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Speaker: Grace Sun, M.D.
Date: February 22, 2021
Time: 1:00pm - 2:00pm
Title: Global Blindness

Zoom info: https://weillcornell.zoom.us/j/95082030968 **Meeting ID**: 950 8203 0968 **Passcode**: 586713

Summary: Focus on identify the leading causes of global blindness, potential treatments and interventions to ameliorate the burden of global blindness and skills to perform a basic eye exam in under-resourced communities'

Suggested Readings:

Tanzania Fact Sheet

Global Data on Visual Impairments, World Health Organization

Woodward, R., Mgaya, E., Mwanansao, C., Peck, R.N., Wu, A. and Sun, G. (2020), Retinopathy in adults with hypertension and diabetes mellitus in Western Tanzania: a cross-sectional study. Trop Med Int Health, 25: 1214-1225. https://doi.org/10.1111/tmi.13463

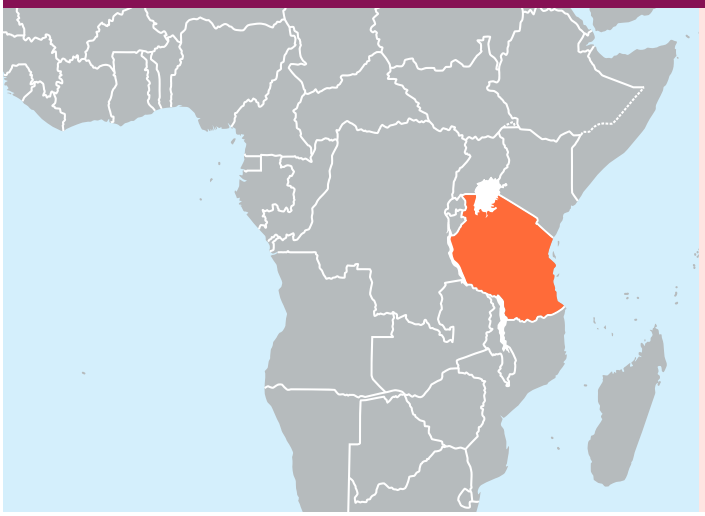
Case Study:

Weill Cornell Ophthalmology's efforts in Tanzania

Tanzania Fact Sheet

seva.org
TRANSFORMING LIVES BY RESTORING SIGHT

SEVA'S WORK AT A GLANCE: In country since 2001 | Partners: 3

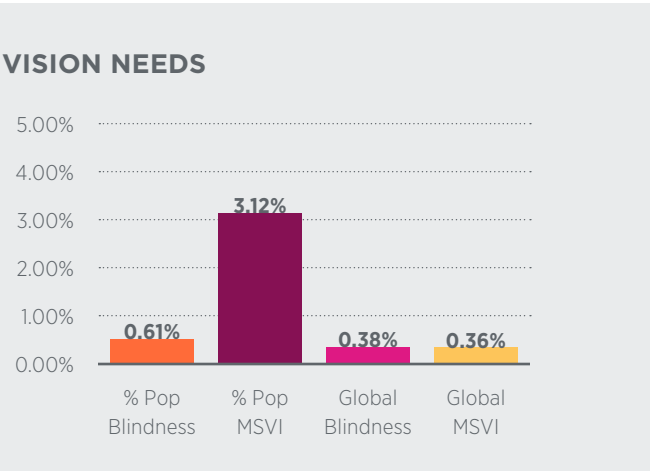


Country Overview

- Located in Eastern Sub-Saharan Africa
- The Republic of Tanzania spans 945,087 square kilometers (364,900 square miles)
- Population: 53.47 million people
- 2016 Human Development Index Ranking: 165 of 188 countries[1]

Scope of Eye Care Needs[2]

- 0.61% of Tanzania's population is blind (136K), as compared to 0.15% in the United States
- 3.12% of the population has moderate to severe vision impairment or MSVI (779k), as compared to 1.25% in the United States
- 0.38% (136,523/36M) of global blindness
- 0.36% (779,643/217M) of global MSVI



Nationwide Eye Care Response

Sub-Saharan Africa's median Cataract Surgical Rate (CSR) is 488 – one third of the global average and 1/13th of the average for high-income countries. Seva works to improve these rates through our hospital management systems and training support in Tanzania, focusing on improvement in the following Global Action Plan indicators for universal eye health.

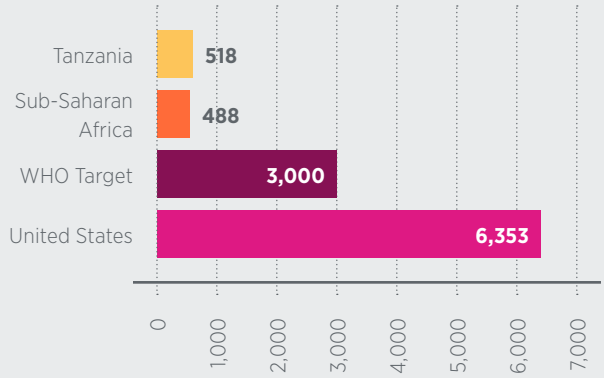
- Tanzania's CSR was 518 surgeries per million in 2010, as compared to the US CSR of 6,353
- 0.8 ophthalmologists per million people in Tanzania (40/50.64M as of 2013 (US = 60 per million people)
- 5.7 optometrists per million people as of 2012 (280)
- 8.8 AOPs per million people (405 in 2011)

1 2016 UNDP Human Development Report: http://hdr.undp.org/en/2016-report

2 Unless otherwise noted, all statistics provided by IAPD Vision Atlas Global Vision Database.

TANZANIA FACT SHEET

CATARACT SURGICAL RATE PER MILLION PEOPLE



SIGHT SERVICES

0.8
Ophthalmologists per million people

5.7
Optometrists per million people

8.8
Ophthalmic personnel per million people

= 1 million people

Seva's Approach in Tanzania

Seva partners with the Kilimanjaro Centre for Community Ophthalmology (KCCO) to reduce blindness in Tanzania. Established in 2001 in response to the VISION 2020 initiative, KCCO is the largest organization in Africa dedicated to reducing blindness through community ophthalmology training. With Seva's support in hospital management systems and training, KCCO partners with local governmental hospitals to train community health workers, conduct outreach trips to rural communities without regular access to eye care, provide clinical training for ophthalmologists and cataract surgeons, and providing funds for medical treatments for those who cannot afford them. In Tanzania, Seva's Global Sight Initiative supports three regional hospitals to bring quality eye care to as many people as possible: Benjamin Mkapa Hospital, Dodoma; Bugando Regional Hospital, Mwanza; and Singida Regional Hospital.

Since partnership began in 2011, Seva has supported three clinics. In 2017 alone, over 10,000 patients were seen and 1,382 surgeries conducted.

Resources:

Seva in Tanzania

Program Videos

KCCO Website

IMPACT (FY17-18)

3	401
Clinics	Surgeries

SPOTLIGHT ON BUILDING CAPACITY

Tanzania's central Singida region is served by only one ophthalmologist for over 1.3 million people. Dr. Ng'hungu Kuzenza works tirelessly to treat eye injuries, remove cataracts, and save the eyesight of people in need. With Seva's support in achieving sustainable management systems, Dr. Kuzenza was able to increase his office hours from four to 12 months per year. Seva helped him to increase the number of surgeries from 563 in 2015 to 940 surgeries in 2016, bringing vision and hope to 67% more patients. With Seva's support, Dr. Kuzenza and KCCO are also developing a robust outreach program to allow patients who cannot afford the journey to the hospital to access eye screenings and other treatments.

WHO/NMH/PBD/12.01

GLOBAL DATA ON VISUAL IMPAIRMENTS 2010

World Health Organization

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FOREWORD

Estimating the global magnitude of blindness and visual impairments is part of the core functions of WHO and since 1995 the Prevention of Blindness team has been issuing regular updates of the estimates.

The estimates, which are provided for the 6 WHO regions offer a tool to monitor the global trend of avoidable blindness and to identify any significant changes in the distribution in the six regions and in the attributed causes .

From the prevalence and the causes of the impairment the need of assessments, the interventions or norms can be defined; plans of action can be developed or monitored.

The data indicate that visual impairment and blindness are lower than in past estimates , with different distribution in WHO regions, and with significant changes in the causes.

INTRODUCTION

In order to set policies and priorities and to evaluate global eye health, it is essential to have up to date information on prevalence and on causes of visual impairment. As it previously did in 1995, 2002 and 2004 (1-3) the WHO Prevention of Blindness and Deafness Programme has carried out a systematic search and review of all available data to obtain a global estimate of visual impairment for 2010. Estimates of visual impairment have been derived at global level and in the six WHO Regions. The major causes of visual impairment and of blindness have been determined. These estimates provide essential information for the prevention of visual impairment and the improvement of eye health globally.

METHODS

Definitions

The definitions of visual impairment used for the estimates in this study follow the categories of the International Classification of Diseases Update and Revision 2006 that defines impairment according to presenting vision (http://www.who.int/classifications/icd/2006updates.pdf).

Visual impairment comprises categories 1 to 5, blindness, categories 3 to 5. The two categories of moderate and severe visual impairment (<6/18 $\geq$ 6/60 and <6/60 $\geq$3/60) are combined in this study (<6/18 $\geq$ 3/60) and they are referred to as "low vision".

Population estimates and WHO Regions

Population size and structure are based on the current population tabulation of WHO according to *World Population Prospects: the 2008 Revision,* from the United Nations Population Division (4).

The estimates are reported for the 6 WHO regions (http://www.who.int/about/regions/en/index.html).

Socio-economic data

Sources of the indicators used are the Human Development Report 2009 from the United Nations Development Programme (5), the World Bank Development Indicators 2009 (6), the Organization for Economic Co-operation and Development Policy Briefs 2009 (7), data from the United Nations Economic and Social Commission for Asia and the Pacific (8), the World Health Statistics 2009 (9) and governmental statistical data.

Sources of epidemiological data and inclusion criteria

Inclusion criteria have been discussed previously (2,3,10): the studies have to be population based, representative of the country and of the area sampled, with sample size adequate to the population sampled (from 1200 to 46000), sufficient response rate (80% or higher), reporting data for persons, with definitions of visual impairment in agreement with the ones for this study.

Medline was searched for published data with no language restriction (search terms: Visual Impairment, Blindness, Prevalence, country and continent names; last search on June 30th, 2010); studies were searched in the WHO regional databases (www.who.int/library/databases/en); unpublished data available to WHO/PBD were also used if satisfying the inclusion criteria.

Estimates of prevalence

The prevalence of visual impairment and blindness were determined for the 6 WHO regions for three age groups: 0 to 14 years, 15 to 49 years and 50 years and older, non disaggregated by gender. These age groups are consistent with the available data sources and with the grouping used in WHO for similar estimates of prevalence. Smaller age groups were not considered since data given in the studies are adjusted by sample composition only for larger age groups and smaller age groups would have much higher uncertainties. Gender stratification was not attempted given the inconsistencies of the data within Regions and countries, the uncertainties in the gender stratification could lead to even higher uncertainties at global level.

Estimates of prevalence for the age group 0 to14 and 15 to 49 years were calculated applying to the actual population size and structure the prevalence from the most recent estimates by WHO (2,3) that were considered still valid. The regional prevalence was obtained from population based studies from countries with data and imputed estimates for countries missing data. The imputation process was based on a model that utilized three parameters, GDP per capita in 2007 measured in Purchasing Power Parity (PPP) (6) , World Bank classifi-

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cation of Economies (Low Income, Lower Middle Income, Upper Middle Income, High Income) (6) and prevalence of blindness in the age group 50 years and older, chosen because of the many studies available, a consequence of the prevailing use of rapid assessment survey protocols focused on this age group. Since prevalence of blindness and visual impairment were strongly correlated with each other, only prevalence of blindness was selected as the parameter. The correlation between PPP and prevalence of blindness was consistently strong in all regions, with coefficients >0.8, other socio-economic (5,7,8) or health indicators (9) were tested and showed only weak correlations (0.5 or less). In each WHO region the countries were clustered into ranges of PPP and World Bank Classification of Economies (6). A weighted prevalence of visual impairment and blindness was calculated for countries with data within a PPP cluster and imputed to the other countries in the same cluster. A discussion of methods for missing data can be found in reference 11.

Estimates of causes of visual impairment

For the age groups 0 to 14 and 15 to 49 years the causes of visual impairment are based on previous estimates (2,3) For the age group 50 years and older the causes were calculated using the causal attribution provided by the studies that were used to estimated the prevalence. Each cause was calculated as an average percentage of the total causes at regional level first and then at global level, by including all the regional values.

Error analysis

Since only simple imputation using deductive methods was used and no regression analysis was conducted, the known errors on the regional estimates come from the reported uncertainties of the studies, which for the age group 50 years and older are around 10%, for the other ages around 20%.

Additional uncertainties are due to data imputation: these can be assumed to be lower in regions with more numerous studies.

RESULTS

Data sources

53 surveys from the 39 countries, listed in Table 1, met the inclusion criteria for this study: details are found in Annex 1 and 2. The majority of the studies, 38, took place between 2005 and 2008, 15 between 2001 and 2004;. the largest majority were rapid assessments of cataract surgical services or of avoidable blindness (12, 13), a minority were national studies for all ages, some were targeting specific age groups or settings.

Other studies not satisfying fully the inclusion criteria provided supporting evidence for the estimates developed by the model.

WHO Region	Countries with studies
African Region	Botswana, Cameroon, Eritrea, Ethiopia, Gambia, Ghana, Kenya, Mali, Nigeria, Rwanda, Uganda, United Republic Of Tanzania
Region of the Americas	Argentina, Brasil, Chile, Cuba, Dominican Republic, Guatemala, Mexico, Paraguay, Peru, Venezuela
Eastern Mediterranean Region	Islamic Republic of Iran, Oman, Pakistan, Qatar
European Region	Russian Federation, Turkmenistan
South-East Asian Region	Bangladesh, Democratic Republic of Timor-Leste, India, Indonesia, Myanmar, Nepal
Western Pacific Region	Cambodia, China, Papua New Guinea, Philippines, Viet Nam

Model of visual impairment in the six WHO Regions

Visual impairment was estimated in each WHO Region with a model built using prevalence of blindness and countries' economic status from available data as described in Methods.

The African Region comprises 46 countries of which 40 are classified by the World Bank either as Low Income (LI) or Lower Middle Income (LMI) within a narrow range of PPP, representing 93.2 % of the population in the Region. Five countries are classified as Upper Middle Income (UMI) and one as High Income (HI) representing 6.8 % of the region population. 19 surveys from 12 countries, all classified as LI or LMI, were available for inclusion in the model for the region. Given the similar economic status of these countries they were considered as a single cluster of PPP. The weighted prevalence of visual impairment and blindness from the 19 surveys was imputed to the whole Region.

In the Region of the Americas the 36 countries were divided into three clusters of PPP corresponding to the World Bank classifications: LMI (10 countries), UMI (20 countries) , HI (6 countries). Data were available from three countries in the LMI cluster, and seven in the UMI cluster. The combined population in the 10 countries with available data in the LMI and UMI clusters represented 80% of the total population in these 30 countries. The weighted average of the prevalence of visual impairment and blindness was derived separately in the two clusters and imputed to the other countries in the

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same cluster. Recent data satisfying the inclusion criteria for this study for the HI cluster were not available: prevalence was derived from previous WHO estimates (2,3).

The 21 countries in the Eastern Mediterranean Region were sorted into two clusters of PPP. The first included 13 countries classified as LI and LMI, the second 8 countries classified as UMI and HI. Data from three countries in the LI/LMI cluster and from one in the UMI/ HI cluster were available for estimates.

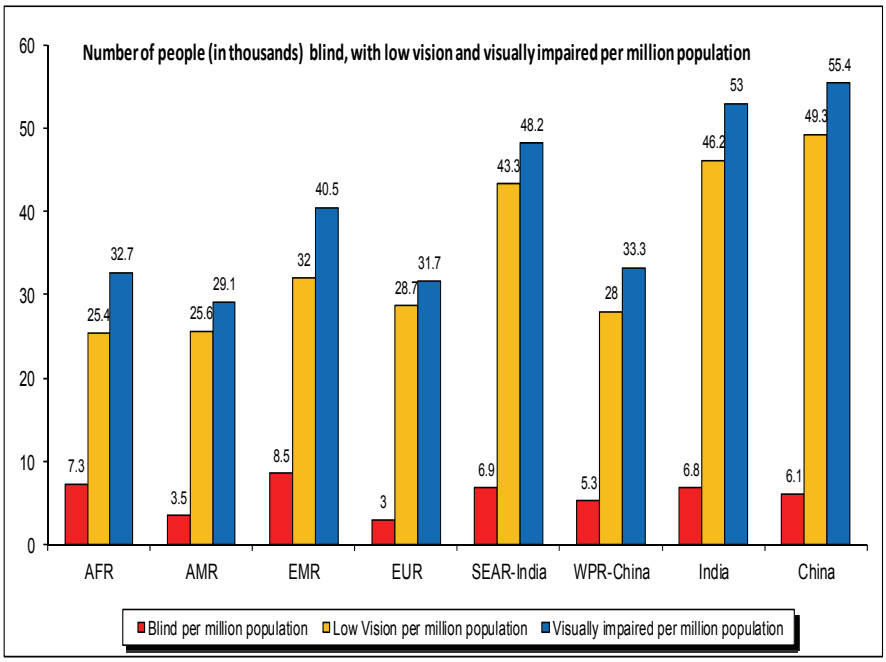
In the European Region three economic clusters were defined, one including 25 HI countries, a second, 11 UMI countries and the third, 14 LMI and 3 LI countries. Data were available from one country each in the UMI and in the LMI /LI clusters. The data from a single country were imputed to the UMI cluster and analogously data from a single country to the LMI/ LI cluster. Recent data for this study were not available for the HI cluster and previous WHO estimates were used (2,3).

The estimates for the South-East Asian Region were derived for India and for the other countries in the Region separately. The prevalence for India was derived from 3 recent surveys (see Annex 1 and 2). The other 10 countries in the Region are classified either as LMI or LI and given the similarity of PPP were all included in one single cluster. Data were available from 5 of the 10 countries comprising almost 80% of the population in the region (India excluded). The weighted prevalence estimated from the data in the five countries was imputed to the whole cluster.

The estimates for China were derived separately from the other countries in the Western Pacific Region and were based on recent surveys conducted in the rural areas combined with data from urban settings (see Annex 1 and 2). The other countries in the Region were sorted into 3 clusters: the first included 7 countries classified as HI and one as UMI ; the second included all 15 Pacific Islands with 14 countries classified as LMI and one UMI ; the third comprised 4 countries, 2 classified as LI and 2 as LMI. For the first cluster prevalence was derived from the previous estimates (2,3). Data from one country were used for the second cluster and data from 3 countries for the third cluster (see Annex 1 and 2).

Global Prevalence of Visual Impairment

The estimated number of people visually impaired in the world is 285 million, 39 million blind and 246 million having low vision; 65 % of people visually impaired and 82% of all blind are 50 years and older (Table 2). The distribution of people visually impaired in the six WHO Regions is shown in Table 3 with the percentage of the global impairment shown in parentheses. Figure 1 shows the number of people visually impaired, with low vision and blind per million population in the six WHO Regions and in India and China separately.



Cause of visual impairment

Globally the principal causes of visual impairment are uncorrected refractive errors and cataracts, 43% and 33 % respectively. Other causes are glaucoma, 2%, age related macular degeneration (AMD), diabetic retinopathy, trachoma and corneal opacities, all about 1%. A large proportion of causes, 18%, are undetermined, (Figure 2A).

The causes of blindness are cataract, 51%, glaucoma, 8%, AMD, 5%, childhood blindness and corneal opacities, 4%, uncorrected refractive errors and trachoma, 3%, and diabetic retinopathy 1%, the undetermined causes are 21% (Figure 2 B).

DISCUSSION

This study presents some limitations, the most significant are the following: the surveys in the last 10 years have been mostly Rapid Assessments for ages 50 years and older, and national studies for all ages with or without WHO Eye Survey Protocol have been few. As a consequence data could be limited in representation of countries and of ages. The imputation of prevalence for missing data can give errors that are difficult to estimate: clearly they could be high in regions with sparse data. In the Eastern-Mediterranean Region recent data were unavailable for most of the countries, hence the estimates were in large extent based on surveys from 1993-1998 (2,3) Data from HI countries were also missing or were dated as far back as 15 years. However it must be noted that in HI countries from available information there was no evidence of major changes in prevalence.

The combined effect of these uncertainties is possibly an over or under estimation of visual impairment and blindness of approximately 20%.

The attribution of the causes of visual impairment and blindness is also prone to uncertainty. This is often the instance in surveys carried out in the field with limited diagnostic capacity, but it is particularly true in the case of

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rapid assessments whose aim is primarily to survey cataract surgical services for ages 40 or 50 years and older. The large percentages of undetermined causes is are also likely to be a reflection of these protocols.

The strengths of the estimates derive firstly from the fact that new data were available to replace previous extrapolations. Furthermore, to estimate the prevalence of visual impairment in countries missing data, a model was used based on the same economic parameters for all countries. This is a new approach in producing estimates of visual impairment. The imputation process via a model is more transparent than using expert assumptions and it provides consistency between countries and regions. It also allows for adjustments and corrections as soon as new information becomes available and it could also be adapted for estimating trends.

Because data available and methods used have changed, it is not possible to draw conclusions from differences in present estimates and previously published estimates. In areas where surveys were repeated with similar protocols for ages 50 years and older a reduction of visual impairment is shown despite the rapid growth of this age group. This decline fits with increased socio-economic development, but it is also the direct consequence of investments made by Governments and of interventions by international partners.

Posterior segment (retinal) diseases are a major cause of visual impairment worldwide, and likely to become more and more important, with the rapid growth of the aging population . The proportion of the total visual impairment and blindness from age related macular degeneration, glaucoma and diabetic retinopathy is currently greater than from infective causes such as trachoma and corneal opacities.

This requires the urgent development of eye care systems that address chronic eye diseases with rehabilitation, education and support services.

CONCLUSION

Monitoring the magnitude of visual impairment is essential for policies aiming at the prevention and elimination of the avoidable causes. The global estimates have significant uncertainties that could be reduced with population based studies from regions with limited or old data and with studies conducted at national level for all ages recording all causes of blindness. Particularly urgent is to determine the extent of posterior segment diseases as causes of visual impairment, since these require the development of eye care systems, including human resources and infrastructures.

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Table 2. **Global estimate of the number of people visually impaired by age, 2010; for all ages in parenthesis the corresponding prevalence (%).**

Ages (in years)	Population (millions)	Blind (millions)	Low Vision (millions)	Visually Impaired (millions)
0-14	1,848.50	1.421	17.518	18.939
15-49	3548.2	5.784	74.463	80.248
50 and older	1,340.80	32.16	154.043	186.203
all ages	6,737.50	39.365 (0.58)	246.024 (3.65)	285.389 (4.24)

Table 3. **Number of people visually impaired and corresponding percentage of the global impairment by WHO Region and country, 2010**

		Blindness	Low vision	Visual Impairment
WHO Region	Total population (millions)	No. in millions (percentage)	No. in millions (percentage)	No. in millions (percentage)
Afr	804.9 (11.9)	5.888 (15)	20.407 (8.3)	26.295 (9.2)
Amr	915.4 (13.6)	3.211(8)	23.401 (9.5)	26.612 (9.3)
Emr	580.2 (8.6)	4.918 (12.5)	18.581 (7.6)	23.499 (8.2)
Eur	889.2 (13.2)	2.713 (7)	25.502 (10.4)	28.215 (9.9)
Sear (India excluded)	579.1 (8.6)	3.974 (10.1)	23.938 (9.7)	27.913 (9.8)
Wpr (China excluded)	442.3 (6.6)	2.338 (6)	12.386 (5)	14.724 (5.2)
India	1181.4 (17.5)	8.075 (20.5)	54.544 (22.2)	62.619 (21.9)
China	1344.9 (20)	8.248 (20.9)	67.264 (27.3)	75.512 (26.5)
World	6737.5 (100)	39.365 (100)	246.024 (100)	285.389 (100)

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Fig. 2A

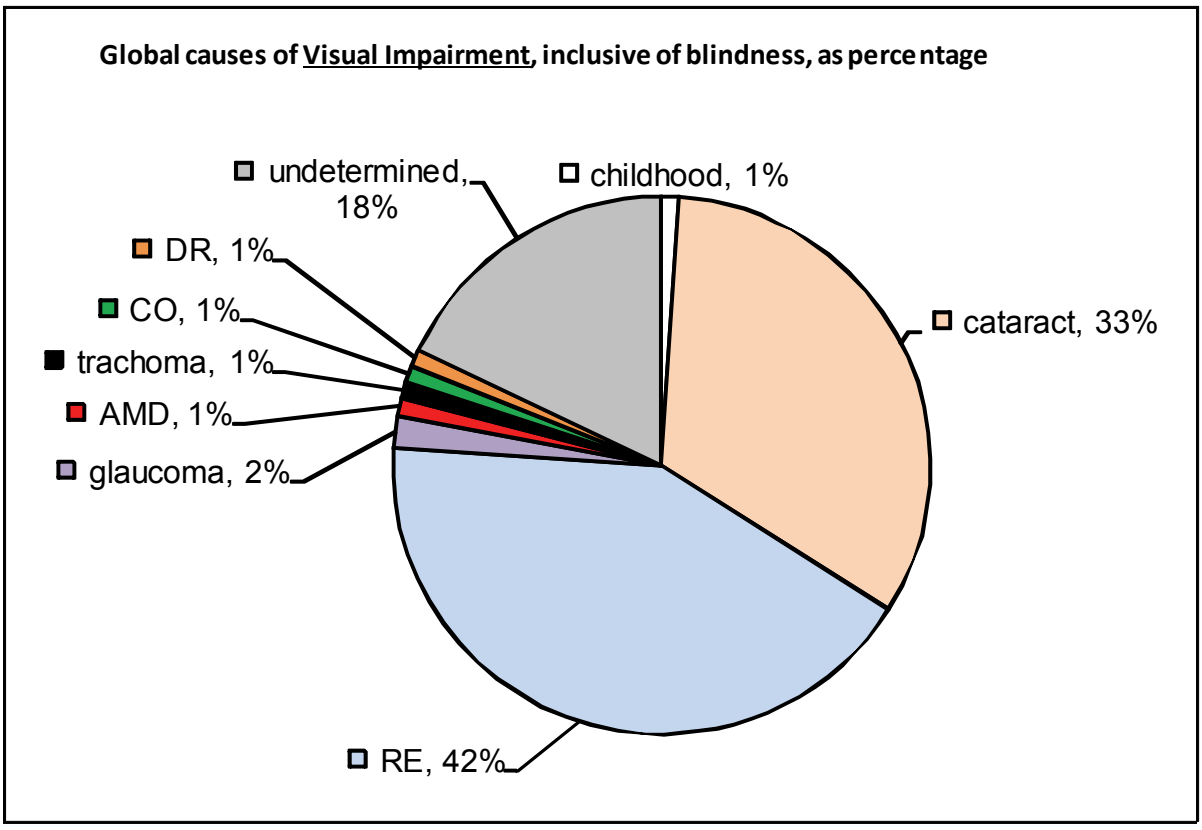
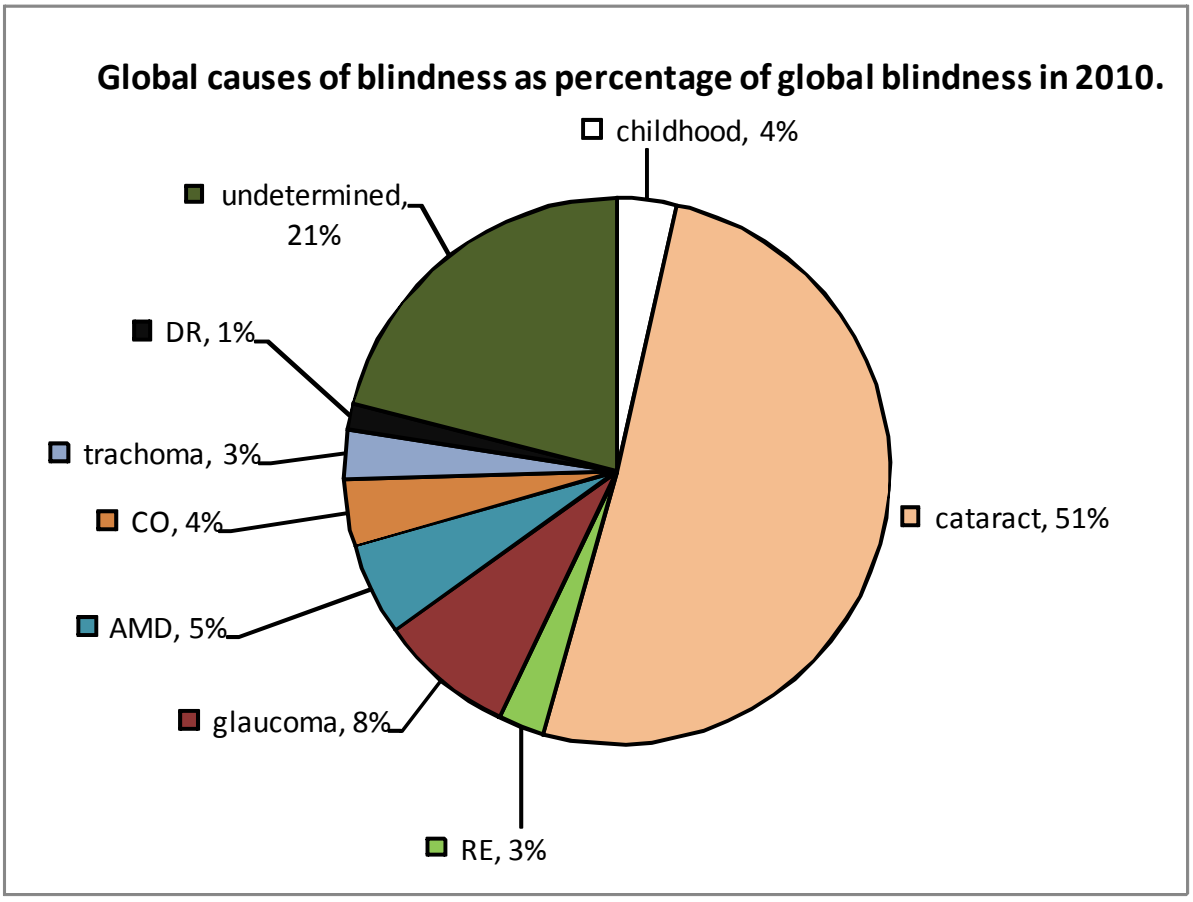


Fig. 2B



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Annex 1

WHO African Region	date of survey	study population	sample size	age group	reference
Botswana	2006	*national urban/rural and rural*	2127	50 years and older	BWA 1
Cameroon	2006	*subnational urban*	2215	40 years and older	CMR 1
Cameroon	2004	*subnational rural urban*	1787	40 years and older	CMR 2
Eritrea	2008	*national urban and rural*	3163	50 years and older	ERI 1
Ethiopia	2005	*national urban and rural*	25650	all ages	ETH 1
Gambia	2007	*national*	2992	50 years and older	GMB 1
Ghana	2001	*subnational*	2289	40 years and older	GHA 1
Ghana	2005	*subnational rural*	9117	40 years and older	GHA 2
Kenya	2005	*subnational rural*	3475	50 years and older	KEN 1
Kenya	2007	*subnational rural*	3376	50 years and older	KEN 2
Kenya	2007	*subnational urban*	2419	50 years and older	KEN 3
Mali	2008	*subnational*	2438	50 years and older	MLI 1
Nigeria	2008	*national urban and rural*	13593	10 to 15 years 40 years and older	NGA 1
Nigeria	2006	*subnational urban and rural*	2424	50 years and older	NGA 2
Rwanda	2006	*subnational rural*	2006	50 years and older	RWA 1
Uganda	2007	*subnational*	3294	50 years and older	UGA 1
UR Tanzania	2007	*subnational rural*	3202	50 years and older	TZA 1
UR Tanzania	2007	*subnational rural*	3463	50 years and older	TZA 2
UR Tanzania	2007	*subnational urban and rural*	3160	50 years and older	TZA 3

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WHO Region of the Americas	date of survey	study population	sample size	age group	reference
Argentina	2004	*subnational peri-urban*	4302	50 years and older	ARG 1
Brazil	2004	*subnational urban*	2224	50 years and older	BRA 1
Chile	2006	*subnational urban and rural*	2915	50 years and older	CHL 1
Cuba	2005	*subnational peri-urban*	2716	50 years and older	CUB 1
Dominican Republic	2008	*national urban and rural*	3873	50 years and older	DOM 1
Guatemala	2004	*subnational urban and rural*	4806	50 years and older	GTM 1
Mexico	2006	*subnational rural*	3764	50 years and older	MEX 1
Paraguay	2002	*national urban and rural*	2136	50 years and older	PRY 1
Peru	2002	*subnational rural*	4782	50 years and older	PER 1
Venezuela	2005	*national urban and rural*	3317	50 years and older	VEN 1
WHO Eastern Mediterranean Region	date of survey	*study population*	sample size	age group	reference
Iran (Islamic Republic of)	2005	*subnational urban and rural*	5456	10 years and older	IRN 1
Oman	2005	*national urban and rural*	2339	40 year and older	OMN 1
Pakistan	2004	*national urban and rural*	16507	30 years and older	PAK 1
Qatar	2008	*urban peri-urban*	2433	50 years and older	QAT 1
WHO European Region	date of survey	*study population*	sample size	age group	reference
Russian Federation	2008	*subnational peri-urban*	3837	50 years and older	RUS 1
Turkmenistan	2001	*subnational urban/rural*	6011	50 years and older	TKM 1

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WHO South-East Asian Region	date of survey	*study population*	sample size	age group	reference
Bangladesh	2005	*subnational rural*	4868	50 years and older	BGD 1
Democratic Republic of Timor Lester	2005	*subnational urban and rural*	1414	40 years and older	TLS 1
India	2007	*national urban and rural*	40447	50 years and older	IND 1
India	2003	*subnational urban and rural*	7084	50 years and older	IND 2
India	2006	*subnational urban and rural*	13016	5 to 15 years 50 years and older	IND 3
Indonesia	2004	*subnational rural*	2629	50 years and older	IDN 1
Myanmar	2005	*subnational rural*	2076	40 years and older	MMR 1
Myanmar	2003	*subnational rural*	2885	50 years and older	MMR 2
Myanmar	2003	*subnational rural*	2990	50 years and older	MMR 3
Nepal	2002	*subnational rural*	5002	45 years and older	NPL 1
Nepal	2005	*subnational rural*	5138	50 years and older	NPL 2
WHO Western Pacific Region	date of survey	*study population*	sample size	age group	reference
Cambodia	2007	*national urban and rural*	5902	50 years and older	KHM 1
China	2007	*subnational rural*	45747	50 years and older	CHN 1
China	2003	*subnational urban and peri-urban*	3040	60 years and older	CHN 2
Papua New Guinea	2005	*subnational urban and rural*	1174	50 years and older	PNG 1
Philippines	2006	*subnational urban and rural*	5951	50 years and older	PHL 1

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WHO Western Pacific Region	date of survey	*study population*	sample size	age group	reference
Viet Nam	2007	*national urban and rural*	28073	50 years and older	VNM 1
Viet Nam	2007	*national urban and rural*	28800	0 to 15 years	VNM 1

Correspondence to: Silvio P. Mariotti, World Health Organization, 20 Avenue Appia, 1211 Geneva 27, Switzerland.

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BWA 1	Nikomazana O. National prevalence survey of visual impairment in Botswana. Submitted for MSc Community Eye Health at the London School of Hygiene and Tropical Medicine. London 2006.
CMR 1	Oye JE, Kuper H. Prevalence and causes of blindness and visual impairment in Limbe urban area, South West Province, Cameroon. Br J Ophthalmol 2007;**91**:1435-1439.
CMR 2	Oye JE, Kuper H, Dineen B, et al. Prevalence and causes of blindness and visual impairment in Muyuka: a rural health district in South West Province, Cameroon. Br J Ophthalmol 2006;**90**:538-542.
ERI 1	Mueller A. Rapid assessment of avoidable blindness in Eritrea. 2008; unpublished report. The Fred Hollows Foundation, 1 Mitchell Street, Enfield NSW 2136, Australia
ETH 1	National survey on blindness, low vision and trachoma in Ethiopia.Federal MOH of Ethiopia, The Carter Center, CBM, ITI, ORBIS Int.Ethiopia and LfW, Opthalmol Society of Ethiopia, Ethiopian Public Health Association. Addis Ababa, Ethiopia 2006. Survey report prepared by Yemane Berhane, Alemayehu Worku, Abebe Bejiga.
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GHA 1	Guzek JP, Anyomi FK, Fiadoyor S, et al. Prevalence of blindness in people over 40 years in the Volta region of Ghana. Ghana Medical J 2005;**39**:55-62.
GHA 2	Ahorsu F, Hagan M, Wanye S, et al. Prevalence of blindness and visual impairment among people aged 40 years and above in three districts in the Northern Region of Ghana. 2005. unpublished report.
KEN 1	Mathenge W, Kuper H, Limburg H, et al. Rapid assessment of avoidable blindness in Nakuru District, Kenya. Ophthalmology 2007;**114**:599-605.
KEN 2	Karimurio J, Sheila M, Gichangi M, et al. Rapid assessment of cataract surgical services in Embu district, Kenya. East Afr J Ophthalmol 2008;**13**:19-25.
KEN 3	Rapid assessment of avoidable blindness in Kericho, Great Rift Valley, Kenya. 2007; unpublished report from P. Huguet.
MLI 1	Traoré L, Oyé J. Appréciation rapide de la cécité évitable dans la région de Koulikoro au Mali en 2008. personal communication.
NGA 1	Kyari F, VSG Murthy, Sivsubramaniam S, et al. Prevalence of blindness and visual impairment in Nigeria: the national blindness and visual impairment survey. Invest Ophthalmol Vis Sci 2009;**50**:2033-2039.
NGA 2	Rabiu MM, Muhammed N. Rapid assessment of cataract surgical services in Birnin-Kebbi Local Government Area of Kebbi State, Nigeria. Ophtahlmic Epidemiology 2008 **15**:359-365.
RWA 1	Mathenge W, Nkurikiye J, Limburg H, et al. Rapid assessment of avoidable blindness in Western Rwanda: blindness in a postconflict setting.PLoS Medicine 2007;**4**:1187-1193.
TZA 1	Rapid assessment of cataract surgical services in Kyela, United Republic of Tanzania. 2007; unpublished report from P. Huguet.
TZA 2	Habiyakire C, Kabona G, Courtright P, et al. Rapid assessment of avoidable blindness and cataract surgical services in Kilimanjaro region Tanzania. Ophthalmic Epidemiology. 2010;**17**:90-94.
TZA 3	Kikira S. Rapid Assessment of avoidable blindness in Zanzibar. Submitted for MSc Community Eye Health at the London School of Hygiene and Tropical Medicine. London 2007.
UGA 1	Rapid assessment of cataract surgical services in Massaka, Uganda. 2007; unpublished report from P. Huguet.

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CUB 1	Hernandez Silva JR, Rio Torres M, Padilla Gonzalez CM. Resultados del RACSS en Ciudad de La Habana, Cuba, 2005. Rev Cubana Oftalmol 2006;**19**:1-9.
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GTM 1	Beltranena F, Casasola K, Silva JC, et al. Cataract blindness in 4 regions of Guatemala. Ophthalmology 2007;**114**:1558-63.
MEX 1	Rapid assessment of avoidable blindness in Nuevo Leon State, Mexico. 2006. unpublished report from Limburg H
PRY 1	Duerksen R, Limburg H, Carron JE, et al. Cataract blindness in Paraguay-results of a national survey. Ophthalmic Epidemiol 2003;**10**:349-357.
PER 1	Aguila LP, Carrion R, Luna W, et al. Ceguera por catarata en personas mayores de 50 anos en una zona semirural del norte del Peru. Pan Am J Public Health 2005;**17**:387-93.
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OMN 1	Khandekar R, Mohammed AJ, Raisi AA. Prevalence and causes of blindness and low vision; before and five years after Vision 2020 initiatives in Oman: a review. Ophthalmic Epidemiol 2007;**14**:9-15.
PAK 1	Jadoon MZ, Dineen B, Bourne RRA, et al. on behalf of the Pakistan National Eye Survey Study Group. Invest Ophthalmol Vis Sci 2006;**47**:4749-4755.
QAT 1	Al Gamra H, Al Mansouri F, Khandekar R, et al. Prevalence and causes of blindness, low vision and status of cataract in 50 years and older citizen of Qatar-a community based survey. Ophthalmic Epidemiol 2010;**17**:292-300.
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RUS 1	Branchevskiy S. Rapid assessment of avoidable blindness in Samara. 2009; personal communication.
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BGD 1	Wadud Z, Kuper H, Polack S, et al. Rapid assessment of cataract surgical services in Sathkhira District, Bangladesh. Br J Ophthalmol 2006;**90**:1225-1229.
TLS 1	Ramke J, Palagyi A, Naduvilath T, et al. Prevalence and causes of blindness and low vision in Timor-Leste. Br J Ophthalmol 2007;**91**:1117-1121.
IND 1	Neena J, Rachel J, Praveen V, et al. for the RAAB India Study Group. Rapid Assessment of Avoidable Blindness in India. Plos One, 2008,**3**:e2867.
IND 2	National Programme for the Control of Blindness. Rapid assessment of blindness in North Eastern States of India 2003. Ophthalmology/ Blindness Control Section, Directorate General of Health Services, Ministry of Health and Family Welfare, Government of India, New Delhi, 110011 India.
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Retinopathy in adults with hypertension and diabetes mellitus in Western Tanzania: a cross-sectional study

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Abstract

OBJECTIVE Little is known about the retinal manifestations of arterial hypertension (HTN) and diabetes mellitus (DM) in Western Tanzania and how to maximise the utilisation of scarce eye health resources. To address this, we determined the prevalence of hypertensive and diabetic retinopathy (DR), associated risk factors and relevant patient knowledge.

METHODS Adults with HTN or DM attending outpatient clinics at Bugando Medical Center (BMC) from June to August 2017 were enrolled. Fundus photographs were obtained, and data were collected on blood pressure (BP), body mass index (BMI), blood sugar, visual acuity (VA) and responses to questions about the effects of HTN and DM on the eye.

RESULTS A total of 180 persons were screened. When only individuals with DR were considered, bivariate regression found systolic BP was significantly associated with severity of DR ($P = 0.034$). Receiver operating characteristic (ROC) curve analysis using the maximum Youden index revealed the optimum cut-off using duration of DM to predict any DR was 8 years (AUC = 0.75, 95% CI 0.65 0.85). Fewer persons with HTN were aware of the effect of high BP on the eye (61.6%) than persons with DM who were aware of the effect of high blood sugar on the eye (74.4%) ($P = 0.048$).

CONCLUSION Efforts should be made to vigorously treat HTN among adults with DM and refer adults with duration of DM of 8 years or more for a dilated retinal examination. Additional efforts should be made to promote awareness of the sight threatening potential of HTN in resource-limited settings.

keywords diabetic retinopathy, hypertensive retinopathy, screening, prevalence, Tanzania, Africa

Sustainable Development Goals SDGs): SDG 3 (good health and well-being), SDG 17 (partnerships for the goals)

Introduction

Non-communicable diseases, including HTN and DM, are emerging as leading causes of death and disability on the African continent. In the last 10 years, the age standardised mean systolic BP has risen in east, west, central and southern Africa more than any other region of the world [1]. The burden of HTN is a particular concern in Tanzania, and data on the prevalence of the sequelae of HTN are limited [2 4].

The number of adults (20 79 years) with DM globally is projected to rise from 463 million to 700 million people by the year 2045, with the highest percentage increase to occur in low-income/lower middle-income countries [5, 6]. Along with the rise in the prevalence of DM is a rise in vison loss due to the sequela of diabetic eye disease, in particular DR [5].

Although some published data exist on the prevalence of DR and associated risk factors in the Kilimanjaro region of Tanzania [7, 8], data are lacking in other regions. Data are available for awareness of Type 2 DM in the adult population of Mwanza city [9], and for awareness of DR among adults with DM attending diabetes clinics in various regions of Tanzania [10]. However, data are lacking on possible associations between patient awareness of DM and prevalence of DR.

Bugando Medical Center (BMC) is a tertiary care hospital in Mwanza serving over 13 million people living in the Lake zone of northwest Tanzania. At the time of this study, there were only two Tanzanian ophthalmologists in the region. BMC has partnered with Weill Cornell to address the increasing burden of eye disease in the Lake zone by combining the expertise of ophthalmologists at both centres to carry out a cross-sectional study of people identified with either DM or HTN attending outpatient clinics at BMC. Together, we sought to determine the hospital-based prevalence of hypertensive and diabetic retinopathy, associated risk factors and awareness about the effect of high BP and high blood sugar on the eye. We aimed to describe clinical parameters that can identify people most likely to have retinopathy and to identify gaps in knowledge among people with DM or HTN that can be addressed, all with the goal of improving patient care.

Methods

Between 14th June and 4th August 2017, BMC conducted a pilot project to screen all adults (over 18 years of age) attending the BMC HTN or DM clinics for retinopathy. The goal of the pilot was to determine the feasibility and possible benefit of a universal screening approach in Tanzanian adults attending HTN and DM clinics. Arterial HTN was defined as a BP of >140/90 on two consecutive clinic visits. DM was defined as fasting blood sugar concentration levels 126 mg/dL (7.0 mmol/L) or random blood sugar concentration levels 200 mg/dL (11.1 mmol/L) on two consecutive clinic visits. Those consenting had one to three 45-degree fundus photographs taken of each eye with a Topcon NW300 nonmydriatic camera (Topcon Medical, Oakland, NJ) without using dilating drops. The images were stored on a password protected laptop with an encrypted hard drive.

Data were collected on BP, BMI, blood sugar and VA. Blood pressure was taken in the right arm with an Omron (Omron Healthcare Co. Ltd; Kyoto, Japan) M6 portable digital BP device that measured systolic and diastolic BP. The cuff was placed on the bare arm, while subjects were seated with their feet on the floor, and BP was measured after subjects were quiet for 3 5 min. A single reading was taken. An extra-large cuff with an integrated aneroid was available to measure BP of individuals with an arm larger than the applicable circumference of the digital device. Blood sugar levels were measured from a fingerstick whole blood sample and measured using Contour glucose test strips and a Contour point-of-care blood glucose meter (Bayer Healthcare LLC; Sunnyvale, CA). Distance VA was measured with a multi-letter Snellen eye chart with subjects positioned 6 metres from the chart. Corrected VA was measured in each eye. For the purpose of analysis, the VA of the best eye was used. Visual impairment was defined as VA less than 6/18 in the better eye.

Demographic information and clinical history were obtained by questionnaire. To assess awareness of the effect of high BP and high blood sugar on the eye, an investigator administered a questionnaire with targeted knowledge questions (Appendix 2).

Comprehensive ophthalmologists at BMC trained in the diagnosis of diabetic and hypertensive retinopathy during their four-year ophthalmology training performed the grading of retina photographs. All ophthalmologists were masked to subjects' diagnosis and history. Ten per cent of the retina photographs were randomly selected to be interpreted by a second reader from the Weill Cornell Department of Ophthalmology (New York, NY, USA) for quality control. The inter-rater agreement was 100% for all grades of DR and maculopathy, and for Grade 3 and 4 hypertensive retinopathy. Per cent agreement including all seven categories measured was 93.9% (263/280). Results for DR and maculopathy were graded based on the minimum data set recommended by the English and Wales National Screening Committee (Appendix 1, 7). Results for hypertensive retinopathy were graded according to modified Scheie's criteria (Appendix 1, 11).

Statistical analysis

Data were entered into an Excel spread sheet and analysed, including graphical output, using R version 3.6.3. The eye having the more advanced diabetic or hypertensive retinopathy was used for the analysis. Characteristics of the study population were described using absolute numbers with percentages for categorical variables. Welch's two-sample *t*-test, one-way ANOVA, chi-squared test (with Yates correction), Fisher's exact test and bivariate regression were used to investigate the relationship between retinopathy outcome and clinical data, demographic factors, and responses to knowledge questions. Bivariate tables were created to summarise independently associated factors with retinopathy outcome. A P value of 0.05 was considered statistically significant. Receiver operating curves and two-sample test of proportions were used to assess viability of selected clinical variables as potential discriminants of retinopathy outcomes.

Ethics

Ethical approval was obtained from the Weill Cornell Medical College Institutional Review Board and from the ethics committees of BMC and the National Institute of

Medical Research in Tanzania. Written informed consent was obtained from all study participants.

Results

During the pilot study period, 185 adults were seen in the DM and HTN clinics. Of these, 180 agreed to undergo screening. Common reasons for refusal to participate included concerns about the duration of time needed to complete clinical data collection and respond to the questionnaires. Of the 180 participants enrolled, 6 (3.3%) had images that were ungradable due to media opacity. A total of 174 people had their fundus images graded for hypertensive and diabetic retinopathy. The distribution of outpatient clinics varied, with 83 (47.7%) participants attending HTN clinic, 24 (13.8%) attending DM clinic and 67 (38.5%) attending with both DM and HTN clinics. Participants were most frequently employed as farmers, and the highest educational level obtained among most participants was primary school (Table 1).

For participants with HTN, the prevalence of any hypertensive retinopathy was 37.3% (95% CI 29.6 45.1%) with Grade I, II, III and IV hypertensive retinopathy having a prevalence of 12.0% (95% CI 6.8 17.2%), 14.0% (95% CI 8.4 19.6%), 8.7% (95% CI 4.2 13.2%) and 2.7% (95% CI 0.1 5.2%), respectively (Table 2a).

For participants with DM, the overall prevalence of any DR was 42.9% (95% CI 32.7-53.0%) with background diabetic retinopathy (BDR), pre-proliferative diabetic retinopathy (PPDR) and proliferative diabetic retinopathy (PDR) having a prevalence of 24.2% (95% CI 15.4 33.0%), 13.2% (95% CI 6.2 20.1%) and 5.5% (95% CI 0.8 10.2%), respectively. The overall prevalence of diabetic maculopathy was 26.5% (95% CI 17.0 36.0%), and prevalence of referable maculopathy/clinically significant macular oedema (CSME) was 22.9% (95% CI 13.9 31.9%) (Table 2b). Fundus images where haziness due to media opacity interfered with the view of the macula were considered ungradable for maculopathy. All participants with any maculopathy also had findings of DR such that 22 patients (24.2% of all adults with DM) had both DR and maculopathy.

Factors associated with hypertensive retinopathy

The characteristics and questionnaire results of participants with HTN with and without any hypertensive

Table 1 Participant characteristics by condition

Characteristic			All (n = 174)	
Proportion (%) or mean (SD)	HTN*,* (n = 150)	Diabetes*,* (n = 91)		n
Gender				172
Female	84 (56.0%)	57 (62.6%)	102 (59.3%)	
Male	64 (42.7%)	34 (37.4%)	70 (40.7%)	
Age	62.3 (10.7)	59.2 (11.4)	60.6 (11.5)	173
Vision				174
No visual impairment	98 (65.3%)	62 (68.1%)	116 (66.7%)	
Visual impairment	52 (34.7%)	29 (31.9%)	58 (33.3%)	
Duration of disease in years	9.5 (8.8)	9.3 (7.6)	n/a	
Clinic blood glucose in mmol/L	8.0 (3.9)	9.7 (4.1)	8.4 (4.0)	128
Body Mass Index (BMI) in kg/m^2	27.41 (5.4)	27.2 (5.4)	27.1 (5.5)	169
Clinic blood pressure in mmHg				171
Systolic	159.8 (27.0)	151.0 (28.8)	155.5 (28.4)	
Diastolic	87.1 (15.7)	83.2 (12.9)	86.4 (15.5)	
Employment				171
Farmer	54 (36.7%)	34 (38.2%)	62 (36.2%)	
Govt, Small business	20 (13.6%)	12 (13.5%)	27 (15.8%)	
Homemaker	22 (15.0%)	10 (11.2%)	24 (14.0%)	
Day labour, Informal	24 (16.3%)	18 (20.2%)	26 (15.2%)	
Student, Unemployed, Other	27 (18.4%)	15 (16.8%)	32 (18.7%)	
Education				167
None, primary	80 (55.5%)	46 (52.9%)	92 (55.1%)	
Secondary, vocational	42 (29.2%)	27 (31.0%)	49 (29.3%)	
University	22 (15.3%)	14 (16.1%)	26 (15.6%)	

*Including participants with both HTN and DM.

Table 2 Prevalence and grade of (a) hypertensive retinopathy among participants with HTN (n = 150) (b) Prevalence and grade of diabetic retinopathy and maculopathy among participants with DM (n = 91)*

(a)

Hypertensive retinopathy	of subjects	As per cent of subjects with HTN	95% CI
Gr 1	18	12.0	6.8 17.2%
Gr 2	21	14.0	8.4 19.6%
Gr 3	13	8.7	4.2 13.2%
Gr 4	4	2.7	0.1 5.2%
Gr 0 (None)	94	62.7	54.9 70.4%
Total HTN retinopathy	56	37.3% = Prevalence HTN Retinopathy	95% CI 29.6 45.1%

(b)

Diabetic Retinopathy	of subjects	As per cent of subjects with DM	95% CI
BDR (Gr 1)	22	24.2%	15.4 33.0%
PPDR (Gr 2)	12	13.2%	6.2 20.1%
PDR (Gr 3)	5	5.5 %	0.8 10.2%
None	52	57.1%	47 67.3%
Total DR	39	42.9% = Prevalence Diabetic Retinopathy	95% CI 32.7 53.0%
Diabetic Maculopathy	**of subjects**	**As per cent of subjects with DM**	**95% CI**
Non-referable	3	3.6%	0 7.6%
Referable (CSME)	19	22.9%	13.9 31.9%
None	61	73.5%	64 83%
Total Diabetic Maculopathy	22	26.5% = Prevalence Diabetic Maculopathy	95% CI 17.0 36.0%
Ungradable for Maculopathy	8		

*Participants classified by the eye with the more advanced disease.

retinopathy are shown in Table 3. Systolic and diastolic BP were strongly associated with any hypertensive retinopathy by bivariate analysis, P = 0.001 and P = 0.001, respectively (Table 3). We explored the relationship between systolic BP and hypertensive retinopathy. Receiver operating characteristic (ROC) curve analysis using the Youden index and the area under the ROC curve (AUC) revealed the optimum cut-off using systolic BP for detecting any hypertensive retinopathy was 154 mm Hg (AUC = 0.66, 95% CI 0.57 0.75, Table 5). The proportion of participants with systolic BP greater than or equal to 155 mm Hg and any hypertensive retinopathy (48.2%) was significantly greater than the proportion of participants with systolic BP less than 155 mm Hg and any hypertensive retinopathy (23.1%) (P = 0.0017, Figure 1).

When participants with HTN were asked 'Can high blood pressure make vision worse?', 85 (61.6 %) responded 'yes' and 53 (38.4%) responded 'no' or 'unsure'. Awareness of the effect of high BP on the eye was not associated with the presence of any hypertensive retinopathy (Table 3).

Factors associated with diabetic retinopathy and maculopathy

The characteristics and questionnaire results of individuals with DM with and without any DR are shown in Table 4. Duration of DM was significantly associated with both any DR (P < 0.001) and any maculopathy (P = 0.002) (Table 4). We explored the relationship between the duration of DM and any DR. ROC curve analysis using the Youden index revealed the optimum cut-off using duration of DM for detecting any DR was 8 years (AUC = 0.75, 95% CI 0.65 0.85, Table 5). The proportion of participants with duration of DM greater than or equal to 8 years and any DR (62.5%) was greater than the proportion of participants with duration of DM <8 years and any DR (19.5%) (P 0.0001, Figure 2).

We also explored the relationship between systolic blood pressure and DR. When only participants with DM and any DR are considered, in a bivariate regression, we found systolic BP was significantly associated with the severity (grade) of DR (P = 0.034). ROC curve analysis

Table 3 Factors associated with hypertensive retinopathy in outpatients with hypertension (n = 150)

Characteristic Proportion (%) or mean (SD)	Hypertensive retinopathy (n = 56)	No hypertensive retinopathy (n = 94)	P-overall*
Gender			
Female	30 (54.5%)	54 (58.1%)	0.806
Male	25 (45.5%)	39 (41.9%)	
Age	61.0 (11.2)	63.0 (10.5)	0.288
Vision			0.975
No visual impairment	36 (64.3%)	62 (66.0%)	
Visual impairment	20 (35.7%)	32 (34.0%)	
Duration hypertension in years	9.0 (8.1)	9.8 (9.3)	0.595
Clinic blood glucose in mmol/L	7.4 (3.7)	8.3 (4.1)	0.282
Body Mass Index (BMI) in kg/m^2	27.1 (5.5)	27.6 (5.3)	0.557
Clinic Blood pressure in mm Hg			
Systolic	169 (24.8)	154 (26.8)	0.001
Diastolic	94.2 (18.7)	84.2 (12.3)	0.001
Employment			0.544
Farmer	16 (29.6%)	38 (40.9%)	
Govt, small business	8 (14.8%)	12 (12.9%)	
Homemaker	8 (14.8%)	14 (15.1%)	
Day labour, informal	12 (22.2%)	12 (12.9%)	
Student, unemployed, other	10 (18.5%)	17 (18.3%)	
Education			0.349
None or primary	29 (53.7%)	51 (56.7%)	
Secondary or vocational	19 (35.2%)	23 (25.6%)	
University	6 (11.1%)	16 (17.8%)	
Knowledge Question 1†			0.840
No	6 (11.8%)	8 (9.2%)	
Unsure	15 (29.4%)	24 (27.6%)	
Yes	30 (58.8%)	55 (63.2%)	

**P*-values calculated via ANOVA, Kruskall Wallis or chi-squared (or Fisher's) depending on whether the row variable is continuous normal, continuous non-normal or categorical.
†Appendix 2.

using the Youden index revealed the optimum cut-off using systolic BP for detecting any DR was 149.5 mm Hg (AUC = 0.64, 95% CI 0.54 0.74. Table 5). The proportion of participants with systolic BP greater than or equal to 150 mm Hg and any DR (56.2%) was greater than the proportion of participants with systolic BP less than 150 mm Hg and any DR (29.3%) (P = 0.0106, Figure 3).

When participants with DM were asked 'Can high blood sugar make vision worse?', 64 (74.4 %) responded 'yes' and 22 (25.6%) responded 'no' or 'unsure'. Awareness of the effect of high blood sugar on the eye was not associated with the presence of any DR (Table 4).

Factors associated with comorbid hypertension and diabetes mellitus

The characteristics of individuals diagnosed with both HTN and DM are shown in Table 6. Among individuals identified with both HTN and DM, duration of DM was significantly associated with any DR (P = 0.004) and any maculopathy (P = 0.015) by bivariate analysis. Among individuals identified with both HTN and DM, diastolic BP (P = 0.004) and younger age (P = 0.014) was significantly associated with any hypertensive retinopathy by bivariate analysis (Table 6).

Discussion

This is the first study of the prevalence of diabetic retinopathy, clinically significant macular oedema, hypertensive retinopathy and associated risk factors among persons with HTN and DM in Western Tanzania. The results of our investigation highlight the high disease burden Western Tanzania faces from DR, CSME and hypertensive retinopathy and provides data to plan screening services and health education for people with DM and/or HTN in the Lake zone.

The prevalence of any DR in our data set (42.9%) is higher than that observed at entry into a DR screening

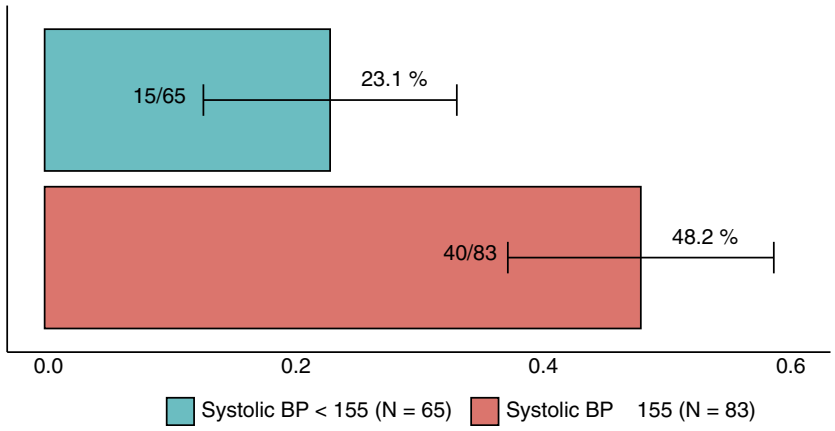

Figure 1 Proportion with any hypertensive retinopathy by systolic BP cut-off

Table 4 Factors associated with Diabetic Retinopathy (n = 91) and Maculopathy* (n = 83) in outpatients with diabetes mellitus

Characteristic Proportion (%) or mean (SD)	Diabetic Retinopathy n = 52	No Diabetic Retinopathy n = 39	P-overall†	Maculopathy n = 22	No Maculopathy n = 61	P-overall†
Gender			1.000			0.712
Female	24 (61.5%)	33 (63.5%)		15 (68.2%)	37 (60.7%)	
Male	15 (38.5%)	19 (36.5%)		7 (31.8)	24 (39.3%)	
Age	58.7 (9.0)	59.5 (13.1)	0.744	60.0 (7.6)	58.8 (12.5)	0.620
Vision			0.974			0.636
No visual impairment	26 (66.7%)	36 (69.2%)		14 (63.6)	44 (72.1)	
Visual impairment	13 (33.3%)	16 (30.8%)		8 (36.4)	17 (27.9)	
Duration of diabetes in years	12.8 (7.8)	6.7 (6.4)	<0.001	14.0 (8.0)	7.5 (6.7)	0.002
Clinic blood glucose in mmol/L	9.9 (4.3)	9.5 (4.0)	0.686	10.5 (5.1)	9.4 (3.9)	0.391
Body Mass Index (BMI) in kg/m^2	26.8 (4.8)	27.5 (5.8)	0.561	26.6 (5.6)	27.0 (5.1)	0.759
Clinic Blood pressure, mm Hg						
Systolic	157 (26.5)	147 (30)	0.095	159 (21.8)	149 (31.4)	0.118
Diastolic	83.8 (11.9)	82.8 (13.8)	0.727	85.0(11.8)	83.0 (13.9)	0.515
Employment			0.508			0.697
Farmer	13 (35.1%)	21 (40.4%)		7 (33.3%)	23 (38.3%)	
Govt, small business	6 (16.2%)	6 (11.5%)		3 (14.3%)	8 (13.3%)	
Homemaker	6 (16.2%)	4 (7.7%)		3 (14.3%)	5 (8.3%)	
Day labour, informal	8 (21.6%)	10 (19.2%)		6 (28.6%)	12 (20.0%)	
Student, Unemployed, Other	4 (10.8%)	11 (21.1%)		2 (9.5%)	12 (20.0%)	
Education			0.187			0.174
None or primary	22 (57.9%)	24 (49.0%)		12 (54.5%)	28 (48.3%)	
Secondary or vocational	13 (34.2%)	14 (28.6%)		9 (40.9%)	17 (29.3%)	
University	3 (7.9%)	11 (22.4%)		1 (4.5%)	13 (22.4%)	
Knowledge question 2‡			0.140			0.049
No	4 (11.1%)	3 (8.3%)		4 (18.2%)	3 (5.4%)	
Unsure	3 (8.3%)	12 (24.0%)		1 (4.6%)	13 (23.2%)	
Yes	29 (80.6%)	35 (70.0%)		17 (77.3%)	40 (71.4%)	

*Those ungradable for maculopathy were removed.
†P-values calculated via ANOVA, Kruskall Wallis or chi-squared (or Fisher's) depending on whether the row variable is continuous normal, continuous non-normal or categorical.
‡Appendix 2.

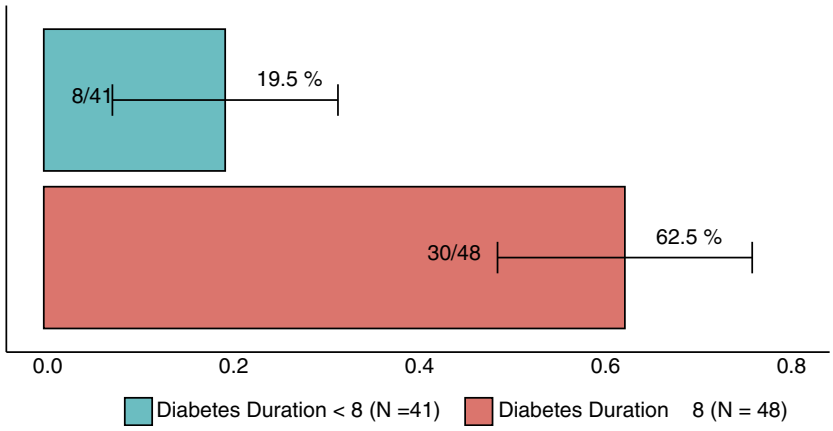

Figure 2 Proportion with any diabetic retinopathy by duration of DM cut-off

programme in the Kilimanjaro region of Tanzania (27.9%) [7]. This may reflect selection bias due to patients attending a tertiary care centre clinic having a greater burden of disease. However, our observed prevalence of DR and maculopathy (42.9% and 26.5%, respectively) is similar to that found in a household-based study in the Kilimanjaro region of Tanzania (48.6% and 25.7%, respectively) [8] suggesting our prevalence results may be generalisable to the population of adults living with DM in Tanzania.

The high prevalence of DR among outpatients attending clinics at BMC will be a heavy burden for the few ophthalmologists in Western Tanzania, especially in light of the expected rise in the prevalence of DM in SSA [5, 6]. The human resources for eye health, including the number of ophthalmologists, in SSA lag behind that of high resource regions [12]. In addition, the ophthalmic practitioner to population ratio is concentrated in large cities in SSA at the expense of those needing services in rural areas [12].

Our results showing a strong association between duration of DM and any DR suggests duration of DM is a reasonable predictor variable for detecting DR by retinal examination and might allow for determining a cut-off for referral that maximises benefits for patients living in a resource-poor setting. The AUC statistic derived from our ROC curve analysis using duration of DM to detect any DR indicates 8 years duration of DM provides acceptable discrimination between those with and without DR [13, 14]. Our goal is to maximally utilise resources spent performing retinal examinations on patients with DM to ensure that those with DR can receive diagnosis and treatment at minimal cost. Thus, referring adults with DM in Western Tanzania with duration of DM of at least 8 years to an ophthalmologist may be a reasonable strategy to increase efficiency of DR screening given the severe resource limitations and high cost for patients.

The finding that systolic BP was positively associated with the severity or grade of DR among participants with DM is consistent with the United Kingdom Prospective Diabetes Study (UKPDS), where tight blood pressure control in patients with type 2 DM reduced the rate of progression of DR by 34% [15]. In another study of 544 high-risk type 2 diabetes patients, high BP was a predictor for progression of DR [16]. This suggests vigorous efforts should be made to identify and treat HTN among all adults with DM in Western TZ. While the AUC statistic for the prediction of any DR from systolic BP is not as high as the AUC statistic for duration of DM, the relationship between systolic BP and any DR is worthy of further investigation given resource limitations.

Our results demonstrate a strong association between systolic BP and any hypertensive retinopathy. The AUC statistic for the prediction of any hypertensive retinopathy from systolic BP indicates systolic BP has discriminatory ability for detecting any hypertensive retinopathy. However, the AUC value falls under the range generally acceptable for screening purposes [14]. When the systolic BP cut-off determined by ROC curve analysis is rounded from 154 to 155 mg Hg, the proportion of participants with any hypertensive retinopathy remains significantly greater for participants with systolic BP equal to or >155 mm Hg compared to <155 mm Hg. This suggests additional investigation of systolic BP to guide referral of patients with HTN to an ophthalmologist is needed.

Duration of HTN was not associated with hypertensive retinopathy. This may be due to the observation that patterns of retinal vascular changes vary with both current

Table 5 Optimal screening cut-offs based on the maximal Youden index and associated measures of performance

Condition (screening parameter)	Value	95% confidence interval
Diabetes (Duration Diabetes)		
Optimal cut point (years)	8.0	
Area under ROC curve (AUC)	0.75	0.65 0.85
Sensitivity (%)	78.9	82.7 90.4
Specificity (%)	64.7	50.1 77.6
Positive predictive value (%)	62.5	47.7 80.8
Negative predictive value (%)	80.5	64.9 88.6
Diagnostic likelihood ratio ( )	2.24	1.49 3.36
Diagnostic likelihood ratio ( )	0.33	0.17 0.62
Diabetes (Systolic Blood Pressure)		
Optimal cut point (mm Hg)	149.5	
Area under ROC curve (AUC)	0.64	0.54 0.74
Sensitivity (%)	69.2	52.4 83.0
Specificity (%)	58.0	43.2 71.8
Positive predictive value (%)	56.2	41.2 70.5
Negative predictive value (%)	70.7	54.5 83.9
Diagnostic likelihood ratio ( )	1.65	1.12 2.43
Diagnostic likelihood ratio ( )	0.53	0.31 0.90
Hypertension (Systolic Blood Pressure)		
Optimal cut point (mm Hg)	154	
Area under ROC curve (AUC)	0.66	0.57 0.75
Sensitivity (%)	74.5	61 85.3
Specificity (%)	53.8	43 4.2
Positive predictive value (%)	48.8	38.3 65.4
Negative predictive value (%)	78.1	78.1 65.6
Diagnostic likelihood ratio ( )	1.61	1.23 2.11
Diagnostic likelihood ratio ( )	0.47	0.29 0.77

and past BP levels [17] and makes it even more vital that people with HTN in Western Tanzania be promptly diagnosed and treated to prevent damage to the retina. This is especially important as Tanzania transitions from a rural to urban society [18, 19] given the higher prevalence of HTN in urban versus rural areas [20].

Age was negatively associated with hypertensive retinopathy among individuals with both HTN and DM, with younger age being a risk factor for developing HTN retinopathy. A possible explanation is that early in the course of HTN, the vascular system has not developed compensatory mechanisms, leading to retina damage [21]. Elevated diastolic BP rather than systolic BP was a risk factor associated with hypertensive retinopathy in individuals with comorbid HTN and DM by bivariate analysis. This finding may be explained by the observation that among local factors affecting the retina, retinal diastolic arterial pressure rises before retinal changes appear and that retinal diastolic retinobrachial ratio is more significant than retinal systolic retinobrachial ratio for the development of hypertensive retinopathy [22].

Our questionnaire results for the effect of high BP on the eye suggest awareness of the complications of hypertensive eye disease could be improved among adults with HTN. Nearly, 40% of participants with HTN were not aware that HTN could cause eye disease. In low resource settings, the perceived severity of medical problems is the most important predictor for healthcare-seeking behaviour [23] and poor knowledge is associated with not seeking care for chronic medical conditions [24]. Thus, a lack of understanding of hypertensive eye disease is a potential barrier for individuals with HTN who need treatment and can be addressed with education programmes.

In conclusion, our findings show a readily obtainable historical parameter can identify adults with DM in

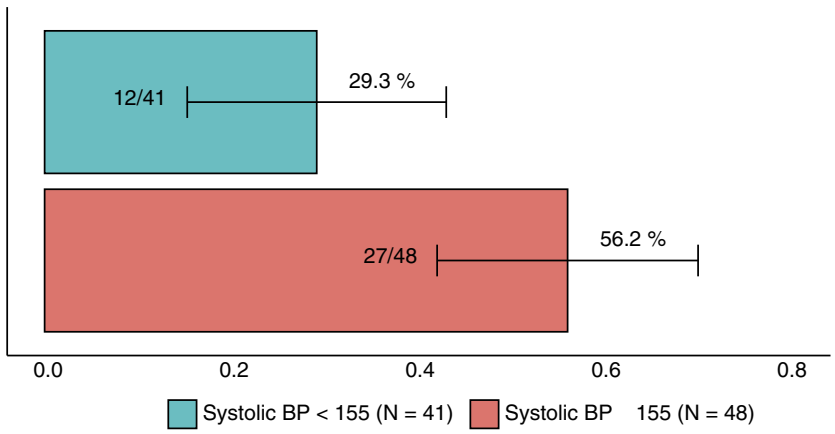

Figure 3 Proportion with any diabetic retinopathy by systolic BP cut-off

Table 6 Factors associated with Hypertensive Retinopathy, Diabetic Retinopathy and Maculopathy in outpatients with both hypertension and diabetes mellitus ($n = 67$)

Characteristic	HTN retinopathy $n = 21$	No HTN retinopathy $n = 46$	*P*-overall*	Diabetic Retinopathy $n = 31$	No diabetic retinopathy $n = 36$	*P*-overall*	Maculopathy $n = 18$	No maculopathy $n = 44$	*P*-overall*
Gender			1.000			1.000			0.552
Female	12 (57.1%)	27 (58.7%)		18 (58.1%)	21 (58.3%)		12 (66.7%)	24 (54.5%)	
Male	9 (42.9%)	19 (41.3%)		13 (41.9%)	15 (41.7%)		6 (33.3%)	20 (45.5%)	
Age	58.5 (6.9)	64.0 (10.4)	0.014	61.0 (6.1)	63.3 (12.0)	0.323	61.2 (6.6)	62.5 (10.5)	0.560
Vision			1.000			0.942			0.812
No impairment	14 (66.7%)	30 (65.2%)		21 (67.7%)	23 (63.9%)		11 (61.1%)	30 (68.2%)	
Impairment	7 (33.3%)	16 (34.8%)		10 (32.3%)	13 (36.1%)		7 (38.9%)	14 (31.8%)	
Duration HTN	8.2 (6.1)	10.8 (9.7)	0.197	12.2 (9.7)	8.4 (7.8)	0.115	10.1 (8.0)	9.78 (8.8)	0.887
Duration DM	11.0 (8.3)	9.4 (8.1)	0.460	13.0 (8.3)	7.2 (7.1)	0.004	13.9 (8.2)	8.10 (7.2)	0.015
Clinic blood glucose	9.0 (4.1)	9.6 (4.3)	0.563	9.6 (4.4)	9.3 (4.4)	0.779	10.4 (5.4)	9.19 (3.8)	0.404
BMI	27.8 (4.8)	27.9 (5.3)	0.922	27.4 (4.5)	28.3 (5.6)	0.448	27.6 (5.5)	27.5 (4.8)	0.972
Blood pressure									
Systolic	166 (17.6)	157 (29.6)	0.122	163 (24.8)	156 (28.3)	0.323	163 (21.7)	159 (28.9)	0.587
Diastolic	92.2 (11.4)	82.5 (12.9)	0.004	84.9 (11.9)	85.9 (14.3)	0.762	86.4 (12.3)	85.6 (13.9)	0.816

**P*-values calculated via ANOVA, Kruskall Wallis or chi-squared (or Fisher's) depending on whether the row variable is continuous normal, continuous non-normal or categorical.

Western Tanzania most likely to have DR and benefit from a retina examination. In particular, referring adults with DM for 8 or more years to an ophthalmologist for a dilated eye examination can allow those with the highest likelihood of DR to be screened. Our findings suggest utilisation of scarce ophthalmic resources may also benefit from further study of systolic BP cut-offs for detecting DR in adults with DM. In addition, efforts should be made to maximise the treatment of HTN among all adults with DM given our results showing the severity of DR is associated with systolic BP and the finding that all subjects with the most severe form of DR, PDR, were diagnosed with both HTN and DM. Our results also suggest further study of the relationship between systolic BP and hypertensive retinopathy may allow for determining an optimal systolic BP cut-off for referring adults with HTN for a retina examination. The feasibility of integrating programmes to promote awareness of the effect of high BP on the eye into community medical clinics should also be explored.

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Appendix 1
Grading schemes

Table A1 The grading scheme used for diabetic retinopathy based on the minimum data set recommended by the English and Wales National Screening Committee [7]

Retinopathy		
Level 0	None	
Level 1	Background	Microanuerysm(s)
		Retinal haemorrhage(s)
		Exudate(s)
Level 2	Pre-proliferative	Venous beading
		Venous loop or reduplication
		Multiple deep round or blot haemorrhages
		Intraretinal microvascular abnormality (IRMA)
Level 3	Proliferative	New vessels on the disc (NVD)
		New vessels elsewhere
		Pre-retinal or vitreous haemorrhage
		Pre-retinal fibrosis
Maculopathy		
No maculopathy		Does not meet any criteria for maculopathy
Non-referable maculopathy		Any microaneurysm or haemorrhage within 1 disc diameter (DD) of fovea
Referable maculopathy		Any exudate within 1 DD of the centre of the fovea

Table A2 The grading scheme used for hypertensive retinopathy based on the modified Scheie classification [11]

Retinopathy	
Grade 0	None
Grade I	Mild arteriolar attenuation
Grade II	AV nicking
	Copper wiring
Grade III	Grade 2 plus:
	Retinal haem
	Cotton wool spots
	Exudate
Grade IV	Grade 3 plus:
	Optic nerve swelling
	Silver wiring

Appendix 2

Table A1 Knowledge and Awareness questionnaire instructions

Question 1: Effects of hypertension on the eye
Instructions: Now I am going to ask you a question about what you know about high blood pressure and the eyes. Please answer the best you can, if you don't know the answer it is fine to say that.
Question: Can high blood pressure make vision worse?
Possible responses: yes, no, unsure
Question 2: Effects of diabetes mellitus on the eye
Instructions: Now I am going to ask you a question about what you know about high blood sugar and the eyes. Please answer the best you can, if you don't know the answer it is fine to say that.
Question: Can high blood sugar make vision worse?
Possible responses: yes, no, unsure

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