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Prevalence of Glaucoma in Patients Attending Glaucoma Screening Program: A Cross-Sectional Study, Benghazi, Libya.

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ABSTRACT

Glaucoma, a leading cause of blindness worldwide, glaucoma afflicted 64.3 million people in 2013 and is expected to affect 111.8 million by 2040. For early detection and treatment, it is essential to look into the prevalence of glaucoma and its risk factors. Finding important clinical and demographic indicators of glaucoma in adults screened as part of a public program in Benghazi, Libya, was the goal of this study. During "Glaucoma Week" in February 2024, 366 adult patients were recruited for this cross-sectional study. The participants were divided into three categories: glaucoma suspect (21.0%, n=77), glaucoma unlikely (34.5%, n=126), and confirmed glaucoma (44.5%, n=163). A first-degree relative with glaucoma (OR =2.08, p = 0.016), a history of ocular inflammation (OR = 5.2; p = 0.008), and a higher left-eye intraocular pressure (IOP) (OR = 1.18, p = 0.003) were all significant predictors of confirmed glaucoma, according to logistic regression analyses. In one model, male gender was also a significant predictor (OR = 1.85, p = 0.027). The development of glaucoma was significantly influenced by these factors. In order to improve glaucoma detection in Libya, this study highlighted the significance of targeted screening and monitoring, especially for people with ocular inflammation, a family history of glaucoma, or elevated left-eye IOP.

KEYWORDS: screening, glaucoma suspicion, blindness, inflammation, intraocular pressure, Libya.

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1.INTRODUCTION

Glaucoma causes progressive damage to the optic nerve and visual fiel,[1،] is the second most common cause of permanent blindness worldwide, after cataracts. [2,3] It is responsible for more than 8% of blindness globall,[4] and the number of cases is predicted to rise from 64.3 million in 2013 to 111.8 million in 2040[5]

Glaucoma is associated with high intraocular pressure (IOP), and risk factors include age, IOP, race, gender, and family history.[6] Glaucoma affects about 4% of adults over the age of 40 in Sub-Saharan Africa; however, limited diagnostic resources frequently result in underreporting and delayed diagnosis. Many cases go undiagnosed until advanced stages, highlighting the necessity of extensive screening programs.[3]

In Libya, data on prevalence and associated risk factors are particularly limited, making it difficult to develop effective screening and prevention strategies. Given the disease's high risk and the importance of early intervention,[7] a targeted screening approach is required to identify and manage high-risk individuals in the Libyan population. Research into the prevalence and associated risk factors of glaucoma is critical for early detection and a better understanding of its pathophysiology [8].

Therefore, the purpose of this study was to determine important clinical and demographic risk factors as well as the prevalence of glaucoma among adults participating in a screening program in Benghazi. The study would fill a significant knowledge gap in the field of ophthalmic epidemiology in Libya and advances evidence-based strategies for early detection and treatment.

2.MATERIALS AND METHODS

A cross-sectional study was carried out at the outpatient department of the Benghazi Teaching Eye Hospital. In collaboration with the ophthalmology department at the University of Benghazi, the hospital organized a glaucoma screening event called "Glaucoma Week," which took place during the last week of February 2024.

Patients were invited to participate through advertisements in local news media. The study included all adult patients who visited the outpatient department at the study site during this week and consented to participate in the screening program. However, participants with corneal surface disease, phthisis, or those unable to fixate were excluded from the study. Adult patients attending the outpatient department that week, recruited via local news ads and giving consent, were included. Participants with corneal surface disease, phthisis, or inability to fixate were excluded from the study.

Demographic, medical, and eye health information, including age, gender, race, glaucoma and other eye disease histories, prior treatments, family glaucoma history, medication use, systemic diseases (heart disease, stroke, hypertension, diabetes), and smoking, was recorded in a database by volunteer ophthalmologists.

During the screening examination, the following parameters were assessed: Visual acuity, refraction, and intraocular pressure (IOP). Myopia was characterized as a spherical equivalent (SE) of ≤ –0·5 diopters [9], and normal IOP was defined as a range of 10 to 21 mmHg. [10] A comprehensive ocular examination was conducted, which included slit-lamp bio-microscopy and a fundus examination with a (+90D) lens to evaluate the optic nerve head.

Each patient was categorized into one of the three groups based on clinical and historical findings: Confirmed glaucoma was diagnosed if classic optic neuropathy (optic disc cupping/ damage) appeared in either eye, irrespective of visual field-testing results, and was validated by medical record review. [11]

Glaucoma suspect was classified as an individual presenting with clinical features or risk factors that increase the risk of glaucoma-related optic nerve damage. [11,12]

Glaucoma unlikely was defined as a patient with IOP below 21 mmHg, a normal appearance of the optic disc, and no family history of glaucoma in a first-degree relative. [11]

Patients were informed of their results and scheduled for follow-up after examination. Multinomial and binary logistic regression assessed associations between glauco-

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ma diagnosis (confirmed vs suspected, or no glaucoma) and predictor variables, with significance set at $p < 0.05$. The study followed the Declaration of Helsinki and was approved by the Ophthalmology Department and Benghazi Teaching Eye Hospital ethics committees.

3.RESULTS

Out of the 366 participants, specifically 211 (57.7%) were aged over 60 years, 218 (59.6%) were male, 343 (93.7%) were White, and 351 (95.9%) were Libyan. In terms of clinical characteristics, 60 (16.4%) were current smokers, 176 (48.1%) had diabetes, 148 \ (40.4%) had hypertension, 51 (13.9%) had ischemic heart disease, and 92 (25.1%) reported migraines (see Figure 1).

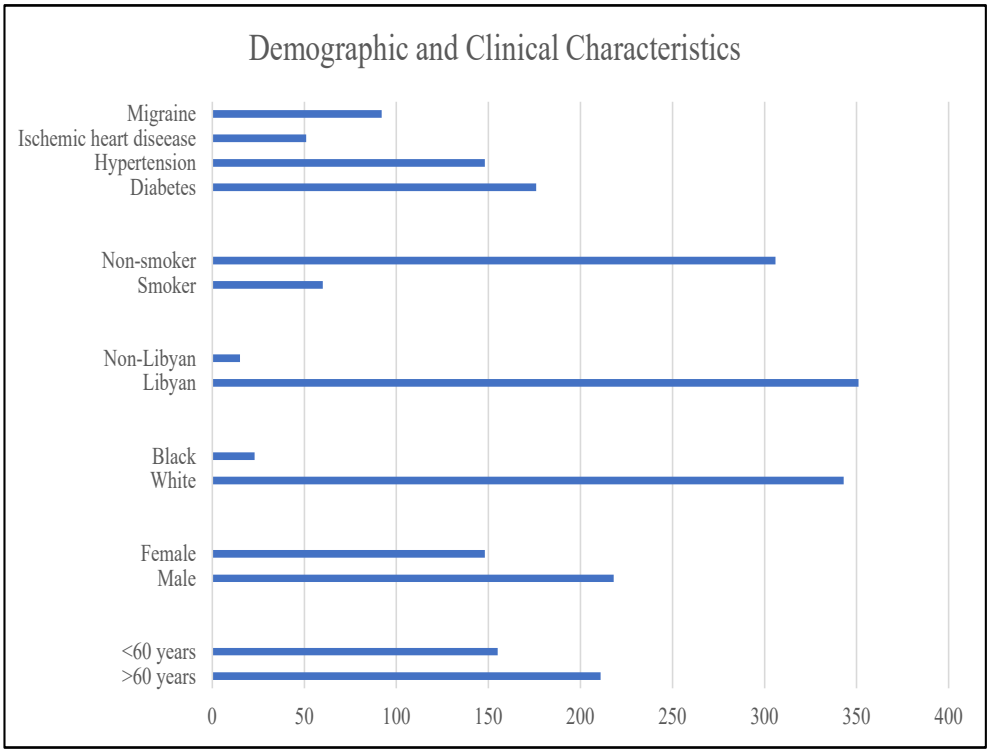

Figure 1. Demographic and Clinical Characteristics (N = 366).

A total of 137 individuals (37.4%) reported no history of ocular conditions. Conversely, 42 (11.5%) had experienced ocular trauma, and 26 (7.1%) had a history of inflammation. Ocular surgery was reported by 108 participants (29.5%), primarily cataract surgery. (Figure 2).

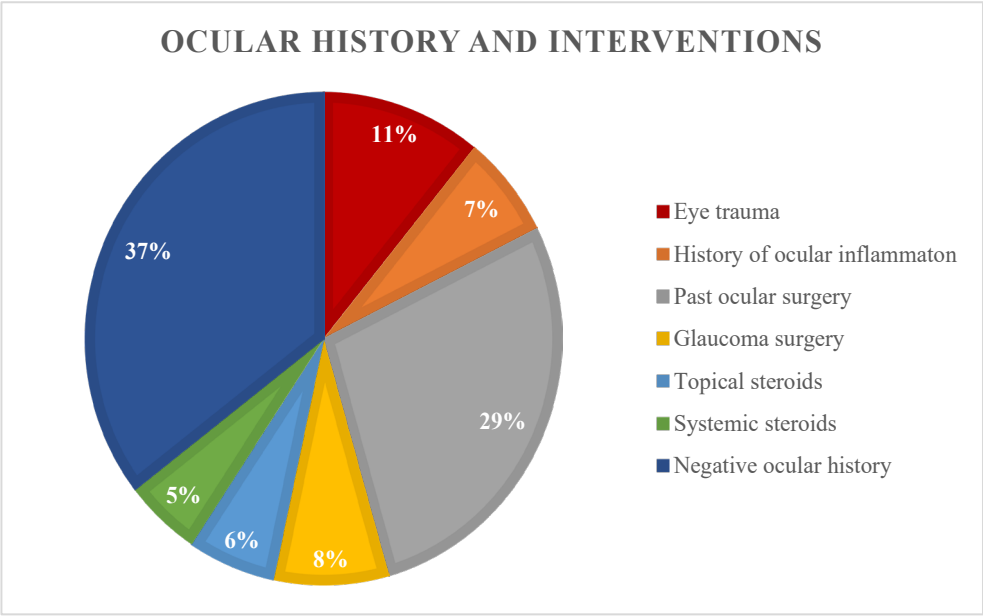

Figure 2: Ocular History and Interventions among Study Participants

Among the 366 studied participants, 163 (44.5%) were confirmed to have glaucoma, 77 (21.0%) were identified as glaucoma suspects, and 126 (34.4%) were considered unlikely to have the disease (Figure 3).

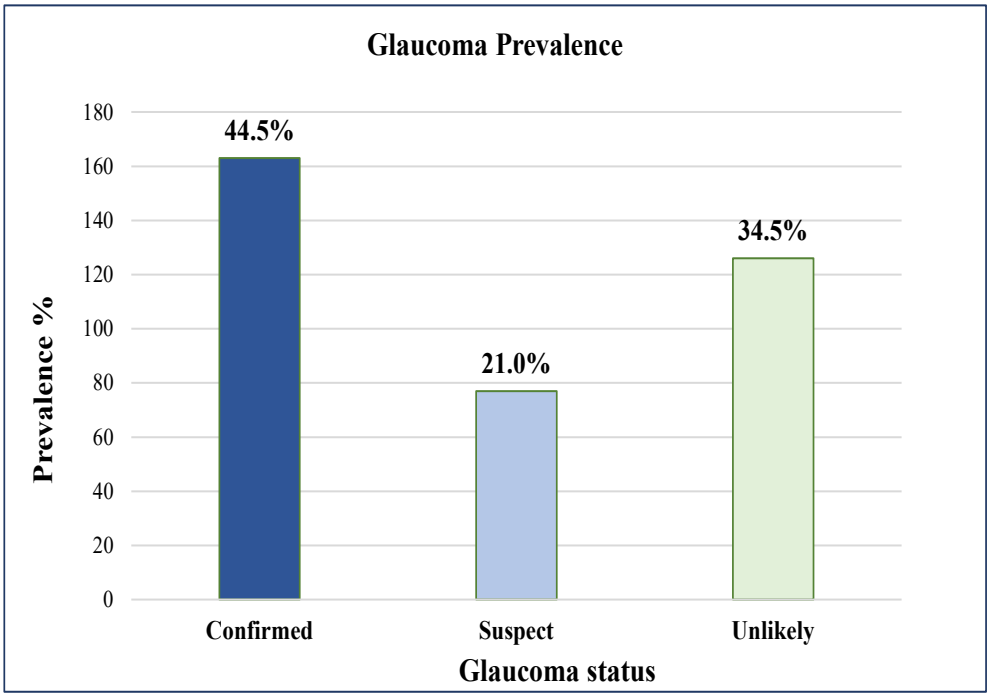

Figure 3. The prevalence of glaucoma status among 366 participants.

Of the participants, 130 (35.5%) reported a family history of glaucoma, with 120 (32.8%) having a first-degree relative affected. Half of the participants, 183 (50.0%), were myopic.

For glaucoma diagnosis duration, 62 (16.9%) had a duration of more than five years,

Regarding glaucoma treatment, 203 participants without a prior history of glaucoma (55.4%) did not receive any specific intervention, and 137 (37.5%) were treated with drops and tablets (see Table 1).

Table 1: Glaucoma History, Familial Predisposition, and Management Approaches Among Study Participants

Glaucoma	Level	Frequency
Family history of glaucoma	No history	236 (64.5%)
	First-degree relative	120 (32.8%)
	Second-degree relative	9 (2.5%)
	3rd-degree relative	1 (0.3%)
Myopic	—	183 (50.0%)
Glaucoma history	No glaucoma	203 (55.4%)
	Less than 1 year	47 (12.8%)
	1–5 years	42 (11.5%)
	More than 5 years	62 (16.9%)
	Don't know	12 (3.4%)
Treatment	No glaucoma	203 (55.4%)
	Drops and tablet	137 (37.5%)
	Laser	3 (0.8%)
	Combination of Laser, drops and tablet	2 (0.5%)
	Surgery combined with laser	1 (0.3%)
	Surgery combined with drops	11 (3.0%)
	Laser combined with drops	9 (2.5%)

Males were frequently categorized as "suspect" for glaucoma (49 cases, 63.6%), while females represented a higher portion of confirmed cases (71 cases, 43.6%). Despite these differences, sex was not significantly linked to glaucoma status ($p = 0.52$), suggesting that sex is not a significant predictor of glaucoma diagnosis in this group. Most participants in all glaucoma categories were White (151 cases, 92.6%). There was no significant association between race and glaucoma status ($p = 0.41$).

Age significantly correlated with glaucoma ($p = 0.003$); confirmed cases rose with age, about 36.8% (60 cases) in ages 61–70 and 16.0% (26 cases) in ages 71–80. This trend suggests that older age markedly increases glaucoma risk (Refer to Table 2).

Table 2: Distribution of Glaucoma Status by Sex, Race, and Age Group

	Glaucoma status			
	Unlikely	**Suspect**	**Confirmed**	**p-value**
Sex				0.518
Male	77 (61.1%)	49 (63.6%)	92 (56.4%)	
Female	49 (38.9%)	28 (36.4%)	71 (43.6%)	
Race				0.413
White	121 (96.0%)	71 (92.2%)	151 (92.6%)	
Black	5 (4.0%)	6 (7.8%)	12 (7.4%)	
Age Group				0.003*
20-30	2 (1.6%)	1 (1.3%)	6 (3.7%)	
31-40	3 (2.4%)	2 (2.6%)	7 (4.3%)	
41-50	28 (22.2%)	13 (16.9%)	22 (13.5%)	
51-60	48 (38.1%)	38 (49.4%)	40 (24.5%)	
61-70	36 (28.6%)	19 (24.7%)	60 (36.8%)	
71-80	9 (7.1%)	3 (3.9%)	26 (16.0%)	
>80	0 (0.0%)	1 (1.3%)	2 (1.2%)	

$p < 0.05$ = Statistically significant (marked with *). Confirmed glaucoma cases had much higher average ranks for both right (117.14) and left (114.13) optic disc cups than suspect cases, with both differences highly significant ($p < 0.001$). This suggests a strong link between increased optic disc cupping and glaucoma severity (Table 3).

Table 3: Comparison of Optic Disc Cup and IOP Between Glaucoma Suspect and Confirmed Cases

Parameter	Glaucoma Status	N	Mean Rank	p-value
Right Optic Disc Cup	Suspect	66	67.99	<0.001*
	Confirmed	135	117.14	
	Total	201		
Left Optic Disc Cup	Suspect	64	68.86	<0.001 *
	Confirmed	134	114.13	
	Total	198		
Right IOP (Goldmann Applanation Tonometer)	Suspect	70	101.53	0.555
	Confirmed	139	106.75	
	Total	209		
Left IOP (Goldmann Applanation Tonometer)	Suspect	67	98.06	0.404
	Confirmed	138	105.40	
	Total	205		

* Statistically significant results ($p < 0.05$)

Mean IOP ranks measured by Goldmann Applanation Tonometer were slightly higher in confirmed glaucoma cases than suspects for both eyes, but differences were not statistically significant (Table 3).

Multinomial logistic regression showed that only left eye IOP significantly predicted glaucoma diagnosis (p = 0.003; OR: 1.18, 95% CI: 1.06–1.31), representing an 18.2% increase in odds per unit. (see Table 4).

Table 4: Multinomial Logistic Regression Findings

Category	Odds Ratio	95% CI Lower	95% CI Upper	p-value
Constant	0.02	0.003	0.16	<0.001*
Age	1.01	0.98	1.03	0.329
Gender	1.57	0.86	2.84	0.136
Race	2.06	0.54	7.74	0.285
Right Optic Disc Cup (REODcup)	1.00	0.99	1.002	0.962
Left Optic Disc Cup (LEODcup)	0.99	0.99	1.001	0.563
Right IOP (REIOP by Goldmann)	1.04	0.94	1.14	0.426
Left IOP (LEIOP by Goldmann)	1.18	1.06	1.31	0.003*

$p < 0.05$: Statistically significant (marked with *).

Older adults, particularly those aged 61–80 and above 80, show higher glaucoma rates of glaucoma, with narrow confidence intervals indicating strong statistical reliability. Elevated glaucoma rates are also associated with larger cup-to-disc ratios (0.71–1.0). In some groups, wider confidence intervals reflect greater variability in estimates. IOP over 30 mmHg is associated with an increased risk of glaucoma, but has more uncertainty (wider confidence intervals), whereas IOP in the range of 11–20 mmHg provides the most reliable estimates (see Figure 4).

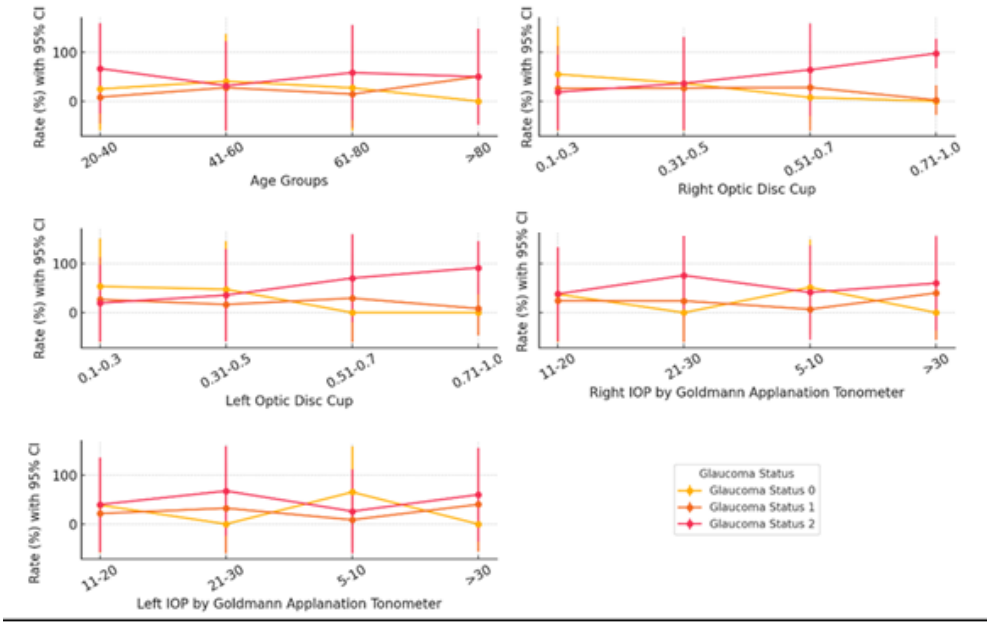

Figure 4: Categorical Risk Plot with 95% Confidence Intervals for Glaucoma Status.

Each subplot illustrates a single predictor variable: Age, Optic Disc Cup, and IOP.

The X-axis displays various categories of the predictor variable.

The Y-axis displays the percentage of individuals in each category corresponding to specific glaucoma statuses: 0 = No Glaucoma, 1 = Suspect, and 2 = Confirmed.

Lines with markers: Indicate the trend of glaucoma risk across categories.

Error bars (95% Confidence Interval (CI)): Represent the confidence level of the rate estimates

According to Model 1 of the binary logistic regression analysis (see Table 5), previous ocular inflammation increased the risk of developing glaucoma by fivefold (OR = 5.2, p = 0.008; 95% CI: 1.53–17.58). Additionally, individuals with a first-degree relative who had glaucoma have a doubled risk (OR = 2.08, p = 0.01; 95% CI: 1.14–3.78). Higher left-eye intraocular pressure (IOP) was another significant factor (OR = 1.10, p = 0.020; 95% CI: 1.02–1.20), where each unit increased in IOP raised the glaucoma risk by 10.3%.

Table 5: Binary Logistic Regression Results for Glaucoma Diagnosis (Model 1: the glaucoma diagnosis adjusted for Age, Gender, Race, Diabetes, Hypertension, Migraine, History of Eye Trauma, History of eye inflammation, Smoking, Ischemic Heart Disease, Family History of Glaucoma, Right Optic Disc Cup, Left Optic Disc Cup, Right IOP, Left IOP)

Variable	Odds Ratio	95% CI Lower	95% CI Upper	p-value
Constant	0.02	-	-	<0.001*
Age	1.02	0.99	1.05	0.07
Gender (Male)	1.83	0.99	3.39	0.05
Race (White)	1.66	0.57	4.78	0.34
Diabetes (Yes)	0.73	0.40	1.35	0.32
Hypertension (Yes)	0.67	0.34	1.31	0.24
Migraine (Yes)	0.87	0.43	1.75	0.70
History of Eye Trauma (Yes)	1.03	0.39	2.76	0.93
History of inflammation (Yes)	5.19	1.53	17.57	0.008*
Smoking (Yes)	1.21	0.49	2.97	0.67
Ischemic Heart Disease (Yes)	1.48	0.61	3.54	0.37
Family History of Glaucoma	-	-	-	-
Family History (Degree 1)	2.08	1.14	3.78	0.01*
Family History (Degree 2)	1.34	0.25	7.03	0.72
Right Optic Disc Cup	1.00	0.99	1.00	0.61
Left Optic Disc Cup	0.99	0.99	1.00	0.38
Right IOP	1.01	0.93	1.09	0.76
Left IOP	1.10	1.01	1.19	0.02*

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$p < 0.05$ indicates a statistically significant predictor (marked with *).

Model 2 (Table 6) indicated that males were 85.3% more likely than women to be diagnosed with glaucoma ($p = 0.02$, OR = 1.85). Additionally, a higher left eye IOP was also significantly associated with an increased risk of glaucoma ($p = 0.003$, OR = 1.09); for each unit rise in left eye IOP the risk grows by 9.7%.

Although age slightly increased the odds of developing glaucoma, this association was not statistically significant ($p = 0.154$, OR = 1.01, 95% CI: 0.99–1.04).

Table 6: Binary Logistic Regression Results for Glaucoma Diagnosis (Model 2: the glaucoma diagnosis adjusted for Age, Gender, Race, Right Optic Disc Cup, Left Optic Disc Cup, Right IOP, Left IOP)

Variable	Odds Ratio	95% CI Lower	95% CI Upper	p-value
Constant	0.03	-	-	<0.001*
Age	1.01	0.99	1.04	0.15
Gender (Male = 1)	1.85	1.07	3.20	0.02*
Race (Non-White = 1)	1.56	0.57	4.26	0.38
Right Optic Disc Cup	1.00	0.99	1.00	0.80
Left Optic Disc Cup	0.99	0.99	1.00	0.56
Right IOP	1.00	0.97	1.04	0.65
Left IOP	1.09	1.03	1.16	0.003*

$p < 0.05$ = Statistically significant (marked with *).

Model 3 (Table 7) showed that having a history of ocular inflammation significantly raised the risk of developing glaucoma (OR = 2.82, $p = 0.02$, 95% CI: 1.17–6.76).

Table 7: Binary Logistic Regression Results for Glaucoma Diagnosis (Model 3: History of Eye Trauma, History of Ocular Inflammation, Myopia)

Variable	Odds Ratio	95% CI Lower	95% CI Upper	p-value
Constant	0.66	-	-	0.00*
History of Eye Trauma (Yes)	1.19	0.61	2.32	0.60
History of ocular inflammation (Yes)	2.82	1.17	6.76	0.02*
Myopia (Yes)	1.21	0.79	1.84	0.36

$p < 0.05$ = Statistically significant (marked with *).

Table 8 provided a comprehensive summary of the findings from the three binary logistic regression models, highlighting the factors associated with glaucoma diagnosis.

Table 8: (Summary Table) Predictors of Glaucoma Diagnosis

Predictor	Model 1	Model 2	Model 3	Overall
Left Eye IOP	√	√	—	Strong Risk Factor
Ocular Inflammation	√	—	√	Strong Risk Factor
First-Degree Relative with Glaucoma	√	—	—	Risk Factor
Gender (Male)	X	√	—	Risk Factor
Age	X	X	—	No clear effect
Race	X	X	—	No clear effect
Right Eye IOP	X	X	—	No effect
Optic Disc Cupping	X	X	—	No effect
Eye Trauma	X	—	X	No effect

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Predictor	Model 1	Model 2	Model 3	Overall
Myopia	—	—	X	No effect
Other Medical Histories (Diabetes, HTN, Smoking, etc.)	X	—	—	No effect

√ Significant finding, X Not significant, — Not included in the model

4.DISCUSSION

The study identified a relatively high prevalence of glaucoma in adults screened in Benghazi, which was likely due to the inclusion of individuals at higher risk. Significant predictors included ocular inflammation, elevated left eye IOP, and family history of glaucoma.

The high prevalence observed in our cohort (44.5%) was substantially higher than population-based studies in the region (e.g., 0.97% in Bahrain, [13] 1.92% in Iran,[14] 1.3% in Egypt [15]). The higher prevalence in our study was likely due to the sampling method, a glaucoma screening program that recruits a pre-diagnosed or high-risk population via local media.

Our findings on a positive family history doubling the risk (OR= 2.08, p= 0.016) aligned with other studies, [11, 16,17] and established literature that underscores the genetic component of the disease. [18]

The strongest predictor identified was a history of ocular inflammation, which increased the odds of glaucoma diagnosis by more than fivefold (OR = 5.2). This supports prior research on uveitic glaucoma [19] and emphasizes the need for early IOP monitoring in all patients with a history of inflammatory conditions in Libya, as inflammation can lead to secondary glaucoma due to trabecular meshwork damage or obstruction. [19]

The finding that left eye IOP was a significant predictor (p=0.003) while the right eye IOP was not, suggests a possible inter-eye asymmetry. While increased IOP was a major, well-established risk factor, [11, 15] the lateralized finding in this cohort warrants further investigation. This asymmetry might be due to differences in measurement or subtle anatomical factors, but it remained a strong, localized indicator in the current study.

Age was a well-established risk factor for glaucoma, with prevalence increasing significantly in older adults. Neelan et al. [20] found that glaucoma became more common after age 60. Zhang et al., [21] in a meta-analysis, noted the highest glaucoma risk in those over 80. In this study, our categorical risk plots similarly indicated higher rates in the 61–80 and >80 age brackets, but regression analyses did not show age as a statistically significant predictor. This discrepancy could be due to a smaller sample of older participants or confounding variables.

Gender's association with glaucoma diagnosis was inconsistent. Males had higher odds of diagnosis (OR = 1.85, p = 0.02 in Model 2), but this was not uniform across models. Some studies report higher male prevalence,[13,14,21] while others find higher rated or incidence in females. [22,23] Several studies found minimal or no sex differences, [15, 24] implying possible population-specific genetic or hormonal influences.

Although prior studies had suggested a higher prevalence of glaucoma in non-White, especially Black and mixed-race, groups.[25,286] The geographic and demographic characteristics of our study— predominantly White populations- may explain why race was not a significant predictor in our analysis. The absence of a significant link between race and glaucoma could also result from the small proportion of Black participants (6.3%, or 23 individuals).

Myopia and eye trauma were not significantly linked to glaucoma risk in this study, unlike previous reports suggesting severe myopia and eye trauma increase such risk.[27,28] This difference may result from variability in myopia severity or trauma among subjects.

Descriptively, optic disc cupping correlated strongly with glaucoma severity ($p < 0.001$): confirmed cases had larger cupping than suspects, underscoring the diagnostic value of optic nerve head evaluation, as also shown by Quigley et al.[29] However, after adjustment in multinomial

logistic regression, optic disc cupping was not an independent predictor, possibly due to collinearity with IOP or age, or smaller numbers within subcategories.

This study found no significant association between systemic conditions (diabetes, hypertension, migraine, smoking, or ischemic heart disease) and glaucoma risk ($p > 0.05$ for all). Although some research tied diabetes and hypertension to glaucoma, likely due to vascular dysregulation, the discrepancy here may result from differences in disease severity or control. Supporting these findings, Torabi et al. [30] found no significant link between diabetes mellitus and glaucoma. Zhau et al. [31] reported a slightly higher glaucoma incidence in diabetics but no connection with DM duration. Langman et al. [32] identified hypertensions as more common in glaucoma patients and suggested β-blockers may offer some protection. Age and cardiovascular disease could independently influence glaucomatous neuropathy (Hayreh SS), [33] and a higher frequency of ischemic heart disease occurs in glaucoma cases (Chen et al.). [34] Despite previous suggestions, this study also found no smoking-glaucoma link, consistent with other studies. [35,35]

5.CONCLUSION

The high prevalence of glaucoma among adults in Benghazi was strongly associated with ocular inflammation, increased left-eye IOP, and family history. Policymakers and health care providers should use these findings to adopt more focused and effective screening methods. Screening should concentrate on older adults, those with a family history of glaucoma, and especially those who have had ocular inflammation. Directing resources toward these high-risk groups will improve early detection, support timely treatment, and help reduce preventable blindness in Libya.

This study had several limitations: Most participants were White or Libyan, which restricts the generalizability of the findings. The cross-sectional nature of the research means causality cannot be established. There was a risk of selection bias, as individuals who are more health-conscious may have been more likely to participate. Inconsistencies in the examiner's evaluations of IOP and optic disc could decrease the accuracy of the results. The small number of participants in the minority subgroup reduced statistical power, and not distinguishing glaucoma type limits the analysis of risk factors

The results highlighted the importance of targeted glaucoma screening for individuals with a history of ocular inflammation or glaucoma in their family. Including such an approach in community health initiatives may improve early diagnosis rates, decrease incidences of blindness, and guide policy decisions to better control glaucoma in Libya.

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