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Risk factors associated with elevated intraocular pressure: a population-based study in a rural community of Bangladesh

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ABSTRACT

Objective High intraocular pressure (IOP) is one of the major modifiable risk factors for glaucoma. The objective was to examine socio-demographic and clinical factors related to IOP.

Methods and analysis This study was conducted among 3097 adults residing in a rural area of Bangladesh, with all participants undergoing clinical and ophthalmological evaluations. The measurement of IOP was carried out using of a rebound Tonometer called Icare pro. Multiple logistic regression analysis was employed to identify variables associated to IOP levels of 21 mm Hg or above. Adjusted OR (aOR) and 95% CI were reported.

Results This study found that, in total, 9% of the study population had high IOP in one or both eyes. Elevated IOP was significantly associated with respondents who were service holders (aOR 2.52; 95% CI 1.48 to 4.31), had a lower education level (aOR 1.55, 95% CI 1.07 to 2.23), used biomass fuel (aOR 2.00; 95% CI 1.09 to 3.67), belonged to a higher socioeconomic position (aOR 1.55, 95% CI 1.07 to 2.23) and had obesity (aOR 2.00; 95% CI 1.07 to 3.73), hypertension (aOR 1.32; 95% CI 1.01 to 1.73) or history of diabetes (aOR 2.44; 95% CI 1.67 to 3.55), after adjusting for covariates including age, sex, marital status, light source and tobacco consumption, in a multiple regression analysis.

Conclusion Chronic diseases, such as hypertension and diabetes, obesity and sociodemographic characteristics such as high socioeconomic status and use of biomass fuels, have all been linked to elevated IOP. Patients with chronic diseases should undergo for IOP testing regularly.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Elevated intraocular pressure (IOP) is one of the major risk factors for developing primary open-angle glaucoma, accounting for 80% of glaucoma cases. A number of health-related factors are associated with elevated IOP, including older age, obesity, high blood pressure, diabetes and hyperglycaemia, and a family history of glaucoma.

WHAT THIS STUDY ADDS

⇒ Our study, which was done on a surveillance area, found that 9% of the participants had high IOP. In addition to chronic health conditions, such as hypertension, diabetes and obesity, sociodemographic characteristics, including high socioeconomic status, lower education level, being service holders and use of biomass fuels, are linked to elevated IOP.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Our study suggests that patients with chronic diseases and obese individuals should undergo regular IOP testing. Service holders should check their IOP regularly. There should be facilities for IOP screening at all levels of healthcare structures, including rural communities. In terms of sociodemographic factors, policies should be implemented to promote higher education, manage obesity and reduce the use of biomass fuels by transitioning to other environmentally friendly alternatives.

INTRODUCTION

High intraocular pressure (IOP) is one of the major risk factors of glaucoma, which has been recognised as the second leading cause of blindness worldwide.[1] Glaucoma is an irreversible condition characterised by progressive degeneration of retinal ganglion cells and their axons, resulting in changes in the appearance of the optic disc and visual field loss.[2] In 2020, approximately 80 million cases of glaucoma occurred worldwide, and it is estimated that the number of cases will reach 111.8 million in 2040.[3] Lowering IOP continues to be the only method to prevent development of glaucoma or reduce its progression rate.[4] The eye wall experiences an IOP higher than atmospheric pressure to prevent the collapse of the eyeball.[5] Elevated IOP is defined as more than 21 mm Hg (normal range 10–21 mm Hg)[6] and is a major risk factor for the development of primary open-angle glaucoma (POAG), which accounts for 80% of glaucoma cases.[7]

However, it is worth noting that most individuals with elevated IOP do not develop POAG, suggesting different aetiological mechanisms for these conditions.[8]

Empirical studies have suggested that several health-related factors are associated with elevated IOP, including older age, obesity, high blood pressure (BP), diabetes and hyperglycaemia, and family history of glaucoma.[9–12]

The magnitude of glaucoma cases worldwide presents a major challenge, particularly in developing countries,[13] as it has significant clinical implications and imposes an economic burden.[14] In response to this challenge, the WHO and the International Agency for the Prevention of Blindness launched 'Vision 2020: The Right to Sight', a programme for eye health which places significant emphasis on the prevention and treatment of glaucoma.[15] However, it is important to note that the reduction of IOP remains the only proven method of treating this disease.[2]

Eye-related diseases are among the leading causes of disability globally,[16] with 1 in 10 Bangladeshi aged ≥40 years experiencing blindness or low vision problems.[17] As mentioned earlier, raised IOP is one of the leading causes of glaucoma which is a primary cause of blindness,[1] yet there is a lack of studies examining the prevalence and risk factors of raised IOP in Bangladesh.

Clinical diagnosis of glaucoma at the community level can be challenging. Therefore, understanding the risk factors of raised IOP can aid in comprehending the burden of eye-related problems like glaucoma within the community. This study aimed to identify potential risk factors associated with elevated IOP in a rural Bangladeshi population.

MATERIALS AND METHODS

Study area and population

This population-based cross-sectional study was carried out in Tarail Upazila (subdistrict), Kishorganj, Bangladesh. Since 2014, the Ohdir Foundation, a national non-profit non-governmental organization, has been maintaining a population-based surveillance system in three unions (lower administrative units of Bangladesh), namely Tarail Sachail, Talganga and Rauti. A total of 91 723 inhabitants live in these areas, and every individual has a unique identification number. For this study, all adults aged 40 years and above who lived in Tarail Sachail union (total of 6683) and had no known medical history of chronic renal disease, liver disease, cardiovascular disease or cancer were included. Since no prevalence data on raised IOP are available in Bangladesh, we assumed a 50% prevalence in the elderly population, a degree of accuracy of 1.8%, a z-value of 1.96, and a non-response rate of 8%, and calculated a sample size of 3201. Ultimately, we received information from 3102 respondents, with a 3% non-response rate.

The data for this study were collected in November and December of 2018. A simple random sampling procedure was used to acquire samples, and a sampling frame consisted of the identification numbers of adults aged 40 and above in the study area. The Ohdir Foundation operates a day-care health clinic that primarily provides eye care to local community people. Using the identification numbers of the sampled population, our data collectors and local volunteers visited the respondents' households and invited them to attend the eye clinic on the following day at their convenience.

Data collection method

A semistructured questionnaire was used to collect information regarding participant sociodemographic variables, that is, age (years); sex (male or female); occupation (service holder engaged in official activities, day laborer-daily wage workers, homemakers, unemployed); educational attainment; marital status (currently in a marital relationship or others); height (in metre); weight (in kg); and clinical variables, that is, systolic BP (SBP) and diastolic BP (DBP), known history of diabetes mellitus (H/O DM) and IOP. Educational attainment was categorised as follows: no formal education, primary school level (up to grade V), secondary school level (grade VI–X), higher secondary level (grade XI–XII) and tertiary level, which included participants who had completed graduate education or above. Finally, educational attainment was grouped into two categories: non-formal to grade V, and grade VI and above.

In addition, we collected socioeconomic information such as the source of household light (non-smoke-producing sources such as electricity or smoke-producing source) and cooking fuel (clean fuel such as electricity, natural gas, or biogas or biomass fuel such as cow dung, wood, leaf, etc). We also assessed household assets, such as a table, chair, bed, almirah, watch, sewing machine, computer, electricity supply, refrigerator, television, radio, mobile phone, bicycle, motorcycle, washing machine, flash toilet and land phone.

We examined participants' ocular health, BP and other anthropometric measurements. The IOP of both eyes was measured in a sitting position using a rebound tonometer (Tonometer Icare pro, Icare Tokyo, Japan)[18] between 8:00 and 12:00 hours. An average of six IOP readings was taken for both eyes, and an ophthalmologist carefully managed the entire procedure.

Operational definitions

Elevated IOP

Ocular pressure is measured in millimetres of mercury (mm Hg). Normal ocular pressure varies from 12 to 21 mm Hg, while pressure greater than 21 mm Hg is considered abnormal. IOP>21 mm Hg in either the left or right eye, or both eyes, is called elevated IOP.[6]

Obesity

According to the WHO, overweight and obesity are defined as 'abnormal or excessive fat accumulation presenting a health risk'. A crude population measure of obesity is the body mass index (BMI), which is defined as weight (in kg) divided by height squared (in m). A

person with a BMI of >30 kg/m^2 is generally considered obese.[19]

Hypertension

Participants' BP was measured three times, with a 5 min interval between measurements, while they were seated with their right arm extended and slightly flexed. We used a digital BP machine (Omron, Kyoto, Japan) following the guidelines of the WHO. The last two readings were averaged for analysis. Hypertension was defined as having an SBP of 140 mm Hg or higher and/or a DBP of 90 mm Hg or higher and/or currently taking antihypertensive medication.[20]

Diabetes mellitus

DM refers to individuals who have a medical H/O DM and have previously been diagnosed by a licensed medical doctor.

Statistical analyses

Descriptive analysis was performed on participants' sociodemographic and other predictive factors. Frequencies and percentages were calculated as summary measures for the categorical variables, and the arithmetic mean and SD were used to describe the quantitative variables. The normality assumption was made by the Shapiro-Wilk test, and a p<5% was considered an asymmetric distribution. Principal component analysis (PCA) was adopted to construct a wealth index based on household assets. According to the wealth index, socioeconomic status (SES) was categorised as upper, middle and lower, considering the first factor of PCA. Pearson's correlation coefficient, r, was used to explore the association between IOP and age, SBP, DBP and BMI. Multiple logistic regression analysis was performed to estimate risk factors associated with elevated IOP. Considering IOP as the dependent variable, all independent variables from the univariate model—including age, sex, occupation, education, marital status, source of light, fuel type, H/O DM, hypertension, obesity, SES and tobacco consumption—were entered into the multiple regression model. ORs and 95% CI were calculated. A p<0.05 was considered significant. SPSS for Windows (IBM, V.22.0) was used for statistical analyses.

Patient and public involvement statement

It was not appropriate or possible to involve patients or the public in the design, or conduct, or reporting, or dissemination plans of our research.

RESULTS

Out of the 3097 participants, there was a nearly equal distribution of men and women, accounting for 52.1% and 47.9%, respectively. The mean (SD) age of the participants was 55.9 (12.1) years. The majority of participants were homemakers (44.8%) or day labourers (34.1%), and 79.5% had either no formal education or had completed up to grade 5. Electricity was the primary source of light for almost all participants (98.4%), and 39.3% reported having hypertension (see table 1).

About 9.0% of the participants had elevated IOP (>21 mm Hg) in one or both eyes. In hypertensive respondents, the prevalence of elevated IOP was 10.7%, whereas in normotensive respondents, this rate was 7.9%. Among the diabetic respondents, the prevalence of elevated IOP was 19.3%, while in non-diabetic respondents, it was 8.2%.

The mean (SD) IOP for the right eye was 14.8 (4.8) mm Hg (range 2–54) and for the left eye was 14.7 (4.5) mm Hg (range 2–57). The average (SD) IOP measurement for both eyes was 14.73 mm Hg (median, 14.0; range 2–57).

No statistically significant difference between elevated IOP and sex or age was seen in the univariate model. However, participant age showed a weak negative correlation with the IOP of both eyes (Pearson correlation, r: right eye, −0.071; left eye, −0.072; p<0.01). Conversely, a significant positive correlation was observed between IOP and SBP (r value: right eye, 0.123; left eye, 0.123; p<0.01) and DBP (r value: right eye, 0.155; left eye, 0.153; p<0.01).

The prevalence of hypertension in the elevated IOP group was 1.38-fold higher than that in the normal IOP group, and this was mirrored by a higher mean SBP (133.3 vs 129.6 mm Hg, respectively) and DBP (75.8 vs 73.4 mm Hg, respectively). Similarly, the prevalence of history of self-reported diabetes in the elevated IOP group (15.4%) was higher than that in the normal group (6.4%). Moreover, BMI also showed a positive correlation with IOP (r value: right eye, 0.164; left eye, 0.146; p<0.01) (table 2). The mean BMI of the elevated IOP group (23.0 kg/m^2) was significantly higher than that of the normal IOP group (21.8 kg/m^2).

Table 3 shows the multiple-adjusted model. Several socioeconomic factors, including service holder occupation (adjusted OR, aOR 2.56; 95% CI 1.50 to 4.37), lower education level (aOR 1.55, 95% CI 1.07 to 2.23), using biomass fuel (aOR 1.99; 95% CI 1.08 to 3.65) and higher SES (aOR 1.74; 95% CI 1.28 to 2.38) showed significant associations with elevated IOP. In addition, elevated IOP was also significantly associated with health factors such as obesity (aOR 2.02; 95% CI 1.08 to 3.79), diabetes (aOR 2.46; 95% CI 1.69 to 3.57) and hypertension (aOR 1.31; 95% CI 1.01 to 1.72).

DISCUSSION

In this study, we found that participants with diabetes were approximately 2.5 times more likely to develop elevated IOP. Additionally, participants with hypertension were found to have a 1.32 times higher risk of elevated IOP. Previous studies,[21 22] including those with a longitudinal study design,[7 23] reported diabetes and hypertension as risk factors for elevated IOP. The reasons for these associations are yet to be elucidated; however, different hypotheses have been proposed to explain the underlying mechanism for the relationship between

Table 1 Sociodemographic, behavioural and clinical characteristics of the participants (n=3097)

Variables	Frequency	Per cent
Sex		
Male	1615	52.1
Female	1482	47.9
Age (years)		
40–50	1649	53.2
51–60	642	20.7
61–70	542	17.5
≥71	264	7.5
Occupation		
Service	178	5.7
Day labourer	1055	34.1
Homemaker	1386	44.8
Unemployed	253	8.2
Business	225	7.3
Education		
Non-formal to grade V	2461	79.5
Grade VI and above	636	20.5
Marital status		
Married	2805	90.6
Other than marital status	292	9.4
Source of light		
Electricity	3047	98.4
Smoke-producing source	50	1.6
Fuel type		
Clean fuel	173	5.6
Biomass fuel	2924	94.4
H/O DM		
No	2875	92.8
Yes	222	7.2
Elevated IOP		
Right eye	208	6.7
Left eye	191	6.2
Either one or both eyes	280	9.0
Hypertension		
No	1880	60.7
Yes	1217	39.3
Obesity		
No	3022	97.6
Yes	75	2.4
SES		
Lower	1118	36.1
Middle	947	30.6
Upper	1032	33.3
Tobacco consumers (smoke and smokeless)		
No	963	31.1
Yes	2134	68.9
Passive smokers		
No	2418	78.1
Yes	679	21.9

Elevated intraocular pressure (IOP) = IOP > 21 mm Hg in either one or both eyes; Hypertension = Systolic BP ≥ 140 mm Hg and/or Diastolic BP ≥ 90 mm Hg and/or those who are currently receiving antihypertensive medication; Obesity= person with a BMI of > 30 kg/m^2; SES on wealth index through principal component analysis) H/O DM, history of diabetes mellitus; IOP, intraocular pressure; SES, socioeconomic status.

diabetes and IOP. One prominent hypothesis proposed that autonomic dysfunction might increase IOP during diabetic conditions.[24] Hypertension has been reported consistently as a risk factor for elevated IOP.[10] Moreover, it was postulated that BP and elevated IOP are driven by a common extrinsic factor, that is, increased sympathetic tone.[25]

In our study, people with obesity were twice as likely to develop elevated IOP. Obesity is also a common risk factor for chronic diseases such as hypertension and diabetes.[26] Therefore, the systemic factors causing elevated IOP are linked. This result is consistent with many cross-sectional and longitudinal studies where participants with obesity, typically represented by BMI, have experienced elevated IOP.[27 28] Obesity has been suspected of increasing IOP by excessive intraorbital adipose tissue, increases in blood viscosity, increased hyperleptinaemia-induced oxidative stress on the trabecular meshwork and outflow facilities and increases in episcleral venous pressure, causing a consequent decrease in the facility of aqueous outflow.[11]

A lower education level was found to be a significant factor related to elevated IOP, with an OR of 1.58. Our findings regarding the association between lower education levels and elevated IOP align with those of Yip *et*

Table 2 Correlation matrix

	Age	IOP (right eye)	IOP (left eye)	SBP	DBP	BMI
Age	1					
IOP (right eye)	0.07	1				
IOP (left eye)	0.07	0.72	1			
SBP	0.29	0.12	0.12	1		
DBP	0.06	0.15	0.15	0.67	1	
BMI	0.19	0.16	0.14	0.14	0.23	1

All p values of correlation coefficient (r) are highly significant (p<0.001).
BMI, body mass index; DBP, diastolic blood pressure; IOP, intraocular pressure; SBP, systolic blood pressure.

Table 3 Univariate and multiple logistic regression analysis of risk factors for elevated IOP

	IOP			
	Normal	Elevated	cOR (95% CI)	adjOR (95% CI)
Sex				
Female	1344 (47.7)	138 (49.3)	Ref	Ref
Male	1473 (52.3)	142 (50.7)	0.94 (0.73 to 1.2)	0.94 (0.46 to 1.93)
Age (year), mean (SD)	53.95 (11.96)	53.47 (11.94)	0.99 (0.99 to 1.01)	0.99 (0.98 to 1.00)
Occupation				
Day labourer	975 (34.6)	80 (28.6)	Ref	Ref
Business	207 (7.3)	18 (6.4)	1.06 (0.62 to 1.85)	0.99 (0.57 to 1.71)
Homemaker	1260 (44.7)	126 (45.0)	1.22 (0.91 to 1.63)	1.02 (0.48 to 2.19)
Unemployed	224 (8.0)	29 (10.4)	1.58 (1.01 to 2.47)	1.44 (0.84 to 2.46)
Service holder	151 (5.4)	27 (9.6)	2.18 (1.36 to 3.48)†	2.56 (1.50 to 4.37)†
Education				
Grade VI and above	2235 (79.3)	226 (80.7)	Ref.	Ref
Non-formal to grade V	438 (20.7)	38 (19.3)	1.09 (0 to 0.79)	1.58 (1.09 to 2.27)*
Marital status				
Married	2555 (90.7)	250 (89.3)	Ref	Ref
Other marital status	262 (9.3)	30 (10.7)	1.17 (0.79 to 1.75)	1.04 (0.67 to 1.60)
Source of light				
Electricity	2769 (98.3)	278 (99.3)	Ref	Ref
Smoke-producing source	48 (1.7)	2 (0.7)	0.42 (0.10 to 1.72)	0.39 (0.09 to 1.64)
Fuel type				
Clean fuel	159 (5.6)	14 (5.0)	Ref	Ref
Biomass fuel	2658 (94.4)	266 (95.0)	1.14 (0.65 to 1.99)	1.99 (1.08 to 3.65)*
H/O DM				
No	2638 (93.6)	237 (84.6)	Ref	Ref
Yes	179 (6.4)	43 (15.4)	2.67 (1.87 to 3.83)†	2.46 (1.69 to 3.57)†
Hypertension				
Normotensive	1730 (61.4)	150 (53.6)	Ref	
Hypertensive	1087 (38.6)	130 (46.4)	1.38 (1.08 to 1.77)*	1.31 (1.00 to 1.72)*
Obesity				
No	2755 (97.8)	267 (95.4)	Ref	Ref
Yes	62 (2.2)	13 (4.6)	2.16 (1.17 to 3.98)*	2.02 (1.08 to 3.79)*
SES				
Lower	1034 (36.7)	84 (30.0)	Ref	Ref
Middle	872 (31.0)	75 (26.8)	1.06 (0.77 to 1.46)	1.13 (0.81 to 1.57)
Upper	911 (32.3)	121 (43.2)	1.64 (1.22 to 2.19)†	1.74 (1.28 to 2.38)†
Tobacco consumers (smoke and smokeless)				
No	867 (30.8)	96 (34.3)	Ref	Ref
Yes	1950 (69.2)	184 (65.7)	0.85 (0.66 to 1.11)	0.87 (0.66 to 1.13)

Figure within parenthesis denotes column percentage if not otherwise mentioned.
*p<0.05.
†p<0.001.
adjOR, adjusted OR; cOR, crude OR; H/O DM, history of diabetes mellitus; IOP, intraocular pressure; Ref, Reference; SES, socioeconomic status.

al.[29] It is possible that individuals with higher education levels are more informed about eye problems.[30] However, in contrast, our study identified higher SES and being a service holder as risk factors for elevated IOP. Notably, in our study, the majority of service holders belonged to the higher SES. Higher SES has been linked to obesity,[31] an established risk factor for elevated IOP. However, in contrast to our finding, Yip *et al*[29] found a relationship between raised IOP and low SES. So, this suggests further investigation to explore whether high SES plays any significant role in raised IOP. In our study, we selected respondents from a rural area. The SES of this particular group might not represent the broader economic stratum of the entire country. Therefore, the association found in our study between higher SES and an increased risk of elevated IOP might be coincidental.

Biomass-fuel users were found to be twice as likely to develop elevated IOP as clean-fuel users. In line with our findings, a previous study reported that ambient air pollution was a risk factor for elevated IOP.[32] One study revealed that using biomass fuels for cooking can led to cataract among young adults of Bangladesh.[33] Another recent study conducted in Nepal found that women who were biomass-fuel users experienced more eye-related symptoms (including redness, burning sensation, grittiness, photophobia, and pain and tearing), than women who were clean-fuel users.[34]

Age has a variable effect on IOP. In the current study, we found a weak negative correlation of age with IOP (Pearson correlation, r: right eye, −0.071; left eye, −0.072; p<0.01), which is similar to the results of most studies conducted in Asian countries.[21 35 36] Conversely, studies conducted among Europeans and Americans, both cross-sectional and longitudinal, reported that IOP increased with age.[9 37 38] The only modifiable risk factor of glaucoma has been identified as increased IOP and lowering IOP to prevent glaucoma progression has become the cornerstone of glaucoma management. A growing body of evidence suggests that IOP is a primary indicator of OAG diagnosis.

In this study, we found no association between tobacco consumption and elevated IOP. However, the high prevalence of tobacco consumption among study respondents, at 68.9%, is concerning due to its implications for various non-communicable diseases. Our findings are consistent with the 2018 STEPS survey,[39] which reported tobacco consumption rates of 59% for the 40–54 age group and 68% for the 55–69 age group among the Bangladeshi population.

To our knowledge, this study is one of the first to reveal factors related to elevated IOP in the Bangladeshi population. A major strength of our study is that we collected samples from a rural NCD-based surveillance area. However, sensitivity and specificity of the tonometer in diagnosing OAG vary according to type and are not significantly reliable in deciding whether to treat or change treatment in a clinical setting. Specially, in a community setting, other diagnostic tools such as ophthalmoscopy, gonioscopy, pachymetry, visual field testing and optic nerve scanning are difficult to set up in the Bangladeshi context. Tonometry, on the other hand, should be considered as a tool for mass screening. Additionally, self-reported DM is one of the limitations of our study, as we are unable to do laboratory diagnosis of DM but we took the self-reported DM who were physician diagnosed. However, these types of data can suggest future directions for risk-factor analysis. Therefore, a further nationwide study is recommended to determine the normal range of IOP in Bangladesh.

Chronic diseases such as hypertension and diabetes, and obesity, as well as sociodemographic factors, including high SES and biomass fuel use, are significantly associated with elevated IOP. These positive associations should be further evaluated in a nationwide survey. In addition, IOP should be measured routinely in light of its relationship to these common chronic diseases and factors.

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