa (p=0.11).

Table 6. Coefficients of the multivariate regression model with *p* values.

Explanatory Variables	Coefficients (95% CI)	*p* value
Prevalence of URE (%)	0.04 (0.003;0.077)	0.03
Log10 CSC 3/60	0.43 (0.17;0.67)	0.002
Log10 Health expenditure per capita	-0.06 (-0.33;0.19)	0.60
Sub-Saharan Africa	-0.33 (-0.54;-0.12)	0.002
Latin America and Caribbean	0.26 (-0.28;0.55)	0.07
Middle East and North Africa	-0.36(-0.81;0.08)	0.11
South Asia	0.28 (-0.029;0.59)	0.07

Survey, N=85, $p<0.001$, R^2 adj. =45.54, RMSE=0.37.

Reference region: East Asia and Pacific.

CI, Confidence Intervals, URE, Uncorrected Refractive Error; R^2 adj, Adjusted coefficient of determination; RMSE: Root Mean Square Error; CSC, Cataract Surgical Coverage.

A quantile-quantile (between predicted values and the outcome variable) plot and residual versus predicted values plot were checked to assess the linear regression assumption. Both plots were found fairly null which showed that the assumptions for linear regression were met (Figure 2 and 3 of Appendix 7).

DISCUSSION

In this analysis we have documented and described the wide variation in the ratio of prevalences between low vision and blindness found in RAAB surveys from around the world and explored several factors which might be correlated with the variation.

We expected that the magnitude of Uncorrected Refractive Error might be important in explaining the variation. It is known from a previous systematic review in Sub-Saharan Africa that URE is responsible for low vision rather than blindness[10] although this has not been assessed in other regions. We also expected that the cataract surgical coverage could affect the ratio since places where cataracts are not operated on, even at very advanced levels might be expected to have relatively higher prevalences of blindness. We also considered a few basic socioeconomic indicators such as GDP per capita and health expenditure per capita.

We included a total of 94 RAAB studies from 43 countries. All World Bank regions were represented although not evenly; 36%, 30%, 17%, 13% and 4% of studies were from East Asia and Pacific, Sub-Saharan Africa, Latin America and Caribbean, South Asia, and Middle East and North African regions respectively. It was interesting to learn that the RAAB Repository provides access for less than 50% (66/156) of the RAAB studies listed.

The ratio between unadjusted prevalences of low vision to blindness varied from 1.35 in Mozambique to 11.03 in India. There was a big variation of the ratio across the regions and it was statistically significant (Kruskal-Wallis test, χ^2=28.23, p<0.001). The highest mean ratio was found in South Asia (approximately 7.0, Range: 3.37 to

11.03) and the lowest ratio was found in Sub-Saharan Africa (approximately 3.0, Range: 1.35 to 6.16) (Table 4). The ratio was found to be in a similar range in Sub-Saharan Africa by a previous study[9], which relied on almost the same data as this one. However a 2002 study conducted using 43 studies from 15 World Health Organization subregions for all-ages found the range of the ratio to be 2.4 to 5.8, which is narrower than our finding.[18]

The prevalence of URE varied widely in our study, between 1.38% in Ninh Thuan, Vietnam-2007 and 14.66% in Ngozi & Kayanza, Burundi-2012. (Table 2). The large variation of prevalence of URE is in agreement with other literature. A review conducted in 2008 found that the prevalence of visual impairment caused by URE in people aged 50 years and above was between 2% and 5% in most regions of the world but nearly 10% in China and 20% in India and the other South East Asian countries (Bangladesh, Nepal, Pakistan).[19] In addition, as in our hypothesis, prevalence of URE was found to be positively associated with the ratio (r_s=0.26, p=0.01).

There was a big difference in Cataract Surgical Coverage among the study surveys. The CSC at 3/60 for persons was 10.1% in the 2011 study in Nampula, Mozambique and 100% in Central Malaysia in the 2014 study. Similarly the CSC at 6/60 and 6/18 were the lowest in Nampula, Mozambique (8.2% and 6.4% respectively) and the highest in Central, Malaysia (98% and 96.7% respectively). The variation of CSC across the surveys reflects the varying level of service provision in the survey sites.

The univariate regression analysis showed that variation in the ratio of prevalences between low vision and blindness could potentially be explained by prevalence of URE, CSC by persons at 3/60, 6/60 and 6/18, logarithm of GDP per capita and logarithm of health expenditure per capita across the WB regions (Table 5). We used variable CSC at 3/60, but not CSC at 6/60 and CSC at 6/18 for multiple regression, because blindness is defined on the basis of Presenting Visual Acuity of 3/60 or worse in the better eye. Similarly, we believed that health expenditure per capita is a better reflection of a country's wealth spent on eye care than GDP per capita. We therefore included health expenditure per capita in the multiple regression analysis. In multivariate regression analysis, prevalence of URE and CSC at 3/60 were found to be associated with the ratio of prevalences between low vision and blindness across the regions (Table 6). However logarithm of health expenditure was not statistically significantly associated with the ratio.

Our study has some limitations. We have included only RAAB surveys so our study is likely to have the same limitations as the RAAB methodology. RAAB does not provide an estimate of the prevalence of refractive error itself; instead it provides an estimate of URE. These may be very similar in low income countries with limited eye services. Another limitation is the potential variability in methodology among surveys. In RAAB, URE is supposed to be reserved as a diagnosis for eyes that achieve normal vision (6/18) with a pinhole; however, sometimes URE is used as the diagnosis in eyes that do not fulfill this criteria (Lewallen's unpublished data). It would have been preferable to use the ratio of age and sex adjusted prevalences of low vison and blindness in our study. The RAAB studies provide prevalence of URE only for the sample population so we could not use age-adjusted ratio for our analysis. It would be interesting to do further analysis on gender adjusted prevalences of low vision and blindness.

To the best of our knowledge this is the first large study to assess the magnitude and determinants of the variation of ratio between prevalences of low vision and blindness using RAAB studies globally. It appears that the prevalence of URE as well as CSC affect this ratio and explain the wide variations that have been reported. When making estimates of the magnitude of people with impaired vision in the world, it is important to realise that the ratio of low vision to blindness will vary widely and not to assume that it will always be 3 to 4 as was suggested in the early stages of the VISION 2020 initiative when the first attempts to estimate this were made.[8] This study helps us to quantify the variation and to understand some of the factors that influence it.

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Part D: Appendices

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APPENDIX 1: INCLUSION CRITERIA CHECKLIST

Inclusion Criteria Checklist

ID	Country	Region	Year	Sample Size	Coverage	Downloadable Report; Yes/No	Inclusion Criteria met: Yes/No
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

APPENDIX 2: DATA CAPTURE SHEET

Data Capture Sheet

ID	Country	Region	Unadj_Prev_LV	Unadj_Pre_BL	Prev_URE	CSC_360	CSC_660	CSC_618	GDP per capita	Health_expd per capita	WB Region

Unadj, Unadjusted; Prev, Prevalence; LV, Low vision; BL, Blindess; URE, Uncorrected refractive error; CSC, Cataract Surgical Coverage; GDP, Gross Domestic Product; Health_expd, Health expenditure;WB, World Bank.

APPENDIX 3: RAPID ASSESSMENT OF AVOIDABLE BLINDNESS SURVEY FORM

RAPID ASSESSMENT FOR AVOIDABLE BLINDNESS

A. GENERAL INFORMATION — **Year - month:** ☐☐☐☐ - ☐☐

Survey area: ______________________ ☐☐ **Cluster:** ☐☐☐ **Individual no.:** ☐☐

Name: ______________________ **Sex:** Male: O (1) Female: O (2) **Age (years):** ☐☐

Optional 1: ☐☐
Optional 2: ☐☐

Examination status:

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

Always ask: "Did you ever have any problems with your eyes?" Yes: O (1) No: O (2)

If not available - details (availability / tel number / address)

B. VISION

Uses distance glasses: No: O (1) Yes: O (2)
Uses reading glasses: No: O (1) Yes: O (2)

Presenting vision	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)

Pinhole vision	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)
Cataract surg. complications:	O (4)	O (4)	O (4)
Trachoma corneal opacity:	O (5)	O (5)	O (5)
Other corneal opacity:	O (6)	O (6)	O (6)
Phthisis:	O (7)	O (7)	O (7)
Onchocerciasis:	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 posterior segment:	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 SURGERY WAS NOT DONE
(Mark up to 2 responses, if VA<6/18, not improving with pinhole, with visually impairing lens opacity in one or both eyes)

Need not felt	O (1)
Fear of surgery or poor result	O (2)
Cannot afford operation	O (3)
Treatment denied by provider	O (4)
Unaware that treatment is possible	O (5)
No access to treatment	O (6)
Local reason (optional)	O (7)

G. DETAILS ABOUT CATARACT OPERATION

	Right eye	Left eye
Age at operation (years)	☐☐	☐☐
Place of operation		
Government hospital	O (1)	O (1)
Voluntary / charitable hospital	O (2)	O (2)
Private hospital	O (3)	O (3)
Eye camp / improvised setting	O (4)	O (4)
Traditional setting	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)

APPENDIX 4: ETHICAL APPROVAL LETTER

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

Room E52-24 Old Main Building
Groote Schuur Hospital
Observatory 7925
Telephone [021] 406 6338 • **Facsimile** [021] 406 6411
Email: shuretta.thomas@uct.ac.za
Website: www.health.uct.ac.za/fhs/research/humanethics/forms

02 March 2016

HREC REF: 069/2016

Prof S Lewallen
Division of Ophthalmology
H53, OMB

Dear Prof Lewallen

PROJECT TITLE: MAGNITUDE AND DETERMINANTS OF THE RATIO BETWEEN PREVALENCES OF LOW VISION AND BLINDNESS IN RAPID ASSESSMENT OF AVOIDABLE BLINDNESS SURVEYS (Masters-candidate Mr D Kaphle)

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.

Approval is granted for one year until the 30th March 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.

We acknowledge that the student Mr D Kaphle will also be involved in this study.

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

Yours sincerely

pp TJBurgess
PROFESSOR M BLOCKMAN
CHAIRPERSON, FHS HUMAN RESEARCH ETHICS COMMITTEE
Federal Wide Assurance Number: FWA00001637.
Institutional Review Board (IRB) number: IRB00001938
This serves to confirm that the University of Cape Town Human Research Ethics Committee complies to the Ethics Standards for Clinical Research with a new drug in patients, based on the Medical Research Council (MRC-SA), Food and Drug Administration (FDA-USA), International Convention on Harmonisation Good Clinical Practice (ICH GCP), South African Good Clinical Practice Guidelines (DoH 2006), based on the Association of the British Pharmaceutical Industry Guidelines (ABPI),and Declaration of Helsinki (2013) guidelines.

HREC REF 069/2016

APPENDIX 5: INSTRUCTIONS FOR AUTHORS

Ophthalmic Epidemiology

Official journal of the International Society of Geographic and Epidemiologic Ophthalmology (ISGEO)

ISSN: 0928-6586 (Print), 1744-5086 (Online)

Publication Frequency: 6 issues per year

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   a) Purpose,

   b) Methods

   c) Results

   d) Conclusion

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Book: Raven JC, Court JH, Raven J. Manual for Raven' Progressive Matrices and Vocabulary Scales. London: H.K. Lewis & Co. Ltd., 1986.

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APPENDIX 6: SUPPLEMENTARY TABLE

Description of included surveys in the study is shown in Tables 7, 8, 9, 10 and 11.

Table 7. Surveys from East Asia and Pacific region.

Country	Province / Region	District	Year	Sample size	Coverage (%)	Source
Cambodia	-	-	2007	6000	98.4	Repository
China	Yunnan	Lancang	2012	2550	94.8	Repository
China	Yunnan	Jianchuan	2012	2100	95.6	Repository
China	Sichuan	Mianning	2011	2850	98.8	Repository
China	Sichuan	Dechang	2011	1749	98.5	Repository
China	Inner Mongolia	Shangdu	2010	2000	98.8	Repository
China	Inner Mongolia	Tuoketuo	2010	2098	96.4	Repository
China	Yunnan	Kunming	2008	2760	93.8	Repository
China	Jiangxi	Xingan	2007	4000	95.9	Repository
China	Jiangxi	Gao'an	2007	5000	94	Repository
China	Jiangxi	Wanzai	2007	3000	95.4	Repository
Malaysia	Eastern	-	2014	2500	98	Obtained on request
Malaysia	Northen	-	2014	2500	96.7	Obtained on request
Malaysia	Sabah	-	2014	2500	95.4	Obtained on request
Malaysia	Sarawahk	-	2014	2500	95.4	Obtained on request
Malaysia	Southern	-	2014	2500	94.8	Obtained on request

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Country	Province / Region	District	Year	Sample Size	Coverage (%)	Source
Malaysia	Central	-	2014	2500	91.3	Obtained on request
Philippines	Antique	-	2006	3842	82.7	Repository
Vietnam	Vung Tau	-	2007	1800	92.5	Repository
Vietnam	Tien Giang	-	2007	1799	95.7	Repository
Vietnam	Thai Nguyen	-	2007	1800	97.2	Repository
Vietnam	Phu Tho	-	2007	1800	100	Repository
Vietnam	Ninh Thuan	-	2007	1800	98.7	Repository
Vietnam	Nghe An	-	2007	1800	94.1	Repository
Vietnam	Lao Cai	-	2007	1800	98.2	Repository
Vietnam	Hue	-	2007	1800	98.1	Repository
Vietnam	Ho Chi Minh	-	2007	1800	97.2	Repository
Vietnam	Ha Tay	-	2007	1799	95.4	Repository
Vietnam	Hai Phong	-	2007	1800	100	Repository
Vietnam	Gia Lai	-	2007	1798	96.7	Repository
Vietnam	Can Tho	-	2007	1800	99.3	Repository
Vietnam	Binh Phuoc	-	2007	1800	98.8	Repository
Vietnam	Binh Dinh	-	2007	1800	96.7	Repository
Vietnam	Bac Ninh	-	2007	1800	96.7	Repository

Table 8. Surveys from Sub-Saharan Africa region.

Country	Province / Region	District	Year	Sample size	Coverage (%)	Source
Botswana	-	-	2013	3310	93.3	Obtained on request
Burundi	Ngozi & Kayanza	-	2012	3879	95	Repository
Democratic Republic of Congo	-	-	2015	3560	93.8	Obtained on request
Eritrea	National	-	2008	3163	95.9	Obtained on request
Guinea Bissau	National	-	2010	2900	99	Obtained on request
Kenya	Coast	Kwale	2011	3250	96.1	Repository
Kenya	Southern Nyanza	-	2010	2603	98.6	Obtained on request
Kenya	Rift Valley	Kericho	2007	2546	95	Repository
Kenya	Rift Valley	Nakuru	2005	3750	92.7	Repository
Madagascar	Analamanga	-	2015	3605	94.9	Obtained on request
Madagascar	Atsinanana	-	2011	3157	87.7	Repository
Malawi	Southen	Chiradzulu	2009	3583	95.7	Repository
Mali	Koulikoro	-	2011	2226	96.8	Obtained on request
Mozambique	Sofala	-	2012	3599	94.1	Repository

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Country	Province / Region	District	Year	Sample Size	Coverage (%)	Source
Mozambique	Nampula	-	2011	2954	96.9	Obtained on request
Senegal	Kaolack	-	2010	2834	97.7	Obtained on request
Senegal	Fatick	-	2010	2514	96.7	Obtained on request
Sierra Leone	National	-	2011	2976	97.6	Obtained on request
South Africa	Kwazu-Natal	INK	2009	1179	92.8	Obtained on request
Sudan	White Nile	-	2010	2097	97.5	Obtained on request
Sudan	Sennar	-	2010	1938	96.7	Obtained on request
Sudan	Northen	-	2010	1952	95.3	Obtained on request
Sudan	Kodorfan	-	2010	2032	94.5	Obtained on request
Tanzania	Kilimanjaro		2007	3597	95.5	Repository
Tanzania	Zanzibar	-	2007	3160	98.8	Obtained on request
Uganda	Western	Hoima	2013	3862	99.1	Repository
Uganda	Central	Mubende	2012	3850	96.9	Repository
Zambia	Southern Province	-	2010	3629	95	Obtained on request

Table 9. Surveys included from Latin America and Caribbean region.

Country	Province / Region	District	Year	Sample Size	Coverage (%)	Source
Argentina	Buenos Aires	Buenos Aires	2003	4600	93.5	Repository
Brazil	Sao Paulo	Campinas	2003	2400	92.7	Repository
Chile	Bio Bio	-	2006	3000	97.2	Repository
Dominican Republic	-	-	2008	3995	96.9	Repository
Ecuador	National	-	2009	4200	95.5	Repository
El Salvador	National		2011	3800	89.4	Repository
Guatemala	4 states	-	2004	4900	98.1	Repository
Honduras	National	-	2013	3150	95.2	Repository
Moldova	National		2012	3885	98	Obtained on request
Mexico	Chipas	Central, Highland & Frialesca	2010	3250	86.8	Repository
Mexico	Nuevo Leon	-	2005	3780	99.6	Repository
Panama	National	-	2013	4200	98.2	Repository
Paraguay	National	-	2011	3000	95.4	Repository
Peru	National	-	2011	5000	97	Repository
Suriname	National	-	2013	3000	93.5	Obtained on request
Uruguay	National	-	2011	3950	94.3	Repository

Table 10. Surveys included from South Asia region.

Country	Province / Region	District	Year	Sample Size	Coverage (%)	Source
Bangladesh	Khulna	Satkhira	2006	5295	91.9	Repository
India	Gujarat	Surat	2011	2200	97.1	Obtained on request
Nepal	Rapti	-	2010	2998	97.4	Repository
Nepal	Dhaulagiri	-	2010	3000	99.7	Repository
Nepal	Sagarmatha	-	2009	3050	95.5	Repository
Nepal	Mechi	-	2009	3050	99.7	Repository
Nepal	Koshi	-	2009	3050	94.9	Repository
Nepal	Bheri	-	2009	3050	98.1	Repository
Nepal	Seti & Mahakali	-	2008	2751	91.3	Repository
Nepal	Karnali	-	2008	1197	97.8	Repository
Nepal	Janakpur	-	2008	1800	94.7	Repository
Nepal	Bagmati	-	2008	2050	93.1	Repository

11. Surveys from Middle East and North Africa region.

Country	Province / Region	District	Year	Sample Size	Coverage (%)	Source
Iran	Tehran	Varamin	2009	3000	94	Repository
Palestine	National	-	2008	3800	94.2	Repository
Yemen	Al Amran	-	2009	1948	91.8	Repository
Yemen	Lahj	-	2009	1948	94.3	Obtained on request

APPENDIX 7: SUPPLEMENTARY FIGURES

Figures 2 and 3 shows the diagnostic plots of the multivariate regression model.

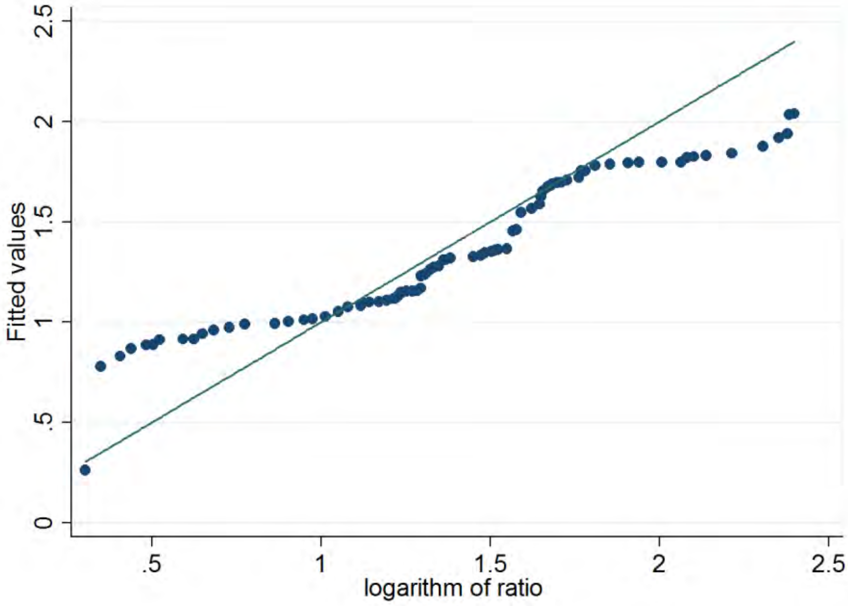

Figure 2. A quantile-quantile plot between fitted values and outcome variable

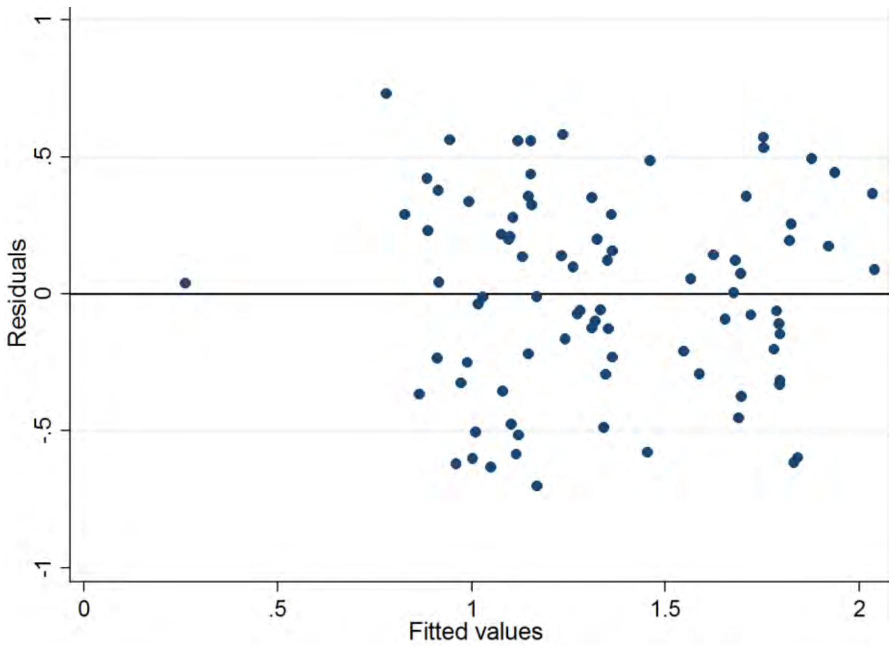

Figure 3. Plot between residuals and fitted values