Proportion of ocular hypertension from a community-based screening program in South-Western Uganda

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ABSTRACT

Background: Glaucoma is the second leading cause of blindness globally. Africa has the highest burden of undetected cases of glaucoma and, the majority of patients present to the hospitals late with severe glaucoma partly due to the limited access to glaucoma screening equipment, and few trained eye care personnel. Ocular Hypertension (OHT), defined as an Intraocular Pressure (IOP) of >21 mmHg with normal optic nerve head findings and no other ocular disease is a risk factor for the development and progression of glaucoma. Uganda has limited data on the prevalence of OHT.
Objective: We aimed to determine the proportion of OHT in South Western Uganda.
Methods: This was a retrospective analysis of the IOP data of 5962 participants from a community-based outreach eye screening program. The IOP was measured using i-care100 rebound tonometer. The eyes were examined using a torch light and a direct ophthalmoscope. History of hypertension and diabetes treatment were obtained, and the blood pressure and random blood sugar measured. Data analysis involved a t-test, and logistic regression using STATA 7.
Results: The mean age was 48.2 years. The majority, 56.2% were female. Systemic hypertension was present in 23.9% and diabetes in 2.3%. The mean IOP was 15.5 mmHg (SD ±4.9). The prevalence of OHT was 12.6% (n = 731). At bivariable analysis, female sex (OR 0.85, 95% CI 0.73–0.99, and p= 0.049), diabetes (OR 1.45, 95% CI 0.85–2.48, and p= 0.17) and systemic hypertension (OR 1.45, 95% CI 1.18–1.77, and p= 0.000) were associated with OHT, while systemic hypertension was the only factor associated with OHT at multivariable analysis (adjusted odds ratio 1.5, 95% confidence interval 1.23–1.92, and p-value = 0.000).
Conclusion: We found a high prevalence of OHT in southwestern Uganda. OHT was associated with systemic hypertension.

Key words: Ocular hypertension, Community, Outreach, Screening, Uganda

INTRODUCTION

Glaucoma is the second leading cause of blindness globally, accounting for 11% of total blindness among adults over 50 years of age[1]. Africa has both the highest prevalence of Primary Open Angle Glaucoma (POAG) and the highest burden of undetected cases of glaucoma in the adult population globally[2,3]. In sub-Saharan Africa (SSA), glaucoma patients tend to be younger with the majority of patients presenting to the hospitals late with at least 60% presenting with severe glaucoma in the worse eye and at least 36% with severe glaucoma in both eyes[4,5]. This late presentation is partly due to the limited knowledge about glaucoma, limited access to glaucoma screening equipment, and few trained eye care personnel [6-8]. In Uganda, glaucoma is the third leading cause blindness, accounting for 11.7% of the cases[9].

Intraocular Pressure (IOP) remains the only modifiable risk factor for glaucoma[10]. Having Ocular Hypertension (OHT) is an important risk factor for the development and progression of POAG, with the 15-year risk of blindness in patients with untreated OHT ranging between 3.1% to 9.4%[11-13]. Early detection and treatment of OHT slows the progression of glaucoma and reduces the risk of blindness[14,15]. Although there are many methods of measuring IOP, using i-care rebound tonometer is a painless and non-invasive means of detecting OHT, with comparable results to Goldman's applanation tonometer[16]. A community outreach screening program is one way for improving access to glaucoma screening program[17].

In Uganda, data on the prevalence of OHT is limited. We aimed to determine the proportion of OHT in South Western Uganda through analysis of IOP measurements from an integrated community-based outreach eye screening program.

MATERIALS AND METHODS

This was a retrospective analysis of IOP measurements from a community outreach from the Glaucoma Screening and Treatment Project for South Western Uganda based at Mbarara University Referral Hospital Eye Center. Permission was obtained from the hospital to analyse and publish the data was obtained from the Eye Hospital. The screening was conducted in 16 districts and 2 cities in south-western Uganda, between July 2023 and January 2024. The analysis included a total of 5962 people, both male and female, aged 1 year to 98 years.

During the screening, a self-reported history of systemic hypertension and diabetes treatment was obtained for each participant, and the blood pressure and random blood sugar were also measured and recorded.

We measured distant and near Visual Acuity (VA) using Snellen's and tumbling-E charts.

The Visual Acuity (VA) was classified below:

- *Normal:* Presenting VA 6/9 or better
- *Mild visual impairment:* Presenting VA worse than 6/12 to 6/18
- *Moderate visual impairment:* Presenting VA worse than 6/18 to 6/60
- *Severe visual impairment:* Presenting VA worse than 6/60 to 3/60
- *Blindness:* Presenting VA worse than 3/60

We performed retinoscopy to screen for possible refractive error for patients who had VA worse than 6/6 but did not have significant ocular media opacity. IOP was measured from both eyes by an ophthalmic clinical officer with the participants in prone position, using the i-care rebound tonometer model IC100 manufactured by ICARE FINLAND OY. Six measurements were taken and the average reading taken according to the manufacturer's recommendation. Patients who had corneal scars were excluded from the analysis. An IOP of >21 mmHg in any eye was considered ocular hypertension. The eyes were examined using a torchlight and direct ophthalmoscopy done for fundoscopy. Ocular Hypertension (OHT) was defined as an IOP of >21 mmHg with normal optic nerve head findings and no other ocular disease. A glaucoma suspect was defined as an IOP of >21 mmHg with a suspicious-looking optic disc and unexplained visual acuity reduction. Glaucoma was defined as a previous confirmed/documented diagnosis of glaucoma with or without current or previous glaucoma treatment and disc changes consistent with glaucoma with or without elevated IOP.

The participants with OHT and other ocular pathologies were referred to nearby tertiary eye facilities for comprehensive glaucoma evaluation that included visual fields and optical coherence tomography, and or treatment. Patients with known history of glaucoma or previous treatment for glaucoma were excluded from the analysis.

Data was entered in Excel, exported to, cleaned, and analyzed using Stata 17. Continuous data was summarized into descriptive statistics, and categorical data were summarized into frequencies and proportions. A t-test was used to test the difference in the mean IOP between men and women. Bivariate analysis tested the relationship between age, sex, systemic hypertension, diabetes, and OHT using binary logistic regression at a p-value of less than 0.2. Significant variables at bivariate analysis were subjected to multivariable logistic regression analysis to determine the factors associated with OHT at a 95% confidence interval and p value of 0.05. Odds ratios and p values were reported.

RESULTS

A total of 11,567 eyes of 5,962 people were examined and IOP measured. There were 2,604 males and 3,358 females. The mean age was 48.3 (±21.8): the mean ages for males and females were 47.8 and 48.9 respectively. Systemic hypertension was found in 24.43%, while 2.37% had diabetes (Table 1).

Table 1: Demographic characteristics of the participants (n=5962)

Characteristic	Frequency (n)	(%)
Sex		
Male	2604	43.68
Female	3358	56.32
Total	5962	100.0
Age group (completed years)		
1-17	746	12.52
18-39	1136	19.07
40-60	2143	35.97
60 and older	1933	32.44
Total	5958	100.0
Diabetes		
No	3789	97.63
Yes	92	2.37
Total	3881	100.0
Systemic hypertension		
No	3102	75.57
Yes	1,003	24.43
Total	4.105	100.0

The majority of people, 70% had normal visual acuity, while 5.4% of the participants were blind in both eyes (Figure 1). Cataract, allergic conjunctivitis and refractive errors were the top three commonly diagnosed conditions (Figure 2).

Figure 1: Presenting visual acuity (VA) of the participants

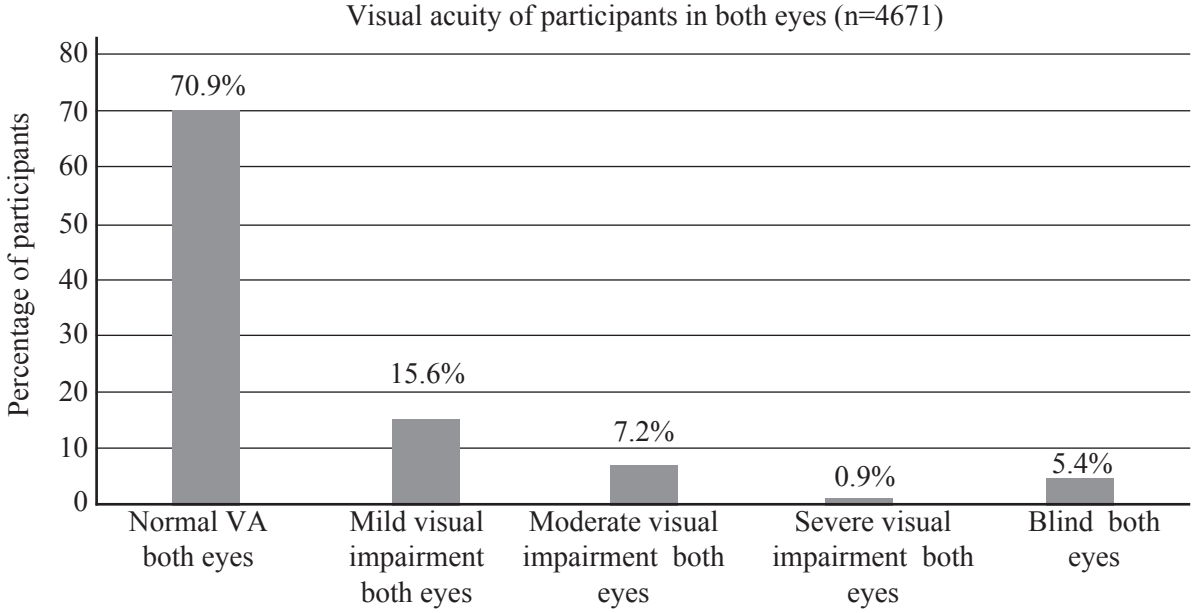
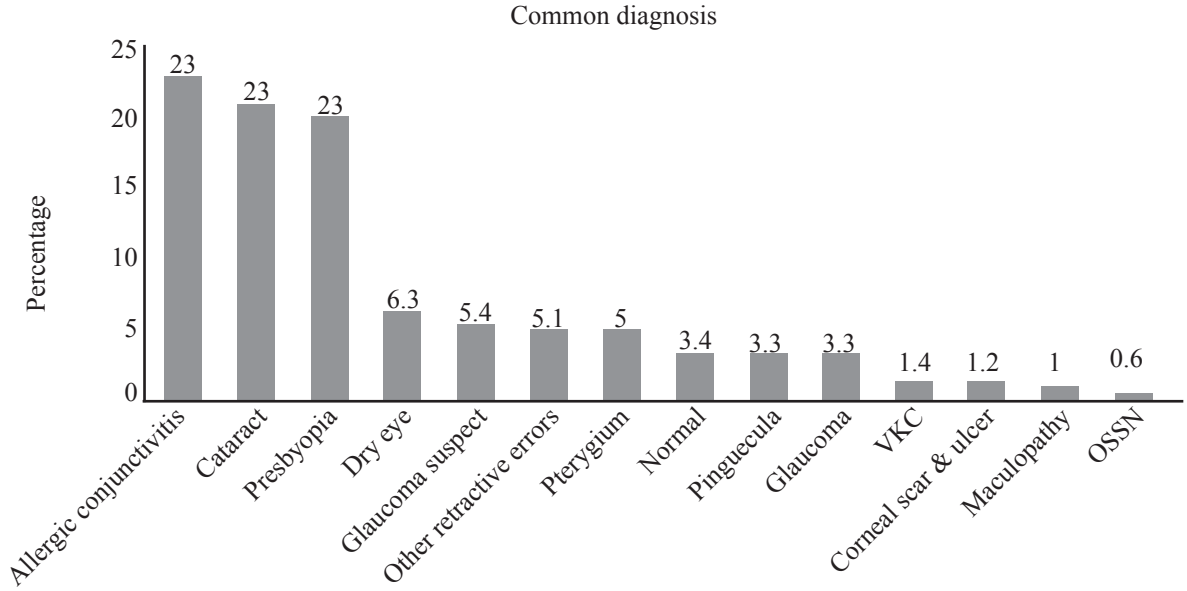


Figure 2: Most commonly diagnosed conditions



A total of 751 people had OHT (an IOP greater than 21 mmHg), representing 12.6% of total. Of the people that had OHT, 352 (47%) had OHT in both eyes, while 399 (53%) had OHT in only one eye. Ocular hypertension was more among the females at 53%, compared to the males at 47%. The proportion of people with OHT increased with increasing age group (Figure 3). The IOP was not normally distributed but had a right skew (Figure 4). The mean IOP was 15.5mmHg (SD = 4.9mmHg). The mean IOP for the male was 15.5mmHg (SD 5.2), while that of the female was 15.4 (SD 4.7). The mean IOP for different age groups were; 16.9mmHg for age-group 1-17 years, 15.8mmHg for age-group 18-39 years, 15.5mmHg for age-group 40-60 years and 15.5mmHg for age-group above 60 years. The median IOP was 15mmHg and the interquartile range (IQR) was 12.5-18mmHg.

Figure 3: Showing the the proportion of OHT, a) in general and b) by age category

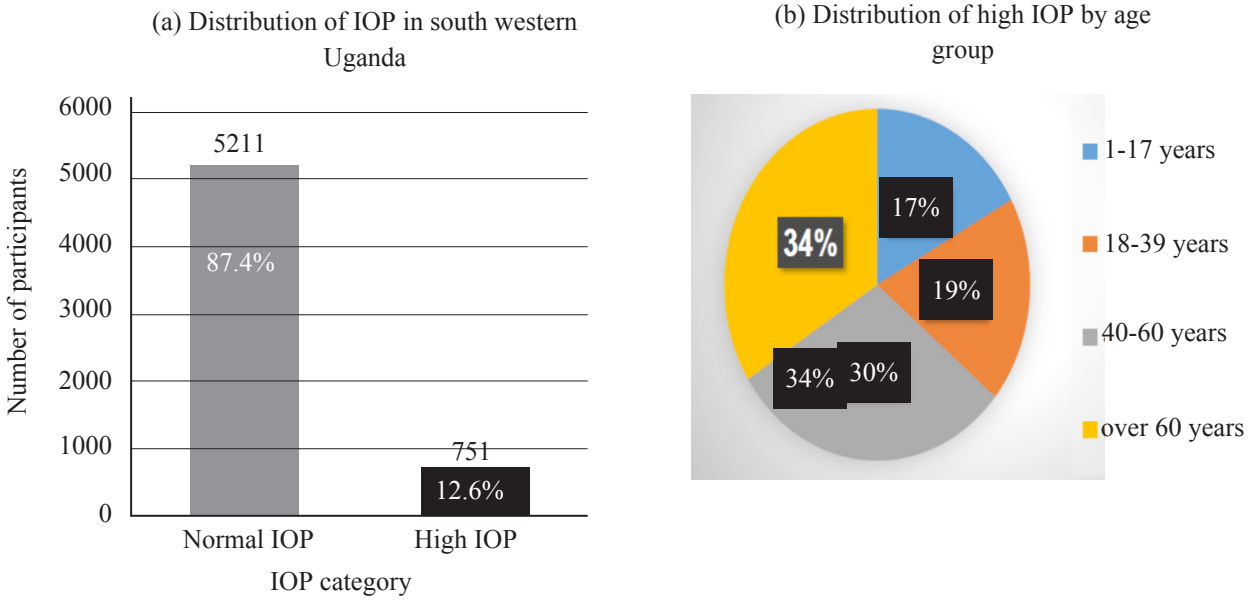
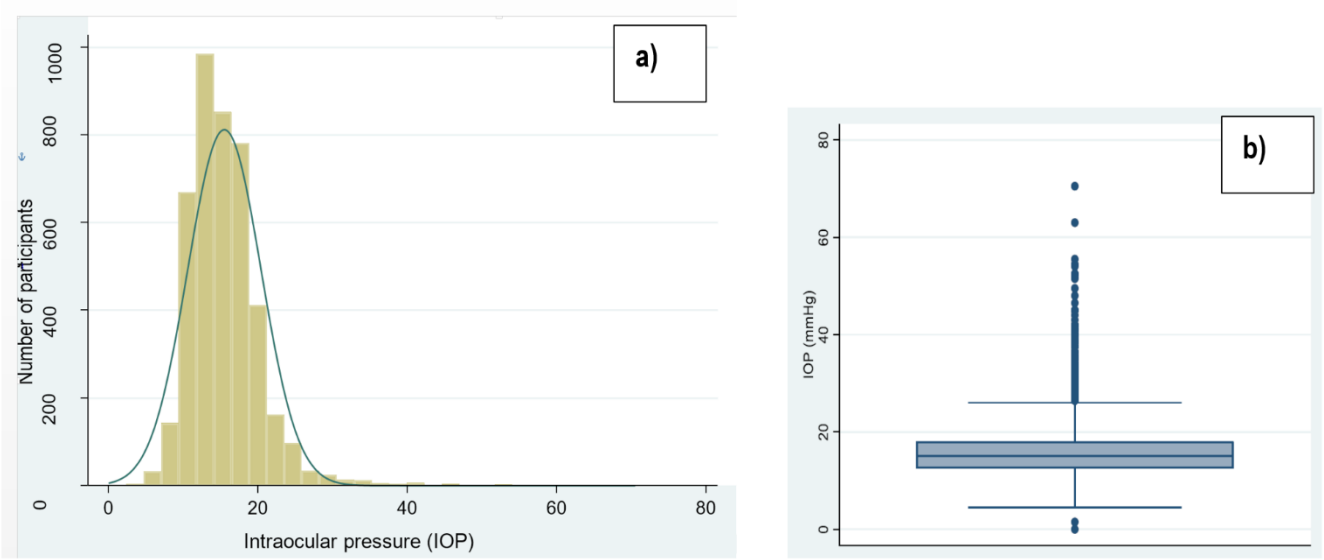


Figure 4: Distribution of intraocular pressure: a) histogram with right skewing and b) box plot



At bivariable analysis, female sex (OR 0.85, 95% CI 0.73–0.99, and p= 0.049), diabetes (OR 1.45, 95% CI 0.85–2.48, and p= 0.17) and systemic hypertension (OR 1.45, 95% CI 1.18–1.77, and p= 0.000) were associated with OHT, while systemic hypertension was the only factor associated with OHT at multivariable analysis (adjusted odds ratio 1.5, 95% confidence interval 1.23–1.92, and p-value = 0.000).

Table 2: Bivariate and multivariate regression of factors associated with ocular hypertension in southwestern Uganda

	Crude Odds Ratio (COR)		Adjusted Odds Ratio (AOR)	
Variables	COR (95% CI)	P-value	AOR (95% CI)	P-value
Sex				
Male	0.16 (0.14 0.18)	0.000	1	
Female	0.85 (0.73 0.99)	0.049	1	
Age group (years)				
1-17	0.2 (0.17 0.25)	0.003	1	
18-39	0.67 (0.52 0.87)	0.003	1	
40-60	0.55 (0.43 0.70)	0.000	1	
>60	0.71 (0.56 0.90)	0.005	1	
Diabetes				
No	0.15 (0.14 0.17)	0.000	1	
Yes	1.45 (0.85 2.48)	0.170	1	
Hypertension				
No	0.13 (0.12 0.15)	0.000	1	
Yes	1.45 (1.18 1.77)	0.000	1.59 (1.28 1.99)	<0.0001

Sex, age, diabetes and hypertension were the factors associated with OHT at bivariate analysis. At multivariable analysis, only hypertension was a significant factor. Hypertension was associated with a 1.59 risk of having OHT.

DISCUSSION

This study determined the proportion of OHT in South Western Uganda through an integrated community-based outreach-screening program. Understanding the proportion of persons with OHT within the community could lay an important foundation in the planning of glaucoma screening and treatment programs.

The study found a high prevalence of OHT at 12.6%. The study had similar findings to a hospital-based, cross-sectional, analytical study done on 422 non-glaucomatous patients aged 18 years and above in Southeast Nigeria, which found a prevalence of OHT at 12.1%. Among those with OHT, 14% of participants were less than 31 years old had OHT in at least one eye, and 31% of those aged 61and 70 years had OHT in at least one eye[18]. However, being a hospital based study on patients, they could have missed asymptomatic people from the community. Additionally, they had a smaller sample size and did not include those younger than 18 years. Another hospital study involving adults aged 18 years and above in Malawi, involving 200 "healthy" individuals without a known history of glaucoma and 1112 patients, found a prevalence of OHT at 11.5% and 13.8%, respectively, which were similar to our findings[19]. One study at a national referral hospital in central Uganda that included 405 hypertensive participants aged 25-90 years found the prevalence of OHT at 11.6%[20], a figure close to our findings of 12.6% from the community survey in southwestern Uganda.

However, our findings contrast the previously documented findings. For example, a population-based descriptive cross-sectional study in Nigeria, involving 1810 Black Africans aged 16 years and older, found a prevalence of OHT at 7.0%[21], significantly lower than our finding of 12.6%. In addition, the 4.8% prevalence in Ethiopia during a large volume cataract outreach[22] and the 2.1% prevalence in the rural Italian community[23] were also significantly lower than our finding. We postulate that this high prevalence of OHT could be due to high levels of self-medication in the Ugandan population that includes steroids, especially with the high prevalence of allergic conjunctivitis in south-western Uganda[24,25]. The mean IOP in our study was 15.5 (±4.9) mmHg. This was similar to findings from China[26-28], Europe[29], Saudi Arabia[30], and Nigeria[21]. In contrast to our study, lower mean IOPs have been reported in Ethiopia, central Australia[31], Iran[32] and other parts of the globe[33-38]. One study in Iran among elderly population aged 60-90 years revealed a mean IOP 16.7 (± 3.2) mmHg which was higher than what we found[39]. The differences in the IOP could be due to variation in population characteristics[35,40]. In Cameroon, a study of 485 patients aged 5 years and above found the mean IOP of 13.01 ± 2.97 mmHg in both eyes (95% CI: 12.82–13.19), which was lower than our findings. This could be due to the population and environmental variance[41].

A hospital-based retrospective review involving 69 Black and White children aged 5 to 17 years found OHT in 7 (10.1%) participants and a mean IOP of 17.7±4.2 mmHg and 19.3±6.0 mmHg for White and Black children, respectively[42]. Their finding is in contrast to the 17% and the mean IOP of 16.9 mmHg that we found in our subgroup of 1 to 17 years. This difference could be explained by the population and geographical differences and sample size differences. A large school-based survey involving 1565 children aged 5-24 years in the Gobi desert region found a significant association of raised IOP with young age; they found a mean IOP was 17.16 ±3.6 mm Hg (median: 16.8 mm Hg; range: 5.6 to 31.5 mm Hg) in the right eye and 17.1 ±63.4 mm Hg (median: 16.9 mm Hg; range: 7.8 to 32.3 mm Hg) in the left eye[43]. These findings indicate possibly a higher than previously thought prevalence of OHT among the younger population that could warrant further studies among the children.

In our study, systemic hypertension was positively associated with having OHT ($p<0.0001$). The European Eye Epidemiologic Study[44], Gutenberg Health Study[36], Barbados Eye Study[45], and several other studies across the globe had similar findings[35,37,39,46–48] sex, systemic blood pressure, diabetes mellitus, Body Mass Index (BMI. Systolic blood pressure has been postulated to increase aqueous filtration leading to increased and sustained rise in IOP[49]. In contrast to our findings, one rural population survey in Sweden did not find a positive association between IOP and hypertension[50]. This is possibly due to the low number of participants with hypertension in their survey.

We did not find a significant relationship between diabetes and OHT. This agrees with two other studies[32,51]. However, several previous studies have found significant association between diabetes and OHT[27,35,38,45,52,53]. This difference could be explained by the population differences and the fact that their population had a higher prevalence of diabetes. Since our study was a community screening program and was not statistically powered, it could have led to our finding, and therefore the result should be interpreted with caution. The osmotic gradient caused by hyperglycemia has been suggested to draw the aqueous humor into the anterior chamber, leading to the increased IOP in patients with diabetes [54,55].

From the existing literature, the relationship between IOP and sex is not conclusive. We did not find evidence of a significant relationship between sex and IOP. This is consistent with several previous findings[34,37,46]. In contrast to our findings, some studies observed a greater IOP among females than among males[33,56], and others found the reverse[23,57]. Although the reasons for the gender-specific variations in the IOP are unclear, physical activity, hormone changes, blood pressure, body mass index and regional and ethnic differences have been postulated[35].

We did not find a significant association between age and OHT, which was an unusual finding, was consistent with a longitudinal study in Korea and Mongolia[47]. However, the Beaver Dam Eye Study found a positive link between age and IOP[29] as did the study in Cameroon[41]. The European Eye Epidemiology found a U-shaped relationship between age and IOP[44]. Because IOP is influenced by aqueous humor dynamics and the anatomy of the eye[58], regional variations in eye characteristics may explain the differences in results among studies.

Strengths of the study

The study included a large sample size and a wide age range. This was a novel community based survey.

Limitations of the study

(i) We did not do measurements of the central corneal thickness, which is known to affect tonometry measurements.
(ii) History of steroid use, eye surgery, family history of glaucoma not elicited during the screening hence failed to determine the causes of OHT
(iii) There was high rate of loss to follow-up as most of the participants who had OHT did not report to tertiary eye facility sooner to confirm if they had glaucoma.

CONCLUSION

This study found a 12.6% prevalence of OHT which was higher than previously reported. Systemic hypertension was significantly associated with having OHT. The study did not find any significant association of IOP with diabetes, age and gender.

Recommendations

(i) Community-based IOP measurement can be used to screen for OHT as a means of glaucoma awareness and prevention strategy.
(ii) Additional studies should be done to identify other factors associated with OHT.
(iii) Stringent and clear referral and follow up measures are required if community IOP screening is to be utilized.

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Consent for publication

This was a retrospective analysis of IOP measurements from a community outreach from the Glaucoma Screening and Treatment Project for South Western Uganda based at Mbarara University Referral Hospital Eye Center. Permission was obtained from the hospital to analyze and publish the data was obtained from the Eye Hospital.

All authors have read and approved the final version of this manuscript.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

MO, VNA, RK, and SA conceived the design. MO, VNA, RK, RK collected the data. MO and SA analysed the data. All authors reviewed all the versions and have approved the final manuscript.

REFERENCES

1. Steinmetz JD, Bourne RRA, Briant PS, Flaxman SR, Taylor HRB, Jonas JB, *et al.* Causes of blindness and vision impairment in 2020 and trends over 30 years, and prevalence of avoidable blindness in relation to VISION 2020: the Right to Sight: an analysis for the Global Burden of Disease Study. *Lancet Glob Health*. 2021; **9**(2):e144–160.
2. Zhang N, Wang J, Li Y, Jiang B. Prevalence of primary open angle glaucoma in the last 20 years: a meta-analysis and systematic review. *Sci Rep*. 2021; **11**(1):13762.
3. Soh Z, Yu M, Betzler BK, Majithia S, Thakur S, Tham YC, *et al*. The global extent of undetected glaucoma in adults: A systematic review and meta-analysis. *Ophthalmology*. 2021;**128**(10):1393–404.
4. Olawoye O, Kizor-Akaraiwe N, Pons J, Sarimiye T, Washaya J, Hughes S, *et al.* Clinical characteristics and stage at presentation of glaucoma patients in sub-Saharan Africa. *J Glaucoma*. 2022; **31**(9):717–723.
5. Bonnemaijer PWM, Lo Faro V, Sanyiwa AJ, Hassan HG, Cook C, GIGA study group, *et al.* Differences in clinical presentation of primary open-angle glaucoma between African and European populations. *Acta Ophthalmol* (Copenh). 2021; **99**(7):e1118–26.
6. Yimam W, Anbesaw T, Seid M, Kumar P, Wolie H. Knowledge about glaucoma among adults in Africa: a systematic review. *BMC Ophthalmol.* 2024; **24**(1):69.
7. Gilmour-White JA, Shah P, Cross V, Makupa W, Philippin H. Glaucoma awareness and access to healthcare: perceptions among glaucoma patients in Tanzania. *Postgrad Med J.* 2015; **91**(1077):373–378.
8. Kyari F, Adekoya B, Abdull MM, Mohammed AS, Garba F. The current status of glaucoma and glaucoma care in sub-Saharan Africa. *Asia-Pac J Ophthalmol Phila Pa.* 2018; **7**(6):375–386.
9. Mulinde B, Atukunda I, Kawooya I, Sebabi FO, Mukunya D, Batte C, *et al.* Prevalence and risk factors for visual impairment among elderly patients attending the eye clinic at Mulago National Referral Hospital, Uganda: a cross-sectional study. *Afr Health Sci.* 2022; **22**(Spec Issue):124–132.
10. Ocular Hypertension Treatment Study Group, European Glaucoma Prevention Study Group, Gordon MO, Torri V, Miglior S, Beiser JA, *et al*. Validated prediction model for the development of primary open-angle glaucoma in individuals with ocular hypertension. *Ophthalmology*. 2007; **114**(1):10–19.
11. Gordon MO, Beiser JA, Brandt JD, Heuer DK, Higginbotham EJ, Johnson CA, *et al.* The Ocular Hypertension Treatment Study: baseline factors that predict the onset of primary open-angle glaucoma. *Arch Ophthalmol Chic Ill 1960*. 2002; **120**(6):714–20; discussion 829-830.
12. Leske MC, Heijl A, Hyman L, Bengtsson B, Dong L, Yang Z. Predictors of long-term progression in the early manifest glaucoma trial. *Ophthalmology*. 2007; **114**(11):1965–72.
13. van Gestel A, Webers CAB, Beckers HJM, Peeters A, Severens JL, Schouten JSAG. Ocular hypertension and the risk of blindness. *J Glaucoma*. 2015; **24**(1):9–11.
14. Lee BL, Wilson MR, Ocular Hypertension Treatment Study (OHTS). Ocular Hypertension Treatment Study (OHTS) commentary. *Curr Opin Ophthalmol.* 2003; **14**(2):74–77.
15. Bengtsson B, Leske MC, Hyman L, Heijl A, Early Manifest Glaucoma Trial Group. Fluctuation of intraocular pressure and glaucoma progression in

the early manifest glaucoma trial. *Ophthalmology*. 2007; **114**(2):205–209.
16. Rao A, Kumar M, Prakash B, Varshney G. Relationship of central corneal thickness and intraocular pressure by iCare rebound tonometer. *J Glaucoma*. 2014; **23**(6):380–384.
17. Olawoye OO, Fawole O, Ashaye AO, Chan VF, Azuara-Blanco A, Congdon N. Effectiveness of community outreach screening for glaucoma in improving equity and access to eye care in Nigeria. *Br J Ophthalmol*. 2023; **107**(1):30–36.
18. Mbatuegwu AI, Achigbu EO, Mbatuegwu CU, Nkwogu FU, Omoti AE. Exploring the relationship between central corneal thickness and intraocular pressure among nonglaucoma patients in a general ophthalmology clinic, *South East Nigeria. Niger J Ophthalmol.* 2021; **29**(1):17.
19. Fertig C. Prevalence of increased intraocular pressure and presentation patterns of glaucoma at a tertiary hospital in Malawi, South-East-Africa. 2017 [cited 2025 Apr 13]; Available from: https://publikationen.uni-tuebingen.de/xmlui/handle/10900/74714
20. Pius M, Pauline A, Denis E, Charity Z, Anne A, C AA. Prevalence and factors associated with raised intraocular pressure among hypertensive patients—A hospital-based study, Uganda. *Open J Ophthalmol.* 2020; **10**(4):351–363.
21. Sarimiye TF, Olawoye O, Bekibele C, Ashaye A. Distribution of intraocular pressure in indigenous Black Africans and related risk factors: A population-based study in Southwest Nigeria. *Niger J Ophthalmol.* 2024; **32**(2):38.
22. McClain IJ, Rooney DM, Tabin GC. Intraocular pressure screening during high-volume cataract surgery outreach in Ethiopia. *BMC Ophthalmol.* 2022; **22**(1):397.
23. Bonomi L, Marchini G, Marraffa M, Bernardi P, De Franco I, Perfetti S, *et al.* Prevalence of glaucoma and intraocular pressure distribution in a defined population. The Egna-Neumarkt Study. *Ophthalmology*. 1998;**105**(2):209–215.
24. Makeri D, Dilli PP, Pius T, Tijani NA, Opeyemi AA, Lawan KA, *et al*. The nature of self-medication in Uganda: a systematic review and meta-analysis. *BMC Public Health.* 2025; **25**(1):197.
25. Kamali A, Whitworth JAG, Ruberantwari A, Mulwanyi F, Acakara M, Dolin P, *et al*. Causes and prevalence of non-vision impairing ocular conditions among a rural adult population in SW Uganda. *Ophthalmic Epidemiol*. 1999; **6**(1):41–48.
26. Yang YQ, Fan SJ, Lyu AG, Miao H, Guo L, Jia Q, *et al.* Distribution and reference intervals of daytime intraocular pressure in the eye health screening population of Handan. *Zhonghua Yan Ke Za Zhi Chin J Ophthalmol.* 2023; **59**(8):620–626.
27. Cui Y, Yang X, Zhang G, Guo H, Zhang M, Zhang L, *et al*. Intraocular pressure in general and diabetic populations from Southern China: the Dongguan Eye Study. *Invest Ophthalmol Vis Sci.* 2019; **60**(2):761–769.
28. Liu X, Pan X, Ma Y, Jin C, Wang B, Ning Y. Variation in intraocular pressure by sex, age, and geographic location in China: A nationwide study of 284,937 adults. *Front Endocrinol.* 2022; **13**:949827.
29. Klein BE, Klein R, Linton KL. Intraocular pressure in an American community. The Beaver Dam Eye Study. *Invest Ophthalmol Vis Sci*. 1992; **33**(7):2224–28.
30. Bashir M, Alghamdi AH, Alzahrani SA, Alhajji AM, Al Thobaiti LY, Alzahrani KA, *et al.* Prevalence of ocular hypertension and other risk factors of open-angle glaucoma among middle-aged adults in Al-Baha City, Saudi Arabia. *Cureus*. 2023; **15**(12):e50304.
31. Landers J, Henderson T, Craig J. Distribution and associations of intraocular pressure in indigenous Australians within central Australia: the Central Australian Ocular Health Study. *Clin Experiment Ophthalmol.* 2011; **39**(7):607–613.
32. Hashemi H, Kashi AH, Fotouhi A, Mohammad K. Distribution of intraocular pressure in healthy Iranian individuals: the Tehran Eye Study. *Br J Ophthalmol.* 2005; **89**(6):652–657.
33. Takahashi S, Hara K, Sano I, Onoda K, Nagai A, Yamaguchi S, *et al*. Systemic factors associated with intraocular pressure among subjects in a health examination program in Japan. *PLoS One*. 2020;**15**(6):e0234042.
34. Fukuoka S, Aihara M, Iwase A, Araie M. Intraocular pressure in an ophthalmologically normal Japanese population. *Acta Ophthalmol* (Copenh). 2008; **86**(4):434–439.
35. Bikbov MM, Kazakbaeva GM, Zainullin RM, Salavatova VF, Gilmanshin TR, Yakupova DF, *et al*. Intraocular pressure and its associations in a Russian population: The Ural Eye and Medical Study. *Am J Ophthalmol.* 2019; **204**:130–139.
36. Hoehn R, Mirshahi A, Hoffmann EM, Kottler UB, Wild PS, Laubert-Reh D, *et al.* Distribution of intraocular pressure and its association with ocular features and cardiovascular risk factors: The Gutenberg Health Study. *Ophthalmology.* 2013; **120**(5):961–968.
37. Park S shin, Lee EH, Jargal G, Paek D, Cho S il. The distribution of intraocular pressure and its association with metabolic syndrome in a community. *J Prev Med Public Health Yebang Uihakhoe Chi.* 2010; **43**(2):125–130.
38. Kim MJ, Park KH, Kim CY, Jeoung JW, Kim SH. The distribution of intraocular pressure and

associated systemic factors in a Korean population: the Korea National Health and Nutrition Examination Survey. *Acta Ophthalmol* (Copenh). 2014; **92**(7):e507-513.
39. Ghanbarnia MJ, Panahi NM, Rasoulinejad SA, Hosseini SR, Shirafkan H, Roustaei GA, *et al*. Age-specific distribution of intraocular pressure in elderly Iranian population and its associated factors. *Casp J Intern Med.* 2023; **14**(1):112–120.
40. Kim JH, Thiruvengadam R. Hypertension in an ageing population: Diagnosis, mechanisms, collateral health risks, treatments, and clinical challenges. *Ageing Res Rev.* 2024; **98**:102344.
41. Eballe AO, Koki G, Ellong A, Owono D, Epée E, Bella LA, *et al.* Central corneal thickness and intraocular pressure in the Cameroonian nonglaucomatous population. *Clin Ophthalmol.* 2010; **4**:717–724.
42. Muir KW, Jin J, Freedman SF. Central corneal thickness and its relationship to intraocular pressure in children. *Ophthalmology*. 2004; **111**(12):2220–23.
43. Yang DY, Guo K, Wang Y, Guo YY, Yang XR, Jing XX, *et al*. Intraocular pressure and associations in children. The Gobi Desert Children Eye Study. *PLoS One.* 2014; **9**(10):e109355.
44. Khawaja AP, Springelkamp H, Creuzot-Garcher C, Delcourt C, Hofman A, Höhn R, *et al.* Associations with intraocular pressure across Europe: The European Eye Epidemiology (E3) Consortium. *Eur J Epidemiol.* 2016; **31**(11):1101–11.
45. Hennis A, Wu SY, Nemesure B, Leske MC. Hypertension, diabetes, and longitudinal changes in intraocular pressure. *Ophthalmology.* 2003; **110**(5):908–914.
46. Oh SW, Lee S, Park C, Kim DJ. Elevated intraocular pressure is associated with insulin resistance and metabolic syndrome. *Diabetes Metab Res Rev.* 2005; **21**(5):434–440.
47. Lee MK, Cho SI, Kim H, Song YM, Lee K, Kim JI, *et al.* Epidemiologic characteristics of intraocular pressure in the Korean and Mongolian populations: the Healthy Twin and the GENDISCAN study. *Ophthalmology.* 2012; **119**(3):450–457.
48. Lin CP, Lin YS, Wu SC, Ko YS. Age- and gender-specific association between intraocular pressure and metabolic variables in a Taiwanese population. *Eur J Intern Med.* 2012; **23**(1):76–82.
49. Bulpitt CJ, Hodes C, Everitt MG. Intraocular pressure and systemic blood pressure in the elderly. *Br J Ophthalmol.* 1975; **59**(12):717–720.
50. Häkkinen M, Ekström C. Distribution of intraocular pressure in a Swedish population. *Ups J Med Sci.* 2022; **127**: 8829
51. Mitchell P, Smith W, Chey T, Healey PR. Open-angle glaucoma and diabetes: the Blue Mountains eye study, Australia. *Ophthalmology.* 1997; **104**(4):712–718.
52. Tielsch JM, Katz J, Quigley HA, Javitt JC, Sommer A. Diabetes, intraocular pressure, and primary open-angle glaucoma in the Baltimore Eye Survey. *Ophthalmology*. 1995; **102**(1):48–53.
53. Wang YX, Xu L, Wei WB, Jonas JB. Intraocular pressure and its normal range adjusted for ocular and systemic parameters. The Beijing Eye Study 2011. *PloS One.* 2018; **13**(5):e0196926.
54. Mapstone R, Clark CV. Prevalence of diabetes in glaucoma. *Br Med J Clin Res Ed.* 1985; **291**(6488):93–95.
55. Hymowitz MB, Chang D, Feinberg EB, Roy S. Increased intraocular pressure and hyperglycemic level in diabetic patients. *PLoS One.* 2016; **11**(3):e0151833.
56. Baek SU, Kee C, Suh W. Longitudinal analysis of age-related changes in intraocular pressure in South Korea. *Eye* Lond Engl. 2015; **29**(5):625–629.
57. Chang YC, Lin JW, Wang LC, Chen HM, Hwang JJ, Chuang LM. Association of intraocular pressure with the metabolic syndrome and novel cardiometabolic risk factors. *Eye* Lond Engl. 2010; **24**(6):1037–43.
58. Qin Z, Meng L, Yang F, Zhang C, Wen B. Aqueous humor dynamics in human eye: A lattice Boltzmann study. *Math Biosci Eng*. 2021;**18**(5):5006–28.