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The Prevalence Trend of Glaucoma by Age and Sex Difference in South Asia: A Systematic Review and Meta-Analysis of Population-Based Studies

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ABSTRACT

Background and Aims: Glaucoma, a group of eye diseases, is a leading cause of irreversible blindness worldwide. However, reports on the prevalence of glaucoma in the South Asian region have not been up-to-date. This systematic review and meta-analysis aimed to estimate the pooled prevalence of glaucoma in South Asia and analyze its trends by age and sex.

Methods: Adhering to the Preferred Reporting Items for Systematic Review and Meta-Analysis guidelines, a comprehensive search was undertaken on several electronic databases, including PubMed, Embase, Google Scholar, and Web of Science, to retrieve relevant studies published until June 2023.

Results: A total of 17 population-based studies, including 77,790 subjects (37,950 male and 39,709 female), were included in the meta-analysis based on set inclusion criteria. The pooled prevalence of glaucoma in South Asia was 2.1% (95% confidence interval [CI] 1.7–2.6). Among the subtypes, the prevalence of primary open-angle glaucoma (POAG) was 1.6% (95% CI: 1.2–2.1), primary angle-closure glaucoma (PACG) was 0.7% (95% CI: 0.4–1.0), and secondary glaucoma was 0.3% (95% CI: 0.1–0.5). The prevalence trend of glaucoma increased with age and was higher in males. POAG prevalence was found to be higher in all age groups than the prevalence of PACG and highest in people > 80 years old (7.25% vs. 2.12%). The prevalence of POAG was also higher in males (2.26%) than in females (1.61%), whereas PACG prevalence was similar for both males and females.

Conclusion: This study highlights a significant burden of glaucoma in South Asia, particularly among older adults and males, with POAG being the most common subtype. These findings may assist public health leaders in understanding the scenario of glaucoma in South Asia and implementing public health strategies to combat glaucoma.

1 | Introduction

Glaucoma is a group of eye diseases that is the second-leading cause of irreversible blindness worldwide, following cataracts [1]. It is sometimes referred to as a "silent killer" and is defined as a group of optic neuropathies characterized by anatomical alterations at the optic nerve head, leading to retinal ganglion cell death, visual field loss, and blindness [2]. It has been estimated that 76 million people were affected by glaucoma globally in 2020, and this figure will increase to 111.8 million in 2040 [3, 4]. The global prevalence of glaucoma is around 3.5% among individuals aged 40 and older [3]. Primary open-angle glaucoma (POAG) is the most prevalent form, with a global prevalence of approximately 3.1%, six times higher than that of

primary angle-closure glaucoma (PACG), which was found to be about 0.5% [3]. POAG is most common in Africa (4.2%), while PACG is most prevalent in Asian populations (1.1%) [3].

The risk and prevalence of glaucoma subtypes differ by race, ethnicity, age, and country [5–7]. According to the World Health Organization (WHO), more than three-quarters of the glaucoma population lives in Asia [3]. South Asia, with a population of 1.94 billion people [8], is the area with the highest number of blind individuals (11.7 million), accounting for 32.5% of the blind population globally [9]. A population-based study in India reported that glaucoma was responsible for approximately 12% of adult blindness [10]. A comparable study in Nepal found that glaucoma was responsible for only 1.7% of blindness [11]. In Bangladesh, the reported overall prevalence of glaucoma was 1.7%, but it affects 2.1% of people over the age of 40 years [12].

Despite these statistics, data on the prevalence of glaucoma in the South Asian region are relatively scarce, and no systematic research has been carried out in this area. This knowledge gap makes it difficult to create and implement effective health policies for controlling the glaucoma burden in South Asia. Therefore, this systematic review and meta-analysis aim to estimate the pooled prevalence of glaucoma in South Asia and investigate its trend based on age and sex differences among South Asian people.

2 | Methods

2.1 | Literature Search Strategy

This study was carried out in accordance with the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines [13] (Supplementary file 1). Four electronic databases, including PubMed, Google Scholar, Embase, and Web of Science, were searched to find relevant published articles up to June 2023. A combination of keywords related to glaucoma ("primary glaucoma," "secondary glaucoma," "PACG," "POAG," "primary angle-closure glaucoma," "primary open-angle glaucoma," "glaucoma in India," "glaucoma in Bangladesh," "glaucoma in Pakistan," "glaucoma in Sri Lanka," "glaucoma in Nepal," "glaucoma in Bhutan," "glaucoma in Maldives," "glaucoma in Afghanistan," and "glaucoma in South Asia") and epidemiology ("prevalence," "prevalent," "population," and "survey") were used during the search. Additionally, a manual search was carried out to identify the target articles from the other reference lists.

2.2 | Inclusion and Exclusion Criteria

We included population-based observational studies reporting on the prevalence of glaucoma in South Asian countries based on the following inclusion criteria: (1) cross-sectional or cohort studies of glaucoma from a defined geographic region; (2) studies that met rigorous criteria for diagnosing glaucoma, including visual field tests and evaluations of the anterior chamber angle; (3) full-text access to reported studies (editorial, conference abstracts, and case reports excluded); (4) studies with a clear definition of random or clustered sampling procedure; (5) more than 60% response rate of eligible population participants; and (6) studies published between 2000 and 2023. The exclusion criteria were as follows: (1) studies were published in languages other than English; (2) studies reported self-diagnosed glaucoma; and (3) studies were based on hospital or clinic interviews.

2.3 | Data Extraction

Data were extracted independently by both authors based on inclusion and exclusion criteria, and any disagreements were settled through careful discussion. Extracted data included first author name, published year, year of data collection, study location (country), sample size, study setting (urban, rural, or mixed), gender, age range (years), number of cases, prevalence, and response rate.

2.4 | Quality Assessment

We used the Cross-Sectional/Prevalence Study Quality Assessment Forms recommended by the Agency for Healthcare Research and Quality (AHRQ) to evaluate study quality [14]. This AHRQ form has eleven questions (Table S1), ten of which are appropriate for cross-sectional investigations. We evaluated the quality score of each study using ten questions, assigning a score of 1 for "Yes" and 0 for "No" or "Unclear."

2.5 | Data Analysis

The pooled prevalence of glaucoma in South Asia was estimated using the Freeman-Tukey double arcsine transformation of proportions [15, 16]. We employed the DerSimonian–Laird random-effects models for meta-analysis with a 95% confidence interval (95% CI), with subgroup analyses by glaucoma type, age, sex, and study location due to its ability to account for heterogeneity among the included studies. The Cochrane chi-square Q-test and the I^2 index with its associated p value were used to assess the presence of heterogeneity across studies. I^2 values of 25%, 50%, and 75% were used to define low, medium, and high heterogeneity, respectively. Publication bias was analyzed using the Doi plot and Luis Furuya-Kanamori asymmetry index (LFK index) [17]. The Doi plot provides a visual illustration of the symmetry of the data, while the LFK index quantifies the degree of asymmetry, with values close to zero indicating minimal publication bias. MetaXL software (meta-analysis in Microsoft Excel) and Review Manager 5.4 (RevMan 5.4, the Cochrane Collaboration, Oxford, United Kingdom) were used to analyze the extracted data.

3 | Results

3.1 | Search Results

A total of 560 individual studies were initially identified and reviewed through multiple database searches. After removing

duplicate records, performing additional screening, and analyzing the titles and abstracts, 37 full-text articles were retrieved for final assessment. Out of the 37 studies, this study finally included 17 articles that met the eligibility criteria and reported the prevalence of glaucoma in South Asia. The literature review, screening, and eligibility assessment of the study articles are illustrated in Figure 1.

3.2 | Characteristics of Included Studies

The characteristics of the 17 included studies, with a total sample size of 77,790, on the prevalence of glaucoma in South Asian countries are presented in Table 1. Eleven studies were conducted in India [18–28], three in Nepal [29–31], two in Sri Lanka [32, 33], and one in Bangladesh [12]. However, no studies were found for Pakistan, Bhutan, Maldives, or Afghanistan. The sample size of the study ranged from 1269 [20] to 14092 [28]. Six studies were conducted in urban settings [18, 23, 26, 29–31], five in rural settings [12, 19, 20, 32, 33], and six studies covered both rural and urban areas [21, 22, 24, 25, 27, 28]. Fourteen studies reported the prevalence of PACG [12, 18–22, 24–27, 29–31, 33], thirteen studies on POAG prevalence [12, 19–22, 24, 26–32], and nine studies reported the prevalence of secondary glaucoma [12, 19–21, 26, 27, 29–31] (Table 2). The majority of the studies reported a participant response rate of more than 80%, and all studies presented sex-specific prevalence data. All the studies were rated as high quality, and their total quality score was higher than five (Table S2).

3.3 | Prevalence of Glaucoma

The overall pooled prevalence of glaucoma in South Asia was 2.1% (95% CI: 1.7–2.6) (Figure 2). The results of the heterogeneity test showed that the included studies were significantly heterogeneous ($I^2 = 94\%$, $p < 0.001$). The prevalence data for different types of glaucoma are summarized in Table 2. The prevalence of POAG was highest in South Asian countries compared to the prevalence of PACG and SG. The estimated POAG prevalence was 1.6% (95% CI: 1.2–2.1), whereas the PACG and SG pooled prevalence rates were 0.7% (95% CI: 0.4–1.0) and 0.3% (95% CI: 0.1–0.5), respectively.

3.4 | Results of Subgroup Analysis

Table 2 shows the results of subgroup analyses based on age groups, sex, and study location among the included studies. The prevalence trend of glaucoma increased steadily with age, and people over the age of 80 had the highest prevalence (7.5%, 95% CI: 3.3–13.1, $p = 0.213$). People aged 40–49 years had the lowest prevalence compared with other age groups (0.8%, 95% CI: 0.4–1.4, $p < 0.001$). This meta-analysis showed that the pooled prevalence of glaucoma was higher in men than in women (2.2% vs. 2.0%) with significant heterogeneity ($I^2 = 90\%$, $p < 0.001$). The prevalence of glaucoma was highest in Sri Lanka (3.2%, 95% CI: 1.3–5.9, $p < 0.001$) and lowest in Nepal (1.6%, 95% CI: 1.1–2.2, $p < 0.001$) compared to other South Asian countries.

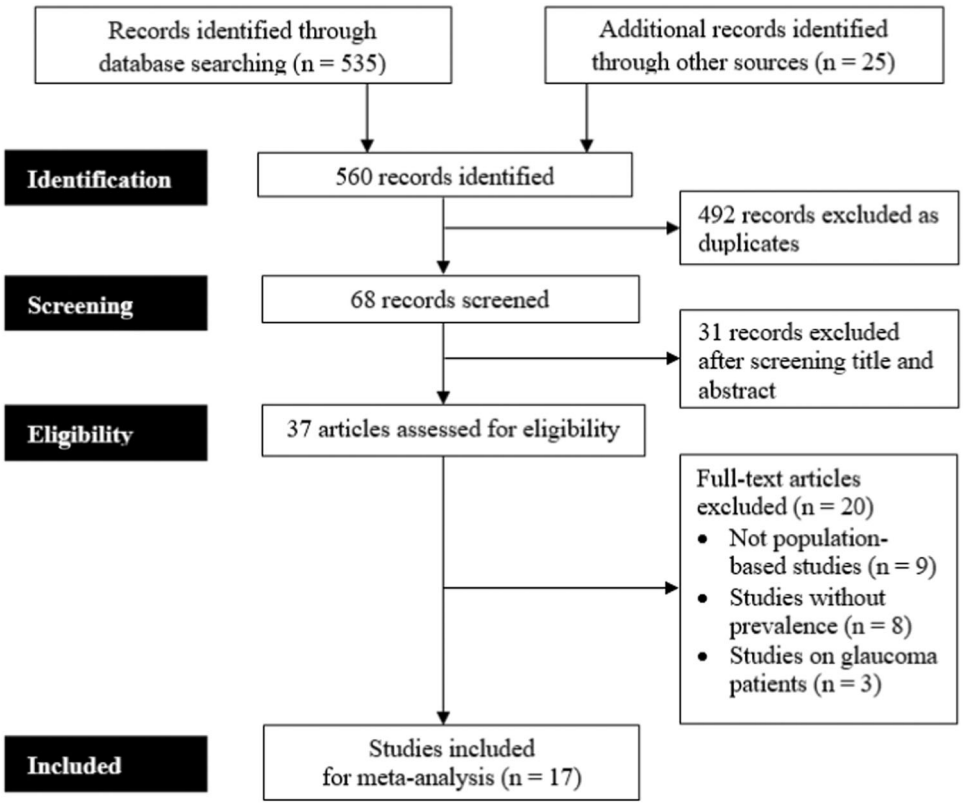

FIGURE 1 | Flowchart summarizing the article selection process based on Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

TABLE 1 | Characteristics of the included studies reporting the prevalence of glaucoma in South Asian countries.

Author (year of publication)	Year of data collection	Country	Study design	Study area	Sample size	Age range (years)	Sex ratio (M/F)	Number of cases			Prevalence (%)	Response rate (%)
								POAG	PACG	SG		
Dandona et al. (2000)	1996–1997	India	Cross-sectional	Urban	2522	≥ 15	1175/1347	—	27	—	1.07	85.4
Ramakrishnan et al. (2003)	2001	India	Cross-sectional	Rural	5150	≥ 40	2314/2836	86	26	16	2.49	93
Rahman et al. (2004)	1997–1998	Bangladesh	Cross-sectional	Rural	2347	≥ 40	1220/1127	29	7	3	1.66	66
Raychaudhury et al. (2005)	2005	India	Cross-sectional	Rural	1269	≥ 50	611/658	46	3	1	3.94	83.1
Sah et al. (2007)	2003–2004	Nepal	Cross-sectional	Urban	1600	≥ 40	789/811	9	2	4	0.94	84
Palimkar et al. (2008)	2001	India	Cross-sectional	Mixed	7438	≥ 35	3570/3868	37	60	60	2.11	86.9
Vijaya et al. (2008a)	2002–2004	India	Cross-sectional	Mixed	3850	≥ 40	1710/2140	135	—	—	3.51	80.2
Vijaya et al. (2008b)	2001–2004	India	Cross-sectional	Urban	3850	≥ 40	1710/2140	—	34	—	0.88	80.2
Casson et al. (2009)	2006–2007	Sri Lanka	Cross-sectional	Rural	1375	≥ 40	548/827	—	64	—	4.65	79.9
Garudadri et al. (2010)	1996–2000	India	Cross-sectional	Mixed	3724	≥ 40	1751/1973	82	35	—	3.14	88
Senthil et al. (2010)	1996-2000	India	Cross-sectional	Mixed	3724	≥ 40	1751/1973	—	35	—	0.94	88
Sia et al. (2010)	2001	Sri Lanka	Cross-sectional	Rural	1375	≥ 40	496/748	32	—	—	2.33	79.9
Thapa et al. (2012)	—	Nepal	Cross-sectional	Urban	3991	≥ 40	1819/2172	51	17	7	1.88	83.4
Narayanaswamy et al. (2013)	2007–2009	India	Cross-sectional	Urban	3400	≥ 40	1706/1694	46	6	26	2.29	75.6
Thapa et al. (2013)	2012	Nepal	Cross-sectional	Urban	3991	≥ 40	2068/1923	51	17	7	1.88	83.15

(Continues)

TABLE 1 | (Continued)

Author (year of publication)	Year of data collection	Country	Study design	Study area	Sample size	Age range (years)	Sex ratio (M/F)	Number of cases			Prevalence (%)	Response rate (%)
								POAG	PACG	SG		
Paul et al. (2016)	2011–2014	India	Cross-sectional	Mixed	14092	≥ 40	7356/6736	251	149	16	2.95	96
Paul et al. (2020)	2011–2014	India	Cross-sectional	Mixed	14092	≥ 40	7356/6736	251	—	—	1.78	96

Abbreviations: F, female; M, male; PACG, primary angle-closure glaucoma; POAG, primary open-angle glaucoma; SG, secondary glaucoma.

3.5 | Risk of Bias

The potential for publication bias among the 17 studies included in this analysis was systematically evaluated using the Doi plot and the LFK index, both of which are widely recognized tools for assessing bias in meta-analyses. The Doi plot visually demonstrated a lack of symmetry, suggesting the possible presence of publication bias or other forms of small-study effects. However, when quantitatively analyzed using the LFK index, the results indicated that there was no significant evidence of publication bias. Specifically, the calculated LFK index value was 0.27, which falls within the range typically considered to reflect the symmetry and the absence of notable bias (Figure 3).

3.6 | Prevalence Trend of Glaucoma by Age and Sex Differences in South Asia

In this meta-analysis, we analyzed the prevalence trend of POAG and PACG by age and sex differences in South Asia (Figure 4). According to reported studies, the prevalence trend of POAG and PACG increased steadily with age in South Asia. The POAG prevalence was found to be higher in all age groups than the prevalence of PACG and highest in people > 80 years old (7.25% vs. 2.12%) (Figure 4A). The prevalence of POAG was higher in men than in women (2.26% vs. 1.61%), whereas the prevalence of PACG was similar for both men and women (0.70% vs. 0.70%) (Figure 4B). We also determined the overall prevalence trend of glaucoma in South Asian countries by gender difference (Figure 5). It was found that glaucoma was more prevalent in men than in women in India (2.52% vs. 2.07%), whereas the opposite was observed in Sri Lanka (3.31% vs. 3.81%). In Bangladesh and Nepal, a similar trend was observed for both men and women.

4 | Discussion

This systematic review and meta-analysis provided an up-to-date assessment of the prevalence of primary and secondary glaucoma in South Asia and its trend by age and sex differences based on published data from the last 20 years. According to this meta-analysis, the overall pooled prevalence of glaucoma in South Asia was 2.1%, which is considerably lower than the global prevalence of glaucoma (3.5%) [3]. In South Asia, secondary glaucoma had a prevalence of 0.3%, PACG had a prevalence of 0.7%, and POAG had the highest prevalence of 1.6%. The findings demonstrated significant heterogeneity among the included studies. This heterogeneity can be attributed to several factors, including variations in study design, diagnostic criteria for glaucoma, population demographics, and geographic location. Previous studies conducted in North America reported prevalence rates of glaucoma ranging from 1.3% to 3.5%, with POAG being the most frequent subtype [34]. Similarly, studies conducted in Europe have revealed glaucoma prevalence rates ranging from 1.0% to 2.9% [35]. These findings suggest that the overall prevalence of glaucoma and its subtypes in South Asia is similar to that observed in other geographical areas. However, it is important to note that the prevalence rates of specific

TABLE 2 | Results of subgroup analysis based on glaucoma type, age, sex, and study location (country).

	Subgroup analysis			
	Number of studies	**Pooled prevalence % (95% CI)**	I^2 **(%)**	***p* value**
Glaucoma type				
POAG	13	1.6 (1.2–2.1)	94.4	< 0.001
PACG	14	0.7 (0.4–1.0)	93.1	< 0.001
SG	9	0.3 (0.1–0.5)	90.6	< 0.001
Age range, years				
40–49	9	0.8 (0.4–1.4)	92.7	< 0.001
50–59	10	1.7 (1.2–2.3)	84.9	< 0.001
60–69	10	2.5 (1.9–3.2)	79.7	< 0.001
70–79	10	4.2 (3.1–5.6)	79.9	< 0.001
80+	3	7.5 (3.3–13.1)	35.3	0.213
Sex				
Male	17	2.2 (1.8–2.8)	90.4	< 0.001
Female	17	2.0 (1.6–2.5)	90.8	< 0.001
Study location (country)				
India	11	2.1 (1.7–2.7)	95.1	< 0.001
Nepal	3	1.6 (1.1–2.2)	75.9	< 0.001
Sri Lanka	2	3.2 (1.3–5.9)	91.1	< 0.001
Bangladesh	1	1.7 (1.2–2.7)	91.1	< 0.001

Abbreviations: PACG, primary angle-closure glaucoma; POAG, primary open-angle glaucoma; SG, secondary glaucoma.

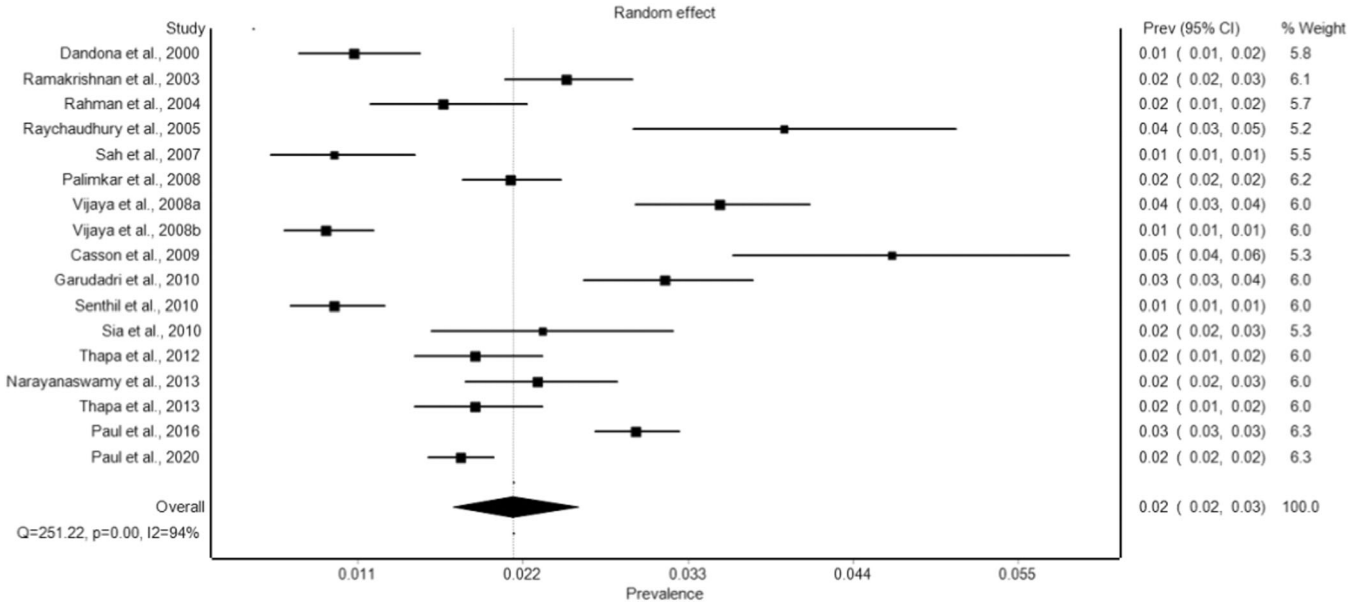

FIGURE 2 | Forest plot showing the pooled prevalence of glaucoma in South Asia with 95% confidence intervals (CIs).

subtypes may fluctuate among diverse populations due to genetic, environmental, and racial/ethnic factors.

According to the findings of the subgroup analysis, the prevalence trend of glaucoma in South Asia exhibited increasing incidences with age, with the highest incidence being recorded in those who were 80 years of age or older. Notably, POAG exhibited a higher prevalence across all age groups compared to PACG. In terms of gender differences, it was observed that the incidence of glaucoma was more prevalent among males than females, specifically for POAG. In contrast, PACG prevalence was similar between men and women. Moreover, there was observed variation in the prevalence of glaucoma in different South Asian countries, with Sri Lanka exhibiting the highest prevalence (3.2%) and Nepal exhibiting the lowest (1.6%). In terms of the age and gender differences in the prevalence of

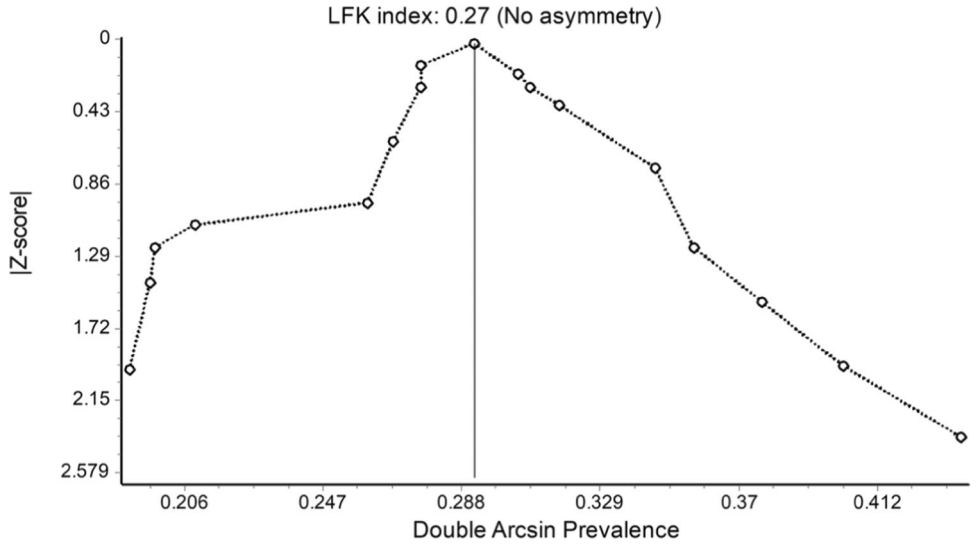

FIGURE 3 | Doi plot and Luis Furuya-Kanamori (LFK) index illustrating the assessment of publication bias in the included studies.

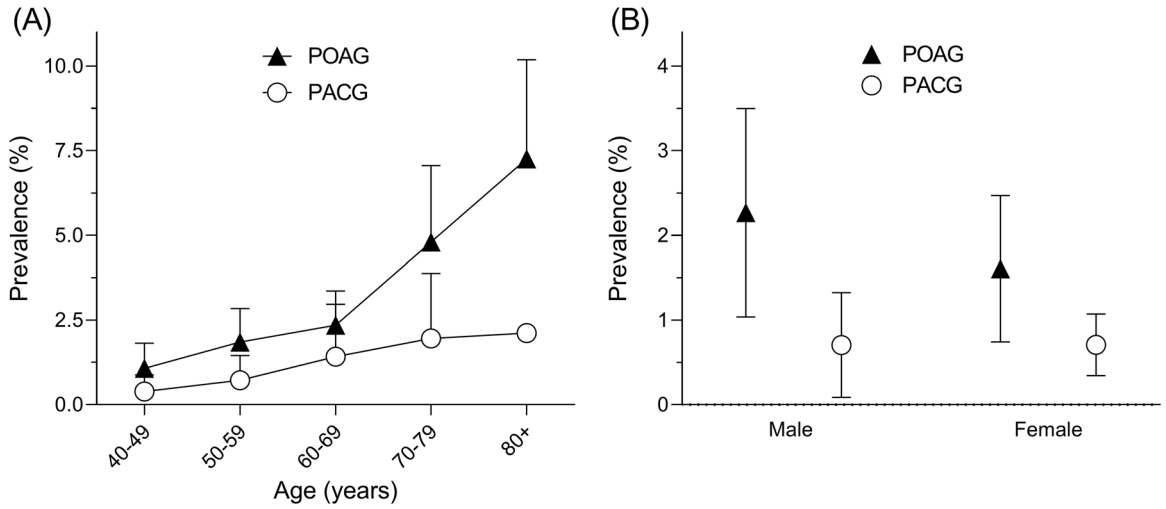

FIGURE 4 | Prevalence of primary open-angle glaucoma (POAG) and primary angle-closure glaucoma (PACG) in South Asia. (A) Age-specific and (B) sex-specific prevalence trends of POAG and PACG in the included studies.

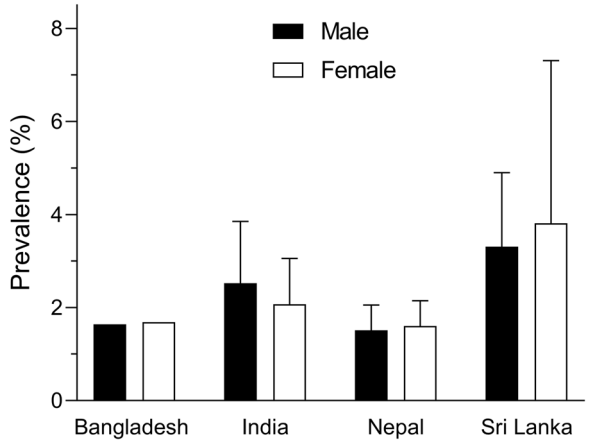

FIGURE 5 | Sex-specific prevalence trends of glaucoma in individual South Asian countries. The figure shows the prevalence rates of glaucoma among males and females across the region, emphasizing country-specific variations and patterns.

glaucoma, the findings of this study are consistent with those of earlier studies that were conducted on various continents or regions [36]. It has been proven that glaucoma rates rise with age in all regions of the world. Further, it was shown that the prevalence of glaucoma was significantly higher in men than it was in women, particularly in cases of POAG. These trends underline the importance of age and gender as risk factors in the development of glaucoma and the need for targeted screening and management strategies [37]. The age-related increase in prevalence emphasizes the necessity of early detection and management of glaucoma, especially for elderly individuals. In addition, it is essential to carry out additional studies to ascertain the factors that are responsible for the discrepancies in the prevalence rates of glaucoma.

Although this study provides valuable insights into the understanding of glaucoma prevalence in South Asia, it is necessary to consider the limitations of the included studies and the possibility of selection bias. The primary limitation is the lack of

studies from certain South Asian nations, such as Pakistan, Bhutan, Maldives, and Afghanistan. This lack of representation may limit the generalizability of our findings to the entire South Asian region, and it emphasizes the necessity for more research in these regions to obtain a comprehensive understanding of glaucoma prevalence. Although this study highlighted the prevalence trends of glaucoma by age and sex differences in South Asia, other factors, such as the socioeconomic conditions, ethnicity, and habitation area (urban or rural) of the participants, are still missing. The observed heterogeneity among the included studies may be attributed to differences in study methodologies, population characteristics, and diagnostic criteria. For instance, variations in the age range of the study population, sampling methods, and diagnostic techniques may influence the estimated prevalence rates. Moreover, variations in healthcare availability, public knowledge, and cultural factors related to regular eye exams may also impact the reported prevalence rates of glaucoma. Furthermore, selection bias may have influenced the study findings, as the included studies were mostly conducted in hospital-based settings, which may not fully represent community-level disease prevalence.

5 | Conclusion

In conclusion, we analyzed data from 17 population-based cross-sectional studies conducted in South Asia over the past 20 years to estimate the prevalence of glaucoma and examine its trends by age and sex. The study revealed that the pooled prevalence of glaucoma in South Asia was 2.1%, which is relatively lower than the global prevalence rate of 3.5%. The higher prevalence of POAG observed among elderly individuals and men aligns with worldwide patterns and demonstrates the highest prevalence rate in the region. Understanding the scenario of glaucoma in South Asia is essential for developing targeted interventions, optimizing resource allocation, and implementing public health measures to reduce vision loss and prevent blindness. However, more research is still needed to fill in the data gaps and improve our understanding of glaucoma prevalence in South Asian populations.

Author Contributions

Sujan Banik: conceptualization, methodology, formal analysis, supervision, writing – original draft, writing – review and editing. **Antara Ghosh:** formal analysis, methodology, visualization, writing – review and editing. **Hoimonti Debi:** methodology, investigation, data curation, writing – original draft. All authors have read and approved the final version of the manuscript. Sujan Banik had full access to all of the data in this study and took complete responsibility for the integrity of the data and the accuracy of the data analysis.

Conflicts of Interest

Sujan Banik is on the Editorial Board of the Health Science Reports and a corresponding author of this article. He was not involved in any of the editorial decisions that led to this paper being accepted for publication in this journal. The other authors have declared that they have no competing interests.

Data Availability Statement

The authors confirm that the datasets used for this study are available on request from the corresponding author.

Transparency Statement

The lead authors, Sujan Banik and Antara Ghosh, affirm that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.