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REVIEW ARTICLE

Global and regional prevalence of age-related cataract: a comprehensive systematic review and meta-analysis

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Abstract

The aim of our study was to estimate regional and global cataract prevalence, its prevalence in different age groups, and the determinants of heterogeneity and its prevalence. For that, we used international databases such as PubMed, Web of Science, Scopus, Embase, and other sources of information to conduct a systematic search for all articles concerning the prevalence of age-related cataract and its types in different age groups. Of the 9922 identified articles, 45 studies with a sample size of 161,947 were included in the analysis, and most of them were from the Office for the Western Pacific Region (19 studies). Age- standardized pooled prevalence estimate (ASPPE) and 95% confidence interval (95% CI) of any cataract, cortical cataract, nuclear cataract, and posterior subcapsular (PSC) cataract were 17.20% (13.39–21.01), 8.05% (4.79–11.31), 8.22% (4.93–11.52), and 2.24% (1.41–3.07), respectively. Significant effects on heterogeneity were observed for the WHO region in the prevalence of any cataract (b: 6.30; p: 0.005) and study year in the prevalence of nuclear cataract (b: −0.66, p: 0.042). In general, the prevalence of cataract not only varies by region but also by age group, and most cases are over the age of 60 years. We examined the sources of variance in the prevalence of cataract and its different types, and identified age as a responsible factor in the prevalence of any cataract, cortical cataract, nuclear cataract, and PSC of cataract, WHO region in the prevalence of any cataract, and study year in the prevalence of nuclear cataract.

Introduction

Although cataract is almost always a curable disease [1], it is still one of the most common causes of visual impairment around the world [2–4]. This disease, which can significantly reduce patients' quality of life [5], is still one of the main ophthalmological public health problems in developed and developing countries [2], and it is known as the main cause of blindness in many countries [2–4, 6–8]. Studies indicate that 36 million people are blind worldwide, and over 12 million of them are due to cataract [4, 8]. It is projected that this estimate will reach 13.5 million people in 2020 [8]. The importance of cataract blindness is that more than 90% of the total disability-adjusted life years lost due to cataract is in developing countries [4].

Cataract is usually an inevitable side effect of aging [2]. However, it should be noted that some genetic and environmental factors such as smoking cigarettes, ultraviolet light exposure, and certain diseases, such as diabetes, uveitis, IOP-lowering medications/surgery, trauma, steroid usage, and certain occupations, increase the risk of developing cataract [4, 7, 9–18]. Hence, various population-based studies have been carried out over the past three decades to provide information on its prevalence and risk factors in different ethnic groups and regions around the world [14, 17–24]. Knowledge of cataract prevalence can

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offer information on the extent and burden of the disease [2], be used for planning and providing the infrastructure for disease control [6], and shed light on the natural evolution of the disease [2].

Despite the availability of information about cataract prevalence in different ethnicities and regions around the world, to our knowledge, only one study has combined data from eye cohorts, and estimated the pooled prevalence estimate (PPE) of cataract in western countries [25]. However, this study has extensive methodological limitations, such as lack of systematic search, statistical methods for estimating the PPE, and data from other countries, as well as including studies using different cataract- grading systems. Therefore, we were prompted to implement a systematic review and meta-analysis study with a sound methodological approach to determine the PPE of cataract and its types by age, gender, and geographical area, as well as its trend of changes over the last three decades. The information generated from this study may certainly be useful for public health policy makers for planning interventions and health policies.

Methods

Search strategy and selection of studies

The search strategy is described below that is applied based on PICOTS for MEDLINE (MeSH, Medical Subject Headings) and then used in other databases:

1. Cataract [text word] OR Cataract [Mesh term].
2. Lens opacity [text word] OR lens opacity [Mesh term].
3. 1 OR 2.
4. Prevalence [text word] OR Prevalence [Mesh term].
5. Frequency [text word] OR Frequency [Mesh term].
6. Incidence [text word] OR incidence [Mesh term].
7. 7: 4 OR 5 OR 6.
8. 8: Cross-sectional studies [text word] OR Cross-sectional studies [Mesh term].
9. 9: cohort studies [text word] OR cohort studies [Mesh term].
10. 10: observational studies [text word] OR observational studies [Mesh term].
11. 11: 8 OR 9 OR 10.
12. 12: 3 AND 7 AND 11.

Also the Google Scholar was used to access gray literature [26]. In addition, a cataract expert was consulted to identify important articles.

Then all the extracted articles from each database were entered in Endnote X6, and screening was done after removing duplicates. The screening was done in three steps. In the first step, the titles were reviewed, and if the article was relevant, then the abstract and then the full text of the article was reviewed. For articles that lacked enough raw data, an email was sent to the corresponding author. The three steps were followed independently by two raters (RP and MKH). Inter-rater discrepancies were resolved based on the third person's opinion (HH). Blinding and task separation were applied in the study selection procedure. The inter-rater agreement was 89%.

Exclusion criteria

In this study, we only reviewed age-related cataract in normal populations; therefore, studies on specific groups such as those in hospitals, nursing home residents, people working in certain professions (e.g., welding), and those with specific ocular or systemic diseases (e.g., Down syndrome, glaucoma, arthritis, and diabetes) were not included. Exclusions were also applied to other types of cataract, including acquired cataracts due to trauma or medications, congenital cataracts, and other types of secondary cataract due to certain diseases such as diabetes. Publications such as letters, conference papers and abstracts, reviews, notes, editorials, clinical studies, retrospective studies, follow-up, and longitudinal studies were also excluded.

In addition, since several cataract-grading systems are available, only studies using Lens Opacity Classification Systems (LOCS) 2 OR 3 were included to allow for data pooling. All studies using other grading systems, those that did not mention their methods, and studies that used self-report or a questionnaire for the diagnosis of cataract, were excluded.

Data extraction and quality assessment

In this study, we closely reviewed all articles on the prevalence of age-related cataract and its different types that reached the final step of screening. Article information such as the name of the author, the publication year, the country of the study, the study design, the characteristics of the participants (including age and gender), sample size, number of cataract cases, and the prevalence of cataract (regardless of aphakia and pseudophakia), and the diagnostic criteria were extracted and entered into the database.

The Newcastle–Ottawa Scale adapted for cross-sectional studies [27] was applied to evaluate the quality of the studies. This scale has three sections: 1—selection (3 items, maximum score: 3 points), 2—comparability (1 item, maximum score: 2 points), and 3—outcome (2 items, maximum score: 3 points). The studies were evaluated by two raters (RP and MKH) independently, and a total score was calculated for each study. The studies were then assigned to one of the following categories accordingly: very good studies: 7–8 scores; good studies: 5–6 scores; satisfactory studies: 3–2 scores; unsatisfactory studies: 0–1 score.

Definition of variables

For age classification, we considered three categories 20–39, 40–59, and ≥60 years. Countries were categorized based on the latest WHO definition that includes the following six regions: Regional Office for Africa (AFRO), Regional Office of Americas (AMRO), Regional Office for the Eastern Mediterranean (EMRO), Regional Office for Europe (EURO), Regional Office for South-East Asia (SEARO), and the Regional Office for the Western Pacific (WPRO).

Statistical analysis

All analyses were conducted with Stata software version 14.0 (College Station, Texas). The number of cases, the prevalence of cataract, and its different types were extracted. If a study did not report the prevalence, it was calculated using a binomial distribution of the sample size, and the number of cataract cases were available. Pooled prevalence was calculated using the "metaprop" command, and presented by a forest plot [28]. We use Freeman–Tukey double-arcsine transformation as a variance- stabilizing meta-analysis technique. Heterogeneity was determined using Cochran's Q test of heterogeneity, and the I^2 index was used to quantify heterogeneity. In accordance with Higgins classification approach, I^2 values above 0.7 were considered as high heterogeneity. To estimate the PPE for subgroup analysis, the fixed-effect model was used, and when the heterogeneity was greater than 0.7, the random effects model was used. We also calculated age-standardized pooled prevalence estimate (ASPPE) of cataract and its subtypes in total by direct standardization and using world health organization population [29] to adjust the structural age between different age groups and regions.

The meta-regression analysis was used to examine the effect of age, gender, sample size, publication date, study quality, and geographical area as factors affecting heterogeneity among studies. The Metabias command was used to check for publication bias [30], and if there was any publication bias, the prevalence rate was adjusted with the Metatrim command using the trim-and- fill method. In all analyses, a significance level of 0.05 was considered.

Method of literature search

All steps in this systematic review and meta-analysis study were registered in the International Prospective Register of Systemic Reviews with CRD42018097105 code [31] based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [32]. For this purpose, a complete and comprehensive search without any restriction was conducted in international databases, including Web of Science, PubMed, Scopus, and Embase to identify articles on age-related cataract prevalence and types including cortical cataract, nuclear cataract, and posterior subscapular (PSC) cataract published by 13th August 2019. Searches were done using text words and MESH terms. The PICOTS explored in this study were

Population: None
Intervention: None
Comparison: None
Outcome: Prevalence of cataract or lens opacity
Time: None
Study design: Observational study

Results

Overall, 9870 studies were found through databases, and 52 studies were identified through other sources. After excluding redundant papers, 6406 studies remained. Screening was done in three steps. In the first step, 5714 studies were excluded after reviewing the titles, and 692 articles remained. After reading abstracts, 493 studies were excluded from the list. Then, the full text of the remaining 199 studies was reviewed, and 145 studies were excluded.

Access to full texts and complete data extraction were not possible for 9 out of the remaining 54 studies, which were excluded from analysis [33–41]. Finally, 45 studies [2, 9, 13, 14, 16–24, 42–61] with a total sample size of 161,947 were included in the analysis (Table 1). The flowchart of this selection process is shown in Fig. 1. WPRO had the highest number of studies (19 studies) and AFRO had the lowest number (1 study). The oldest studies were published in 1994 [44], and the most recent study was published in 2019 [57, 61]. The minimum age range of the subjects was 19–29 years, and the maximum age range was 90–99 years. Four studies provided the prevalence of cataract in the 20–39-year age group, 24 studies reported the prevalence in the 40–59-year age group, and 40 studies in the over-60-year age group. Twenty-eight studies were very good quality, 14 studies were good quality, and 3 studies were found to be satisfactory quality (Table 1).

The minimum and maximum reported prevalence was 1% in the 20–39-years age group [2] and 88.17% in the over-60 age group for any cataract [17], 0.99% in the under-40 age group [22] and 61.75% in the over-60 age group for cortical cataract [24], 0.08% in the 20–39-years age group [53], and 66.96% in the over-60 age group for nuclear

Table 1 Summary of the studies included in this meta-analysis.

Author	Country	Design	Publication year	Age	Sample size	Any cataract, *N* (%)	Cortical cataract, *N* (%)	Nuclear cataract, *N* (%)	PSC cataract, *N* (%)	Diagnostic criteria based on LOCS[a]			QAS
										Cortical	Nuclear	PSC	
Husain et al. [62]	Indonesia	PBCSS	2005	20–39	500	21 (4.20)	19 (3.80)	9 (1.80)	5 (1.00)	≥4.0	≥4.0	≥2.0	7
				40–59	298	84 (28.48)	66 (22.14)	76 (25.50)	19 (6.37)				
				≥60	116	96 (82.75)	58 (50.00)	69 (59.48)	45 (38.79)				
				Male	420	88 (20.95)	65 (15.48)	67 (15.95)	31 (7.38)				
				Female	494	113 (22.87)	78 (15.79)	87 (17.61)	39 (7.89)				
Stocks et al. [63]	United Kingdom	PBCSS	2002	≥60	903	398 (44.07)	75 (8.30)	470 (52.04)	15 (1.66)	>1.9	>2.9	>1.9	7
Vashist et al. [64]	India	PBCSS	2011	≥60	5871	3241 (55.20)	198 (3.37)	1559 (26.55)	242 (4.12)	≥3	≥4	≥2	7
Varma et al. [6]	United States	PBCSS	2004	40–59	4216	NA	194 (4.60)	54 (1.28)	39 (0.92)	≥2	≥2	≥2	6
				≥60	1926	NA	606 (31.46)	483 (25.07)	148 (7.68)				
				Male	2559	NA	320 (12.50)	203 (7.93)	79 (3.08)				
				Female	3583	NA	480 (13.40)	334 (9.32)	108 (3.01)				
Yu et al. [7]	China	PBCSS	2016	40–59	458	41 (8.95)	12 (2.62)	5 (1.10)	9 (1.96)	≥2	≥2	≥2	6
				≥60	355	199 (56.05)	92 (25.91)	45 (12.67)	7 (1.97)				
Li et al. [3]	China	PBCSS	2009	40–59	572	75 (13.11)	51 (8.91)	37 (6.46)	9 (1.57)	≥1	≥1	≥1	7
				≥60	672	331 (49.25)	230 (34.22)	261 (38.83)	56 (8.33)				
				Male	433	109 (25.17)	70 (16.17)	76 (17.55)	21 (4.85)				
				Female	811	297 (36.62)	211 (26.02)	222 (27.37)	44 (5.42)				
Nam et al. [4]	Korea	NWCSS	2015	Male	6833	3351 (49.04)	736 (10.77)	1754 (25.67)	37 (0.54)	≥2	≥2	≥1	7
				Female	9033	4431 (49.05)	877 (9.70)	2205 (24.41)	51 (0.56)				
Hashemi et al. [65]	Iran	PBCSS	2017	40–59	292	69 (23.63)	10 (3.42)	23 (7.87)	17 (5.82)	≥2	≥2	≥2	8
				≥60	645	208 (32.24)	85 (13.17)	40 (6.20)	30 (4.65)				
				Male	435	133 (30.57)	51 (11.72)	33 (7.58)	22 (5.05)				
				Female	502	144 (28.69)	44 (8.76)	30 (5.97)	25 (4.98)				
Hashemi et al. [1]	Iran	PBCSS	2009	40–59	1003	93 (9.27)	NA	NA	NA	≥3	≥3	≥2	8
				≥60	330	155 (46.96)	NA	NA	NA				
				Male	634	111 (17.51)	NA	NA	NA				
				Female	656	137 (20.88)	NA	NA	NA				
Rim et al. [66]	Korea	NWCSS	2014	40–59	6372	1348 (21.15)	NA	NA	NA	≥3	≥4	≥2	8
				≥60	5219	4175 (79.99)	NA	NA	NA				
Athanasiov et al. [10]	Myanmar	PBCSS	2008	40–59	1258	187 (14.86)	32 (2.54)	76 (6.04)	21 (1.66)	≥2	≥4	≥2	8
				≥60	777	547 (70.39)	44 (5.66)	254 (32.68)	19 (2.44)				
				Male	829	298 (35.95)	28 (3.37)	145 (17.49)	18 (2.17)				
				Female	1215	436 (35.88)	48 (3.95)	185 (15.23)	22 (1.81)				
Athanasiov et al. [11]	Sri Lanka	PBCSS	2009	40–59	801	146 (18.22)	NA	NA	NA	≥2	≥4	≥2	8
				≥60	501	290 (57.88)	NA	NA	NA				
				Male	528	241 (45.64)	202 (38.26)	39 (7.38)	62 (11.74)				
				Female	777	169 (21.75)	143 (18.40)	21 (2.70)	40 (5.14)				
Wang et al. [42]	China	NWCSS	2016	≥60	4369	2121 (48.54)	1776 (40.65)	1349 (30.87)	414 (9.47)	≥2	≥4	≥2	6
Cristina Leske et al. [43]	Barbados	PBCSS	1997	40–59	2325	NA	292 (12.56)	48 (2.06)	22 (0.94)	≥2	≥2	≥2	8
				≥60	1806	NA	1012 (56.03)	638 (35.32)	101 (5.59)				
				Male	1902	NA	562 (29.55)	336 (17.67)	72 (3.78)				

Table 1 (continued)

Author	Country	Design	Publication year	Age	Sample size	Any cataract, *N* (%)	Cortical cataract, *N* (%)	Nuclear cataract, *N* (%)	PSC cataract, *N* (%)	Diagnostic criteria based on LOCS[a]			QAS
										Cortical	Nuclear	PSC	
				Female	2457	NA	895 (36.43)	502 (20.43)	99 (4.02)				
Giuffre et al. [44]	Italy	PBCSS	1995	40—59	576	41 (7.11)	30 (5.20)	33 (5.72)	18 (3.12)	≥2	≥2	≥2	6
				≥60	492	237 (48.17)	132 (26.82)	209 (42.47)	115 (23.37)				
				Male	479	118 (24.63)	NA	NA	NA				
				Female	589	156 (26.49)	NA	NA	NA				
Lee et al. [45]	Korea	NWCSS	2015	40–59	4305	945 (21.95)	NA	NA	NA	≥2	≥2	≥2	8
				≥60	609	364 (59.77)	NA	NA	NA				
				Male	2134	551 (25.82)	137 (6.42)	308 (14.43)	NA				
				Female	2780	690 (24.82)	171 (6.15)	413 (14.86)	NA				
Nirmalan et al. [46]	India	PBCSS	2003	40–59	3532	1142 (32.33)	NA	NA	NA	≥3	≥3	≥2	7
				≥60	1618	1307 (80.77)	NA	NA	NA				
				Male	2314	NA	34 (1.46)	521 (22.52)	30 (1.29)				
				Female	2836	NA	31 (1.09)	628 (22.14)	38 (1.34)				
Tsai et al. [47]	Taiwan	PBCSS	2002	≥60	1361	631 (46.36)	298 (21.89)	530 (38.94)	125 (9.18)	≥3	≥3	≥3	6
				Male	822	NA	159 (19.34)	300 (36.50)	63 (11.5)				
				Female	539	NA	139 (25.79)	230 (42.67)	62 (7.02)				
Hirvelii et al. [14]	Finland	PBCSS	1995	≥60	500	293 (58.60)	NA	NA	NA	≥2	≥2	≥2	6
				Male	179	85 (47.49)	NA	NA	NA				
				Female	321	208 (64.80)	NA	NA	NA				
Kim et al. [17]	Korea	PBCSS	2014	20–39	3415	60 (1.75)	NA	NA	NA	≥3	≥4	≥2	8
				40–59	4659	1351 (29.00)	NA	NA	NA				
				≥60	2174	1917 (88.17)	NA	NA	NA				
				Male	4397	1404 (31.93)	NA	NA	NA				
				Female	5851	1924 (32.88)	NA	NA	NA				
Ostberg et al. [19]	Sweden	NWCSS	2006	≥60	495	102 (20.60)	29 (5.85)	56 (11.31)	33 (6.66)	>3	≥4	≥2	7
				Male	251	35 (13.94)	NA	NA	NA				
				Female	262	47 (17.94)	NA	NA	NA				
Paunksnis et al. [22]	Lithuania	NWCSS	2007	20–39	403	17 (4.21)	4 (0.99)	10 (2.48)	3 (0.74)	≥2	≥2	≥1	7
				40–59	435	49 (11.26)	15 (3.44)	28 (6.43)	6 (1.37)				
				≥60	444	170 (38.28)	58 (13.06)	106 (23.87)	6 (1.35)				
				Male	573	101 (17.63)	30 (5.23)	65 (11.34)	6 (1.04)				
				Female	709	135 (19.04)	47 (6.62)	79 (11.14)	9 (1.26)				
Park et al. [21]	Korea	PBCSS	2014	40–59	7487	3778 (50.46)	NA	NA	NA	≥3	≥2	≥3	7
				≥60	7297	3588 (49.17)	NA	NA	NA				
				Male	4811	2199 (45.71)	NA	NA	NA				
				Female	6265	3402 (54.30)	NA	NA	NA				
Richter et al. [23]	United States	PBCSS	2012	Male	1610	452 (28.07)	197 (12.24)	88 (5.46)	13 (0.80)	≥2	≥2	≥2	6
				Female	3222	643 (19.96)	271 (8.41)	129 (4.01)	14 (0.43)				
Park et al. [20]	Korea	NWCSS	2013	Male	1421	892 (62.77)	185 (13.02)	490 (34.48)	7 (0.49)	≥4	≥4	≥2	8
				Female	1827	1147 (62.78)	594 (32.51)	15 (0.82)	NA				
Seah et al. [24]	Singapore	PBCSS	2002	40–59	565	132 (23.36)	87 (15.39)	61 (10.79)	20 (3.53)	≥2	≥4	≥2	7

Table 1 (continued)

Author	Country	Design	Publication year	Age	Sample size	Any cataract, *N* (%)	Cortical cataract, *N* (%)	Nuclear cataract, *N* (%)	PSC cataract, *N* (%)	Diagnostic criteria based on LOCS[a]			QAS
										Cortical	Nuclear	PSC	
				≥60	557	391 (70.19)	344 (61.75)	373 (66.96)	110 (19.74)				
				Male	503	329 (65.41)	194 (38.57)	214 (42.54)	58 (11.53)				
				Female	619	360 (58.16)	237 (38.29)	236 (38.13)	72 (11.63)				
Krishnaiah et al. [18]	India	PBCSS	2005	40–59	2420	NA	NA	267 (11.03)	NA	NA	≥3	NA	6
				≥60	1137	NA	NA	628 (55.23)	NA				
				Male	3319	NA	NA	405 (12.2)	NA				
				Female	3929	NA	NA	496 (12.62)	NA				
Cedrone et al. [2]	Italy	PBCSS	1999	40–59	498	5 (1.00)	NA	NA	NA	≥2	≥4	≥2	6
				≥60	362	27 (5.42)	NA	NA	NA				
				Male	376	15 (3.01)	NA	NA	NA				
				Female	484	17 (3.41)	NA	NA	NA				
Mahdi et al. [9]	Nigeria	PBCSS	2014	40–59	1008	54 (5.35)	35 (3.47)	14 (1.38)	10 (0.99)	≥2	≥4	≥2	8
				≥60	629	270 (42.92)	156 (24.80)	130 (20.66)	38 (6.04)				
				Female	872	198 (22.70)	119 (13.64)	90 (10.32)	27 (3.09)				
				Male	765	126 (16.47)	72 (9.41)	54 (7.05)	21 (2.75)				
Pan et al. [48]	Singapore	PBCSS	2012	≥60	5768	NA	1486 (25.76)	620 (10.40)	173 (2.99)	≥2	≥4	≥2	7
Rauf et al. [49]	United Kingdom	PBCSS	2013	≥60	922	651 (70.60)	NA	NA	NA	≥2	≥3	≥2	6
Hashemi et al. [50]	Iran	PBCSS	2011	40–59	1316	222 (16.86)	29 (2.20)	171 (12.99)	76 (5.77)	≥3	≥3	≥2	7
Wong et al. [51]	Singapore	PBCSS	2003	≥60	989	NA	324 (32.76)	338 (34.17)	98 (9.90)	NA	NA	NA	6
Tang et al. [52]	China	PBCSS	2015	≥60	2006	883 (44.01)	827 (41.22)	607 (30.25)	29 (1.44)	≥2	≥2	≥2	8
Delcourt et al. [13]	France	PBCSS	2000	≥60	2468	NA	89 (3.60)	134 (5.42)	138 (5.59)	≥4	≥4	≥2	6
				Female	1386	NA	59 (4.25)	81 (5.84)	93 (6.71)				
				Male	1082	NA	30 (2.77)	53 (4.89)	76 (7.02)				
Duan et al. [53]	China	PBCSS	2013	20–39	1192	34 (2.85)	25 (2.09)	1 (0.08)	2 (0.16)	≥2	≥4	≥2	8
				40–59	3717	433 (11.64)	403 (10.84)	20 (0.53)	28 (0.75)				
				≥60	1614	895 (55.45)	768 (47.58)	313 (19.39)	66 (4.08)				
				Female	3506	829 (23.64)	751 (21.42)	201 (5.73)	58 (1.65)				
				Male	3017	533 (17.66)	445 (14.74)	133 (4.40)	38 (1.25)				
Nirmalan et al. [16]	India	PBCSS	2004	Female	1314	NA	1249 (95.05)	407 (30.97)	604 (45.96)	≥3	≥3	≥2	7
				Male	1135	NA	986 (86.87)	309 (27.22)	519 (45.72)				
Carlos et al. [54]	Brazil	PBCSS	2009	≥60	4229	209 (4.94)	NA	NA	NA	NA	NA	NA	6
Germano et al. [55]	Brazil	PBCSS	2017	≥60	377	50 (13.26)	NA	NA	NA	NA	NA	NA	4
Huang et al. [56]	Taiwan	PBCSS	2010	≥60	2316	1913 (82.59)	NA	NA	NA	≥2	≥3	≥2	6
				Female	1390	1146 (82.44)	NA	NA	NA				
				Male	927	767 (82.74)	NA	NA	NA				
Singh et al. [57]	India	PBCSS	2019	≥60	4331	2588 (59.75)	376 (8.68)	221 (5.10)	466 (10.75)	≥2	≥4	≥2	8
				Female	2399	986 (41.10)	NA	NA	NA				
				Male	1932	757 (39.18)	NA	NA	NA				
Tang et al. [58]	China	PBCSS	2016	40–59	5303	964 (18.17)	533 (10.05)	669 (12.61)	98 (1.84)	≥2	≥2	≥2	7
				≥60	4931	3296 (66.84)	2123 (43.05)	2501 (50.71)	370 (7.50)				
				Female	6073	2571 (42.33)	1962 (32.30)	1568 (25.81)	286 (4.70)				

Table 1 (continued)

Author	Country	Design	Publication year	Age	Sample size	Any cataract, *N* (%)	Cortical cataract, *N* (%)	Nuclear cataract, *N* (%)	PSC cataract, *N* (%)	Diagnostic criteria based on LOCS[a]			QAS
										Cortical	Nuclear	PSC	
				Male	4160	1689 (40.60)	1208 (29.03)	1088 (26.15)	182 (4.37)				
Bojarskien et al. [59]	Lithuania	PBCSS	2005	40–59	2708	247 (9.12)	NA	NA	NA	≥2	≥2	≥1	7
				Female	596	106 (17.78)	NA	NA	NA				
				Male	759	141 (18.57)	NA	NA	NA				
Xu et al. [60]	China	PBCSS	1996	≥60	1817	NA	550 (30.26)	520 (28.61)	158 (8.69)	NA	NA	NA	
Yoshikawa et al. [61]	Japan	PBCSS	2019	≥60	490	NA	106 (21.63)	66 (13.46)	28 (5.71)	≥2	≥3	≥2	3

PBCSS Population-Based Cross-Sectional Study, *NWCSS* Nation-Wide Cross-Sectional Survey, *NA* not available, *LOCS* Lens Opacity Classification System, *QAS* Quality Assessment Score, *PSC* posterior subcapsular cataract. Any cataract was defined as the presence, in either eye, of any cataract (nuclear, cortical, or posterior subcapsular cataract).

Italic numbers are based on LOCS II.

[a]Lens grading is based on LOCS III.

cataract [24], and 0.16% in the 20–39-years age group [53] and 38.79% in the over-60 age groups for PSC cataract [62].

The ASPPE and PPE of cataract and its types based on age, gender, and WHO region

The ASPPE of any cataract was 17.20% (95% CI: 13.39–21.01). The SPPE of cortical, nuclear, and PSC cataract was 8.05% (95% CI: 4.79–11.31), 8.22% (95% CI: 4.93–11.52), and 2.24% (95% CI: 1.41–3.07), respectively. The PPE of cataract and its types by age is illustrated in Fig. 2. As demonstrated, the PPE of any cataract in the 20–39-year, 40–59-year, and over-60-year age groups was 3.01 (95% CI: 1.68–4.34), 16.97% (95% CI: 11.36–22.57), and 54.38% (95% CI: 47.57–61.18), respectively. These values were respectively 2.18% (95% CI: 0.82–3.54), 7.26% (95% CI: 4.95–9.57), and 24.78% (95% CI: 14.84–34.73) for cortical cataract, 1.12% (95% CI: 0.70–2.94), 5.77% (95% CI: 2.58–8.96), and 31.19% (95% CI: 23.88–38.50) for nuclear cataract, and 0.52% (95% CI: 0.07–1.13), 1.91% (95% CI: 1.31–2.50), and 7.29% (95% CI: 5.50–9.07) for PSC cataract. These results indicated an age-related increase in the prevalence of cataract and its different types.

Figure 2 also shows the PPE of cataract and its types by gender. Accordingly, the prevalence in females and males was respectively 33.67% (95% CI: 25.90–41.44) and 32.57% (95% CI: 26.29–38.85) for any cataract, 15.22% (95% CI: 9.79–20.65) and 13.64% (95% CI: 9.17–18.11) for cortical cataract, 14.09% (95% CI: 9.67–18.51) and 15.63% (95% CI: 11.44–20.33) for nuclear cataract, and 3.66% (95% CI: 3.34–4.98) and 3.70% (95% CI: 2.35–5.05) for PSC cataract.

Figure 3 illustrates the ASPPE of cataract and its types in the six WHO regions. Accordingly, the ASPPE of any cataract, cortical cataract, nuclear cataract, and PSC cataract was the highest in SEARO, WPRO, and WPRO and SEARO, respectively.

Heterogeneity and meta-regression

According to Cochran's Q test of heterogeneity, there was significant heterogeneity among studies (all $p < 0.001$). The heterogeneity for cataract and its types was higher than 97% based on the I^2 index, which indicates high heterogeneity. Table 2 presents the results of the univariate meta-regression; age had a significant and direct relationship with any cataract (b: 29.83; $p < 0.001$), cortical cataract (b: 15.06; $p < 0.001$), nuclear cataract (b: 19.78; $p < 0.001$), and PSC cataract (b: 4.54; $p <$ 0.006). There was also a significant difference in the prevalence of any cataract in the six WHO regions (b: 6.30; p: 0.005); as such, the average prevalence of cataract

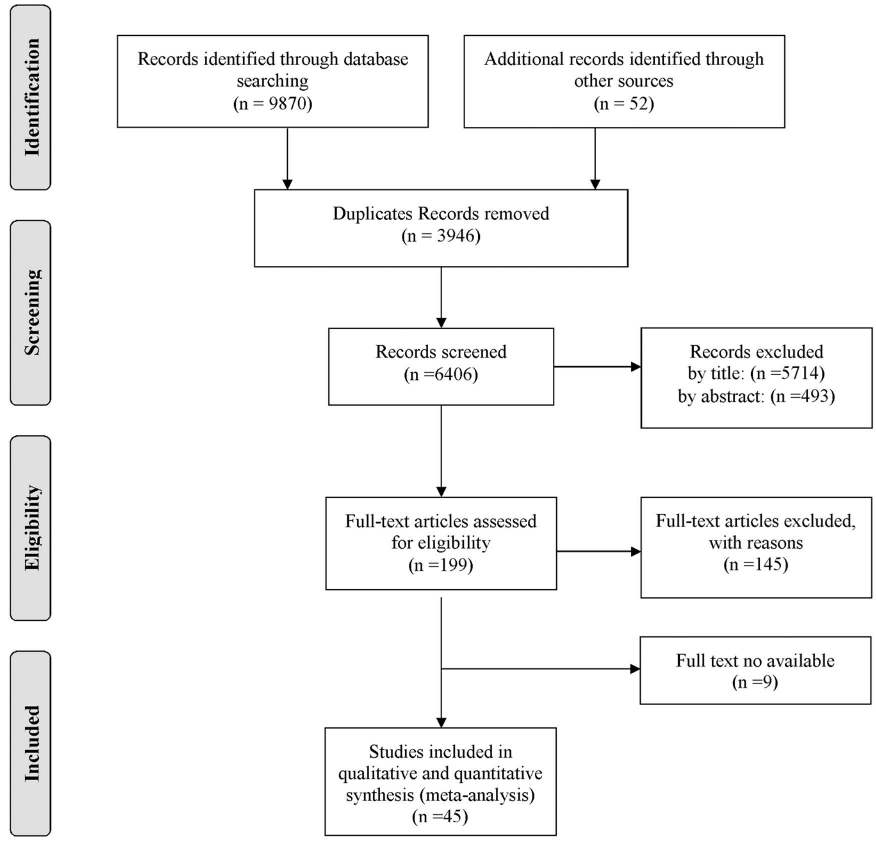

Fig. 1 Flowchart of the study selection process.

varied by 6.30% among the six WHO regions. In other words, the prevalence of any cataract in EMRO was 6.30% higher compared with AMRO or SERO in contrast to EURO. This finding is demonstrated in Fig. 3, which is the ASPPE of any cataract based on the WHO-Region subgroup analysis. There was also an inverse relationship between the study year and the prevalence of nuclear cataract, but the significance level was borderline (b: −0.66, p: 0.042). Variables of gender, sample size, and quality assessment had no significant effect on the variation in the prevalence of cataract and its types (heterogeneity) (Table 2).

Publication bias

Based on the results of Begg's test, significant publication bias was observed for PSC cataract (Z score: 2.67; p: 0.009). Therefore, the fill- and trim-adjusted ASPPE of PSC cataract (2.20%, 95% CI: 1.45–3.20) was generated, which was not significantly different from the original ASPPE (2.24%, 95% CI: 1.41–3.07). The results of the publication bias analyses, based on Begg's test, indicated no publication bias for any cataract (Z score: −0.41, p: 0.899), cortical cataract (Z score: 1.42, p: 0.091), or nuclear cataract (Z score: 1.23, p: 0.29).

Discussion

Our study is the first meta-analysis that provides comprehensive information on the global prevalence of age-related cataract and its types based on LOCS in different age groups. Accordingly, the ASPPE of cataract was 17.20%. In other words, of every 1000 people who were selected randomly from all over the world, with 95% confidence, we expected to find 133–210 people to have cataract, especially the elderly. This prevalence, which was extracted from all studies without considering aphakic and pseudophakic status, indicates that untreated cataract is still one of the major unsolved ophthalmology problems in the world [63], which affects a large percentage of the global population, and despite being easily treatable [1], no measure has been taken to do so.

Unfortunately, to date, there has been no systematic study on the global prevalence of cataract, and only one study in the United States [25] attempted to estimate the PPE of cataract, with no systematic search strategy, and by integrating data from several large eye cohort studies that applied different lens-grading systems, and any comparison with this study should be done with caution. Accordingly, the PPE of cataract in the mentioned study [25] was 17.20%, which was similar to our study (17.20%). It should

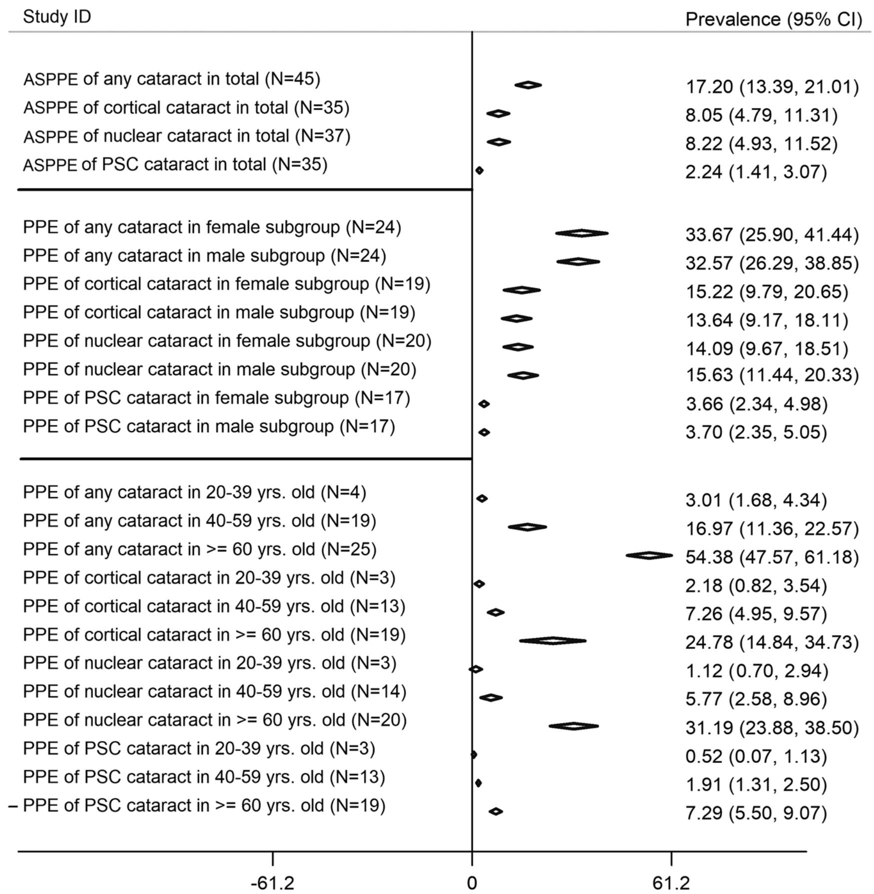

Fig. 2 Age-standardized pooled prevalence estimate (ASPPE) of any cataract, cortical, nuclear, and posterior subcapsular (PSC) cataract based on the random effects model in total and pooled prevalence estimate (PPE) in sex and different age subgroups. The diamond mark illustrates the pooled estimate.

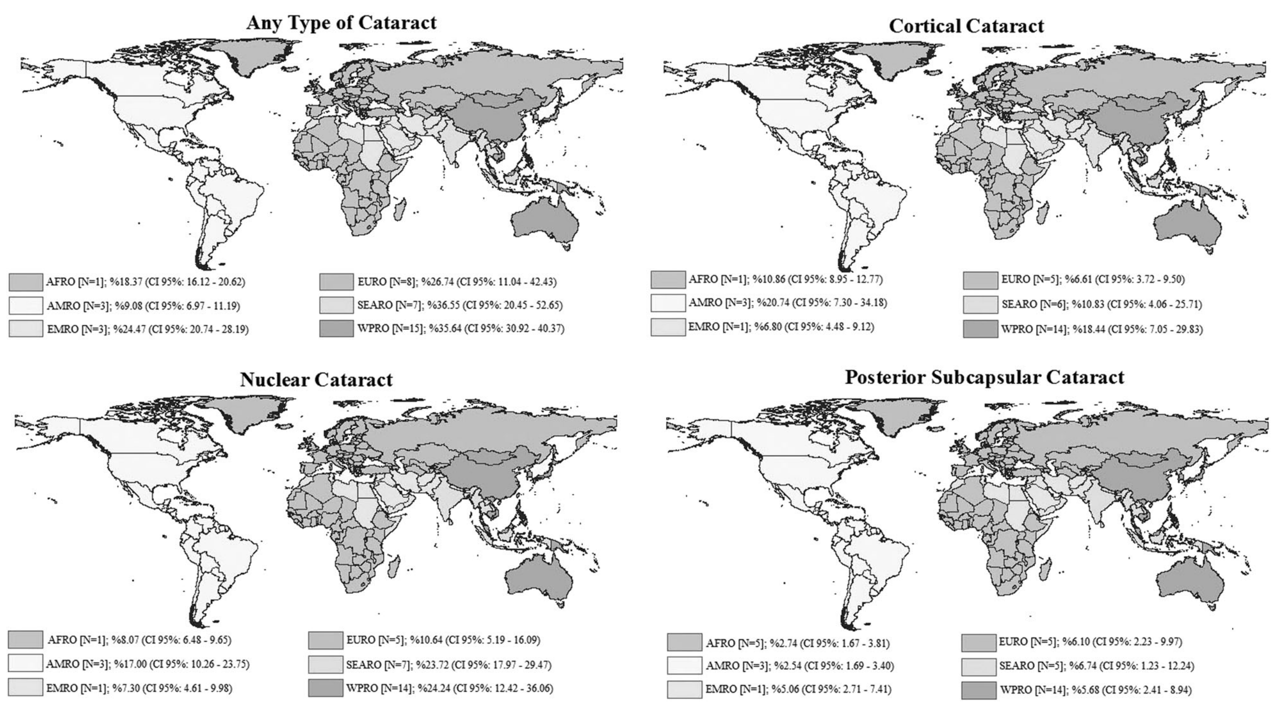

Fig. 3 Age-standardized pooled prevalence estimate (ASPPE) and 95% confidence interval of any cataract, cortical, nuclear, and posterior subcapsular (PSC) cataract based on WHO regions.

Table 2 Results of the univariate meta-regression analysis on the heterogeneity of the determinants.

Variables	Any cataract		Cortical cataract		Nuclear cataract		PSC cataract	
	Coefficient (95% CI)	*p* value	Coefficient (95% CI)	*p* value	Coefficient (95% CI)	*p* value	Coefficient (95% CI)	*p* value
Age group	29.83 (22.57–37.09)	<0.001*	15.06 (7.36–22.75)	<0.001*	19.78 (12.32–27.23)	<0.001*	4.54 (1.37–7.70)	0.006*
Sex	1.03 (−9.88 to 11.95)	0.850	1.75 (−5.78 to 9.30)	0.640	−1.12 (−8.38 to 6.13)	0.755	−0.03 (−2.29 to 2.21)	0.974
WHO Regional Office	6.30 (2.02–10.59)	0.005*	3.19 (−1.63 to 8.03)	0.187	−2.58 (−0.80 to 5.97)	0.130	0.37 (−0.65 to 1.40)	0.463
Year	0.43 (−0.60 to 1.47)	0.400	−0.20 (−1.17 to 0.76)	0.670	−0.66 (−1.30 to 0.02)	0.042*	−0.16 (−0.36 to 0.02)	0.092
Sample size	0.01 (−0.01 to 0.02)	0.160	−0.01 (−0.01 to 0.01)	0.740	−0.01 (0.01 to 0.02)	0.726	−0.01 (−0.01 to 0.01)	0.067
Quality assessment	−2.71 (−10.01 to 6.01)	0.488	−3.02 (−12.01 to 3.99)	0.392	−1.02 (−9.13 to 8.03)	0.886	−2.13 (−3.85 to 1.86)	0.159

*Significance.

Coding of age group: 20–40 years old = 1; 40–60 years old = 2; ≥60 years old = 3.

Coding of WHO Regional Office: AMRO = 1; EMRO = 2; EURO = 3; SERO = 4; WPRO = 5; there is no study in AFRO.

PSC posterior subcapsular.

be noted that due to the increasing trend of population aging in the world, it is expected that the ASPPE of cataract will increase in the future; although effective surgical methods are available [1], it should receive more attention from health policy makers as one of the reasons for blindness [6].

That is, while people with cataracts usually depend on others for their daily tasks due to poor vision, this is accompanied by a decline in the quality of life [5]. On the other hand, the PPE of any cataract ranged between 3% in the 20- to 39-year age group and 54% in the over-60 age group. The ascending trend of age-related cataract was seen for other types of cataract, including nuclear, cortical, and PSC cataract, and these changes were significant even in the meta-regression analysis (Table 2). In other words, age directly correlated with cataract and its types. An increase in the prevalence of cataract with age has also been observed in other studies [1, 2, 10, 11, 14, 17, 18, 22, 44–46, 53, 62, 64, 65], and is often considered a normal part of the aging process [23]. However, some scholars disagree with this theory and do not consider the relationship between age and cataract a completely causal one. They believe that this is a cumulative effect of certain risk factors [66] such as ultraviolet radiation or oxidative damage [7, 9–14, 16, 23, 65]. The ASPPE of any cataract was significantly different in the six geographical regions; the highest rate was 36.55% in the SEARO region, and the lowest prevalence was 9.08% in the AMRO region. The difference in cataract prevalence in different races and regions has been reported previously [17, 24]. However, it should be noted that the comparison of prevalence rates based on geographical areas should be done with caution, because inter-study differences can be due to different methodologies and diagnostic criteria. Regardless of these issues, many studies consider environmental factors, ethnic and racial differences, and UV radiation to be strong determinants [4, 7, 9, 15, 16, 62, 67–70], such that the high prevalence of cataract in the SEARO region can be attributed to countries being underdeveloped in this region. The prevalence of cataract is higher in lesser-developed societies due to the low economic status [4], low literacy [7, 15, 62, 69, 70], high rate of outdoor activity [62], and less access to cataract surgery services [9, 16]. The low prevalence of cataract in the study that was conducted by integrating studies conducted in developed Western countries [25] confirms this hypothesis. Of course, the role of environmental and other risk factors such as UV radiation [67, 68], high rates of smoking [13], and certain diseases associated with cataract such as diabetes, hypertriglyceridemia [71], and genetic factors [72] should not be overlooked.

Different studies have reported conflicting results regarding the most common type of cataract. Studies in

Nigeria [9], Barbados [15], Tanzania [25], Sri Lanka [11], and the United States [71] reported the most common type to be cortical cataract, followed by nuclear and PSC cataract. In contrast, other studies in India [46, 73–75], Australia [76], Taiwan [12], Finland [14], China [77], and Myanmar [10] reported nuclear cataract as the most common type followed by cortical and PSC cataract. This difference was attributed to differences in the prevalence of risk factors such as UV radiation, smoking, and the different prevalence of cataract-related diseases such as pterygium, diabetes, and radiation [9, 24, 78]. However, in our review of 45 studies, the calculated ASPPE showed that the most common type of cataract was nuclear cataract, followed by cortical and PSC cataract, which was in line with some studies [10, 12, 14, 46, 74–77].

According to available evidence on cataract, there is still no agreement on the inter-gender differences. Some studies have suggested that female gender is a risk factor for cataract, and they have attributed this to hormonal changes, especially at older ages, higher exposure to biomass-cooking fuels, lack of access to reproductive health services, and genetic variations [9, 16, 19, 22–24, 66, 73]. Nonetheless, some other studies have reported a reverse trend, and suggested male gender as a risk factor due to higher exposure to UV rays, cigarette smoking, and other known risk factors [16]. The results in our study and the report by Munoz et al. [79] were different in that the overall prevalence of cataract and its types was not much different between the two genders, and the difference was not significant in the meta-regression analysis. In other words, gender does not seem to be related to cataract, and the differences observed in previous studies can be due to selection bias or methodological limitations.

We expected to find a higher cataract prevalence over the past few years on account of changes in lifestyle [80], increased exposure to known risk factors [81], and an increase in the prevalence of diseases associated with cataract such as diabetes [82], and improved diagnostic methods. However, our study did not show such increase, and there was no significant change in the trend of any cataract, nuclear cataract, or cortical cataract, except that the exception was PSC cataract, which showed a very slight decrease during this period. It seems that many patients have managed to treat their cataract due to better access to surgical services, improved surgical procedures, and better distribution of surgical facilities. As such, an ascending trend in cataract surgery, which is one of the goals of the Vision 2020: Right to Sight Initiative [83], has been observed in many countries including Iran [84, 85], Australia [86], America [87], Singapore [88], England [89], and Canada [90].

In light of the numerous exclusion criteria applied in this study, our team was concerned about possible bias; therefore, we examined the reported prevalence of cataract and its types in terms of publication bias. The results indicated that there was no publication bias for any cataract, nuclear cataract, or cortical cataract, and significant publication bias was only observed for PSC cataract. Next, we used the trim-and-fill approach to adjust this bias, and we observed that the publication bias had very little effect (less than 0.04%) on the ASPPE.

Although we made every effort to conduct a flawless study, there were certain limitations that should be mentioned. First, we aimed to include all studies reporting cataract prevalence into the analyses, there were large differences in cataract-grading methods, and since the results could not be converted, we had to exclude many studies. Second, there were very few studies from certain continents, and thus, it was not possible to get a more robust estimate based on WHO region.

However, our study had several strengths, including the fact that it is the first to estimate the prevalence of age-related cataract and its types globally and in each WHO region. The extensive search allowed us to retrieve a large number of articles, and finally 45 studies with a sample size of 161,947 were included in the analyses that support a sufficient statistical power. Moreover, direct standardization was used to estimate the pooled prevalence, and neutralize different age structures, which made comparison possible. We also calculated the cataract prevalence and its types, particularly in different age groups, including the 20- to 39-year age group, which is usually neglected in most of ophthalmologic studies; this is being done for the first time in the past three decades. By including studies that had implemented LOCS, we were able to calculate the pooled cataract prevalence, and this can be the most important strength of our study.

Conclusion

From the public health point of view, cataract is still a global challenge, especially in Western Pacific countries. Despite the lack of inter-gender differences, cataract prevalence increases with age, especially after the age of 60 years. Knowledge about cataract prevalence can inform health-care planners in planning and prioritizing resource allocation.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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