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Impact of coronavirus disease 2019 pandemic on the trends of care-seeking behavior for ocular diseases: a systematic review and meta-analysis

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We aimed to assess the clinical and epidemiological impacts of the coronavirus disease 2019 pandemic on the number of ophthalmology outpatient department (oOPD) visits. PubMed and EMBASE were searched for literature published between January 1, 2020, and December 5, 2022. The extracted data were pooled using a random-effects model. The primary outcome was the number of oOPD visits. Of the 335 screened articles, 21 and 16 were included in the qualitative and quantitative syntheses, respectively. Among the 16 studies included in the meta-analysis, 7 involving 4,204,209 individuals reported the number of oOPD visits during the pandemic. Compared with the number of pre-pandemic visits, the numbers of oOPD visits declined to 58.1% (95% confidence interval [CI], 0.378–0.784) and 29.8% (95% CI 0.130–0.465) during the pandemic and lockdown, respectively. The proportions of female patient visits decreased from 50.9 to 47.8% and from 48.3 to 42.3% during the pandemic and lockdown, respectively. The proportions of adult visits increased from 86.3 to 89.6% and decreased from 90.6 to 80.1% during the pandemic and lockdown, respectively. The decrease in oOPD visits during the pandemic may have caused delays in diagnosis and treatment, potentially exacerbating the existing ocular diseases.

Keywords Coronavirus disease, Pandemic, Ophthalmology outpatient visits, Ocular diseases

The global spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and the subsequent coronavirus disease (COVID-19) pandemic profoundly impacted the healthcare systems, leaving a lasting effect on both public behavior and medical paradigms[1]. Many countries implemented lockdown measures to enforce safe social distancing and curb disease transmission[2]. These restrictions, along with behavioral changes and decreased participation in routine medical activities, may have lasting negative consequences on public health[3–5].

Even in the absence of activity restrictions, patients exhibited higher reluctance to seek medical care due to concerns about acquiring COVID-19[6]. This trend was evident in ophthalmology departments, where a significant reduction in outpatient visits was observed. A key factor contributing to this decline may have been increased public awareness that the conjunctiva could serve as a route of SARS-CoV-2 transmission via aerosol particles[7,8]. A recent meta-analysis reported a 63.6% reduction in the number of ophthalmic emergency patients or outpatients presenting to the emergency department during the pandemic compared with that during the pre-pandemic period[9]. Despite several independent studies have indicated a reduction in ophthalmology outpatient department (oOPD) visits for chronic ocular diseases such as cataracts, glaucoma, and allergic conjunctivitis[5,10,11], further investigations into their global trends and epidemiological characteristics are warranted.

Emerging evidence suggests that patients with chronic ocular diseases, including glaucoma and diabetic retinopathy, experienced vision deterioration during the pandemic lockdown, likely due to restrictions in regular surveillance[12–14]. Additionally, concerns have been raised regarding pediatric amblyopia, which may

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have remained undiagnosed and untreated during the pandemic, leading to irreversible vision loss among young children[15]. Hence, a systematic analysis of COVID-19's impact on oOPD visits could provide crucial insights into the evolving care-seeking behaviors and specialty-wide trends, helping to improve the quality of care and enabling the allocation of medical resources to address the anticipated and unmet medical needs.

Herein, this systematic review and meta-analysis of the existing literature was conducted to determine the clinical and epidemiological impacts of the COVID-19 pandemic on decreasing number of oOPD visits and elucidate the characteristics of these trends.

Results

Search results

Figure 1 illustrates the screening process. A database search according to the research strategy identified 335 articles, of which 76 were excluded due to duplication. The remaining 259 articles were reviewed based on their titles and abstracts. Of these, 231 articles that were classified as editorials, letters, commentaries, book chapters, reviews, systematic reviews, conference proceedings, and conference abstracts or had unrelated topics were excluded. Of the remaining 28 articles, 1 article written in Hungarian, three that did not report the number of oOPD visits, 1 that did not define the post-COVID-19 period, and two that included patients visiting the ophthalmic emergency department were excluded. Consequently, only 21 articles met the inclusion criteria and were included in the qualitative synthesis[16–36]. Of these, five were subsequently excluded from the meta-analysis due to the following reasons: to account for the seasonality of oOPD visits, three articles with different seasons between the comparison period and COVID-19 pandemic or lockdown period were excluded from the meta-analysis[25,27,29]. One article was excluded as it only listed the total number of visits during and immediately after the lockdown periods[34]. Another article, which only reported data obtained immediately after the lockdown period, was excluded as conducting a meta-analysis was not feasible[16]. Ultimately, 16 articles were included in the quantitative meta-analysis for evaluating oOPD visit trends[17–24,26,28,30–33,35,36].

Study and demographic characteristics

This systematic review included studies published between July 24, 2020, and November 2, 2022 (Table 1). Four studies were conducted in the United States (US)[24–27], four in India[16,17,34,35], two in Italy[29,36], two in Germany[21,31], and two in Taiwan[19,28], one in the United Kingdom[33], one in South Korea[18], one in Singapore[20], one in Poland[23], one in Pakistan[22], one in Nigeria[30], and one in Brazil[32]. Table 1 presents a summary of the data on dates, the number of oOPD visits, and the percentage change in oOPD visits during the post-COVID-19 and pre-COVID-19 pandemic periods.

Trends in the number of oOPD visits during the COVID-19 pandemic period

Seven studies reported the number of oOPD visits during the COVID-19 pandemic period[17–19,23,28,30,32], all of which revealed a decrease in oOPD visits. The largest decrease was observed in a study conducted in patients

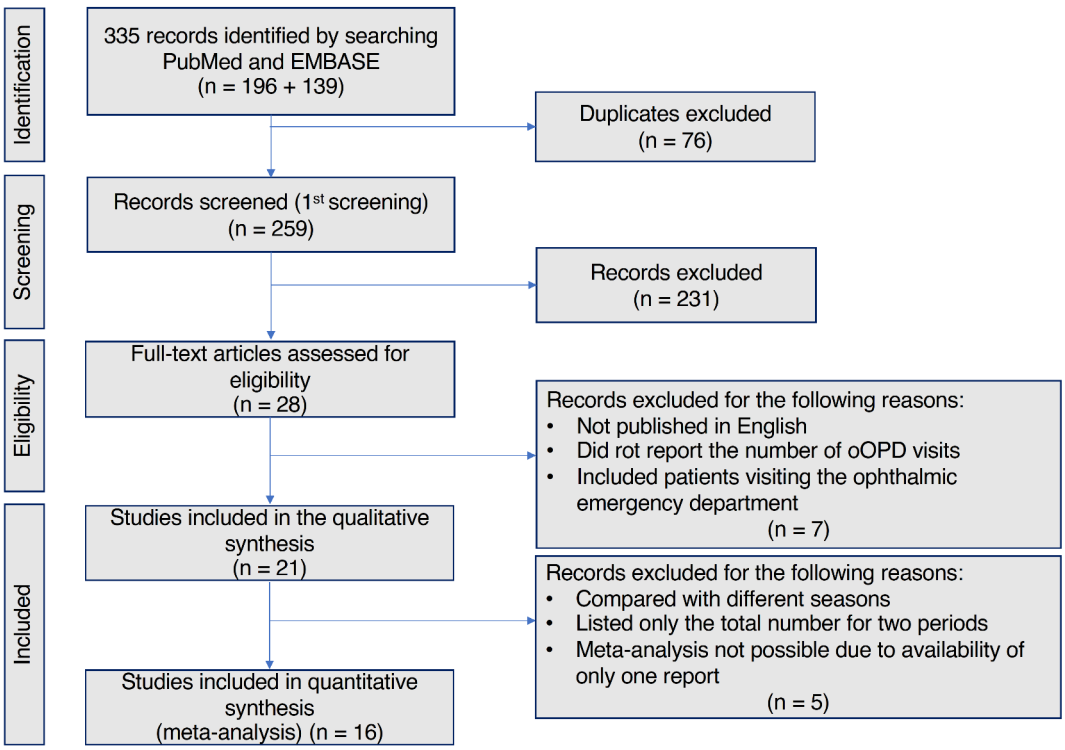

Fig. 1. Flowchart of the study selection process. oOPD, ophthalmology outpatient department.

Author	Year	Country	Date				Number of oOPD visits			
				Post-COVID-19 pandemic				Post-COVID-19 pandemic		
			Pre-COVID-19 pandemic (compared period)	COVID-19 pandemic	Lockdown	Immediately after lockdown or COVID-19 endemic	Pre-COVID-19 pandemic (compared period)	COVID-19 pandemic	Lockdown	Immediately after lockdown or COVID-19 endemic
Sood et al.[16]	2022	India	2019/6–2019/8			Immediately after lockdown 2020/6–2020/8	108,251			52,801
Muralikrishnan et al.[17]	2022	India	First wave 2019/3/24–2019/10/31 Second wave 2019/4/1–2019/6/30 COVID-19 endemic 2019/11/1–2019/12/31, 2019/1/1–2019/3/31	First wave 2020/3/24–2020/10/31 Second wave 2021/4/1–2021/6/30		COVID-19 endemic 2020/11/1–2021/3/31	First wave 1,939,472 Second wave 832,688 COVID-19 endemic 1,227,380	First wave 818,902 Second wave 473,475		1,224,222
Sim et al.[18]	2022	South Korea	2019/1–2019/12	2020/1–2020/12		COVID-19 endemic 2021/1–2021/11	35,380	31,298		34,376
Yen et al.[19]	2022	Taiwan	2020/5/1–2020/7/31	2021/5/1–2021/7/31			6125	3251		
Lim et al.[20]	2022	Singapore	2019/4–2019/5		2020/4–2020/5		58,653		13,913	
Maiassi et al.[21]	2022	Germany	2019/3/18–2019/5/8		2020/3/18–2020/5/8		3194		1711	
Shahid et al.[22]	2022	Pakistan	2019/4/1–2019/7/31		2020/4/1–2020/7/31		10,209		2974	
Grudziaz-Sekowska et al.[23]	2022	Poland	2019/1/1–2019/12/31	2020/1/1–2020/12/31			4278	3272		
Moss et al.[24]	2021	USA	2019/3/15–2019/6/15		2020/3/15–2020/6/15		682		594	
Berkenstock et al.[25]	2021	USA	2020/2/17–2020/3/21		2020/3/22–2020/4/30		25,336		5672	
Sethi et al.[26]	2021	USA	2019/3/15–2019/5/15		2020/3/15–2020/5/15		14,486		1774	
Brant et al.[27]	2021	USA	2020/1/1–2020/2/29		2020/3/16–2020/5/31		44,153	33,919		
Chang et al.[28]	2021	Taiwan	2019/3/1–2019/3/31	2020/3/1–2020/3/31			13,006	10,489		
Savastano et al.[29]	2021	Italy	2020/1/1–2020/3/8		2020/3/9–2020/5/18	Immediately after lockdown 2020/5/19–2020/11/2	2207		166	3669
Osaguona et al.[30]	2021	Nigeria	2019/1–2019/8	2020/1–2020/8			16,189	8,735		
Schuh et al.[31]	2021	Germany	2019/3/25–2019/4/21		2020/3/16–2020/4/12		3824		814	
Ayub et al.[32]	2021	Brazil	2019/3/1–2020/2/28	2020/3/1–2021/2/28			7117	532		
Wood et al.[33]	2021	UK	2019/3/25–2019/5/17		2020/3/23–2020/5/15		2377		304	
Agarwal et al.[34]	2020	India	2019/3/25–2019/7/15		2020/3/25–5/30	Immediately after lockdown 2020/6/1–2020/7/15	102,697		2936*	
Babu et al.[35]	2020	India	2019/3/25–2019/5/3		2020/3/25–2020/5/3		102,262		3434	
Borrelli et al.[36]	2020	Italy	2019/3/9–2019/5/3		2020/3/9–2020/5/3		303		75	

Author	Year	Country	Ratio of the number of oOPD visits to the number of visits in the pre-COVID-19 pandemic period (compared period)							
			COVID-19 pandemic	Lockdown	Immediately after lockdown or COVID-19 endemic					
Sood et al.[16]	2022	India			48.8%					
Muralikrishnan et al.[17]	2022	India	First wave 42.2% Second wave 56.9%		99.7%					

Continued

Author	Year	Country	Ratio of the number of oOPD visits to the number of visits in the pre-COVID-19 pandemic period (compared period)							
			COVID-19 pandemic	Lockdown	Immediately after lockdown or COVID-19 endemic					
Sim et al.[18]	2022	South Korea	88.5%		106.0%					
Yen et al.[19]	2022	Taiwan	53.1%							
Lim et al.[20]	2022	Singapore		23.7%						
Maiassi et al.[21]	2022	Germany		53.6%						
Shahid et al.[22]	2022	Pakistan		29.1%						
Grudziaz-Sekowska et al.[23]	2022	Poland	76.5%							
Moss et al.[24]	2021	USA		87.1%						
Berkenstock et al.[25]	2021	USA		19.0%						
Sethi et al.[26]	2021	USA		12.2%						
Brant et al.[27]	2021	USA	59.9%							
Chang et al.[28]	2021	Taiwan	80.6%							
Savastano et al.[29]	2021	Italy		7.2%	67.3%					
Osaguona et al.[30]	2021	Nigeria	54.0%							
Schuh et al.[31]	2021	Germany		21.3%						
Ayub et al.[32]	2021	Brazil	7.5%							
Wood et al.[33]	2021	UK	12.8%							
Agarwal et al.[34]	2020	India		2.9%*						
Babu et al.[35]	2020	India		3.4%						
Borrelli et al.[36]	2020	Italy		24.8%						

Table 1. Characteristics of all included studies and comparison of the number of oOPD visits before and after the COVID-19 pandemic. oOPD, ophthalmology outpatient department; COVID-19, coronavirus disease; USA, United States of America; UK, United Kingdom * As only the total number of lockdown and immediately after lockdown periods are listed, both periods were combined.

with glaucoma admitted at a tertiary hospital in Brazil, reporting a 92.5% decrease compared with the pre-COVID-19 levels[32]. The smallest decrease was reported by a study conducted in outpatients at the ophthalmology department of a hospital in South Korea, which observed an 11.5% decrease[18].

Trends in the number of oOPD visits during the lockdown period

Thirteen studies reported the number of oOPD visits during the lockdown period[20–22,24–27,29,31,33–36], showing a decrease in the number of oOPD visits during this period. The largest decrease was reported by a study on outpatients at an Indian tertiary ophthalmology center, with a 96.6% decrease compared with the pre-COVID-19 values[35]. The smallest decrease was reported by a multicenter study in the US on neuro-ophthalmology patients, showing a 12.9% decrease in the number of oOPD visits compared with those in the pre-COVID-19 period[24].

Trends in the number of oOPD visits during the immediately after lockdown period

Three studies reported the number of oOPD visits immediately after the lockdown period[16,29,34]; however, none indicated a return to pre-COVID-19 levels. Sood et al.[16] documented a 51.2% reduction (38.2–61.3%) in the number of oOPD visits during the first 2 months after lockdown at four Indian tertiary ophthalmology hospitals, with significantly higher reductions observed among women and children compared with the numbers reported in a similar period in the previous year. Agarwal et al.[34] reported the number of oOPD visits in the 1.5 months after lockdown at an apex ophthalmology center in India, noting a recovery trend in the number of outpatient visits although the numbers did not fully return to pre-lockdown levels. Savastano et al.[29] reported the number of oOPD visits in the 5.5 months after lockdown at a tertiary care hospital in Italy, noting a 32.7% decrease in the number of oOPD visits per day immediately after lockdown compared with the pre-pandemic levels.

Trends in the number of oOPD visits during the COVID-19 endemic period

Two studies reported the number of oOPD visits during the COVID-19 endemic period[17,18], with both studies indicating a recovery in the number of oOPD visits. Muralikrishnan et al.[17] reported the number of oOPD visits 5 months after the first wave of the COVID-19 pandemic at tertiary and secondary ophthalmology hospitals in India. Following the removal of travel restrictions, the number of oOPD visits rapidly increased, reaching 99.7% of the pre-COVID-19 numbers. Sim et al.[18] reported the number of oOPD visits over 11 months during the

COVID-19 endemic period at an ophthalmology hospital in South Korea, revealing that oOPD visits exceeded the pre-pandemic levels along with a decrease in outpatient cancellation rates.

Meta-analysis of the number of oOPD visits

Of the 16 studies, 7[17–19,23,28,30,32] and 9[20–22,24,26,31,33,35,36] reported the number of oOPD visits during the COVID-19 pandemic and lockdown periods, respectively. The numbers of oOPD visits decreased during the COVID-19 pandemic (pre-COVID: 2,854,255 individuals; post-COVID: 1,349,954 individuals) and lockdown periods compared with those during the pre-pandemic period (pre-COVID: 195,990 individuals; post-COVID: 25,593 individuals). A meta-analysis of the number of oOPD visits reported in the included studies before and during the COVID-19 pandemic or lockdown period (forest plot shown in Fig. 2) was performed. During the COVID-19 pandemic and lockdown periods, the numbers of oOPD visits decreased to 58.1% (Fig. 2a: 95% confidence interval [CI], 0.378–0.784) and 29.8% (Fig. 2b: 95% CI 0.130–0.465) compared with the pre-pandemic levels.

Meta-analysis of the number of oOPD visits by sex

Of the 16 studies, 3 studies reported the number of oOPD visits by sex during the COVID-19 pandemic[17,19,30] and lockdown periods[24,35,36]. A meta-analysis was performed to compare the number of outpatient visits by sex before and during the COVID-19 pandemic, along with the influence of the lockdown period (forest plot shown in Fig. 3). During the COVID-19 pandemic period, the proportion of visits by female patients decreased from 50.9% (1,423,085/2,794,474) to 47.8% (623,426/1,304,363) compared with the pre-pandemic period values (Fig. 3a: odds ratio [OR], 0.882; 95% CI 0.878–0.886). The proportion of visits by female patients decreased from

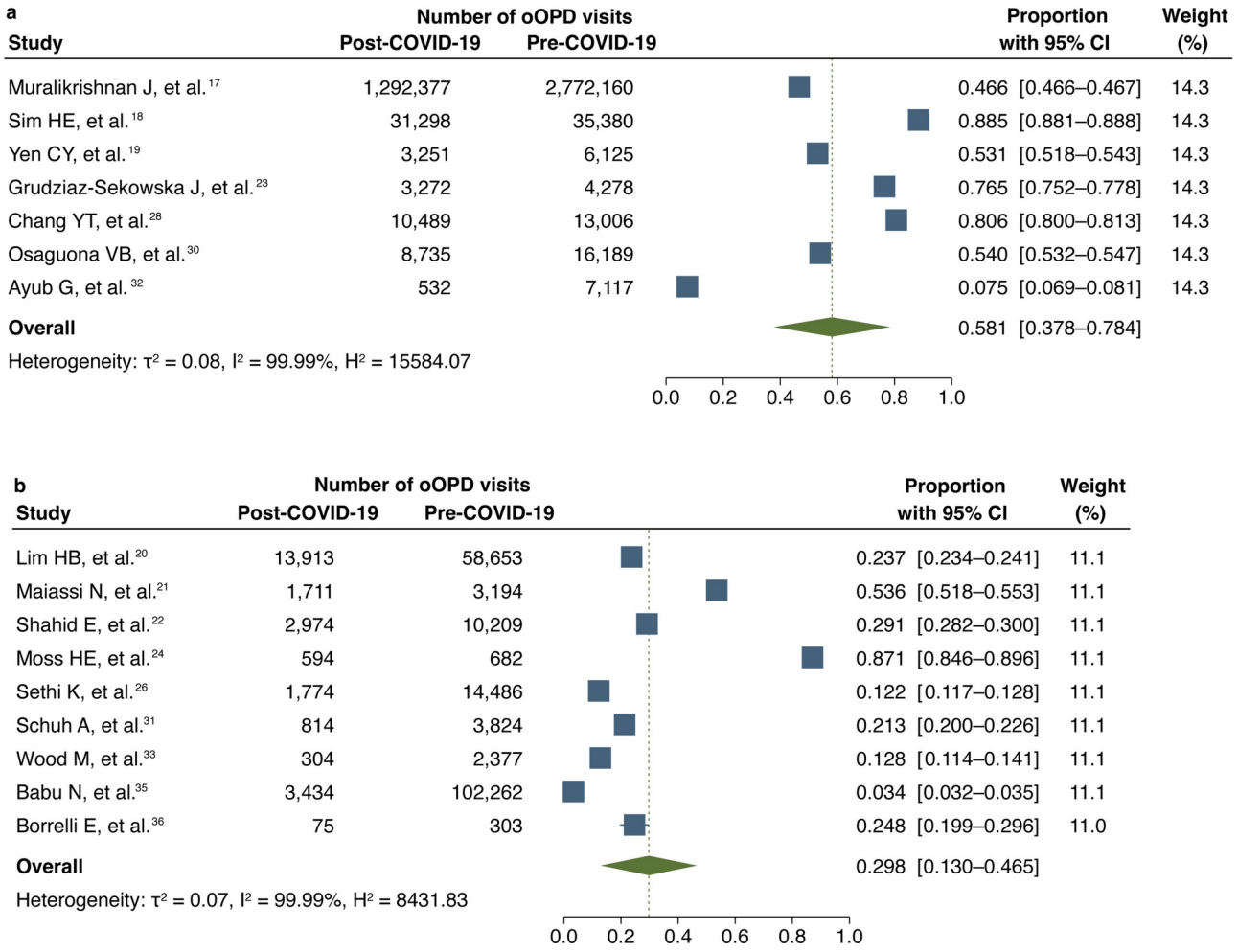

Fig. 2. Forest plot of the proportion of the number of oOPD visits. Forest plots of the number of oOPD visits during the COVID-19 pandemic period (**a**) and lockdown period (**b**). (**a**) During the COVID-19 pandemic period, the number of oOPD visits was estimated to have decreased by 58.1% (95% CI 0.378–0.784) compared with the pre-pandemic levels. (**b**) During the lockdown period, the number of oOPD visits was estimated to have decreased by 29.8% (95% CI 0.130–0.465) compared with that during the pre-pandemic period. oOPD, ophthalmology outpatient department; COVID-19, coronavirus disease; CI confidence interval.

48.3% (49,859/103,247) in the pre-pandemic period to 42.3% during the lockdown period (1737/4103) (Fig. 3b: OR, 0.663; 95% CI 0.545–0.807).

Meta-analysis of the number of oOPD visits by age

Of the 16 studies, 2[17,30] reported oOPD visits by age during the COVID-19 pandemic period[17,30] and the lockdown period[21,35]. A meta-analysis was performed to compare the number of oOPD visits by age before and during the COVID-19 pandemic, along with the influence of the lockdown period (forest plot shown in Fig. 4). The proportion of visits by adult patients increased from 86.3% during the pre-pandemic period (2,405,870/2,788,349 individuals) to 89.6% (1,166,252/1,301,112 individuals) during the pandemic period (Fig. 4a: OR, 1.154; 95% CI 0.809–1.645). The proportion of visits by adult patients decreased from 90.6% during the pre-pandemic period (95,554/105,456 individuals) to 80.1% (4120/5145 individuals) during the lockdown period (Fig. 4b: OR, 0.692; 95% CI 0.353–1.358).

Meta-analysis of the number of oOPD visits by region

Of the 16 included studies, 7[17–19,23,28,30,32] reported the number of oOPD visits by region during the COVID-19 pandemic period: four from Asia[17–19,28], one from Europe[23], one from South America[32], and one from Africa[30]. Additionally, nine studies[20–22,24,26,31,33,35,36] reported the number of oOPD visits during the lockdown period, including four from Europe[21,31,33,36], three from Asia[20,22,35], and two from North America[24,26].

A meta-analysis was conducted to compare the number of oOPD visits before and during the COVID-19 pandemic (forest plots presented in Supplementary Fig. S1) or lockdown (forest plots presented in Supplementary Fig. S2) periods across different regions. During the COVID-19 pandemic period, the numbers of oOPD visits decreased to 67.2% (95% CI 0.472–0.873) in Asia, 76.5% (95% CI 0.752–0.778) in Europe, 7.5% (95% CI 0.069–0.081) in South America, and 54.0% (95% CI 0.532–0.547) in Africa compared with the pre-pandemic levels. During the lockdown period, the numbers of oOPD visits decreased to 18.7% (95% CI 0.034–0.341) in Asia, 28.1% (95% CI 0.107–0.455) in Europe, and 49.7% (95% CI − 0.237 to 1.230) in North America compared with the pre-pandemic levels.

Meta-analysis of the number of oOPD visits by health insurance system

Of the 16 included studies, 7[17–19,23,28,30,32] reported the number of oOPD visits by health insurance system during the COVID-19 pandemic period. Among the seven studies, five[18,19,23,28,32] were conducted in countries with universal health insurance systems, whereas two[17,30] were from countries with non-universal health insurance systems. Additionally, nine studies[20–22,24,26,31,33,35,36] reported the number of oOPD visits by health insurance system during the lockdown period, with four[21,31,33,36] conducted in countries with a universal health insurance system and five[20,22,24,26,35] in countries with a non-universal health insurance system.

A meta-analysis was performed to compare the number of oOPD visits before and during the COVID-19 pandemic (forest plots presented in Supplementary Fig. S3) or lockdown (forest plots presented in Supplementary

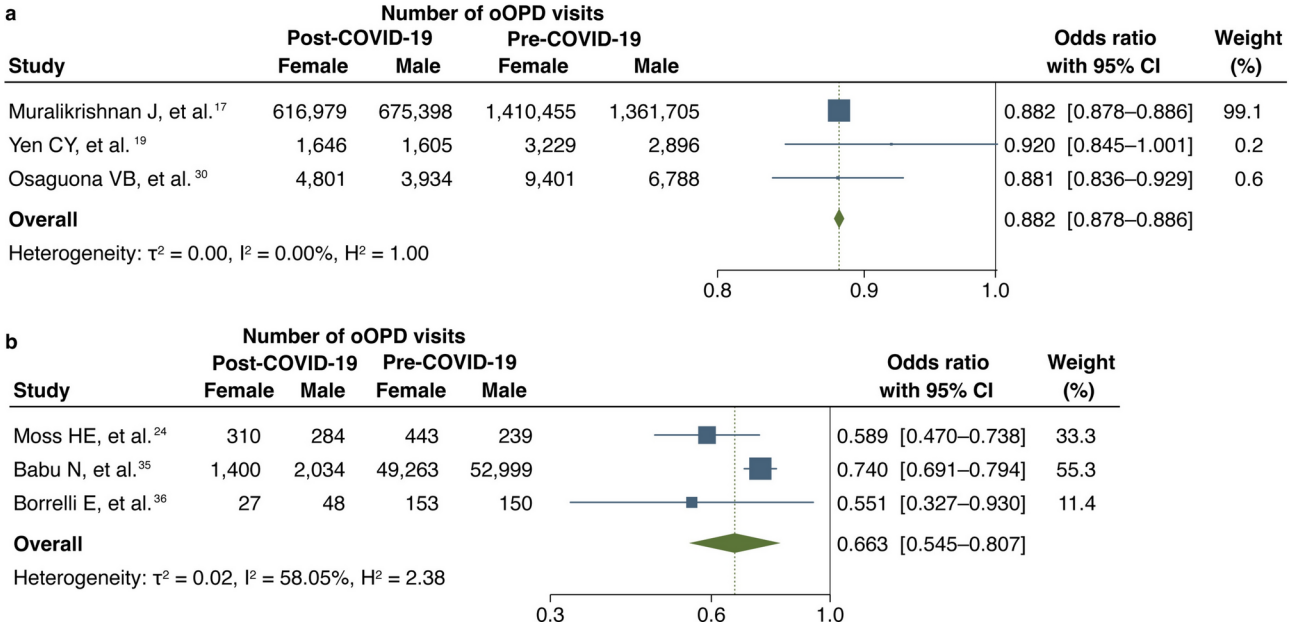

Fig. 3. Forest plot showing the odds ratio of the number of oOPD visits between men and women. Forest plots showing the odds ratio of the number of oOPD visits during the COVID-19 pandemic period (**a**) and lockdown period (**b**). In the forest plot, the green diamond represents the pooled odds ratio, with its width reflecting the 95% confidence interval. If the diamond does not intersect the vertical solid line (which indicates an odds ratio of 1.0), the result suggests statistical significance. oOPD, ophthalmology outpatient department; COVID-19, coronavirus disease.

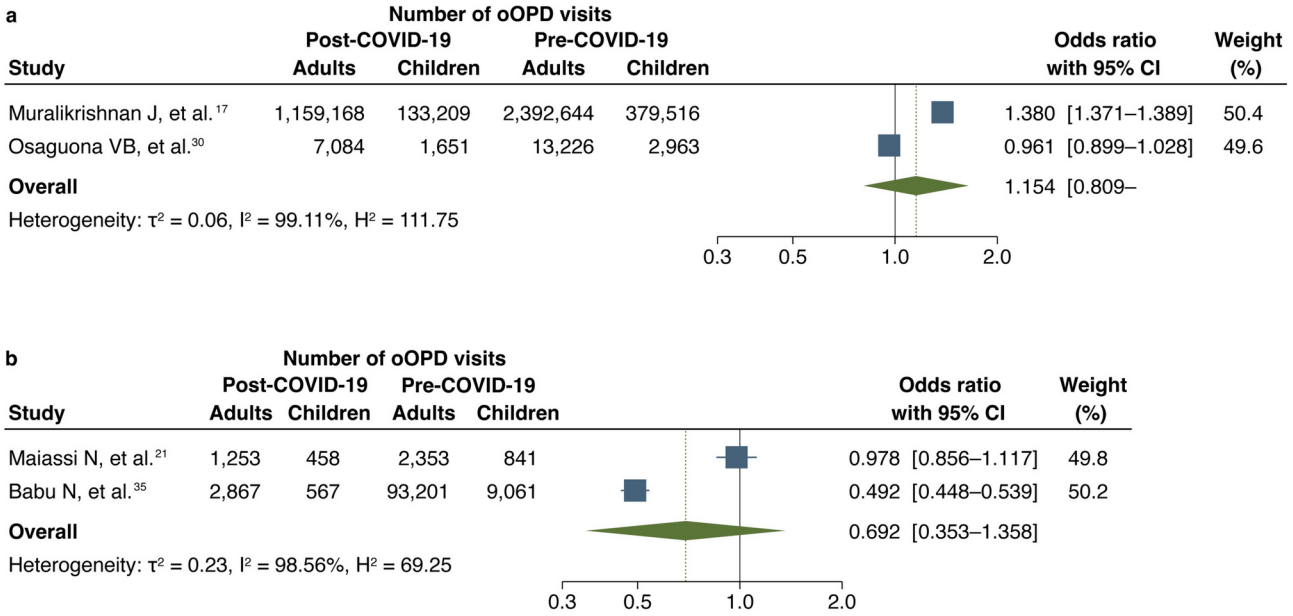

Fig. 4. Forest plot showing the odds ratio of the number of oOPD visits between adults and children. Forest plots showing the odds ratio of the number of oOPD visits during the (**a**) COVID-19 pandemic period and (**b**) lockdown period. In the forest plot, the green diamond represents the pooled odds ratio, with its width reflecting the 95% confidence interval. If the diamond does not intersect the vertical solid line (which indicates an odds ratio of 1.0), the result suggests statistical significance. oOPD, ophthalmology outpatient department; COVID-19, coronavirus disease.

Fig. S4) period, based on health insurance system. During the COVID-19 pandemic period, the numbers of oOPD visits decreased to 61.2% (95% CI 0.325–0.900) in countries with universal health insurance systems and 50.3% (95% CI 0.431–0.575) in countries with non-universal health insurance systems compared with the pre-pandemic levels. During the lockdown period, the numbers of oOPD visits decreased to 28.1% (95% CI 0.107–0.455) in countries with universal health insurance systems and 31.1% (95% CI 0.023–0.599) in countries with non-universal health insurance systems compared with the pre-pandemic levels.

Quality of included studies

The responses to the Joanna Briggs Institute Critical Appraisal Checklists for case series are summarized in Supplementary Table S1. Twenty articles and one article were rated as high quality and moderate quality, respectively.

Publication bias assessment

Publication bias was assessed using Egger's test, Begg's test, and a funnel plot based on the number of oOPD visits before and after the COVID-19 pandemic. The results of Eggers test ($P = 0.824$) and Begg's test ($P = 0.964$) indicated that there was no significant publication bias. Additionally, the funnel plot was symmetric, further confirming the absence of publication bias (Supplementary Fig. S5).

Discussion

This systematic review and meta-analysis assessed the impact of the pandemic on the number of oOPD visits and elucidated the trends during this period. Compared with the pre-pandemic levels, our meta-analysis revealed a 58% decrease in oOPD visits during the COVID-19 pandemic and a 30% decrease during the lockdown phase. These findings suggest that many patients may have been lost to follow-up during the pandemic, potentially experiencing disease progression due to infrequent evaluations. The decrease in care-seeking behaviors for ocular diseases during the pandemic underscores the necessity of public health initiatives aimed at supporting patients who may require regular evaluations but lose motivation to pursue oOPD visits.

Our results indicate a significant reduction in oOPD visits during the pandemic and lockdown periods compared with the pre-pandemic levels. In medical fields beyond ophthalmology, the number of outpatient visits significantly decreased during the COVID-19 pandemic compared with the pre-pandemic period. For example, outpatient visits in cancer care decreased to 62%[37], whereas orthopedic care showed a reduction from 50 to 74%[38]. The fear of contracting COVID-19 during oOPD visits, financial burden, and transportation restrictions imposed by governmental bodies appear to be the primary contributors to the decline in visits[39]. During the lockdown, which involved strict measures to curb disease spread, including stay-at-home orders and limited public transportation[40], a more pronounced decrease in the number of oOPD visits was observed compared with the pandemic averages. Liang et al. reported similar trends, although a higher decrease of 63.6% was noted in ophthalmic emergency or outpatient patients presenting to the emergency department during

the post-COVID-19 period[9]. This gap may be attributed to the nature of individuals seeking emergency care for ophthalmic concerns during the pre-pandemic period[41,42]. A meta-analysis of the number of oOPD visits during the COVID-19 endemic period was not performed due to the varying tracking periods of oOPD visits pre- and post-COVID-19 pandemic in the included studies. However, our systematic review suggests that the number of oOPD visits during the COVID-19 endemic period may have recovered to pre-COVID-19 levels[17,18]. The rapid recovery of oOPD visits likely stems from the rapid distribution of effective COVID-19 vaccines and the lifting of activity restrictions, reducing barriers to seeking medical care. Despite the quick recovery, studies suggest that patients may have already experienced negative health consequences, including permanent vision loss from infrequent checkups and dropouts[43,44] or delayed diagnosis of intraocular malignancies[45]. In diabetic retinopathy care, an increase in the number of patients with low glycated hemoglobin levels who discontinued regular visits after the COVID-19 pandemic[46]. Identifying patients whose care was interrupted due to the COVID-19 pandemic and facilitating their return to regular follow-up are important public health strategies to mitigate delays in diagnosis and treatment for future pandemics and crises. The ramifications of the pandemic on ocular pathologies must remain a key consideration for all practicing ophthalmologists, with continued surveillance and management being crucial. Our findings further emphasize the necessity of promoting ophthalmic care, particularly for patients with known pathologies or risk factors such as diabetes or a family history of glaucoma, as this may help prevent further irreversible vision loss. In addition, effective screening and management for a range of ocular diseases is feasible through telemedicine[47]. Telemedicine minimizes the risk of infection associated with face-to-face interactions between physicians and patients, making it a valuable tool for the continuous monitoring of ocular conditions during periods when oOPD visits are reduced, such as during pandemic and lockdown periods. Beyond telemedicine, other potential interventions include enhancing patient education on the importance of regular follow-up, implementing reminder systems to improve appointment adherence, and establishing community-based outreach programs to identify and support at-risk populations. These strategies could help mitigate the decline in the number of oOPD visits and ensure timely diagnosis and management of ocular diseases in future public health crises.

This study examined the various epidemiological characteristics of oOPD visits influenced by the COVID-19 pandemic. During both the pandemic and lockdown periods, the proportion of visits by male patients increased. Although this trend is likely multifactorial, it could suggest a unique health disparity between men and women[48–50]. The unequal distribution of housework, childcare responsibilities[51], and financial burdens[52] may have contributed to this sex gap. Additionally, several studies indicate that women perceived the COVID-19 pandemic as a more significant event, leading to a higher adherence to preventive behaviors such as wearing masks, social distancing, and frequent handwashing[53,54]. These additional burdens, along with stricter health precautions, may have presented as barriers to oOPD visits, causing a relative increase in the number of male patient visits during the pandemic. Although no significant differences were observed in oOPD visits by age, higher and lower proportions of visits were observed during the pandemic and lockdown, respectively. In the pediatric population, failure to manage ocular diseases frequently leads to irreversible visual loss or even death when ocular malignancies are involved[55,56]. Unfortunately, difficulty communicating with children and their limited ability to express complaints hinder timely diagnoses, necessitating parental involvement in their care. The relatively lower decrease in the number of pediatric patient visits during the lockdown phase could indicate higher adherence to pediatric health maintenance by parents. Despite the disruption to healthcare services during the pandemic, parents maintained a strong awareness of the importance of oOPD visits and continued ocular care for their children.

Growing evidence suggests the detrimental effects of the COVID-19 pandemic on various ocular conditions. The direct consequences of COVID-19 and global vaccination efforts appear to be far-reaching, with reports of retinal vascular occlusions[57], uveitis[58], and corneal transplant rejection[59]. The potential indirect effects include increased myopia due to lifestyle changes[60], decreased follow-up for cataracts and diabetic retinopathy[17], less frequent administration of anti-VEGF injections for macular degeneration[61], and delayed intervention for retinal detachments[62]. Our systematic review and meta-analysis affirm concerns regarding the global decrease in ophthalmic care brought about by the pandemic, highlighting the negative impact on patients with various ocular pathologies. The significant decrease in the number of oOPD visits observed in the meta-analysis indicates that both direct and indirect disruptions from the pandemic hindered the regular monitoring of known ocular pathologies, delayed timely interventions, and exacerbated preventable diseases. Given that ocular diseases present with varying follow-up schedules, intervention frequencies, prognoses, and urgencies, the effects of the pandemic are highly variable. Despite the limited availability of published literature, the impact of the COVID-19 pandemic on several ocular diseases appears to be significant, particularly for macular diseases[61], myopia[60], and ocular trauma[9]. However, the effects on other common ophthalmic diseases remain less thoroughly investigated. Although reduced oOPD visits for less urgent conditions, including presbyopia, mild conjunctivitis, and early cataracts, may not substantially affect timely diagnosis and treatment, the situation is more concerning for chronic, progressive ocular diseases. For example, the COVID-19 pandemic has resulted in decreased treatment compliance among patients with glaucoma[63], exacerbated visual field defects due to delayed treatment[64], and contributed to the progression of diabetic retinopathy due to prolonged visits[13,65]. The potential long-term impacts of these delays due to the COVID-19 pandemic are particularly concerning, as both visual field deterioration in glaucoma and worsening of diabetic retinopathy are often irreversible. Furthermore, the broader mental health impact of the COVID-19 pandemic[66] raises concerns regarding its indirect influence on chronic ocular diseases, such as dry eye disease and glaucoma, where psychological stress may exacerbate disease progression[67]. Investigating changes in oOPD visit patterns for specific ocular diseases due to the COVID-19 pandemic could provide valuable insights for improving public health responses. Future studies should focus on elucidating the long-term consequences of delayed care on ocular health and developing new strategies to mitigate these impacts. Ongoing research into the COVID-19 pandemic's effects on individual

ocular pathologies will be essential for guiding public health interventions and optimizing resource allocation to ensure resilient ophthalmic care systems.

This study has some limitations. First, although this study aimed to focus on routine oOPD visits, some included studies may have inadvertently encompassed urgent or emergent eye visits as part of their oOPD visit data. We carefully reviewed the existing literature and excluded studies explicitly focusing on emergent ocular pathologies[68]. However, not all studies provided strict criteria for differentiating emergent cases. Given that patients with true emergent cases presenting to routine oOPD settings are relatively rare, their impact on our overall findings is likely minimal. Second, each governmental body had varying restrictions, durations, and timing of declaring the pandemic and lockdown; hence, the heterogeneity between international studies is considered high[2]. However, based on the Joanna Briggs Institute Critical Appraisal Checklists, of the 21 articles included in our systematic review, 20 articles (95.2%) were of high quality, whereas one article (4.8%) was of moderate quality, suggesting that the quality of the reviewed articles was generally high. The high heterogeneity between the articles may be attributed to the differences in study settings and pandemic conditions. Although this study aimed to illustrate the global trends in oOPD visits and COVID-19 pandemic effects, practicing clinicians should exercise caution regarding the generalizability of our findings on a local scale. Third, this study was unable to investigate the long-term impact of COVID-19 on oOPD visits. Although many studies have reported a decrease in the number of oOPD visits during the COVID-19 pandemic or lockdown period, only a few studies have focused on the subsequent recovery of the number of oOPD visits. Additionally, some studies[17,18] have suggested a recovery in the number of oOPD visits during the COVID-19 endemic period, but data on specific recovery rates remain limited. Future studies should aim to assess the long-term trends in the number of oOPD visits and clarify the enduring impact of the COVID-19 pandemic on ocular health outcomes. Fourth, this study only included face-to-face oOPD visits and did not account for treatment continuation and consultations via telemedicine. In addition, we could not investigate the changes in the number of oOPD visits for each ocular disease. Furthermore, the fact that some medical resources were allocated to the treatment of patients with COVID-19 and that only non-essential oOPD visits decreased may have influenced the study results. Consequently, our findings indicate that patients may have experienced delays in ocular disease diagnosis, timely treatment, and exacerbation of existing pathologies during and after the pandemic. Future studies should investigate changes in the number of oOPD visits for each ocular disease and consider the changes in the number of telemedicine oOPD visits.

In conclusion, our systematic review and meta-analysis demonstrated a significant decrease in the number of oOPD visits during the COVID-19 pandemic. These findings imply that patients may have experienced delays in ocular disease diagnosis and timely treatment, potentially leading to the exacerbation of existing pathologies during and after the pandemic. These findings highlight the need for widespread public health initiatives to improve patient education strategies in both specialty and primary care settings and promote ophthalmic care for individuals whose regular surveillance schedules were disrupted by the pandemic.

Materials and methods

Eligibility criteria for considering studies

The inclusion and exclusion criteria for this systematic review and meta-analysis are presented in Supplementary Table S2. (1) Studies involving patients visiting oOPDs during the COVID-19 pandemic, (2) retrospective or prospective studies, and (3) outcomes reporting the number of oOPD visits were included in the analysis. By contrast, (1) non-original articles including editorials, letters, commentaries, book chapters, reviews, systematic reviews, conference proceedings, and conference abstracts; (2) studies unrelated to the research topic; (3) studies not published in English; (4) studies not reporting the number of oOPD visits; (5) studies lacking a clear definition of the COVID-19 pandemic period; (6) studies explicitly including ophthalmology emergency department visits (e.g., nationwide database studies that incorporate emergency visits and studies exclusively focused on emergency cases); and (7) studies addressing patient visits to primary care centers without ophthalmologists present were excluded.

Search methods for identifying relevant studies

This systematic review and meta-analysis adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses reporting guidelines[69]. As all reported data were obtained from publicly available published literature, institutional review board approval and informed consent were not required for this study. All studies adhered to the ethical principles outlined in the Declaration of Helsinki.

A comprehensive search of articles published in the PubMed and EMBASE databases was conducted between January 1, 2020, and December 5, 2022, using an optimized combination of search terms: ("COVID-19") AND ("ophthalmology") AND ("ambulatory care" OR "outpatient"). The specific search terms used are detailed in the Supplementary Table S3. Search results were compiled using the EndNote X9.3.3 software (Clarivate Analytics, Philadelphia, PA, USA).

Study selection

Two independent researchers (K.H. and K.N.) screened the retrieved articles and evaluated the full text of potentially eligible articles, reaching a consensus through discussions. Disagreements between reviewers were resolved through discussions with a third reviewer (T.I.).

Data collection and quality assessment

Data extraction was conducted by two independent reviewers (K.H. and K.N.) using a standardized data extraction sheet, and the results were cross-checked for accuracy. The extracted information included the

authors' information, title, year of publication, country of publication, study objectives, study period, number of oOPD visits, and population characteristics.

The quality of extracted studies was assessed using the Joanna Briggs Institute Critical Appraisal Checklist[70] for case series. This checklist consists of 10 questions with the following response options: "yes," "no," "unclear," or "not applicable." "Not applicable" responses were excluded from the quality assessment[71]. The quality of studies was identified according to the total number of "yes" responses, with rates of ≥ 70%, 69–50%, and ≥ 49% indicating high, moderate, and low quality, respectively[71,72]. All studies that met the inclusion criteria were included in this review, regardless of their quality ratings.

Data synthesis and analysis

The data extracted from the included studies were summed and compared with the data from the pre-COVID-19 and post-COVID-19 (COVID-19 pandemic, lockdown, immediately after the lockdown, and COVID-19 endemic) periods. Supplementary Fig. S6 shows the time series for these defined periods. The pandemic, lockdown, and endemic periods in each country were determined by referring to the specific studies or government websites from each respective country. The proportion of oOPD visits from the post-COVID-19 period to the pre-COVID-19 period was calculated using a one-group meta-analysis[71,73]. The number of oOPD visits by men and women, including adults and children, was combined; the ORs and 95% CIs were calculated. Meta-analyses were performed using a restricted maximum likelihood random-effects model[74]. Publication bias was assessed using the Egger's test, Begg's test, and funnel plot method[75,76]. Study heterogeneity was assessed using the I^2 statistic. All analyses were performed using the Stata software package (v18.0; Stata Corp, College Station, TX, USA) with the metadata command.

Data availability

All data are available in the main text or the supplementary materials.

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References

1. Chang, A. Y., Cullen, M. R., Harrington, R. A. & Barry, M. The impact of novel coronavirus COVID-19 on noncommunicable disease patients and health systems: A review. *J. Intern. Med.* **289**, 450–462. https://doi.org/10.1111/joim.13184 (2021).
2. Onyeaka, H., Anumudu, C. K., Al-Sharify, Z. T., Egele-Godswill, E. & Mbaegbu, P. COVID-19 pandemic: A review of the global lockdown and its far-reaching effects. *Sci. Prog.* **104**, 368504211019854. https://doi.org/10.1177/00368504211019854 (2021).
3. Ojo, O. et al. The effects of COVID-19 lockdown on glycaemic control and lipid profile in patients with type 2 diabetes: A systematic review and meta-analysis. *Int. J. Environ. Res. Public Health* https://doi.org/10.3390/ijerph19031095 (2022).
4. Rubio-Tomás, T., Skouroliakou, M. & Ntountaniotis, D. Lockdown due to COVID-19 and its consequences on diet, physical activity, lifestyle, and other aspects of daily life worldwide: A narrative review. *Int. J. Environ. Res. Public Health* https://doi.org/10.3390/ijerph19116832 (2022).
5. Akasaki, Y. et al. Impact of COVID-19 on care-seeking patterns for hay fever in Japan: A retrospective claims database cohort study. *Allergy* https://doi.org/10.1111/all.15947 (2023).
6. Akahane, T., Nakanishi, Y., Yoshiji, H. & Akahane, M. Esophagogastroduodenoscopy screening intentions during the COVID-19 pandemic in Japan: Web-based survey. *JMIR Cancer* **8**, e40600. https://doi.org/10.2196/40600 (2022).
7. Li, J. O., Lam, D. S. C., Chen, Y. & Ting, D. S. W. Novel coronavirus disease 2019 (COVID-19): The importance of recognising possible early ocular manifestation and using protective eyewear. *Br. J. Ophthalmol.* **104**, 297–298. https://doi.org/10.1136/bjophthalmol-2020-315994 (2020).
8. Tingley, J., Tauber, J., Thuma, T., Moon, J. Y. & Barmettler, A. Impact of the COVID-19 pandemic on quantity and characteristics of ophthalmology consults. *Telemed. J. E. Health* **28**, 1547–1551. https://doi.org/10.1089/tmj.2021.0512 (2022).
9. Liang, H. et al. Ocular trauma during COVID-19 pandemic: A systematic review and meta-analysis. *Asia-Pac. J. Ophthalmol.* **11**, 481–487. https://doi.org/10.1097/apo.0000000000000539 (2022).
10. Sahay, P., Sharma, N., Sinha, R. & Sachdeva, M. S. Ophthalmology practice during COVID-19 pandemic: A survey of Indian ophthalmologists. *Indian J. Ophthalmol.* **69**, 3638–3642. https://doi.org/10.4103/ijo.IJO_1589_21 (2021).
11. Kavadarlı, I. & Mutlu, M. Effects of the COVID-19 pandemic on Turkish ophthalmologists. *Turk. J. Ophthalmol.* **51**, 95–101. https://doi.org/10.4274/tjo.galenos.2020.52563 (2021).
12. Barış, M. E., Çiftçi, M. D., Güven Yılmaz, S. & Ateş, H. Impact of COVID-19-related lockdown on glaucoma patients. *Turk. J. Ophthalmol.* **52**, 91–95. https://doi.org/10.4274/tjo.galenos.2021.83765 (2022).
13. Prajapati, V., Shah, K., Shah, D., Wanjari, M. B. & Singhal, D. Effect of the COVID-19 pandemic lockdown on the management of diabetic retinopathy: A cross-sectional study. *Cureus* **14**, e27623. https://doi.org/10.7759/cureus.27623 (2022).
14. Al-Dwairi, R., Rwashdeh, H. & Otoom, M. The influence of COVID-19 lockdown in Jordan on patients with diabetic retinopathy: A case-control study. *Ther. Clin. Risk Manag.* **17**, 1011–1022. https://doi.org/10.2147/tcrm.S316265 (2021).
15. Toro, M. D. et al. COVID-19 outbreak and increased risk of amblyopia and epidemic myopia: Insights from EUROCOVCAT group. *Eur. J. Ophthalmol.* **32**, 17–22. https://doi.org/10.1177/11206721211053175 (2022).
16. Sood, I. et al. Comparison of eyecare utilization at two service delivery levels during the COVID-19 pandemic as a measure of their impact: A multicentric retrospective analysis across four North Indian high-volume eyecare organizations. *Indian J. Ophthalmol.* **70**, 2146–2152. https://doi.org/10.4103/ijo.IJO_104_22 (2022).
17. Muralikrishnan, J. et al. Access to eye care during the COVID-19 pandemic, India. *Bull World Health Organ.* **100**, 135–143. https://doi.org/10.2471/blt.21.286368 (2022).
18. Sim, H. E., Jeong, K. D. & Hwang, J. H. Impact of the coronavirus disease 2019 pandemic on the ophthalmology department. *J. Clin. Med.* https://doi.org/10.3390/jcm11061722 (2022).
19. Yen, C. Y., Fang, I. M., Tang, H. F., Lee, H. J. & Yang, S. H. COVID-19 pandemic decreased the ophthalmic outpatient numbers and altered the diagnosis distribution in a community hospital in Taiwan: An observational study. *PLoS ONE* **17**, e0264976. https://doi.org/10.1371/journal.pone.0264976 (2022).
20. Lim, H. B. et al. Clinical operational considerations and responses to lockdown and reopening in the Covid-19 pandemic: Experience of a tertiary ophthalmology centre in Singapore. *Eye* **36**, 1924–1933. https://doi.org/10.1038/s41433-021-01566-2 (2022).

21. Maiassi, N., Xanthopoulou, K., Löw, U. & Seitz, B. The impact of the first COVID-19 lockdown period on the inpatient and outpatient volume of a university based Tertiary Referral Center with corneal subspecialization in Germany. *Clin. Ophthalmol.* **16**, 1795–1805. https://doi.org/10.2147/opth.S335551 (2022).
22. Shahid, E., Fasih, U., Taqi, U. & Jafri, A. R. An unusual rise in cases of assault in ophthalmic practice during COVID-19 lockdown in a tertiary care hospital. *Oman J. Ophthalmol.* **15**, 309–314. https://doi.org/10.4103/ojo.ojo_323_21 (2022).
23. Grudziąż-Sękowska, J., Sękowski, K. & Kobuszewski, B. Healthcare utilization and adherence to treatment recommendations among children with type 1 diabetes in Poland during the COVID-19 pandemic. *Int. J. Environ. Res. Public Health* https://doi.org/10.3390/ijerph19084798 (2022).
24. Moss, H. E. et al. The impact of COVID-19 on neuro-ophthalmology office visits and adoption of telemedicine services. *J. Neuroophthalmol.* **41**, 362–367. https://doi.org/10.1097/wno.0000000000001356 (2021).
25. Berkenstock, M. K., Liberman, P., McDonnell, P. J. & Chaon, B. C. Changes in patient visits and diagnoses in a large academic center during the COVID-19 pandemic. *BMC Ophthalmol.* **21**, 139. https://doi.org/10.1186/s12886-021-01886-7 (2021).
26. Sethi, K., Levine, E. S., Roh, S., Marx, J. L. & Ramsey, D. J. Modeling the impact of COVID-19 on retina clinic performance. *BMC Ophthalmol.* **21**, 206. https://doi.org/10.1186/s12886-021-01955-x (2021).
27. Brant, A. R. et al. The impact of COVID-19 on missed ophthalmology clinic visits. *Clin. Ophthalmol.* **15**, 4645–4657. https://doi.org/10.2147/opth.S341739 (2021).
28. Chang, Y. T., Chiang, S. C., Lee, W. C., Chen, T. J. & Hwang, S. J. Varied impacts on outpatient services among departments and divisions in the early phase of the COVID-19 pandemic: Implications for personnel mobilization and preparatory training. *J. Chin. Med. Assoc.* **84**, 951–955. https://doi.org/10.1097/jcma.0000000000000569 (2021).
29. Savastano, A. et al. Impact of the COVID-19 pandemic on ophthalmologic outpatient care: Experience from an Italian Tertiary Medical Center. *Ann. Med.* **53**, 1349–1357. https://doi.org/10.1080/07853890.2021.1964036 (2021).
30. Osaguona, V. B., Osahon, A. I. & Uhumwangho, O. M. Impact of COVID-19 on ophthalmic outpatient services in an eye care center in southern Nigeria. *Niger J. Clin. Pract.* **24**, 1338–1342. https://doi.org/10.4103/njcp.njcp_668_20 (2021).
31. Schuh, A. et al. Effects of the first COVID-19 lockdown on ophthalmological patient care. *Klin Monbl Augenheilkd* **238**, 1220–1228. https://doi.org/10.1055/a-1529-6726 (2021).
32. Ayub, G., de Vasconcelos, J. P. C. & Costa, V. P. The impact of Covid-19 in the follow-up of glaucoma patients in a Tertiary Center: a comparison between pre-pandemic and pandemic periods. *Clin. Ophthalmol.* **15**, 4381–4387. https://doi.org/10.2147/opth.S334147 (2021).
33. Wood, M., Gray, J., Raj, A., Gonzalez-Martin, J. & Yeo, D. C. M. The impact of the first peak of the COVID-19 pandemic on a paediatric ophthalmology service in the United Kingdom: Experience from Alder Hey Children's Hospital. *Br. Ir. Orthopt. J.* **17**, 56–61. https://doi.org/10.22599/bioj.164 (2021).
34. Agarwal, R. et al. Impact of COVID-19 pandemic, national lockdown, and unlocking on an apex tertiary care ophthalmic institute. *Indian J. Ophthalmol.* **68**, 2391–2395. https://doi.org/10.4103/ijo.IJO_2366_20 (2020).
35. Babu, N. et al. To evaluate the effect of COVID-19 pandemic and national lockdown on patient care at a tertiary-care ophthalmology institute. *Indian J. Ophthalmol.* **68**, 1540–1544. https://doi.org/10.4103/ijo.IJO_1673_20 (2020).
36. Borrelli, E. et al. Impact of COVID-19 on outpatient visits and intravitreal treatments in a referral retina unit: let's be ready for a plausible "rebound effect". *Graefes Arch. Clin. Exp. Ophthalmol.* **258**, 2655–2660. https://doi.org/10.1007/s00417-020-04858-7 (2020).
37. Angelini, M., Teglia, F., Casolari, G., Astolfi, L. & Boffetta, P. Decrease of visits and hospital admissions for cancer patients during the COVID-19 pandemic. A systematic review and meta-analysis. *Z Gesundh Wiss* https://doi.org/10.1007/s10389-023-01857-w (2023).
38. Blum, P., Putzer, D., Liebensteiner, M. C. & Dammerer, D. Impact of the Covid-19 pandemic on orthopaedic and trauma surgery—a systematic review of the current literature. *In Vivo* **35**, 1337–1343. https://doi.org/10.21873/invivo.12386 (2021).
39. Czeisler, M. et al. Delay or avoidance of medical care because of COVID-19-related concerns—United States, June 2020. *MMWR Morb. Mortal. Wkly. Rep.* **69**, 1250–1257. https://doi.org/10.15585/mmwr.mm6936a4 (2020).
40. Haider, N. et al. Lockdown measures in response to COVID-19 in nine sub-Saharan African countries. *BMJ Glob. Health* https://doi.org/10.1136/bmjgh-2020-003319 (2020).
41. Hsu, M. H., Hsu, C. A., Hsiao, S. H., Chu, D. & Yen, J. C. Utilization of emergency ophthalmology services in Taiwan: A nationwide population study. *Sci. Rep.* **10**, 17703. https://doi.org/10.1038/s41598-020-74815-1 (2020).
42. Channa, R. et al. Epidemiology of eye-related emergency department visits. *JAMA Ophthalmol.* **134**, 312–319. https://doi.org/10.1001/jamaophthalmol.2015.5778 (2016).
43. Zarranz-Ventura, J. et al. International impact of the Covid-19 pandemic lockdown on intravitreal therapy outcomes: Fight retinal blindness registry. *Retina* **42**, 616–627. https://doi.org/10.1097/iae.0000000000003368 (2022).
44. Robbins, C. C. et al. An initiative to improve follow-up of patients with glaucoma. *Ophthalmol. Sci.* **1**, 100059. https://doi.org/10.1016/j.xops.2021.100059 (2021).
45. Wang, H. et al. Impact of COVID-19 pandemic on eye cancer care in United Kingdom. *Br. J. Cancer* **124**, 1357–1360. https://doi.org/10.1038/s41416-021-01274-4 (2021).
46. Hirosawa, K. et al. Impact of the coronavirus disease 2019 pandemic on outpatient visits for diabetic retinopathy in Japan: A retrospective cohort study. *Transl. Vis. Sci. Technol.* **13**, 6. https://doi.org/10.1167/tvst.13.9.6 (2024).
47. Sommer, A. C. & Blumenthal, E. Z. Telemedicine in ophthalmology in view of the emerging COVID-19 outbreak. *Graefes Arch. Clin. Exp. Ophthalmol.* **258**, 2341–2352. https://doi.org/10.1007/s00417-020-04879-2 (2020).
48. Binns, C. W. et al. COVID and gender: A narrative review of the Asia-Pacific region. *Int. J. Environ. Res. Public Health* https://doi.org/10.3390/ijerph20010245 (2022).
49. Yerkes, M. A. et al. "Intelligent" lockdown, intelligent effects? Results from a survey on gender (in)equality in paid work, the division of childcare and household work, and quality of life among parents in the Netherlands during the Covid-19 lockdown. *PLoS ONE* **15**, e0242249. https://doi.org/10.1371/journal.pone.0242249 (2020).
50. Profeta, P. Gender equality and public policy during COVID-19. *CESifo Econ. Stud.* **66**, 365–375. https://doi.org/10.1093/cesifo/ifaa018 (2020).
51. Del Boca, D., Oggero, N., Profeta, P. & Rossi, M. Women's and men's work, housework and childcare, before and during COVID-19. *Rev. Econ. Househ.* **18**, 1001–1017. https://doi.org/10.1007/s11150-020-09502-1 (2020).
52. Salami, V. U., Okoduwa, S. I. R., Chris, A. O., Ayilara, S. I. & Okoduwa, U. J. Opinion review of socioeconomic impact of COVID-2019 on women's health. *Front. Glob. Womens Health* **2**, 647421. https://doi.org/10.3389/fgwh.2021.647421 (2021).
53. Haischer, M. H. et al. Who is wearing a mask? Gender-, age-, and location-related differences during the COVID-19 pandemic. *PLoS ONE* **15**, e0240785. https://doi.org/10.1371/journal.pone.0240785 (2020).
54. Clark, C., Davila, A., Regis, M. & Kraus, S. Predictors of COVID-19 voluntary compliance behaviors: An international investigation. *Glob. Transit.* **2**, 76–82. https://doi.org/10.1016/j.glt.2020.06.003 (2020).
55. McConaghy, J. R. & McGuirk, R. Amblyopia: Detection and treatment. *Am. Fam. Phys.* **100**, 745–750 (2019).
56. Abramson, D. H. et al. Screening for retinoblastoma: presenting signs as prognosticators of patient and ocular survival. *Pediatrics* **112**, 1248–1255. https://doi.org/10.1542/peds.112.6.1248 (2003).
57. Yeo, S., Kim, H., Lee, J., Yi, J. & Chung, Y. R. Retinal vascular occlusions in COVID-19 infection and vaccination: a literature review. *Graefes Arch. Clin. Exp. Ophthalmol.* **261**, 1793–1808. https://doi.org/10.1007/s00417-022-05953-7 (2023).

58. Cherif, Y. Y. S. et al. The characteristics of COVID-19 vaccine-associated uveitis: A summative systematic review. *Vaccines* https://doi.org/10.3390/vaccines11010069 (2022).
59. Fujio, K. et al. Characteristics and clinical ocular manifestations in patients with acute corneal graft rejection after receiving the COVID-19 vaccine: A systematic review. *J. Clin. Med.* https://doi.org/10.3390/jcm11154500 (2022).
60. Najafzadeh, M. J. et al. Myopia progression during the COVID-19 era: A systematic review and meta-analysis. *Semin. Ophthalmol.* **38**, 537–546. https://doi.org/10.1080/08820538.2023.2168490 (2023).
61. Im, J. H. B., Jin, Y. P., Chow, R., Dharia, R. S. & Yan, P. Delayed anti-VEGF injections during the COVID-19 pandemic and changes in visual acuity in patients with three common retinal diseases: A systematic review and meta-analysis. *Surv. Ophthalmol.* **67**, 1593–1602. https://doi.org/10.1016/j.survophthal.2022.08.002 (2022).
62. Chiku, Y., Hirano, T., Hoshiyama, K., Iesato, Y. & Murata, T. Impact of local COVID-19 alert levels on rhegmatogenous retinal detachment. *Jpn. J. Ophthalmol.* **67**, 255–263. https://doi.org/10.1007/s10384-023-00980-1 (2023).
63. Mylona, I., Dermenoudi, M., Glynatsis, N. M. & Glynatsis, M. N. Patient adherence to glaucoma treatment during the COVID-19 pandemic. *Cureus* **13**, e15545. https://doi.org/10.7759/cureus.15545 (2021).
64. Inoue, K., Shiokawa, M., Kunimatsu-Sanuki, S., Ishida, K. & Tomita, G. Glaucoma progression due to refraining examination amid the pandemic of COVID-19. *Int. Ophthalmol.* **44**, 196. https://doi.org/10.1007/s10792-024-03151-4 (2024).
65. Ahearn, B. E., Nguyen, H. & Sohn, J. H. Proliferative diabetic retinopathy requiring vitrectomy over clinic management during COVID-19: Impact of delayed care. *Korean J. Ophthalmol.* **37**, 292–298. https://doi.org/10.3341/kjo.2022.0147 (2023).
66. Penninx, B., Benros, M. E., Klein, R. S. & Vinkers, C. H. How COVID-19 shaped mental health: from infection to pandemic effects. *Nat. Med.* **28**, 2027–2037. https://doi.org/10.1038/s41591-022-02028-2 (2022).
67. Bouhout, S. et al. Impact of the COVID-19 pandemic on mental health among patients with chronic ocular conditions. *Vision* https://doi.org/10.3390/vision7030049 (2023).
68. Choi, H. G., Kim, S. Y. & Baek, S. U. Changes in mean and variance of ophthalmic disease incidences during COVID-19 pandemic in Korea. *Sci. Rep.* **12**, 20364. https://doi.org/10.1038/s41598-022-24975-z (2022).
69. Moher, D., Liberati, A., Tetzlaff, J. & Altman, D. G. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *BMJ* **339**, b2535. https://doi.org/10.1136/bmj.b2535 (2009).
70. Peters, M. *et al. The Joanna Briggs Institute Reviewers' Manual 2015: Methodology for JBI Scoping Reviews*. 24 (The Joanna Briggs Institute, 2015).
71. Nagino, K. et al. Prevalence and characteristics of dry eye disease in Parkinson's disease: a systematic review and meta-analysis. *Sci. Rep.* **12**, 18348. https://doi.org/10.1038/s41598-022-22037-y (2022).
72. Goplen, C. M. et al. Preoperative opioid use is associated with worse patient outcomes after total joint arthroplasty: A systematic review and meta-analysis. *BMC Musculoskelet. Disord.* **20**, 234. https://doi.org/10.1186/s12891-019-2619-8 (2019).
73. Inomata, T. et al. Clinical and prodromal ocular symptoms in coronavirus disease: A systematic review and meta-analysis. *Investig. Ophthalmol. Vis. Sci.* **61**, 29. https://doi.org/10.1167/iovs.61.10.29 (2020).
74. Partlett, C. & Riley, R. D. Random effects meta-analysis: Coverage performance of 95% confidence and prediction intervals following REML estimation. *Stat. Med.* **36**, 301–317. https://doi.org/10.1002/sim.7140 (2017).
75. Egger, M., Davey Smith, G., Schneider, M. & Minder, C. Bias in meta-analysis detected by a simple, graphical test. *BMJ* **315**, 629–634. https://doi.org/10.1136/bmj.315.7109.629 (1997).
76. Begg, C. B. & Mazumdar, M. Operating characteristics of a rank correlation test for publication bias. *Biometrics* **50**, 1088–1101 (1994).

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Author contributions

KH was responsible for the methodology, data curation, software, visualization, formal analysis, investigation, writing of the original draft, and writing – reviewing and editing. TI was responsible for the conceptualization, methodology, validation, investigation, funding, writing of the original draft, and writing – reviewing and editing. KN was responsible for the conceptualization, methodology, data curation, software, visualization, formal analysis, investigation, writing of the original draft, and writing – reviewing and editing. JS was responsible for the investigation, writing of the original draft, and writing – reviewing and editing. AMI performed the validation, investigation, funding, writing of the original draft, and writing – reviewing and editing. KI performed the investigation, writing of the original draft, and writing – reviewing and editing. HK performed the supervision, writing of the original draft, and writing – reviewing and editing. SN performed the supervision, writing of the original draft, and writing – reviewing and editing. All authors reviewed the manuscript.

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Declarations

Competing interests

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Additional information

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