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RESEARCH ARTICLE

PRIMARY OPEN-ANGLE GLAUCOMA SEVERITY PREDICTION USING DEEP LEARNING TECHNIQUE

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Abstract – Glaucoma is a neuro optical disorder that lead to blindness over a period of time. In recent years, studies have revealed that diabetic patients are more common victims of glaucoma. The present research aims to investigate the relationships between intraocular pressure (IOP), refractive error, and primary open-angle glaucoma (POAG) in the wheatish population. Population-based research provide important information on the prevalence and hazards for glaucoma, such eye refractive defects. At low IOP stages, the correlation between glaucoma and myopia is strong, and it gradually decreases as IOP rises. A Deep learning tool is developed to analyze the severity of glaucoma using fundus image. According to this research, the association between IOP and glaucoma is strong at low mean values of 15±3.23 level and gradually weakens as IOP increases in the wheatish population, reaching 17.59±3.33 for PACG, 18.85±1.20 for POAG, 18.59±2.52 for PIGM, and 19.12±1.42 for OH. With increasing IOP, the glaucoma image in myopic eyes degraded, and no correlation with IOP ≥35 mmHg has been found.

Keywords *– Refraction Error, Populace-based Study, POAG, Wheatish population, Deep Learning, Glaucoma.*

1. INTRODUCTION

Glaucoma is a neurological degeneration of optical cells that emerge due to multiple optical disorders. Generally, glaucoma is termed as “Silent thief of vision” as it gradually dwindles sight without any primary symptoms. Refractive error and Intra Ocular Pressure (IOP) are significant risk influences for POAG, and the commonness of refractive error is ascending over the world, indicating that plays a significant part in the improvement of POAG. Diplopia, haziness, glare or halos around bright lights, squinting, headaches, blurred vision, and eye strain are the most common recognized manifestations of refractive error (RE). Glaucoma is an unpredictable sickness that causes destruction to the optic nerve and prompts dynamic, irreversible vision calamity. It is the second main problem that can lead to blindness globally [1,2]. The optical field test, optic nerve imaging, corneal thickness and point checks, and the eye weight examination are all types of glaucoma eye tests. The main role of RE in the etiology of glaucoma has play a significant role in glaucoma detection. This prompts to a condition referred Diabetic Retinopathy. The unending entanglements of diabetes related to eye infection is given in fig.1. Among these chronic complications, Diabetic retinopathy is an important reason for blindness in Indian adults. In some human beings with diabetic retinopathy, retinal blood vessels may also swell and outflows fluid. 1.8 million (4.8%) of the 376 million individuals are visually impaired because of eye infections all through the world. Globally around 171 million diabetes patients are there, and it is expected to 367 million at the end of 2030. About half of the persons with diabetes are unconscious, albeit around 2 million died consistently are owing to complexities of diabetes.

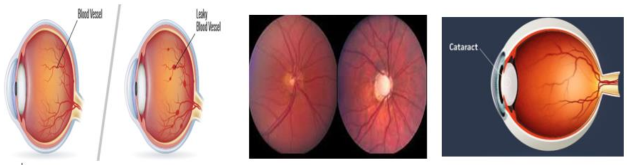


Figure 1. a) Diabetic Retinopathy b) Glaucoma c) Cataract

In the next 20 years, over 75% of patients is expected to have some type of diabetic retinopathy [3]. Glaucoma Research Foundation (GRF) conducted a review and discovered that, 74% of quite 1,000 people met afore mentioned criteria and their eyes must be tested at regular intervals and 61% of those with enlarged eyes were identified to have glaucoma. 16% of African Americans were reported to have recently affected with glaucoma [4,5]. Comprehensively, 1.31 billion people worldwide are thought to have some form of blindness. Additionally, 188.4 million people have mild vision disability, 216 million had modest to extreme vision hindrance, and 36 million people are visually impaired [6]. Regarding close vision, 827 million people living with a close vision weakness [7].

In this paper, a huge populace overview has been performed so as to distinguish patients with undetected glaucoma. The subsequent material, comprising of in excess of 4000 people among Wheatish populace. The reason for the present examination is to contemplate the connection among RE and glaucoma, all the more explicitly to see whether nearsightedness can be affirmed as a significant hazard factor for glaucoma, and the relationship among myopia and glaucoma depend on IOP. Here a deep learning tool is implemented to evaluate the refractive error using the fundus image obtained from the survey among wheatish people. The ametropic condition (refractive index of light) of the eye were calculated to evaluate the occurrence of glaucoma.

This paper is organized in the following manner: In Chapter 2, a summary of the research is presented. Chapter 3 provides a description of the resources and procedures. The experiment's outcomes and insights are presented in Chapter 4, which also serves as the conclusion of the research.

2. REVIEW OF LITERATURE

Numerous elements have recently been accounted to influence IOP. A higher IOP was reported to be associated with greater central corneal thickness [8], blood pressure [9], and body mass index [10]. It has also been stated that the existence of diabetes mellitus was a hazard factor for high IOP. Because these confirmations are the most part of dependent on cross-sectional investigations which can't exhibit temporal causation, it is important to assess their relationship with IOP longitudinally.

The relationship among RE and glaucoma subtypes with 95% confidence intervals (CIs) measured as odds ratios (ORs). Myopia was related with an expanded occurrence of all types of POAG and OHTN, while hyperopia is related significantly to PACG occurrence.

While higher myopia was a strong hazard factor for subtypes of glaucoma, low and medium myopia often affects the risk of glaucoma. Also, there were significant racial differences in the correlation of myopia with the danger of POAG and NTG [11].

In [12], researchers examined the connection among refractive mistake, glaucoma, and IOP in a specific white community and discovered an overall link between myopia and high IOP and common glaucoma. In [13], evaluated primary congenital glaucoma (PCG)-related refractive results of cataract surgery with intraocular lens (IOL) implantation. After IOL implantation, there was a bigger myopia shift in the PCG eyes as well as a larger error in forecasting. Since their variations in axial dimension become more sensitive to IOP fluctuations, the eyes of kids with PCG are more vulnerable to optical abnormalities.

One study thought about the eyes that have undergone phacoemulsification with eyes that have not experience glaucoma surgery at least 3 months after trabeculectomy and revealed that the adjustment in IOP was adversely related with refractive surprise; a connection was expected among lower postoperative IOP or greater reduction in IOP and reduction in axial length [14]. What's more, an ongoing report has uncovered that combined versus subsequent trabeculectomy, the refractive result was lower [15]. Then again, there were no differences in refractive and visual results in a study involving combined trabectome-cataract surgery with cataract-alone surgery, and a retrospective analysis demonstrated favorable refractive results in patients experiencing concurrent cataract removal with trabeculectomy or glaucoma drainage system surgery.

There are few population-based studies have been directed outside the USA or UK that inspected the frequency of DR, in which patients who were resolved to have diabetes from 1980 to 1984 had a 47% reduction in the risk of DR compared to patients analyzed from 1975 to 1979[16]. The diminishing in risk was significantly more unmistakable in the associate broke down from 1985 onwards, at 64 %. This assessment shows that while virtually all patients with type 1 diabetes may eventually make DR after some time, the frequency of type 1 diabetes patients with DR was undoubtedly on the decline. A population-based study between the wheatish population-Diabetic individuals was directed in this paper to discover the relationship between Refractive Error, IOP, and Glaucoma Etiology. A deep learning tool is implemented to evaluate the refractive error

3. PROPOSED METHODOLOGY

The proposed work is a population-based study of optical disorder in people with diabetic mellitus. The objective of the study is to evaluate the relationship of intraocular pressure, refractive error and the etiology of glaucoma among diabetic patients of wheatish populace. In this work, a survey is conducted among both men and women (age ≥ 40) with the history of diabetics. Along with a free eye test, it included a brief assessment about any previous eye conditions and current drugs.

3.1 Study Population

The targeted individual number is 4000 with the age group of greater than 40 years with male and female diabetes. The workflow diagram of this study is given in fig.2. Here, totally 4529 individuals have been investigated from 2018. In that 529 individuals have been excluded due to certain reasons which includes people aged less than 40 years, some of the individuals are already diagnosed their eye disease and are non-diabetic. Visual and refraction test have been performed on the identified individuals. If the individuals have clear vision, they are excluded from the study. Then the identified individuals are checked for blood pressure, eye tension and sugar test. Based on the testing results, final diagnosing has been 5.

3.2 Evaluation of Refractive error and Intraocular Pressure

The refractive status is obtained using a standardized automated refractor. As part of an ophthalmologic test, participants underwent perceptual refractive and also color fundus images at baseline and following visits. In addition, retinoscopy was used in the refraction protocol and then further refining of subjective refraction. Thirty-five-degree field color fundus images were obtained using a reading center-approved reflection film using a fundus camera [17]. The equivalent macula-centered images were used in this analysis for each visit in which refraction was done. Based on baseline refraction, the refractive status of a specific eye was determined. Spherical equivalent (SE) of +1.00 D or below is Myopia (nearsightedness), SE of +1.00 D or above is hyperopia (farsightedness) and SE between -0.75 and +0.75D is emmetropia [18].

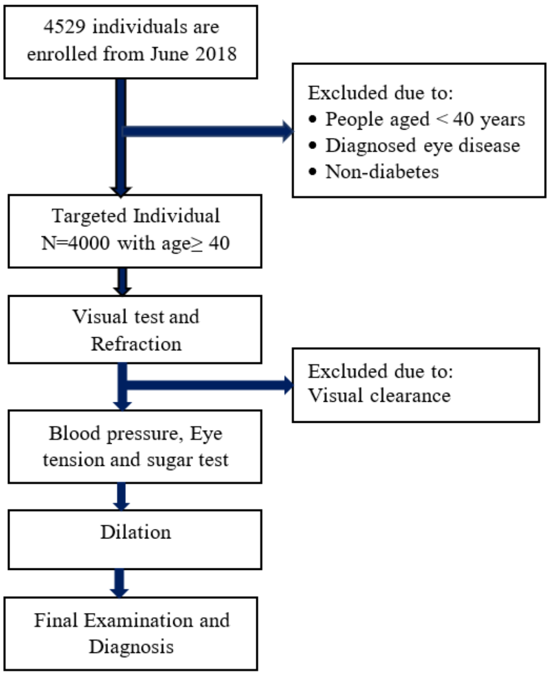


Figure 2. Work flow of Study population

Each subject has a visual field as part of the baseline study. After the threshold is defined, the analysis was conducted within the central 25 ° of the visual field using patterns of two, three or four stages (26 stimuli in all). If at the first attempt any point was not shown, it was retested, with any point twice missing on three attempts identified as a reported miss, constituting a screening test loss [19]. Subjects who lost in screening test underwent full perimetric testing of central visual field and only the threshold is analyzed those passed in screening test.

The IOP is measured using applanation tonometry followed by instilling a drop of tropicamide (dilation eye drop). During the dilation period the patient is enquired regarding their visual condition, occurrence of glaucoma and medication process. Images of the fundus and lens were taken for affected patients. The obtained data is trained and tested using a deep learning tool to determine the severity of POAG [20].

3.3. Implementation of Deep learning algorithm

The Fundus images taken from the patients were trained and tested to analyze the occurrence and severity of Diabetic Glaucoma among Wheatish populace. A Deep Convolution neural network classifiers is designed for automatic detection and classification of the medical diseases. Multiple convolutional layers, pooling layers, and fully linked layers often make up a DCNN. The RGB Fundus image is considered in this work to the output process of proposed retinal fundus image is evaluated through several steps such as preprocessing, feature extraction and classification are illustrated as follows;

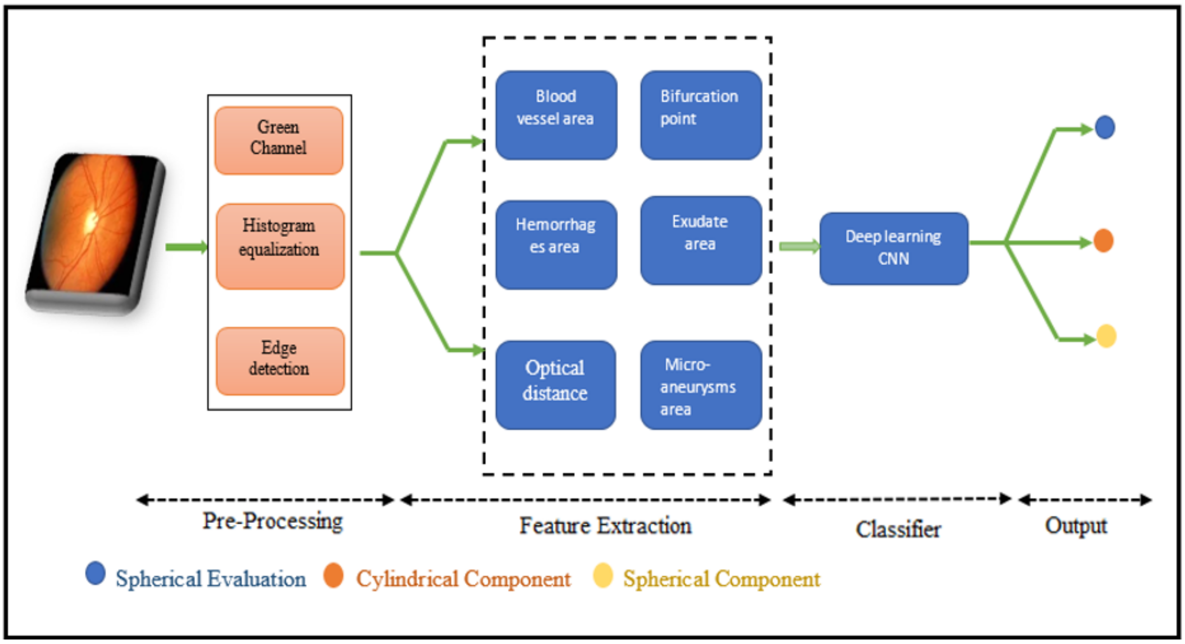


Figure 3. Block diagram of proposed deep learning technique

3.3.1. Pre-processing

Image preprocessing is a significant step to reduce the noise distortion and enhance image. It is an essential process that simplify the process of classification. In the proposed method preprocessing enhance the colour fundus image obtained from the patients in three steps. Green channel isolation, histogram equalization and edge detection.

Green Channel

The RGB fundus image has three colour channels (Red, Green and Blue). Here the Green channel (GC) manifests the contrast between exudates area, hemorrhages area, blood vessels and bifurcation point. Unlike the other two, green channel is neither low-illuminated nor high-saturated. Therefore, in this process only the green channel is extracted for classification of glaucoma.

Histogram equalization

Image Contrast is enhanced to elevate the features of the image. Histogram equalization is implemented to equalize and contrast the image. The images are segmented into small blocks and contrast is efficiently applied based on the intensity value of pixel. It enhances the contrast of local area to gain high contrast [21].

Edge detection

The enhanced images were resized and cropped as to make it standardized. Canny edge detection algorithm is used for edge detection where Gaussian filter smoothen the boundaries and gradient intensity is calculated to detect the edges.

3.3.2 Feature extraction

The preprocessed fundus image of the patients is subjected to feature extraction to analyse the exudate area. Feature extraction is olates all features from the fundus image to evaluate the exudate area; optical disc is removed as it develops similar colour and intensity to other features of retinal fundus image. The optical disc is generally removed by elevating the contrast around the optical disc. The blood vessels inside the optical disc can be removed by applying a Grayscale closing technique. In this study, optical features such as blood vessels, hemorrhage, bifurcation point, optical distance, micro aneurysms area and exudate area were isolated from the fundus image [23].

Figure 4. Optical Disc Elimination

The features extracted from the fundus image provides clear information for analytical study of glaucoma.

Optical blood vessels underneath the conjunctiva are subtle and may breakdown cause irritation and redness in eye resulting in sub conjunctival hemorrhage, if it is untreated that leads to retinal glaucoma. Similarly, the optical distance and bifurcation point provides detailed view of optical nerves. That simplify the isolation of extrude area. The extracted features were classified based using deep neural network.

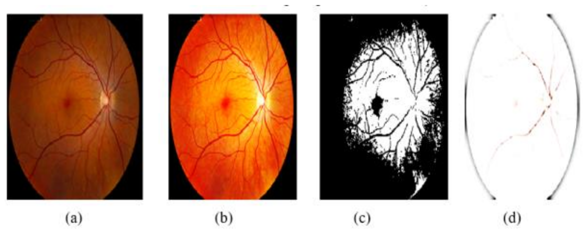


Figure 5. Extracted features of retinal fundus image. (a) Input fundus image, (b) Blood vessels, (c) bifurcation point and optical distance and (d) Micro aneurysm and exudate area.

3.3.3 Deep neural network

The categorization of health-related images is made easier by the multi-layered network approach known as deep neural networks. The initial data for a DNN network consists of training and test sets. Verification data from the training set was created using a DNN parameter with randomized thresholds set. The neural network is then fed the sample source image, and it compares and predicts the missing section based on the intensity of each pixel of the fundus image in the training set.

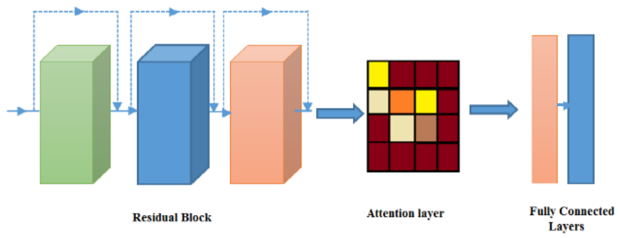


Figure 6. Architecture of Deep Neural Network

To effectively train a data set for forecasting glaucoma, this procedure is repeated with various fundus images [22]. The DNN design of our suggested approach uses a residual block, an attention layer, and A fully linked layer needed to understand the features of the retinal.

The residual block estimates the features extracted from the fundus images. The attention layer grasp more crucial features of images and the FC layers compare the extracted features with trained dataset.

The convolution layer containing three remaining components makes up the remaining network. The neural network's forward-feedback layers are what residual units are simple. For learning tiny parameters that reduce error, the residual unit has a bottleneck design of several convolution neural networks. In the ResNet design, a steady reduction in error is achieved by expanding the training layer. The precise traits are chosen by the layer of attention. Following the attention layer comes the layer that is totally connected, and the output is created utilizing the fundus image's spherical and cylindrical attributes.

4. RESULTS AND DISCUSSIONS

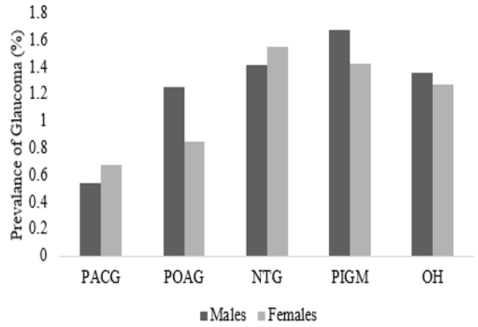
The commonness of glaucoma in screened subjects are arranged in table.1 at the hour of the screening assessment, all members were somewhere in the range of 40 and 78 years old. We distinguished 742 people with beforehand undiscovered essential open edge glaucoma (POAG), ordinary strain glaucoma (NTG), essential point conclusion glaucoma, pigmentary and visual hypertension (OH) relating to 18.55% of those screened. We found an extra 268 people with glaucoma who had been recently determined and 23 people to have different kinds of glaucoma.

Table 1. Frequency of glaucoma in screened subjects

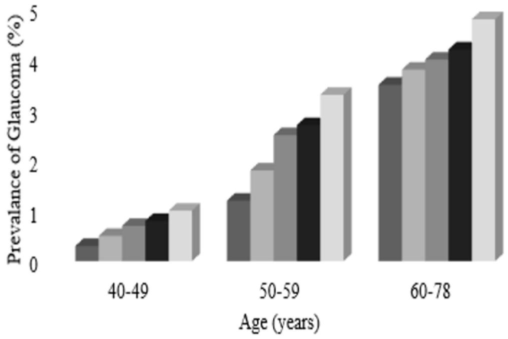
	N (subjects)	%
Patients with detected glaucoma	742	18.55
Early diagnosed glaucoma patients	268	6.7
Angle closure glaucoma patients	23	0.57
Normal	2,967	74.17
Total	4,000	100

A total of 1,484 eyes are comprised in the present investigates, amongst them 1,216 (81.94%) are glaucoma eyes. In that, 598 right eyes and 618 left eyes. We excluded 268 (18.05%) cases which are unable to obtain pictorial acuteness, visual clearance, and eyes that had before experienced cataract operation and the details are tabulated in table.2.

The connection among the glaucoma and RE is detected in both males and females (fig.7 (a)), and across the age group is shown in fig.7 (b). We found a solid relationship among glaucoma and myopia, but also a strong reliance on IOP for the relationship. With rising IOP, glaucoma over-representation in the myopic group deteriorated slowly. There was a striking, practically straight connection among the occurrence of glaucoma with IOP ≤20 mmHg (Fig. 8) which occurred entirely in the eyes with IOP ≥35 mmHg and this distinction shows the huge connection among IOP and RE. The association is good at minor IOP levels and completely vanished at higher IOP levels indicates that for normal stress glaucoma, myopia was an important risk factor.



a) RE for males and females



b) RE with age groups

Figure 7. Frequency of glaucoma in eyes

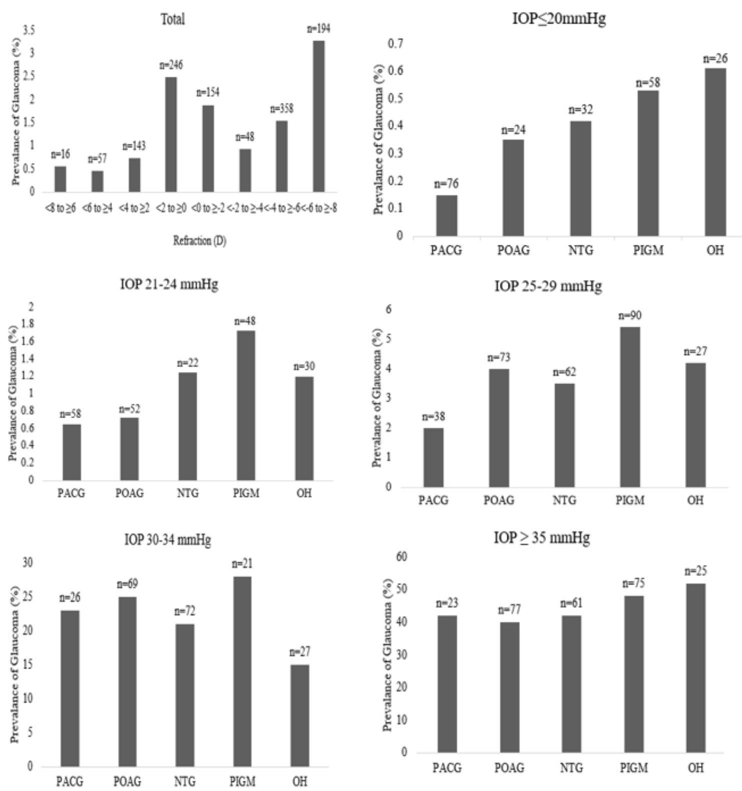


Figure 8. Frequency of glaucoma in eyes with various RE and IOP-levels

Table 2. Number of eyes (both left and right) involved in this paper

	N (eyes)	%
Overall quantity of eyes tested	1,484	
non-eligible	268	18.05
IOP≤25 mmHg eyes are eligible glaucoma	785	52.89
IOP>25 mmHg eyes are eligible glaucoma	431	29.04

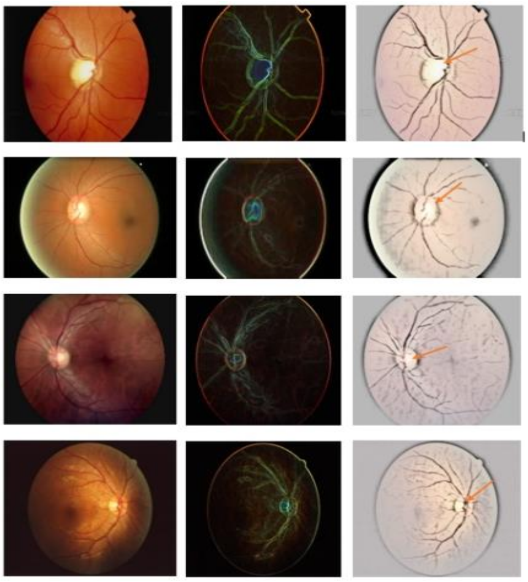


Figure 9. Experimental result of fundus images trained through deep learning network to predict severity of primary open-angle glaucoma in diabetics among Wheatish populace.

Table 3 gives the highlights of the 5-glaucoma case and non-glaucoma controls. Glaucoma patients with ≥40 years with diabetic patients have been considered for this trial. Ladies set up 62% of controls, 71% of PACG patients, 56% of POAG, 49% of PIGM and 69% of OH with diabetic patients.

For men 59% of controls, 37% of PACG patients, 56% of POAG, 62% of PIGM and 44% of OH independently. The regularity of glaucoma subclasses is moved by race and ethnicity. Clinical incorporates moreover fluctuated with the subclasses of glaucoma. True to form, glaucoma cases commonly greater CDRs and greater IOPs than controls. Similarly, the diabetics by and large have higher estimation of IOP, lower estimation of CDR, and higher estimation of RE, however various patients had respectably lower estimation of IOP, higher estimation of CDR, and lower estimation of RE.

4.1 Experimental Analysis

Retinal fundus image taken from the patient is trained using a deep learning algorithm to evaluate the severity of glaucoma among Wheatish populace. The investigation evaluation of the fundus image is given below.

In experiment result, the fundus images obtained from patients with glaucoma is tested using the deep neural network where the images are classified based on the spherical and cylindrical components. The features of optical disc and optical cup are calculated. The spherical equivalent worse than -0.6 (myopic), spherical equivalent between -1.0 and+1.0 (Neutral) and spherical equivalent worse than 5.0 (hyperopic) are analysed to evaluate the occurrence and severity of POAG. From the analysis the DNN classification technique.

Table 3. Features of Glaucoma and controls for Wheatish population

	Controls	PACG	POAG	NTG	PIGM	OH
Gender						
Female	62.25	71.23	56.34	58.69	49.64	69.48
Male	58.95	36.92	56.34	48.64	62.76	44.68
Age						
40-49	27.30	4.29	6.14	5.89	13.79	11.32
50-59	40.10	28.36	31.40	32.59	43.69	40.69
60-78	32.50	65.89	62.50	62.25	45.95	51.69
Mean±SD	57.28 ±13.5	67.27±10.65	68.51±10.38	67.58±9.68	63.89±12.21	65.58±13.50
CDR						
Mean±SD	0.31±0.13	0.45±0.11	0.56±0.23	0.64±0.19	0.51±0.25	0.45±0.36
IOP						
Mean±SD	15.98±3.23	17.59±3.33	18.85±1.20	14.58±3.273	18.59±2.52	19.12±1.42

In India, 4.042 million with the age gathering of 40-49 years and 30.970 million with more noteworthy than 50 years are influenced from uncorrected refractive error [16]. The average IOP is 15.61 ± 3.09 mm Hg for women and 15.54 ± 3.54 mm Hg for men separately [14].

IOP for women and men is comparative within the same age group, while IOP in earlier age is greater when contrasted with older-age groups. For diabetic populace, the mean IOP was 15.08 ± 2.18 mm Hg.

Spherical Equivalent (SE)=Sphere Power+1/2(Cylinder Power) (1)

With a spectacle amendment of -3.01 +1.01 x 180, the SE = -3.00D + ½(+1.00D) = -3.00D + 0.50D = -2.50D. Nearsightedness has been characterized using SE as ≤−0.50 diopters (D); mellow nearsightedness is characterized as >−3.0 D; moderate nearsightedness is characterized as ≤−3.0D; and high nearsightedness is characterized as ≤−6.0D. Mean IOP has been found that 15.98 mmHg in typical hyperopic eyes and ultimately raised with myopia progression to 16.2 mmHg. The table 4. below lists the normal and abnormal eyes in relation to refractive errors and IOP.

Table 4. Normal and POAG Mean IOP related to RE

	Normal		**POAG**	
	Mean IOP (mmHg)	N	Mean IOP (mmHg)	N
SE ≤−0.50 D (Myopia)	15.6	1823	23.6	167
SE >−3.0 D (Slight Myopia)	15.9	1526	21.3	256
SE ≤−3.0 D (Moderate Myopia)	16.4	532	22.1	92
SE ≤−6.0 D (High Myopia)	16.9	425	21.2	45

As a result, analysis of this massive population-based study revealed that the occurrence of glaucoma is strongly influenced by RE and manifested in bigoted eyes. Eyes with low IOP have a stronger link to glaucoma than eyes with the middle pressure tests, which have a weaker link, and eyes with excessive pressure have no link at all.

5. CONCLUSION

Populace based health examination and has been directed for analyzing diabetes retinopathy in India. Increasingly serious nearsightedness was related with a more prominent probability of glaucoma in a Wheatish population matured forty and further years. This constructive connection among the RE and IOP underlines the significance of glaucoma observation in the nearsighted populace in light of the fact, that both raised IOP and nearsightedness are significant hazard factors for glaucoma development. This paper demonstrates that, there is a solid association among RE, IOP, visual biometry and POAG for diabetes more protuberant than 40 years in Wheatish populace. The incorrected RE can be rectified with eyeglasses while cataracts medical procedure can reestablish image. Vision recovery is additionally powerful in enlightening irretrievable vision debilitation. Here a deep learning algorithm is developed to detect the severity of glaucoma in diabetic patients with the fundus image. In this study, it is found that, the individual group with the age of 60-69 are more affected by glaucoma with 65.89% of PACG, 62.50% of POAG, 62.25% of NTG, 45.95% of PIGM and 51.69% of OH among Wheatish population. Curiously the relationship among refractive error and IOP varied by age group, yet IOP was unequivocally connected with glaucoma and refractive error for diabetes.

CONFLICTS OF INTEREST

The authors affirm the fact that there are no known conflicts of interest that might have seemed to an impact on the research presented in this study.

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