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Indian Journal of Clinical and Experimental Ophthalmology

Journal homepage: www.ijceo.org

Review Article

# Global prevalence and risk factors of primary open-angle glaucoma: A systematic review and meta-analysis

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## Abstract

**Background:** POAG is a major cause of irreversible blindness globally, characterized by progressive optic nerve damage and visual field loss. Despite its association with intraocular pressure (IOP), many patients develop the disease within the normal IOP range, highlighting its multifactorial nature.
**Aim and Objective:** To determine the global prevalence and risk factors of primary open-angle glaucoma (POAG) and answer the research question: "What demographic, clinical, and methodological factors most significantly influence the prevalence of POAG across populations worldwide?"
**Materials and Methods:** A systematic review and meta-analysis were conducted on studies published from January 2014 to March 2025 across PubMed, Embase, and Scopus. Ten studies with a combined sample of 839,940 participants were included. Data extraction focused on prevalence, demographics, and risk factors, and analysis was performed using SPSS and R Studio. Study quality was assessed via the Newcastle–Ottawa Scale.
**Results:** The mean pooled prevalence of POAG was 3% (range 1.9–31.7%). Major risk factors identified included advancing age, elevated IOP, hypertension, diabetes, family history, myopia, and polygenic susceptibility. Considerable heterogeneity was noted ($p < 0.001$).
**Conclusion:** POAG is a heterogeneous, multifactorial disease. Integration of genetic risk profiling, AI-based screening, and early detection strategies can enhance prevention and reduce the global burden of blindness.

**Keywords:** Prevalence, Primary open-angle glaucoma, Risk factors, Increased intraocular pressure.

**Received:** 20-05-2025; **Accepted:** 11-08-2025; **Available Online**: 16-12-2025



## 1. Introduction

Primary open-angle glaucoma (POAG) is one of the leading causes of irreversible blindness worldwide, with progressive damage to the optic nerve and associated visual field defects being the characteristic.[1] POAG is prevalent in every region of the world, but in proportion differing in populations and regions. POAG epidemiology plays a central role in planning effective public health interventions, early diagnosis, and treatment. There is a large number of undiagnosed or undertreated patients who become blind, although therapeutic interventions exist. Glaucoma, despite treatment, was the second most frequent cause of worldwide blindness following cataract, but cataract but not glaucoma is irreversible. This highlights the importance of early diagnosis and risk prediction.

Recent projections suggest that by 2040, over 110 million people globally will be affected by glaucoma, highlighting the necessity for more aggressive screening and management strategies. Heterogeneity in prevalence rates can be explained by a variety of factors, such as genetic, environmental factors, and access-related issues.[2] Of interest, individuals of African descent have a greater prevalence and more aggressive course of disease, while normal-tension glaucoma is more common in the East Asian population. The geographical differences highlight the importance of ethnicity and population-based risk stratification in the presentation of the disease. Genetic studies have recognized over 100 single nucleotide polymorphisms (SNPs) that are associated with glaucoma, and these form the basis for

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https://doi.org/10.18231/j.ijceo.11351.1761133779

predictive modeling using polygenic risk scores (PRS). These methods can in theory enable the detection of at-risk individuals even before the onset of clinical symptoms.

Previous estimates varied between 1% and more than 10%; thus, comprehensive studies are needed that are able to pool available data and identify patterns. The present systematic review aims to answer an important question: What are the most important demographic, clinical, and methodological variables that influence the reported prevalence of primary open-angle glaucoma in various populations? In asking, we aim to explain why variability in prevalence rates arises and provide evidence that can guide future research and clinical practice.

The systematic review will comprise all study types, i.e., cross-sectional, cohort, and case-control studies, to encompass all the evidence available, and sophisticated statistical techniques to elucidate how different factors affect the prevalence estimates. In addition, the intersection of big data analytics and real-world electronic health records (EHRs) has made mapping of risk factor interactions possible, especially in large national health datasets. This will allow us to analyze potential moderators such as age, sex, ethnicity, and socioeconomic status, responsible for the noted variations in the prevalence rates.[3] Refractive errors such as high myopia, blood pressure rise, and Body Mass Index (BMI) are also risk factors.

There are cases of normal intraocular pressure in primary open-angle glaucoma (POAG). An elevated risk of POAG has been found independently of the strongest current phenotypic risk factors, family history, and follow-up period. Reduction of intraocular pressure in the early phases has been noted to delay the detectable progression of the disease. Recent advances, such as polygenic risk scoring (PRS) and optical coherence tomography (OCT), have greatly improved the potential for early detection of glaucomatous changes before the onset of visual field impairment. Moreover, new methods involving smartphone-based fundus photography coupled with artificial intelligence-based processing are also being noted as scalable interventions in low- and middle-income countries, where specialists are not readily available. Moreover, machine learning algorithms are also engaged in improving the completeness and comprehensiveness of the outcomes, especially when used in large population data and fundus image screens. Finally, understanding and measuring the complex interactions among modifiable and non-modifiable risk factors is necessary for the shift of glaucoma management from reactive treatment to proactive prevention.

## 2. Material and Methods

The research was conducted find the articles published over 12 years (Jan 2014- March 2025), the total number of patients 8,39,940 were included. (**Figure 1**) shows the flowchart (PRISMA) for the final selection of 10 studies for systematic review. While eight studies were selected for meta-analysis. The risk of bias was also analysed (**Figure 2**).

### *2.1. Literature search*

A comprehensive literature search was done to find studies published between 2014 to 2025 on the incidence, risk factors, and prevalence of POAG, and a total of 3,100 articles were analysed; the articles that completely fulfilled the inclusion criteria were selected after the exclusion of the duplicate. Finally, 10 articles were selected from the electronic database, PubMed, Embase, and Scopus using the keywords, “Prevalence of Primary open-angle glaucoma”, “Risk Factors”, “Increased intraocular pressure”.

### *2.2. Inclusion criteria*

1. Studies reporting on the prevalence of POAG.
2. Studies identifying risk factors associated with POAG.
3. Peer-reviewed articles published between 2014 and 2025 in English.
4. Studies with clear diagnostic criteria for POAG.
5. Studies conducted in diverse populations across the globe.

### *2.3. Exclusion criteria*

1. Studies lacking clear diagnostic criteria for POAG.
2. Non-English language publications.
3. Case reports or small case series with insufficient sample size.
4. Exclusion of other identical conditions causing optic nerve and disc damage.

No ethical approval was required because the systematic review and meta-analysis study was conducted.

### *2.4. Diagnostic criteria*

1. Examination of the optic nerve head to see the optic nerve damage by an ophthalmologist using Optical Coherence Tomography (OCT) to find out the thickness of the retinal nerve fiber layer (RFNL) and visual Field Testing (Perimetry) to visualize the pattern of vision loss, both in the periphery and central.
2. Gonioscopy to visualize the anterior chamber angle and to confirm it is open.
3. Pachymetry to find out the thickness of the cornea is significant as IOP is often affected.
4. Exclusion of the other conditions causing increased intraocular pressure and optic nerve damage is essential.

### *2.5. Data collection*

Data were extracted from each study regarding sample size, demographic characteristics, prevalence rates, and identified risk factors.

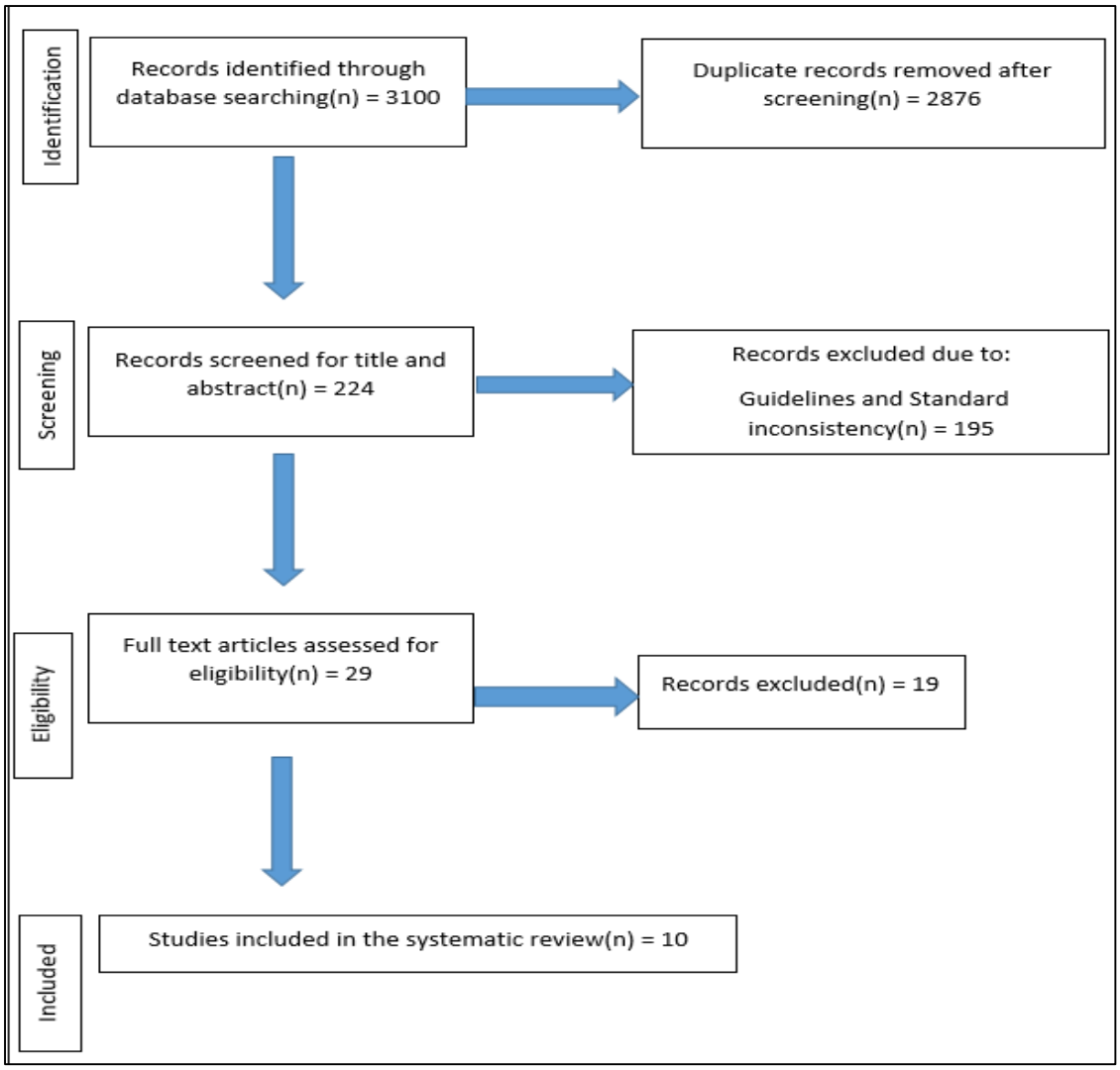


**Figure 1:** Primary open angle glaucoma PRISMA chart

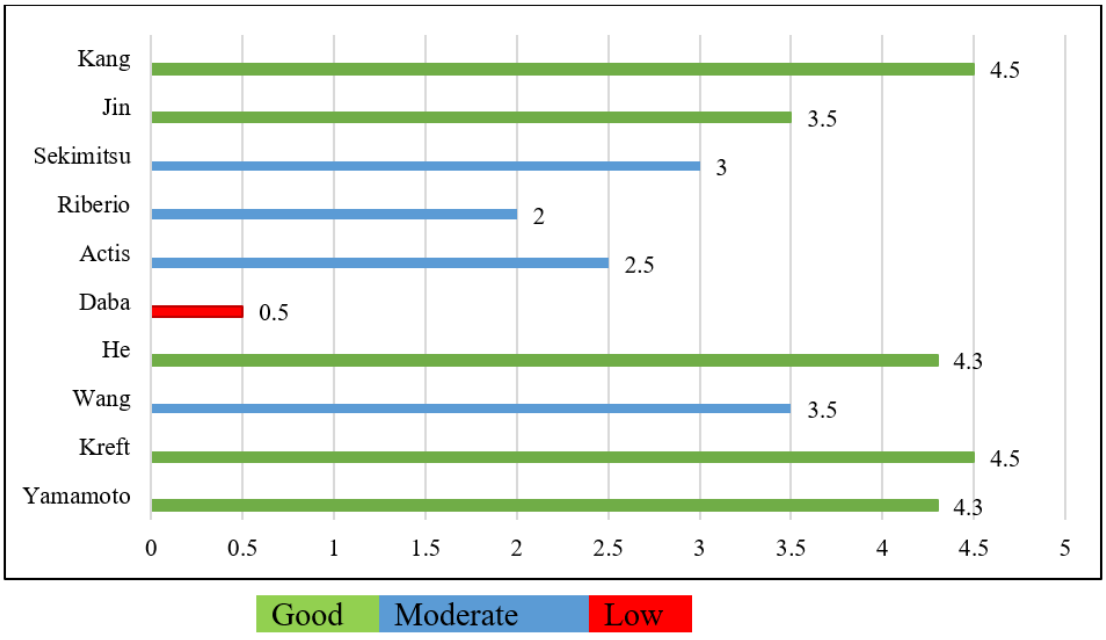


**Figure 2**: Risk of bias for the studies selected for POAG

*2.6. Data extraction and analysis*

The eligibility of the article based on a criteria search was completed by 2 authors (TV & S.S.) and the full text of the studies was analysed by using Microsoft Excel 2016. The two authors assessed the methodology and the quality of the articles by using the New Castle Ottawa assessment scale. Finally, a total of 10 studies met the quality of assessment. The data shows different studies from different parts of the world, namely India, the USA, the Netherlands, Iran, France, Spain, and Korea. The first author with year, country of study, study design, sample size, and characteristics findings were all tabulated (**Table 1**). The data was analysed using Microsoft SPSS software version 28. R Studio was used for graph preparations by authors (ABJ & SA).

*2.7. Statistical analysis*

Statistical methods used also help in the insights into the findings and easy management of POAG. Asymmetry publication bias due to a small sample. (**Table 2**).

**Table 1:** Study characteristics

| S. No | Author Name (Year) | Sample Size | Study Design | Country | Characteristic Findings |
|---|---|---|---|---|---|
| 1 | Yamamoto et al[4] 2014 | 3762 | Population-based cross-sectional study | Japan | The prevalence of POAG was 4.0% (95% confidence interval [CI], 3.4%-4.7%). |
| 2 | He et al[5] 2015 | 2528 | Population-based study | China | A total of 2528 citizens out of 3,146 eligible residents (80.36%) participated in this study. |
| 3 | Jin et al[6] 2025 | 459,195 | Retrospective | South Korea | Found 14 genetic links to eye traits and glaucoma (POAG). The lower blood pressure to the eye (MOPP) seems to *cause* POAG. Raised intraocular Pressure is a key factor. |
| 4 | Actis[7] 2016 | 190 patients (377 eyes) | Retrospective, observational study | Italy | Factors reaching statistical significance were age (p 0.009), standard deviation (SD) of pattern deviation (p 0.038) and therapy (p 0.039). |
| 5 | Ribeiro[8] 2018 | 425 | Cross-sectional and analytical study | Brazil | Females predominate (56.8%), the age group of 60 years or older (44%) and mixed skin (81.7%). |
| 6 | Kreft[9] 2019 | 250,000 | Cohort study | Germany | The age-standardized prevalence of POAG at age 50+ in 2010 was 2.79% (95%-CI: 2.72-2.85%). |
| 7 | Daba Kumale[10] 2022 | 205 (116 cases and 89 controls) | Case-control study | Ethiopia | Family history of blindness, presenting IOP, type of glaucoma and age were independently associated with late presentation. |
| 8 | Wang[11] 2023 | 2695 | Longitudinal observational population-based study | China | Incident OAG was found in 75 participants among 2494 individuals free of glaucoma at baseline. |
| 9 | Sekimitsu[12] 2024 | 1010 | Post Hoc Analysis of a Randomized Clinical Trial | US | A polygenic risk score (PRS) threshold may be used to identify individuals at low risk of disease onset. |
| 10 | Kang et al[13] 2015 | 1,19,930 | Prospective cohort, 1986-2010 | USA | Identified risk factors include age, family history<br>19% higher incidence for women<br>POAG subtypes have distinct risk factors |

**Table 2:** Statistical analysis for POAG

| S. No. | First Author Name (Year) | Sample Size | Prevalence (Effect Size) | ES | SE | Lower | Upper |
|---|---|---|---|---|---|---|---|
| 1 | Yamamoto et al.[4] (2014) | 3,762 | 0.040 (4.0%) | 0.04 | 0.003195 | 0.033738 | 0.046262 |
| 2 | He et al.[5] (2015) | 2,528 | 0.0285 (2.85%) | 0.0285 | 0.003309 | 0.022013 | 0.034987 |
| 3 | Kang et al.[13] (2015) | 1,19,930 | 0.019 (1.9%) | 0.019 | 0.000394 | 0.018227 | 0.019773 |
| 4 | Actis et al.[7] (2016) | 190 | 0.021 (2.1%) | 0.021 | 0.010402 | 0.000612 | 0.041388 |
| 5 | Kreft et al.[9] (2019) | 2,50,000 | 0.0322 (3.22%) | 0.0322 | 0.000353 | 0.031508 | 0.032892 |
| 6 | Ribeiro et al.[8] (2018) | 425 | 0.035 (3.5%) | 0.035 | 0.008915 | 0.017527 | 0.052473 |
| 7 | Daba et al.[10] (2022) | 205 | 0.058 (5.8%) | 0.058 | 0.016325 | 0.026002 | 0.089998 |
| 8 | Jin et al.[6] (2025) | 1,500 | 0.035 (3.5%) | 0.035 | 0.004745 | 0.025699 | 0.044301 |

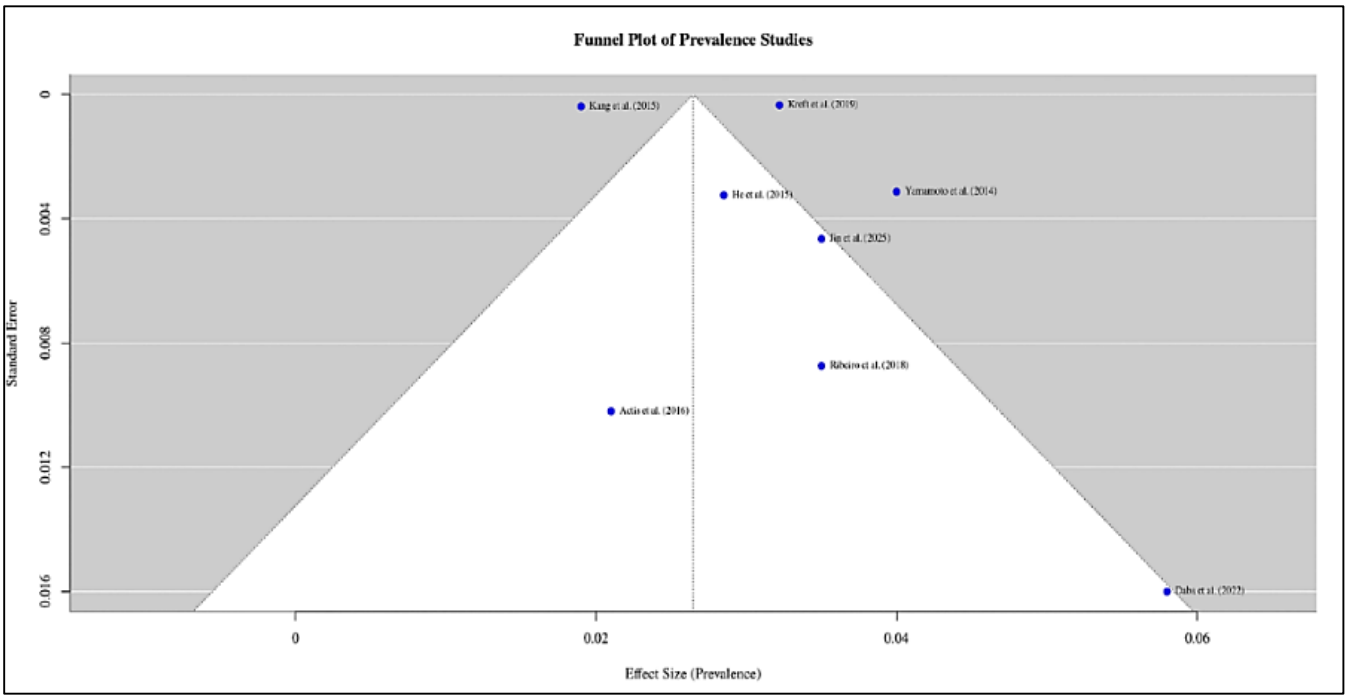


**Figure 3:** Funnel plot for the studies taken for POAG

## 3. Results

The prevalence of POAG in various studies showed the following results. Yamamoto et al in their study in Japan showed a prevalence of 4%.[4] He et al in their study in Shanghai China depicted a prevalence of 2.85.%.[5] Jin et al in their research in South Korea found prevalence in cases of 14 genes associated with Primary open-angle pressure.[6] Actis et al study done in Italy threw light on the fact that an increase in the age above 60, increases the chance of POAG.[7] For the patients with thyroid problem, the prevalence was 4.6% while for the rest of the population, it was only 2.8%. The Brazilian study by Ribeiro et al signified that females predominantly had the disease with a percentage of 56%.[8] The age group of 60 years and above showed 44%. The mixed skin group depicted 81%, other risk factors like high myopia had 6.3%, while diabetes had 17.9%. Increased optic nerve excavation of more than 0.8 and thickness of cornea less than 535 microns were characteristic as far as the clinical examination was concerned. Kreft et al from Germany in their study quoted the female sex had more prevalence of 19% higher.[9] The highest prevalence rate of 31.7% by Daba et al noted in Ethiopia.[10] Wang et al quoted 3% in China.[11] Sayuri Sekimitsu et al 14.2% quoted as prevalence.[12] Kang et al studied and analysed a population of 1,19,930 individuals majority of them were females and noted 19% higher.[13] The study after comprehensive analysis, the risk factors, and prevalence in POAG were tabulated (**Table 3**). The overall average prevalence calculated from our review article was 23.8075

All the studies were analysed and a funnel plot was performed which showed high heterogeneity. Heterogeneity was noted due to variability in the methods, sample size, chronological and geographical variations. The largest studies show the difference. (**Figure 3**). The funnel plot appears relatively symmetrical, though there are fewer studies on the left side. However, it's not asymmetrical. No

strong evidence of substantial publication bias. Statistical tests for funnel plot asymmetry (e.g., Egger's test) are often used to provide a more objective assessment. Eggers test p value was 0.0207 less than 0.05 indicates publication bias.

Bubble regression test was plotted, and depicted a negative linear association between sample size and the prevalence. (**Figure 4**). A sloping line suggested that the regression coefficient (1.222 in the equation) indicating the direction and magnitude of the effect of the covariate on prevalence that as the covariate increases, prevalence tends to increase. The $R^2$ value (0 in this case) indicated how well the covariate explains the variability in prevalence. An $R^2$ of 0 means that the covariate (Standard Error) explained none of the variability in prevalence. Statistical Analysis for forest plot (**Figure 5**) showed the effect sizes of eight studies with variability on glaucoma prevalence. The mean prevalence is 3% ranging from 2% to 4%. $p < 0.001$ is significant. Due to variations in methods, population and the pooled estimate showed p<0.001. The heterogeneity (p<0.001) suggested considerable inconsistency among the study results. It's crucial to consider all these plots together to get a comprehensive understanding of the meta-analysis results. The high heterogeneity observed in the forest plot warrants further investigation using subgroup analyses or meta-regression with other relevant covariates to identify potential sources of variation in POAG prevalence.

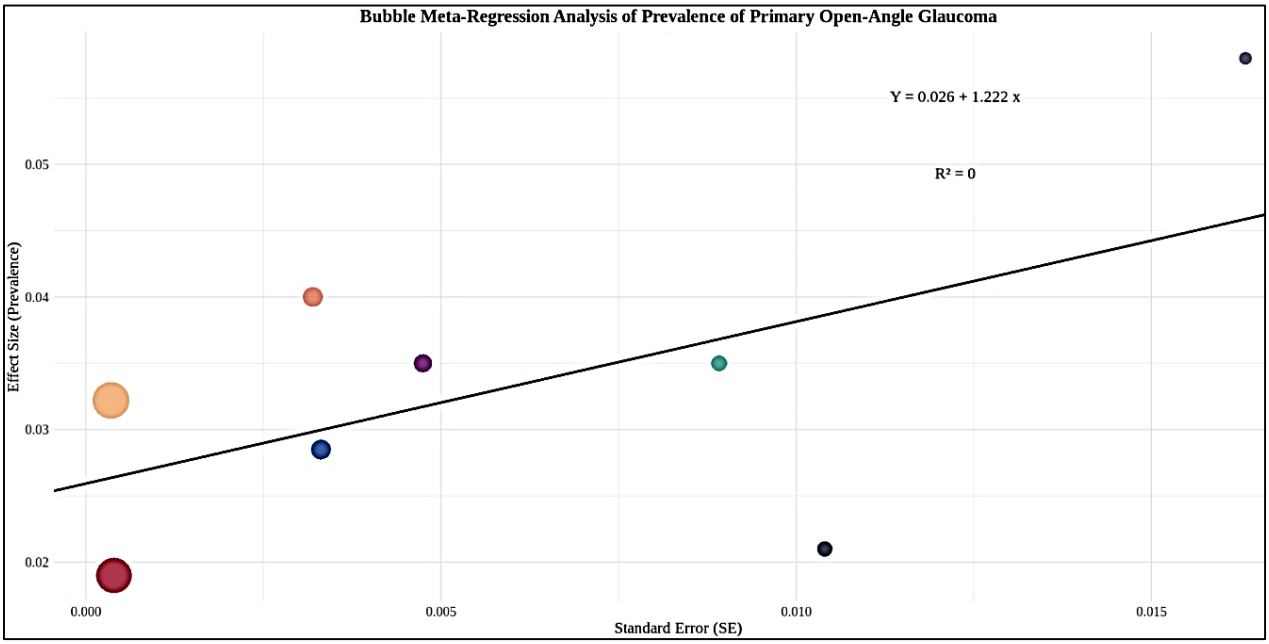


**Figure 4:** Bubble meta-regression analysis of prevalence of primary open-angle glaucoma

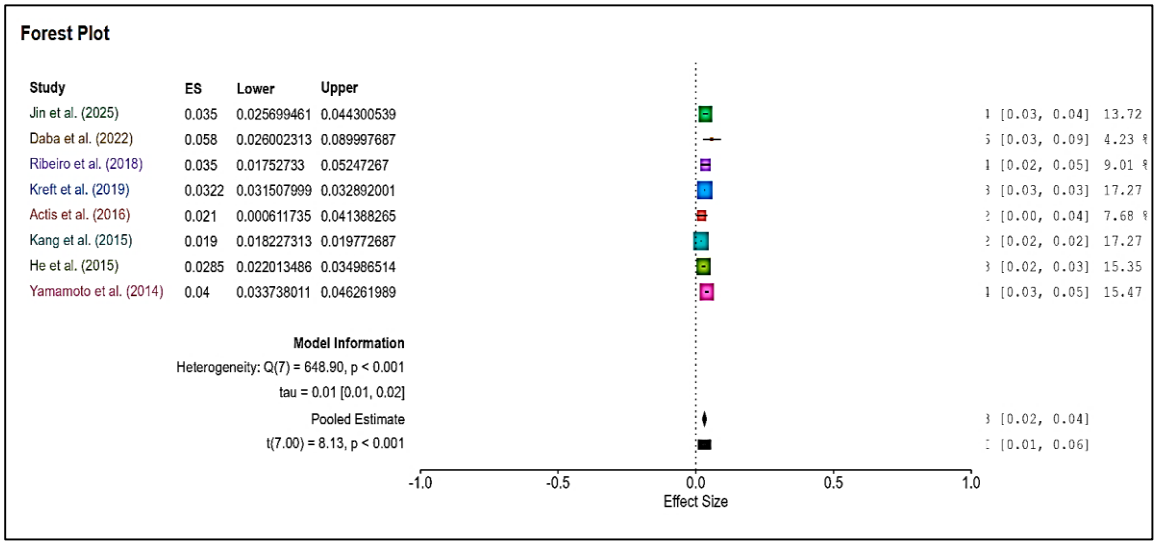


**Figure 5:** Forest plot studies in primary open angle glaucoma

**Table 3:** Risk factors and prevalence POAG

| S. No. | First Author | Year | Risk Factors | Prevalence/ Incidence |
|---|---|---|---|---|
| 1 | Yamamoto et al.[4] | 2014 | Male gender, older age, higher IOP, myopia, and a thinner cornea. | 4 |
| 2 | He et al.[5] | 2015 | Age, family history of glaucoma, IOP, myopia, and hypertension | 2.85 |
| 3 | Jin et al.[6] | 2025 | Age, elevated intraocular pressure (IOP), vascular factors, genetic factors, ocular phenotypes, such as corneal hysteresis (CH), corneal resistance factor (CRF), refractive error (RE) more than 100 novel single nucleotide polymorphisms | 3.5 |
| 4 | Actis et al[7] | 2016 | Age, standard deviation (SD) of pattern deviation, and therapy | 2.1 |
| 5 | Ribeiro et al.[8] | 2018 | High myopia, diabetes mellitus, age, and skin color increased optic nerve excavation by more than 0.8 and thickness of the cornea less than 535. | 3.5 |
| 6 | Kreft et al[9] | 2019 | Age, female sex, injuries of the eye and orbit, degeneration of the iris and ciliary body, myopia, retinal vascular occlusions, hypertension, and diabetes mellitus | 2.79 |
| 7 | Kumale T.D et al.[10] | 2022 | Family history of blindness, presenting IOP, type of glaucoma, and age | 31.7 |
| 8 | Wang et al.[11] | 2023 | Older age, longer axial length, higher intraocular pressure (IOP), higher vertical cup/disc ratio (VCDR), high myopia | 3 |
| 9 | Sekimitsu et al.[12] | 2024 | The polygenic risk group, known clinical risk factors faced the highest risk of developing POAG | 14.2 |
| 10 | Kang et al[13] | 2015 | Risk factors: African heritage, glaucoma family history body mass index (BMI), mean arterial blood pressure, diabetes mellitus, physical activity, cigarette smoking, caffeine, and alcohol intake. | 1.9 |

**Table 4:** Merits and gaps in studies

| S. No | Author Name | Year | Merits | Gaps |
|---|---|---|---|---|
| 1. | Yamamoto et al.[4] | 2014 | Large sample size (3,762 participants); comprehensive diagnostic criteria. | Limited to rural Japanese population; no longitudinal follow-up. |
| 2. | He et al.[5] | 2015 | First study in Shanghai; tele medical screening model. | Self-reported diabetes/hypertension may underestimate true prevalence. |
| 3. | Jin et al[6] | 2025 | Genetic factor with POAG study | Retrospective study |
| 4. | Actis et al.[7] | 2016 | Long follow-up (79 months); GLM analysis for progression. | Small sample for GDx data (56 patients); retrospective design. |
| 5. | Ribeiro et al.[8] | 2018 | Focus on advanced glaucoma; detailed clinical metrics. | Skin color self-reporting bias; no IOP fluctuation analysis. |
| 6. | Kreft et al.[9] | 2019 | Health claims data are an important data source for estimating POAG occurrence and help overcome the problems of small sample sizes. | Study on USA population. |
| 7. | Kumale T.D.et al.[10] | 2022 | A family history of blindness, high intraocular pressure at presentation, pseudoexfoliative glaucoma, and increased age are risk factors for glaucoma's late onset. | Population based study related only to the advanced stage of glaucoma |
| 8 | Wang et al.[11] | 2023 | Based on the population-based Longitudinal Beijing Eye Study | Only limited to population-based study. Lack of general ability. |
| 9 | Sekimitsu et al.[12] | 2024 | The prospective OHTS dataset with a 20-year follow-up period and definition of POAG by both structural and functional changes | Small sample size. |
| 10 | Kang et al.[13] | 2015 | Large cohort | Limited to healthcare professionals |

## 4. Discussion

There is a commonality running through most of the studies that have found prominent risk factors for glaucoma. The strength and weaknesses of each study were listed (**Table 4**). Out of all the variables, increasing age and elevated intraocular pressure (IOP) time and again stood as strong risk factors. In the study by Yamamoto et al., 82% of the subjects had an IOP of less than 22 mmHg, but POAG was present in 4.0% of them, pointing out that the disease can be present even in normotensive individuals. This observation bears testimony to the multifactorial etiology of POAG and points out the limitation of relying on IOP alone as a screening test. Primary open angle glaucoma is also positively associated with vascular risk factors.[14] The reports by Kreft et al. and Wang et al. re-emphasized the role of aging and optic disc features such as vertical cup-to-disc ratio as important risk factors. This was reinforced by yet another study.[15] Myopia—especially high myopia—has been very strongly associated with POAG, as another author discussed.[16] Regional and ethnic diversities of prevalence and expression of risk factors is most likely a reflection of a multifactorial interaction between genes, socioeconomic status, access to medical facilities, and diagnostic criteria. He et al. reported a crude prevalence of 4.52.85% in Shanghai, and 22 of 72 cases had IOP >21 mmHg. Daba et al. in Ethiopia investigated advanced-stage glaucoma and reported strong association with advanced age, family history, and elevated presenting IOP. A rise in 1 year of age raised risk by 3.4%, highlighting the importance of early screening. Pseudoexfoliation, when present, raised risk of progression, as another author discussed.[17] Public education, particularly in rural and disadvantaged populations, contributes to prevention of late diagnosis. Genetic factors also remain important. Actis et al. reconfirmed elevated intraocular pressure, family history, and female gender as important risk factors. Although the sample was small, it replicated previous findings.[18,19] Ribeiro et al. highlighted female predominance, hypertension, and skin color, as in Brazil and other Latin American populations.[20,21] Diabetes was noted in 20% of the subjects, reconfirming metabolic associations with POAG.[1] Other risk factors are orbital trauma, iris degeneration, and vascular occlusions. Transient IOP elevation even from head injury can also cause POAG in the long term.[23] Sekimitsu et al. proposed polygenic risk scores (PRS) as a genetic susceptibility measure. In conjunction with structural imaging and intraocular pressure (IOP) data, PRS can push early detection. Trabeculectomy with Mitomycin-C, investigated by a different group, is a case in point regarding a contemporary method of intraocular pressure control.[24] Genetic loci for IOP were investigated by Abu-Amero et al. and Qassim et al., demonstrating that glaucoma is influenced by factors other than merely pressure.[25,26] Jin et al. investigated the interaction between ocular perfusion pressure and significant loci associated with vascular characteristics. Growing evidence increasingly favours the vascular hypothesis for primary open-angle glaucoma (POAG), indicating that dysregulation of microvascular function could be a significant determinant—specifically in phenotypes of normal-tension glaucoma.

Systemic risk predictors like BMI, blood pressure, and African heritage were identified by Kang et al., corroborated by another large study.[27] Machine learning algorithms from fundus images are now on par with experts in detecting POAG and are soon likely to be standardized for population-level screening. Underdiagnoses among specific ethnic groups could be due to optic disc morphology that is too subtle for existing diagnostics. AI platforms can potentially fill this diagnostic gap. POAG is also being investigated together with neurodegenerative diseases like Alzheimer's, triggering potential common mechanisms of optic nerve and brain tissue degeneration.

In conclusion, while high IOP is the highlight, POAG is a heterogeneous multifactorial disorder with determinants of age, genetics, vascular status, and general health. Integration of such technologies as PRS, OCT, and AI can hold potential for enhanced accuracy in detection and prevention. Integration of early POAG screening in non-communicable disease clinics can be the key to reducing global blindness burden.

## 5. Conclusion

This systematic review and meta-analysis aims to elucidate the multifactorial determinants of the prevalence of primary open-angle glaucoma (POAG) across different populations. By analysing the various factors through which demographic, clinical, and methodological factors influence prevalence rates, we aim to provide insights that can be helpful to inform public health programs and clinical practice. In the case of high-risk patients, it is essential to have frequent testing, especially in early detection and prevent visual loss. Technological innovations, including Optical Coherence Tomography (OCT) and artificial intelligence (AI), are also potential solutions to enhance the efficacy and efficiency of diagnosis. Telemedicine is also one sector that can better deliver access, especially to the underserved, through remote monitoring and consultations. In the future, longitudinal research will be necessary to track the incidence and progression of POAG, and genetic and environmental determinants studies. Especially in low and middle-income countries, the health issue has to be improved a lot with the collaboration of developed countries. From understanding of the risk factors, the results of the studies will help in the prevention of glaucoma, early detection and management.

## 6. Strength and Limitations

Meta-analysis was done on prevalence and risk factors for POAG from the studies selected from all over the country by renowned authors. However, the study had its own limitations. The period for review was short with a time span

of ten years and the sample size was considerably variable and high heterogeneity was also observed.

## 7. Author Contributions

Conceptualization and methodology, S.S & T.V; Formal analysis, S.S, T.V & A.B.; Visualization and writing – original draft S.S, T.V & A.B.; Writing – review and editing, S.S, T.V & A.B and J.H. All authors have read and agreed to the final version of the manuscript.

## 8. Source of Funding

This research was not supported by any specific grants from public, commercial, or non-profit funding agencies.

## 9. Conflicts of Interest

The authors report no conflict of interest.

## 10. Ethical Approval

Not required since the study was a systematic review and meta-analysis

## 11. Consent to Publication

Not applicable.

## 12. Availability of Supporting Data

Not applicable as the study is a systematic review and meta-analysis.

## 13. Acknowledgments

We would like to thank our Principal, Dr. Vasanthamalai, and General Manager, Mr. Rahim for their immense involvement. And Mrs. Sowmya Krishnadas for her technical assistance and Miss Swathi for her aid with data analysis and illustrations in the preparation of this study.

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**Cite this article:** Babu JA, Vaishnavi T, Swaminathan S, Ahamed S, Hameed J. Global prevalence and risk factors of primary open-angle glaucoma: A systematic review and meta-analysis. *Indian J Clin Exp Ophthalmol*. 2025;11(4):591–600.