ORIGINAL RESEARCH ARTICLE

Prevalence and Predictors of Diabetic Retinopathy: A Community-Based Study in North India Among Type 2 Diabetes Patients

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ABSTRACT

Background: Between 1970-1975, DR was the 20th cause of blindness, and today, it is the 6th most common cause of blindness in India. This study aimed to estimate the prevalence of DR among type 2 diabetes patients and identify associated socio-demographic determinants.

Methods: Total of 316 type 2 diabetics patients through systematic random sampling were enrolled. Fundus examination was performed using Volk iNview iPhone fundus camera following ETDRS protocol. Data on demographics, anthropometric measurements, and clinical parameters were collected. Statistical analysis included chi-square tests and logistic regression to identify the risk factors.

Results: Prevalence of any grade of DR was 35.4% (95% CI: 30%-41.5%) which included mild non-proliferative (15.5%), moderate non-proliferative (11.7%), severe non-proliferative (3.8%), proliferative (1.6%), and diabetic macular edema (2.8%). Multivariate analysis identified significant independent risk factors: age >60 years (adjusted OR=1.11), diabetes duration >5 years (adjusted OR=1.20), uncontrolled glycemia (adjusted OR=2.25), hypertension (adjusted OR=1.04), previous cataract surgery (adjusted OR=1.76), and overweight/obesity (adjusted OR=1.202).

Conclusion: Predominance of early-stage disease highlights the opportunity for early intervention through community-based screening initiatives. The findings emphasize the importance of integrated diabetes management addressing multiple risk domains, particularly glycemic control, blood pressure management, and weight optimization, for effective DR prevention and management.

Keywords: Diabetic retinopathy, Prevalence, Risk factors, Diabetes mellitus, Fundus photo

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Introduction

Diabetes mellitus, or simply diabetes, is a serious, chronic disease that results when there are raised blood glucose levels, either because body is unable to produce any or enough of the hormone insulin, or cannot effectively utilize the insulin it produces.[1] Diabetes is one of the fastest growing health conditions of the our 21st Century. In the year 2000, the estimated prevalence of diabetes globally was 151 million. Since then, the prevalence has increased at an alarming rate. In 2019, as per the estimate, 463 million people in age group of 20-79 years had diabetes (9.3% of all adults in this age group). A little over three-fourth (79.4%) of these live in low and middle-income countries (LMICs) such as India. This number is projected to reach 578 million (10.2% prevalence) by 2030, and 700 million (10.9% prevalence) by 2045.[2] As of 2019, India was home to 77 million (8.9% prevalence) people with diabetes which is second highest in the world after China. This is number is expected to rise steeply to 101 million by 2030 and to 134.2 million by 2045.[3]

Type II diabetes particularly is a major public health concern worldwide. Type 2 diabetes has an insidious onset and it may be completely symptomless. As a result, there is often a long pre-diagnostic period and when unrecognized for a long time, its complications such as diabetic retinopathy or a lower-limb ulcers may be present at diagnosis itself.[4]

Diabetic eye disease (DED) is a much-feared complication of diabetes, consisting predominantly of diabetic retinopathy (DR), diabetic macular oedema (DMO), cataract and glaucoma, but also diplopia and inability to focus. Retinal manifestations of DED are common and particularly debilitating. Diabetic retinopathy (DR) is the fifth leading cause of visual impairment and the fourth leading cause of blindness in the world.[5] In India, with the epidemic rise in type 2 diabetes patients, diabetic retinopathy is fast becoming an important cause of visual impairment. Between 1970-1975, DR was the 20th cause of blindness, and today, it is the 6th most common cause of blindness in the country.[6]

While studies on Diabetic Retinopathy in India have been conducted, there seems to be dearth of literature from the northern part of the country. Thus, the present study to estimate prevalence of Diabetic Retinopathy (DR) and its determinants conducted in Aligarh district of Uttar Pradesh, seeks to fill literature gap on this subject from the northern part of the country and to explore the geographical variation in findings if any.

Methodology

Study Design and Setting: This community-based cross-sectional study was conducted in rural and peri-urban areas of Aligarh, UP India between 2020 and 2021. Population in field practice areas of rural health training centre (RHTC) and urban health training centres (UHTC) under department of community medicine, Jawaharlal Nehru Medical College, AMU, Aligarh along with population covered under CHC, Harduaganj, and CHC, Jawan, Aligarh, UP was chosen for the study.

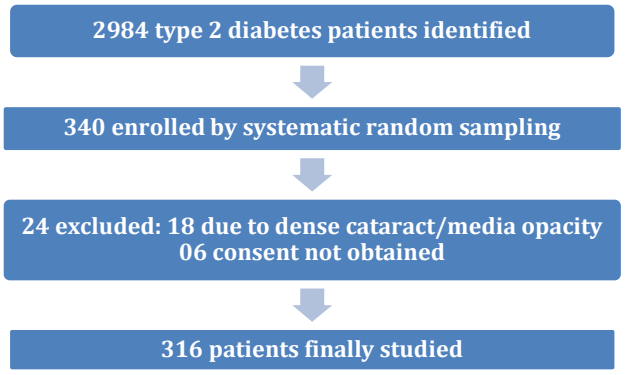
Study Population and Sampling: The study population consisted of individuals diagnosed with Type 2 Diabetes Mellitus. For field practice areas, the list of type II DM patients was prepared with the help of updated data available with Medical Social Workers (MSWs) of respective areas. For areas under CHCs, the list was obtained from non-communicable diseases (NCD) register obtained from NCD clinic. A line listing of patients was then done and patients were recruited in the study by means systematic random sampling. PPS was employed to ensure recruitment of representative sample from all areas. The selected patients were approached at home for data collection.

Sample Size: The sample size was calculated based on previous research by Raman et al. (2010), which estimated the prevalence of diabetic retinopathy among diabetics to be 26.35%.[7] Using this prevalence rate with an absolute error of 5% and a 95% confidence interval (CI), the minimum required sample size was determined to be 298 participants, calculated using the formula:

$$n = Z_{(1-\alpha/2)}^2 \times P \times (1-P)/l^2$$
$$n=311$$

Where n represents the required sample size, $Z_{1-a/2}$ corresponds to the level of significance (1.96 for 95% CI), P is the expected prevalence (26.35%)[7], and l denotes the absolute error or precision (5%). Accounting for a potential 10% non-response rate, the final target sample size was established at 340 participants.

Inclusion and Exclusion Criteria: Patients with Type 2 Diabetes Mellitus from the aforementioned areas who provided informed consent were included in the study. Exclusion criteria comprised patients with dense cataracts or other ocular diseases causing media opacity that would interfere with fundus examination, and those who declined to participate in the study.



Flowchart of the enrolment procedure

Study Tools and Measurements: A comprehensive set of study tools was utilized to collect data. Ophthalmic examination was conducted using a Volk iNview Fundus Camera and Direct Ophthalmoscope, with mydriatic eye drops employed for pupillary dilatation. Data collection was facilitated through a semi-structured questionnaire. Anthropometric measurements were obtained using a digital weighing machine (Rylan), a metallic measuring tape for height measurement, and a fiber measuring tape for waist circumference assessment. Blood pressure was measured using a Dial Deluxe Blood Pressure Apparatus, while blood glucose levels were assessed using a glucometer.

Retinal Examination: Currently, the gold standard for detection of diabetic retinopathy is 30°color stereoscopic photography of 7-standard fields, which was developed for the Early Treatment Diabetic Retinopathy Study (ETDRS) classification of Diabetic Retinopathy.[8] The same method was followed in our study. Distant Direct Ophthalmoscopy (DDO) was performed to look for clarity of the media.

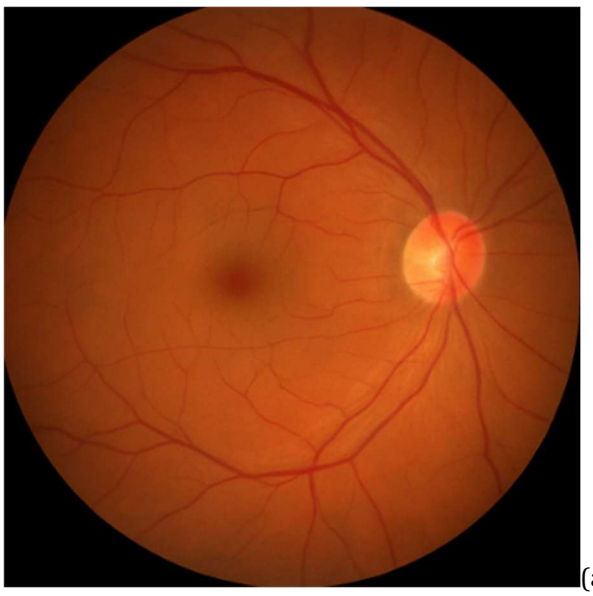
Retinal Photography protocol: Both eyes of all the patients was dilated with 1% tropicamide hydrochloride eye drops. After the pupil got mid-dilated, retinal photography was performed with Volk iNview Iphone fundus camera. Non-stereoscopic, 30° images of the fundus were taken in the seven retinal fields as per the ETDRS protocol.[8] The description of the seven fields is as follows: Field 1 with optic disc at the centre, field 2 with macula centred and nasal end passing through the optic disc, field 3 was temporal to the macula with the nasal end passing through the macula, fields 4-7 were tangential to the horizontal lines passing through the upper and lower poles of the disc and to a vertical line passing through its center. (Figure 1)

Two independent Ophthalmologists graded the severity of Diabetic Retinopathy as per the ETDRS classification based on the fundus photo. The Interobserver reliability of the two grading was checked using Cohen's Kappa which yielded a coefficient of 0.79 which is a 'substantial agreement'. In cases, where the two gradings did not match, the patients were given the worst of two gradings.

Ethical Considerations: The study protocol received approval from the institutional ethics committee (IEC/JNMC/241) dated 11th May 2019, and written informed consent was obtained from all participants prior to enrolment. Patient confidentiality was maintained throughout the study process, and all procedures adhered to the ethical standards.

Data Management and Statistical Analysis: All collected data were entered into MS Excel (2010) following thorough verification and validation. The data was imported to IBM SPSS version 20.0 software for analyses. Categorical variables are presented as frequencies and percentages, and continuous variables as means with standard deviations. The prevalence of diabetic retinopathy was calculated with 95% confidence intervals, and associations with various risk factors were assessed using appropriate statistical tests with a significance level set at $p<0.05$. For categorical outcomes Chi square test or Fisher exact test as applicable was used. Univariate and Multivariate binary logistic regression used to study independent predictors of diabetic retinopathy.

We utilized 'Enter' method for building the multivariate logistic regression model. All variables included in the final model were adjusted for age-group, gender, residence, hypertension, family history of diabetes, glycemic control, duration of diabetes, and BMI. We assessed the goodness-of-fit using the Hosmer-Lemeshow test. The p-value (0.49) obtained indicated that the model fit the data adequately. Multicollinearity among predictor variables was evaluated using Variance Inflation Factor (VIF). All values of VIF were <10 suggesting no significant multicollinearity.


(a)

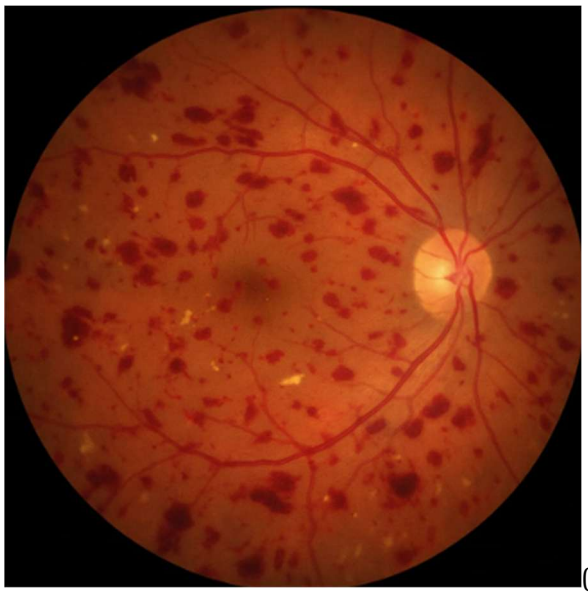

(b)

Figure 1: a) Image from a patient with normal fundus; b) Image from a patient with diabetic retinopathy changes (Haemorrhages, hard exudates).

RESULTS

A total of 325 patients were interviewed and examined of which 316 proformas were considered complete for analysis.

Sociodemographic Profile of Participants: Of the 316 participants with Type 2 Diabetes Mellitus, majority were in the age group of 41-60 years (221 participants, 69.9%). The majority of participants were over 40 years old, with 25.3% (80 individuals) being over 60 years of age and only 4.7% (15 individuals) aged 40 or younger. With regards to gender distribution, 212 participants were females (67.1%) compared to 104 males (32.9%).

The geographical distribution was nearly balanced, with 161 participants (50.9%) from rural areas and 155 participants (49.1%) from peri-urban regions. Religious composition was evenly split, with 159 Muslim participants (50.3%) and 157 Hindu participants (49.7%). Dietary habits revealed that more participants in this study were on non-vegetarian diets, with 202 participants (63.9%) following a non-vegetarian diet compared to 114 vegetarians (36.1%).

Educational status showed a notable pattern of low literacy, with 95 participants (30.1%) being illiterate and another 95 participants (30.1%) having only primary school education. Only a small fraction possessed higher education, with 8 participants (2.5%) having professional or honors degrees and 11 participants (3.5%) being graduates or post-graduates.

Socioeconomic stratification using the Modified BG Prasad Classification (2024 update) revealed a concentration in the lower economic classes. The majority of participants (54.4%, 172 individuals) belonged to Class IV, followed by Class III with 20.9% (66 participants). Only 1.9% (6 participants) were classified in the highest socioeconomic Class I.

Prevalence of Diabetic Retinopathy: The prevalence of any grade of Diabetic Retinopathy in one or both the eyes in our study participants was found to be 35.4% (95% Confidence Interval; 30%-41.5%). [Figure 2]

Severity of Diabetic Retinopathy: The diabetic retinopathy assessment showed a significant variation in disease progression. The majority of participants, 204 (64.6% with 95% CI of 59.2-69.6%), demonstrated no apparent diabetic retinopathy. Mild non-proliferative diabetic retinopathy was observed in 49 participants (15.5% with 95% CI of 11.7-19.6%), while moderate non-proliferative diabetic retinopathy was found in 37 participants (11.7% with 95% CI of 8.2-15.5%).

More advanced stages of the disease were less prevalent. Severe non-proliferative diabetic retinopathy was detected in 12 participants (3.8% with 95% CI of 1.6-6.0%), while proliferative diabetic retinopathy was the least common, affecting only 5 participants (1.6% with 95% CI of 0.5-3.2). Diabetic macular edema was observed in 9 participants (2.8% with 95% CI of 1.3-4.7%). [Table 2]

Table 1: Sociodemographic Profile of Participants

Variable	Participants (%)
Age-group (in years)	
≤40	15 (4.7)
41-60	221 (69.9)
>60	80 (25.3)
Gender	
Male	104 (32.9)
Female	212 (67.1)
Address	
Rural	161 (50.9)
Peri-urban	155 (49.1)
Religion	
Islam (Muslim)	159 (50.3)
Hinduism (Hindu)	157 (49.7)
Dietary habit	
Vegetarian	114 (36.1)
Non-vegetarian	202 (63.9)
Education	
Professional/Honors	8 (2.5)
Graduate/Post-Graduate	11 (3.5)
Intermediate/Post high school diploma	13 (4.1)
High school	16 (5.1)
Middle school	43 (13.6)
Primary school/Literate	95 (30.1)
Illiterate	95 (30.1)
Profession	
Professional	7 (2.2)
Semi-professional	7 (2.2)
Clerical/Shop owner/Farmer	9 (2.8)
Skilled worker	28 (8.9)
Semi-skilled worker	31 (9.8)
Unskilled worker	43 (13.6)
Unemployed	191 (60.9)
Socio-economic status (Modified BG Prasad, Update-2024)	
CLASS I	6 (1.9)
CLASS II	56 (17.7)
CLASS III	66 (20.9)
CLASS IV	172 (54.4)
CLASS V	16 (5.1)

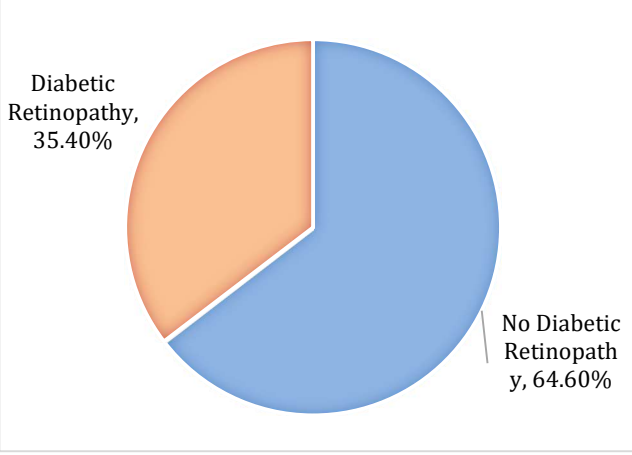


Figure 2: Prevalence of Diabetic Retinopathy

Table 2: Severity of Diabetic Retinopathy

Grade	Cases (%)	95%CI
No Apparent Diabetic retinopathy	204 (64.6)	59.2-69.6
Mild Non-proliferative Diabetic Retinopathy	49 (15.5)	11.7-19.6
Moderate Non-proliferative Diabetic Retinopathy	37 (11.7)	8.2-15.5
Severe Non-proliferative Diabetic Retinopathy	12 (3.8)	1.6-6.0
Proliferative Diabetic Retinopathy	5 (1.6)	3.2
Diabetic Macular Edema	9 (2.8)	1.3-4.7

Table 3: Association of Diabetes with Putative Risk Factors

Variable	Diabetic Retinopathy (DR)		Total	Significance (p value)
	Any DR	DR Absent		
Age group				
≤4o years	1 (6.7)	14 (93.3)	15	0.001
41-60 years	71 (32.1)	150 (67.9)	221	
>60 years	40 (50)	40 (50)	80	
Gender				
Male	34 (32.7)	70 (67.3)	104	0.474
Female	78 (36.8)	134 (63.2)	212	
Residence				
Rural	63 (39.1)	98 (68.9)	161	0.163
Peri-urban	49 (31.6)	106 (68.4)	155	
Hypertension				
Yes	66 (40.5)	97 (59.5)	163	0.05
No	46 (30.1)	107 (69.9)	153	
History of Cataract Surgery				
Yes	28 (51.9)	26 (48.1)	54	0.006
No	84 (32.1)	178 (67.9)	262	
Family history of Diabetes				
Yes	35 (43.8)	45 (56.8)	80	0.073
No	77 (32.6)	159 (67.4)	236	
Glycaemic control				
Controlled	61 (35.5)	111 (64.5)	172	<0.001
Uncontrolled	42 (48.3)	45 (51.7)	87	
Duration of Diabetes Mellitus				
Newly Diagnosed (< 3 months)	9 (15.8)	48 (84.2)	57	<0.001
< 5years	54 (30.2)	125 (69.8)	179	
5-10 years	20 (50.0)	20 (50.0)	40	
10-15 years	17 (85.0)	3 (15.0)	20	
>15 years	12 (60.0)	8 (40.0)	20	
BMI				
Underweight	0 (0.0)	10 (100)	10	<0.001
Normal	45 (25.6)	131 (74.4)	176	
Overweight	55 (47.8)	60 (52.2)	115	
Obesity	12 (80)	3 (20.0)	15	

Association of Diabetes with Putative Risk Factors: The association with putative risk factors is shown in table 3. The analysis of risk factors revealed several statistically significant associations with diabetic retinopathy. Age emerged as a critical factor, with a statistically significant relationship (p=0.001). While only 6.7% of participants under 40 years showed diabetic retinopathy, this increased markedly to 32.1% in the 41-60 age group and was 50% in participants over 60 years.

Gender did not show a statistically significant association (p=0.474), with minimal difference between male (32.7%) and female (36.8%) participants. Residence also did not demonstrate a significant association (p=0.163), with rural (39.1%) and peri-urban (31.6%) areas showing similar rates.

Hypertension showed considerable difference with 40.5% of hypertensive participants developing diabetic retinopathy compared to 30.1% of non-hypertensive individuals (p=0.05). A history of cataract surgery revealed a significant association (p=0.006), with 51.9% of those with previous cataract surgery developing diabetic retinopathy.

Family history of diabetes showed marked difference (p=0.073), with 43.8% of participants with a family history of diabetes developing diabetic retinopathy compared to 32.6% without such history. Glycemic control showed a significant association (p<0.046), with 48.3% of uncontrolled diabetic patients developing retinopathy versus 35.5% of those with controlled diabetes.

The duration of diabetes was strongly associated with diabetic retinopathy (p<0.001). Newly diagnosed patients (less than 3 months) showed only

15.8% retinopathy, which progressively increased with disease duration. Notably, participants with 10-15 years of diabetes showed the highest rate of retinopathy at 85%, perhaps highlighting the cumulative impact of long-standing diabetes on retinal health.

It was observed that the prevalence of diabetic retinopathy increased with increasing BMI. Out of the total 10 underweight patients, none showed evidence of diabetic retinopathy. Retinopathy was present in 45 (25.6%) of 176 normal BMI patients, in 55 (47.8%) of 115 overweight patients and in 12 (80%) of 15 obese patients.

Regression Analysis of Risk Factors for Diabetic Retinopathy: Table 4 presents the results of both univariate and multivariate logistic regression analyses examining potential risk predictors for diabetic retinopathy among the study participants.

The analysis demonstrates a clear age-related increase in diabetic retinopathy risk. Using patients aged 40 years and younger as the reference group, the study found that middle-aged patients (41-60 years) had a significantly elevated risk in the adjusted analysis, with an odds ratio of 5.92 (95% CI: 3.01-9.54, p=0.04). The risk becomes even more pronounced in patients over 60 years, who showed the highest risk with an adjusted odds ratio of 11.76 (95% CI: 1.89-103.42, p=0.036). However, the wide confidence interval suggests some uncertainty in the precise magnitude of this effect. Gender did not demonstrate a significant association with diabetic retinopathy in either the univariate (crude OR=0.83, 95% CI: 0.51-1.37, p=0.474) or multivariate analysis (adjusted OR=0.91, 95% CI: 0.72-1.23, p=0.543), suggesting that biological sex may not be an independent determinant of retinopathy risk in this population. Similarly, residential status (rural versus peri-urban) showed no statistically significant relationship in either analytical approach, though there was a trend toward higher risk in rural residents (crude OR=1.39, 95% CI: 0.87-2.21, p=0.163; adjusted OR=1.28, 95% CI: 0.92-1.47, p=0.245).

Hypertension demonstrated borderline significance in the univariate analysis (crude OR=1.58, 95% CI: 0.99-2.52, p=0.060), but emerged as a statistically significant independent predictor in the multivariate model (adjusted OR=1.04, 95% CI: 1.006-1.070, p=0.020).

A history of cataract surgery exhibited one of the strongest associations with diabetic retinopathy in both univariate (crude OR=2.28, 95% CI: 1.26-4.13, p=0.006) and multivariate analyses (adjusted OR=1.76, 95% CI: 1.10-3.16, p=0.040).

Family history of diabetes demonstrated borderline significance in the univariate analysis (crude OR=1.61, 95% CI: 0.956-2.70, p=0.070) but after adjustment, there was no significant difference (adjusted OR=0.84, 95% CI: 0.40-1.79, p=0.656), suggesting that its apparent effect might be mediated through other variables included in the multivariate model.

Table 4: Univariate and Multivariate Regression Analysis for Risk Predictors of Diabetic Retinopathy

Variable	Crude OR (95% CI)	P Value	Adjusted OR (95% CI)	P Value
Age Group				
≤ 4o years	Ref.	---	Ref.	---
41-60 years	6.62 (0.85-51.39)	0.07	5.92 (3.01-9.54)	0.04
>60 years	14.0 (1.76-111.56)	0.013	11.76 (1.89-103.42)	0.036
Gender				
Male	0.83 (0.51-1.37)	0.474	0.91 ().72-1.23)	0.543
Female	Ref	--	Ref	--
Residence				
Rural	1.39 (0.87-2.21)	0.163	1.28 (0.92-1.47)	0.245
Peri-urban	Ref	---	Ref	---
Hypertension				
Yes	1.58 (0.99-2.52)	0.060)	1.04 (1.006-1.070)	0.020)
No	Ref	---	Ref	---
H/O Cataract Surgery				
Yes	2.28 (1.26-4.13)	0.006	1.76 (1.10-3.16)	0.040
No	Ref	---	Ref	---
Family h/o Diabetes				
Yes	1.61 (0.956-2.70)	0.070)	0.84 (0.40- 1.79)	0.656
No	Ref	---	Ref	---
Glycemic Control				
Controlled	Ref	---	Ref	---
Uncontrolled	1.698 (1.01-2.87)	0.048	2.25 (1.66-5.34)	0.001
Duration of Diabetes				
< 5 years	Ref	---	Ref	---
> 5 years	3.66 (2.12-6.35)	<0.001	3.95 (2.61-11.59)	0.001
BMI				
Normal	Ref	---	Ref	---
Underweight	0.14 (0.01-2.40)	0.174	0.17 (0.08-1.2.21)	0.231
Overweight/Obese	3.09 (1.91-5.02)	<0.001	3.95 (2.08-4.89)	0.001

Glycemic control emerged as a critical determinant of diabetic retinopathy risk. Uncontrolled diabetes was associated with significantly higher odds of retinopathy in the univariate analysis (crude OR=1.698, 95% CI: 1.01-2.87, p=0.048), with the effect magnitude substantially increasing in the multivariate model (adjusted OR=2.25, 95% CI: 1.66-5.34, p=0.001).

The duration of diabetes emerged as one of the most robust predictors of diabetic retinopathy development. Patients with diabetes for more than five years showed consistently elevated risk in both crude and adjusted analyses. The adjusted odds ratio of 3.95 (95% CI: 2.61-11.59, p<0.001) indicates that patients with longer diabetes duration have nearly four times higher odds of developing diabetic retinopathy compared to those with shorter disease duration. The significant p-value (p<0.001) underscores the strength and reliability of this association, making diabetes duration a key clinical marker for risk stratification. The relationship between body mass index and diabetic retinopathy risk showed a notable pattern. While underweight patients demonstrated a protective trend with an adjusted odds ratio of 0.17 (95% CI: 0.08-1.21), this association was not statistically significant (p=0.231). In contrast, overweight and obese patients showed a significantly elevated risk, with an adjusted odds ratio of 3.95 (95% CI: 2.08-4.89, p<0.001). This nearly four-fold increase in odds suggests that excess body weight represents an important modifiable risk factor for diabetic retinopathy development.

Discussion

This community-based cross-sectional study conducted in rural and peri-urban areas of Aligarh provides important insights into the epidemiology of diabetic retinopathy (DR) and its associated risk factors among Type 2 Diabetes Mellitus (T2DM) patients. The higher representation of participants aged 41-60 years (69.9%) reflects the typical age distribution of T2DM in developing countries, where the disease tends to manifest earlier than in Western populations.[9]

The socioeconomic profile of our participants- predominantly from lower socioeconomic classes with limited formal education highlights the penetration of T2DM across socioeconomic strata in India, contradicting its historical perception as a "disease of affluence."[10]

The study revealed a prevalence of 35.4% (95% CI: 30%-41.5%) for any grade of diabetic retinopathy, which aligns with but is slightly higher than the prevalence of 26.35% reported by Narendran et al.[7] However, a systematic review Brar et al[11] reported a pooled prevalence of 16.10% (95% CI: 13.16-24.32). Another study by Raman et al[12] estimated a national prevalence of 12·5% (95% CI, 11·0-14·2). This variation may reflect regional differences in healthcare access, diabetes management, and screening practices, as well as potential socio-demographic differences between study populations.

The severity distribution of diabetic retinopathy in our study population demonstrated a predominance of early-stage disease, with mild non-proliferative diabetic retinopathy (NPDR) accounting for 15.5% of cases and moderate NPDR comprising 11.7%. The more advanced forms severe NPDR and proliferative diabetic retinopathy (PDR) were less common at 3.8% and 1.6% respectively, with diabetic macular edema present in 2.8% of participants. This pattern is consistent with findings from other community-based studies in developing countries and suggests an opportunity for early intervention to prevent progression to vision-threatening stages of retinopathy.[13]

The relatively low prevalence of PDR in our study (1.6%) compared to hospital-based reports may be attributed to the community-based nature of our sampling strategy, which captured a broader spectrum of diabetes patients including those with newly diagnosed and well-controlled disease.[14-15] Hospital-based studies tend to overrepresent severe cases due to referral bias. Additionally, the substantial proportion of participants in our study with no apparent diabetic retinopathy (64.6%) underscores the importance of regular screening and early diabetes detection, as these individuals represent a target population for preventive interventions.

Our multivariate analysis identified several significant independent risk factors for diabetic retinopathy, with age and diabetes duration emerging as non-modifiable but crucial predictors. The strong association between advancing age and diabetic retinopathy risk (adjusted OR=11.76, 95% CI: 1.89-103.42, p=0.036 for those >60 years) likely reflects the cumulative impact of aging on microvascular integrity, compounded by longer exposure to diabetes-related metabolic derangements.[16] The pronounced relationship between diabetes duration and retinopathy risk (adjusted OR=3.95, 95% CI: 2.61-11.59, p<0.001 for duration >5 years) represents one of the most consistent findings across diabetic retinopathy epidemiology studies. Our observation that 85% of participants with diabetes duration of 10-15 years exhibited retinopathy underscores the time-dependent nature of microvascular complications in diabetes.[17] This finding highlights the critical importance of early diabetes detection and emphasizes that duration-based risk stratification should be a fundamental component of retinopathy screening protocols, particularly in resource-constrained settings where universal screening may not be feasible.

Among the modifiable risk factors identified, glycemic control demonstrated the strongest association with diabetic retinopathy in our multivariate model (adjusted OR=2.25, 95% CI: 1.66-5.34). This substantiates the fundamental pathophysiological role of chronic hyperglycemia in retinal microvascular dam-

age and aligns with landmark clinical trials such as the UK Prospective Diabetes Study (UKPDS) and Diabetes Control and Complications Trial (DCCT), which established glycemic control as a cornerstone of retinopathy prevention. The significantly higher prevalence of retinopathy among participants with uncontrolled diabetes (48.3% vs. 35.5% in those with controlled diabetes) reinforces the importance of achieving and maintaining glycemic targets in clinical practice.[18,19]

Hypertension emerged as another significant independent predictor of diabetic retinopathy (adjusted OR=1.04, 95% CI: 1.006-1.070), consistent with its established role in exacerbating retinal vascular damage through mechanisms including increased hydrostatic pressure, endothelial dysfunction, and exacerbation of retinal hypoxia.[20] This finding underscores the importance of integrated diabetes management that addresses both glycemic control and comorbid vascular conditions.

The significant association between elevated BMI and diabetic retinopathy risk (adjusted OR=3.95, 95% CI: 2.08-4.89, p<0.001 for overweight/obese participants) merits particular attention. Our observation of a dose-response relationship with retinopathy prevalence increasing from 25.6% in normal BMI patients to 47.8% in overweight patients and 80% in obese patients suggests that adiposity may contribute to retinopathy pathogenesis beyond its effects on glycemic control. Proposed mechanisms include adiposity-associated chronic inflammation, oxidative stress, dyslipidaemia, and dysregulation of adipokines such as adiponectin and leptin, which have been implicated in microvascular dysfunction. This finding suggests that weight management should be considered an integral component of retinopathy prevention strategies alongside glycemic and blood pressure control.[21]

The strong association between history of cataract surgery and diabetic retinopathy (adjusted OR=1.76, 95% CI: 1.10-3.16) could be interpreted through several lenses. It may reflect the common pathophysiological pathways underlying diabetic cataract and retinopathy formation, represent a marker of longer diabetes duration or poorer glycemic control, or potentially suggest a causal relationship mediated through surgical inflammation or altered ocular fluid dynamics. While our cross-sectional design precludes definitive causal inference, this finding suggests that patients with diabetes undergoing cataract surgery warrant particularly vigilant retinopathy screening and follow-up.

Family history of diabetes demonstrated considerably higher odds of diabetic retinopathy preponderance (OR 1.61, 95% CI, 0.956-2.70) on univariate analysis although it did not reach the level of statistical significance. However, on multivariate analysis, there was no considerable difference (=P0.84; 95% CI, 0.40- 1.79). This may be due to confounding effect but this finding does not negate the potential genetic underpinnings of diabetic retinopathy susceptibility but suggests that established clinical risk factors may have greater utility for risk stratification in clinical practice.[22]

Our findings have several important implications for clinical practice and public health strategies. First, they reaffirm the importance of established modifiable risk factors glycemic control, blood pressure management, and weight optimization as cornerstones of diabetic retinopathy prevention. The persistence of these associations in our multivariate model suggests that integrated diabetes management addressing these multiple risk domains could substantially reduce retinopathy burden in similar populations.

Second, our findings provide an evidence base for risk-stratified screening approaches in resource-constrained settings. The strong associations with diabetes duration and age suggest that these factors could form the basis for prioritized screening protocols, with more frequent examinations for individuals with long-standing diabetes, advanced age, or multiple risk factors.

Third, the predominance of early-stage retinopathy in our community-based sample highlights the window of opportunity for secondary prevention through early detection and intervention. This underscores the potential value of community-based screening initiatives, particularly in rural and peri-urban areas where specialist ophthalmological services may be limited. DR screening may be included in services provided through Non-communicable Disease (NCD) clinic under the NP-NCD program.

Finally, the sociodemographic profile of our participants predominantly from lower socioeconomic strata with limited formal education highlights the need for accessible, culturally appropriate diabetes education and retinopathy awareness programs.

Conclusion

This community-based study has documented a substantial burden of diabetic retinopathy among Type 2 Diabetes Mellitus patients in rural and peri-urban areas of Aligarh, with approximately one-third of participants affected. We identified both non-modifiable (age, diabetes duration) and modifiable (glycemic control, hypertension, elevated BMI) risk factors, with the latter offering tangible targets for preventive interventions. The predominance of early-stage disease highlights the potential value of community-based screening initiatives for early detection. Our findings underscore the importance of integrated diabetes management addressing multiple risk domains and suggest that risk-stratified screening approaches may optimize resource utilization in similar settings. As diabetes prevalence continues to rise in India and globally, implementation of evidence-based strategies for diabetic retinopathy prevention, detec-

tion, and management remains an urgent public health priority.

This study has several strengths, including its community-based design which ensures population representativeness, the systematic random sampling approach which minimizes selection bias, and the comprehensive assessment of multiple potential risk factors which allows for identification of independent predictors through multivariate analysis. The inclusion of both rural and peri-urban populations provides insights into diabetic retinopathy epidemiology across different settlement types within the same geographical region.

Several limitations need attention too. The cross-sectional design precludes establishment of temporal relationships and causal inference. Self-reported data on variables such as diabetes duration may be subject to recall bias. Furthermore, the study's regional focus may limit generalizability to populations with substantially different sociodemographic profiles or healthcare systems.

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