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Time trends in disability-adjusted life years for cataracts attributable to indoor air pollution across 17 low- and middle-income countries

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Abstract

Indoor air pollution (IAP) is a risk factor leading to cataracts. The disease burden of cataracts due to IAP is currently greater in low- and middle-income countries, an in-depth analysis is necessary to track the current time trend of cataracts caused by IAP in low- and middle-income countries. Our data from the global burden of disease 2021 study. In our study, disability-adjusted life years (DALYs) and DALYs rate were used to assess the disease burden of cataracts due to IAP across 17 low- and middle-income countries. The contribution of IAP exposure to the associated burden of cataracts was quantified by using population attribution fractions. Additionally, the estimated annual percentage change was calculated to quantify the long-term trend in the burden of cataracts due to IAP from 1990 to 2021. An age-period-cohort model was used to estimate the effects of age, period, and cohort on time trend of disease burden. In 2021, age-standardized DALY rates (ASDR) values varied widely across the 17 countries. Pakistan had the highest ASDR 122.5 (–35.3 to 247.4). ASDR declined in all 17 countries. For all countries, the age effect increases rapidly after about age 55. South Africa, Brazil, and Mexico have made great progress in the period and cohort effects. The situation of burden for IAP-related cataracts varies across countries, and it is necessary to set targeted public health strategies and interventions.

Abbreviations: APC model = age-period-cohort model, ASDR = age-standardized DALY rates, DALYs = Disability-Adjusted Life Years, EAPC = estimated annual percentage change, GBD = Global Burden of Disease, GHDx = Global Health Data Exchange, IAP = Indoor air pollution, PAFs = population attribution fractions.

Keywords: age-period-cohort model, cataracts, indoor air pollution

1. Introduction

Cataracts are the primary reason for vision loss leading to blindness.[1] Cataracts are estimated to cause blindness in over 10 million people worldwide.[2] A trend analysis based on data from the 2019 global burden of disease (GBD) study[3] reveals an escalation in the global burden of visual impairment due to cataracts, marked by a 58.45% increase in prevalence and a 32.18% rise in disability-adjusted life years (DALYs) over the last 3 decades. Several factors, including age, genetics, unhealthy lifestyle, and environmental conditions, influence the risk of developing cataracts.[4] Controlling risk factors can reduce the incidence of cataracts and subsequent poor prognosis.[2] From both an epidemiological and economic perspective, prioritizing primary prevention efforts that target modifiable risk factors is crucial for lessening the burden of cataracts.

Indoor air pollutants (IAP) rank as the eighth-largest risk factor impacting human health,[5] mainly stemming from the combustion of traditional fuels like solid fuels and kerosene.[5,6] Currently, about 49 percent of the world's population is still exposed to IAP from burning solid fuels for heating and cooking.[7] At present, there were evidences show that IAP might significantly contribute to cataracts risk.[8,9] Household fuel burning can release large amounts of PM2.5, a stressor for cataracts.[10] It can cause reactive oxygen species and nitrogen oxidative

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Patient consent was not required because the study was retrospective in nature, and there was no direct patient contact.

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The datasets generated during and/or analyzed during the current study are publicly available.

Institutional review board approval was not required according to our institution's policy.

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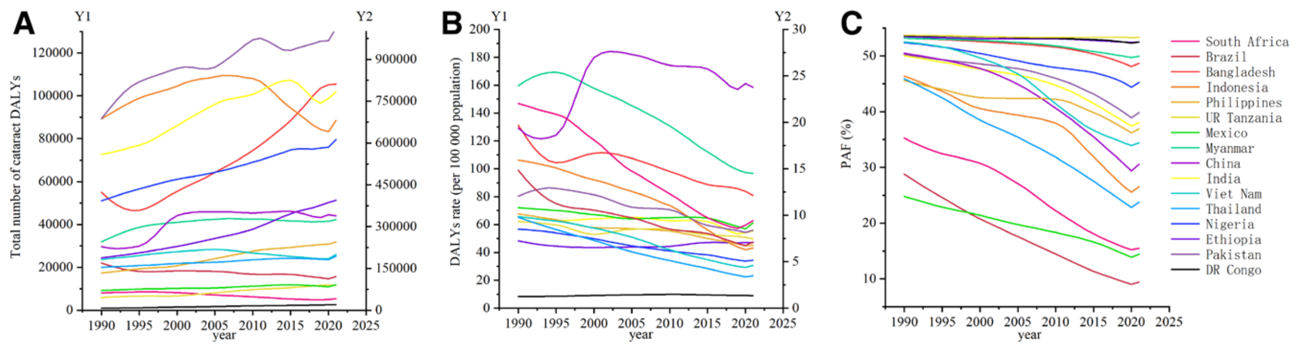

Figure 1. Total number of DALYs resulting from cataract due to IAP, ASDRs, and PAF for cataracts caused by IAP across 17 countries between 1990 and 2021. (A) Y2 axis for China and India, (B) Y2 axis for China, South Africa, Brazil and Mexico. ADSRs = age-standardized DALYs rates, DALYs = disability-adjusted life years, IAP = indoor air pollution, PAF = population attribution fraction.

stress, which destroys the membrane cavity and secretes proteins.[10] Extended exposure to oxidative stress can result in the accumulation of impaired lens proteins, precipitating the onset of cataracts.[11,12]

Previous study[13] has analyzed the DALYs of IAP-related cataracts from a more global and regional perspective. However, there are significant inequalities in the disease burden of cataracts and exposure to IAP between countries.[14,15] Especially in low- and middle-income countries, differences in IAP-related cataract DALYs among these countries remain unclear. In order to understand the epidemiological dynamics of the DALYs of IAP-related cataracts in various countries, and to accurately identify its causes, it is urgent to carry out in-depth and detailed research in low- and middle-income countries.

2. Methods

2.1. Data sources

GBD 2021 provides newer estimates of descriptive epidemiological data encompassing 371 diseases and injuries across 204 countries and territories and 811 subnational locations from 1990 to 2021.[16] Data pertaining to DALYs and age-standardized DALYs rates (ASDRs) for cataracts caused by IAP during 1990 and 2021 were retrieved from the Global Health Data Exchange (GHDx) website.[17] Using standardized tools under a Bayesian framework, the GBD network integrates all available data across time, age, geography, and different health causes and domains to generate disease estimates. This approach allows information to be "borrowed" from existing data to provide estimates for countries that lack raw data. This process allows to estimate DALYs for IAP-related cataracts in various regions of the world.[16,18] For additional details on the GBD database and accessing the data, please visit the website of the Institute for Health Metrics and Evaluation.[19] Low- and middle-income countries with a population of more than 50 million and at least 10% of the population cooking with solid fuels were studied in our study.[7]

2.2. Description of disease burden and analysis of overall temporal trend

This study used DALYs to assess the disease burden of cataracts due to IAP across 17 low- and middle-countries. population attribution fractions was used to quantify the contribution of IAP exposure to the associated burden of cataracts, based on the prevalence of IAP exposure and the relative risk of disease occurrence.[20] To standardize for age structure differences, ASDRs were utilized to estimate the disease burden.[21] Additionally, the estimated annual percentage change (EAPC) was derived to quantify the long-term trend in the burden of cataracts due to IAP from 1990 to 2021. Previous studies have detailed calculation methods for EAPC.[21,22] A 95%CI > 0 of the EAPC estimate indicates an upward trend in the age-standardized measure, <0 indicates a downward trend, and contains 0 is considered stable.

2.3. Definitions

The information on DALYs measures healthy life years lost to morbidity and mortality.[23] ASDR, which adjust for variations in age structures among populations or changes in age distribution within the same population over time.[21]

2.4. Age-period-cohort modeling analysis

The age-period-cohort (APC) model was utilized to examine the effects of age, period, and cohort on the DALYs rate of cataracts caused by IAP.[24] Estimates of net and local drift values for the DALYs rate were also computed to evaluate overarching and age-specific temporal trends.[25] For APC modeling analysis, we categorized the DALYs rate and population data into 20 consecutive cohorts, spanning from those born between 1896 and 1904 (median year 1900) to those born between 1991 and 1999 (median year 1995), choosing the birth cohort from 1951 to 1959 (median year 1955) as the reference group.[25] All analyses were performed on the APC Network Tool provided by the National Cancer Institute.

3. Results

3.1. Temporal trend of DALYs for cataracts attributable to IAP from 1990 to 2021

Figure 1 and Table 1 show the temporal trend of DALYs for cataracts attributable to IAP.

In 2021, ASDR values varied widely across the 17 countries. Pakistan had the highest ASDR 122.5 (−35.3 to 247.4), and the following Ethiopia, Myanmar, Nigeria, and Bangladesh and India all showed ASDRs exceeding 70 per 100 k. China, South Africa, Mexico, Democratic Republic of the Congo and Brazil had a lower ASDR < 20 per 100 k. The number of DALYs only decreased in Brazil, South Africa and Indonesia, and increased in the other countries from 1990 to 2021. ASDR declined in all countries except Democratic Republic of the Congo. Of these, Democratic Republic of the Congo was the only country to rise, with an EAPC value of 0.4 (0.3–0.6). And of all the countries that fell, Ethiopia showed the least change, with EAPC values of −0.3 (95% CI: −0.3 to −0.2). In contrast, the largest change has been in Brazil, with EAPC values of −4.5 (95% CI: −4.6 to −4.4). With the exception of Ethiopia, Democratic Republic of the Congo, Bangladesh, Myanmar and United

Table 1

The DALYs number, age-standardized DALYs rate, and age-standardized PAF (%) of cataract due to IAP in 1990 and 2021 and the temporal trends across 17 countries.

	1990			2021			
Countries	DALYs number (1000)	ASDRs per 100,000	Age-standardized PAF (%)	DALYs number	ASDRs per 100,000	Age-standardized PAF (%)	EAPC_CI
Brazil	22.0 (−5.3 to 47.5)	28.6 (−7 to 62)	28.8 (−6.1 to 59.4)	15.7 (−2.5 to 43.9)	6.5 (−1.0 to 18.1)	9.4 (−1.3 to 25.5)	−4.5 (−4.6 to −4.4)
China	227.9 (−94.4 to 420.6)	33.5 (−14.2 to 61.8)	50.5 (−18.5 to 84.9)	338.5 (−77.7 to 753.5)	17.0 (−3.9 to 38.0)	30.6 (−6.0 to 65.0)	−2.0 (−2.5 to −1.5)
Ethiopia	24.4 (−10.5 to 44.9)	131.2 (−57.7 to 236.8)	53.5 (−22.5 to 87.0)	51.3 (−22.4 to 93.9)	116.1 (−51.2 to 210.5)	52.5 (−21.5 to 86.1)	−0.3 (−0.3 to −0.2)
India	558.4 (−231.9 to 1010.7)	140.9 (−59.6 to 255.8)	50.0 (−19.1 to 84.1)	783.3 (−267.6 to 1551.6)	71.1 (−24.4 to 142.4)	38.0 (−11.4 to 70.5)	−2.1 (−2.3 to −1.9)
Mexico	9.2 (−2 to 20.5)	24.4 (−5.5 to 54.3)	24.8 (−5.1 to 54.7)	11.9 (−2.0 to 32.0)	10.0 (−1.7 to 26.8)	14.4 (−2.1 to 35.8)	−3.0 (−3.1 to −2.9)
Nigeria	51 (−22.8 to 93.1)	123.7 (−55.8 to 224.9)	52.4 (−21.3 to 86.2)	79.5 (−28.1 to 151.6)	92.5 (−32.9 to 177.6)	45.3 (−14.5 to 79.9)	−1.0 (−1.1 to −0.9)
Pakistan	89.4 (−36.3 to 163.9)	172.3 (−70.6 to 316.2)	50.3 (−18.3 to 84.6)	131.5 (−37.4 to 268.8)	122.5 (−35.3 to 247.4)	39.8 (−10.2 to 75.6)	−1.4 (−1.6 to −1.2)
South Africa	8.1 (−2.3 to 17.3)	41.1 (−11.9 to 86.4)	35.3 (−9.1 to 69.4)	5.4 (−0.9 to 13.3)	12.9 (−2.2 to 32.0)	15.5 (−2.3 to 37.9)	−4.3 (−4.5 to −4.1)
Philippines	17.4 (−6.7 to 33)	67.7 (−26.5 to 129)	45.3 (−15.4 to 80.3)	31.9 (−9.1 to 66.5)	45.2 (−13.2 to 93.9)	36.6 (−9.9 to 72)	−1.2 (−1.3 to −1.1)
Democratic Republic of the Congo	1.0 (−0.5 to 1.8)	8.3 (−4.2 to 15.6)	53.6 (−22.8 to 87.1)	2.5 (−1.2 to 4.6)	9.0 (−4.4 to 16.8)	52.5 (−21.2 to 86.3)	0.4 (0.3 to 0.6)
Bangladesh	55.1 (−25.6 to 98.9)	131.2 (−61.4 to 235.3)	53.2 (−21.9 to 86.8)	105.5 (−38.8 to 201.2)	81.0 (−29.9 to 153.7)	48.7 (−15.8 to 83.4)	−1.1 (−1.3 to −1)
Myanmar	31.9 (−14.6 to 58.1)	159.5 (−74.1 to 290)	53.2 (−22 to 86.8)	42.3 (−17.2 to 78.9)	96.6 (−39.8 to 180.6)	50 (−17.9 to 84.5)	−1.9 (−2.1 to −1.7)
Thailand	20 (−6.8 to 39.3)	65.3 (−22.5 to 129.5)	45.9 (−13.9 to 81.3)	25.2 (−4.7 to 62.4)	23.3 (−4.3 to 57.6)	23.8 (−3.7 to 57.7)	−3.4 (−3.5 to −3.4)
United Republic of Tanzania	5.9 (−2.8 to 10.6)	62.2 (−29.6 to 111.1)	53.7 (−22.9 to 87.1)	11.7 (−5.5 to 21.5)	49.9 (−23.8 to 91.1)	53.3 (−22.3 to 86.9)	−0.5 (−0.7 to −0.4)
Indonesia	89.2 (−31 to 169.9)	106.2 (−37.8 to 202.8)	46.2 (−14.5 to 81)	88.4 (−18.7 to 208.7)	43.1 (−9.3 to 102.4)	26.4 (−4.9 to 59.1)	−3.0 (−3.3 to −2.7)
Viet Nam	23.7 (−11.1 to 43.7)	65.7 (−30.9 to 121.2)	52.5 (−20.8 to 86.3)	26.1 (−6.7 to 57.6)	30.7 (−8 to 67.8)	34.5 (−7.4 to 71)	−2.8 (−3 to −2.6)

Abbreviations: DALYs = disability-adjusted life years, PAF = population attribution fraction.

Republic of Tanzania, the population attribution fraction (PAF) in all countries showed a downward trend until 2020, with a slight increase after 2020. In addition to the above 5 countries, Nigeria, Pakistan, the Philippines, India, Vietnam and China have relatively high PAF, all >30%. Among these countries, the fastest decline in PAF was in China, with relatively little change in Nigeria.

3.2. Cohort-specific DALYs rates for 17 low- and middle-income countries

As shown in Figure 2, China and Democratic Republic of the Congo showed a rising trend followed by a falling trend in all age groups in IAP-related cataract DALYs rate. This suggests a reduced risk of IAP-related cataract DALY rates in recent birth cohorts. And other counties showed a decrease trend across the birth cohort.

3.3. Age-period-cohort model on IAP-related cataract DALYs rate

Figure 3 shows the estimated effects of age, period, and cohort on IAP-related cataract DALY rates across 17 countries. For all countries, the age effect increases rapidly after about age 55 and then declines around age 85. The age effect varies slightly between countries, with the effect being most pronounced after age 60 in all countries, but in South Africa it begins to increase in the mid-50s, earlier than in other countries. In some countries, the age effect begins to decline after age 90, especially in India. India, Pakistan, Nigeria (the highest), Ethiopia Bangladesh and Myanmar have significantly higher DALY rates than other countries. South Africa, Brazil, Mexico, Thailand, and Viet Nam have made great progress in the period effect. In China, the period effect rose first and then began to decline around 2005. Nigeria, Ethiopia, Pakistan, Bangladesh, United Republic of Tanzania had relatively flat period effects, indicating little improvements for the population as a whole throughout the study period. And Democratic Republic of the Congo has a slight increase in period effect.

The countries that showed significant improvements in their birth cohorts were South Africa, Mexico, Brazil, Indonesia, Thailand and Viet Nam where improvements in older cohorts were favorable, but improvements in cohorts born after 1960 appeared to stall. India, China, Pakistan and Myanmar showed moderate improvement and maintained a downward trend in all birth cohorts. Other countries have barely improved.

4. Discussion

Our findings show that in 17 low- and middle-income countries, while ADSR for IAP-related cataracts declined between 1990 and 2021 in most countries, overall DALYs increased.

This is consistent with the overall trend in the global burden of cataracts. Although the PAF in all countries has a downward trend, the value is still high, indicating that IAP continues to

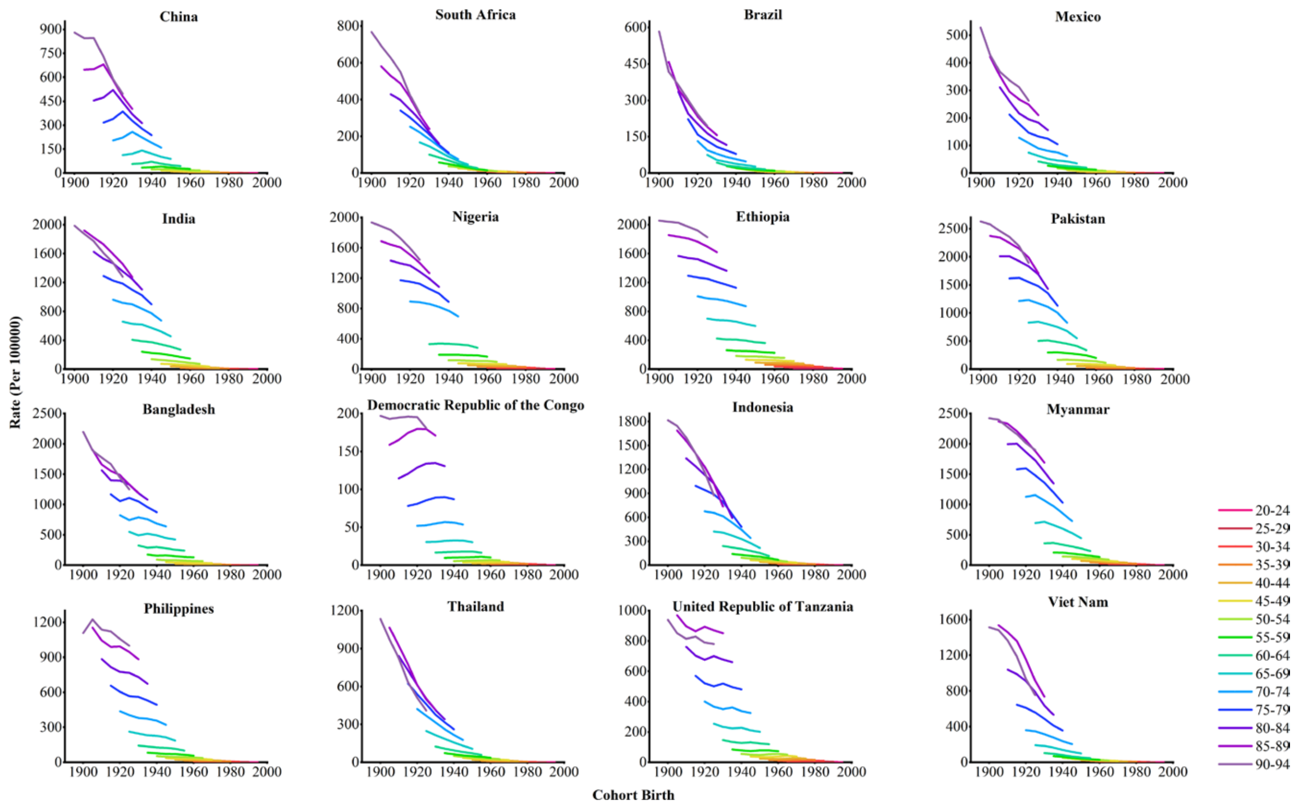

Figure 2. Cohort-specific DALYs rate of cataracts caused by IAP by age group across the 17 countries between 1990 and 2021. DALYs = disability-adjusted life years, IAP = indoor air pollution.

be a significant risk factor for cataract burden. The APC model analysis for each country found that the DALYs rate of cataract caused by IAP increased with age, and the period effect and cohort effect of each country basically showed a falling trend, with differences in the rate of descent.

Cataracts are an age-related disease,[26] a fact corroborated by our findings. As age advances, the rate of IAP-related cataract DALYs showed an increasing trend, especially in the age group of 60 years and above. This phenomenon could be attributed to the gradual waning of immunity among the elderly, making them more susceptible to air pollutants.[27] Moreover, we speculate that the increase in the total IAP-related DALYs may be related to the aging of the global population.[28] However, we also noticed that in the analysis of APC model, the growth rate of DALYs in different countries showed some small differences in the performance of age. For example, South Africa began to increase rapidly at the age of 55, while other countries began to increase after the age of 60. The age at which cataract-related health education and health care policies may begin needs to be in accordance with the actual situation in the country. At the same time, in our current study, we found that the DALYs rate showed a decreasing trend after the age of 90, which requires more exploration to find out the reasons.

In Democratic Republic of the Congo, the problem of cataracts caused by IAP has increased compared to the past. This may be due to the low level of electrification in rural areas in the Democratic Republic of the Congo and the widespread reliance on biomass fuels for cooking,[29] which has not improved significantly in recent years.[30] In addition, our study found that people born in the 1970s in the Democratic Republic of the Congo face a higher risk of cataracts. Although the exact cause has not yet been identified, this finding suggests that more attention should be paid to the health issues of this specific population. Ethiopia and Nigeria have not seen much improvement in indoor air pollution-related cataracts over the past 32 years. In Nigeria and Ethiopia,[31,32] most of the population still uses biomass as fuel wood in unmodified stoves and poorly ventilated kitchens, resulting in much higher DALY rates for IAP-related cataracts than in other countries, and the period and cohort effects are not as well improved. Similarly, in developing countries like Ethiopia, much of the research has concentrated on measuring pollutant levels and their associated diseases, with limited exploration of mitigation strategies against IAP.[33]

In China, our findings reveal an initial increase followed by a decline in the period effects, starting from the early 2000s. Before 2000, Chinese energy infrastructure was inadequate. And with the onset of rapid economic development in the early 2000s, China shifted its energy policy towards promoting clean energy usage and improving air quality.[34] Despite China active participating in the clean energy movement,[13] leading to their period and cohort effects to decline, the rate of improvement is relatively slow. There may be multiple reasons for this slow progress. First, the large and aging populations of China exacerbates exposure to IAP.[35] Furthermore, disparities in energy consumption between urban and rural areas may contribute, as many rural households still predominantly use traditional biomass fuels like wood and charcoal for daily cooking and heating purposes,[36] despite the apparent transition to electricity and natural gas in modern household energy over the past few decades.[34] Although Chinese urbanization rates are about 61.9%,[37] the rural population will be about 491 million by 2022,[38] which is still not negligible. India faces similar challenges for the slow decline in the period and cohort effects.[37,39] In the face of population growth, population aging, and urban-rural energy consumption inequality, these countries need to take more targeted measures to address the disease burden of IAP-related cataracts.

In conclusion, heightened attention should be directed towards the cataract risks stemming from IAP among low- and middle- income countries, with active pursuit of solutions. IAP

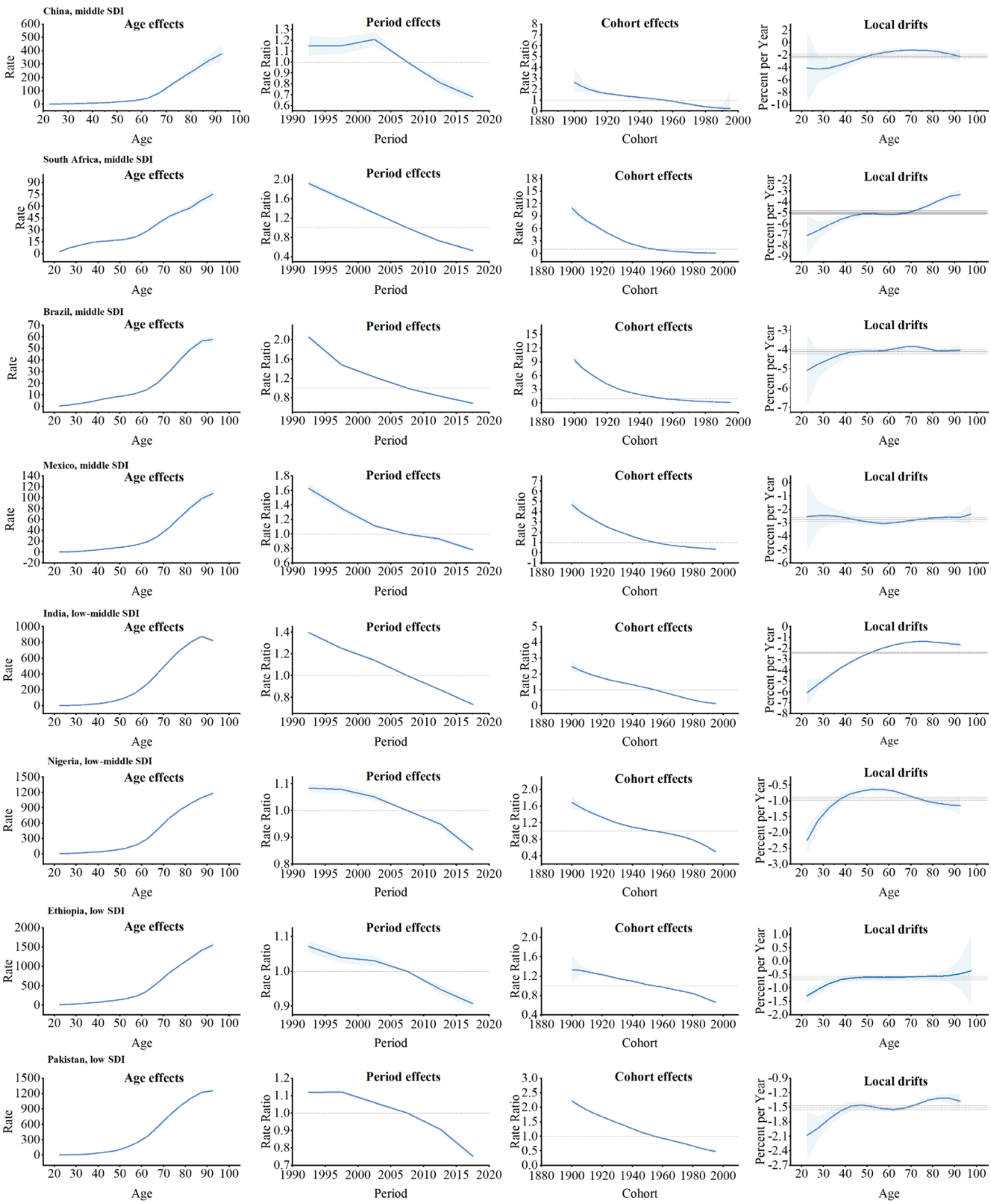

Figure 3. Age, period and cohort effects on cataract due to IAP DALYs by countries. DALYs = disability-adjusted life years, IAP = indoor air pollution.

mainly arises from heating and cooking activities, thus reducing the utilization of these activities is a priority.[34] The adoption of clean energy can be incentivized by boosting investment in the adoption of energy-efficient appliances and buildings.[40] Simultaneously, modern energy-efficient stoves and heating systems can enhance the efficiency of traditional solid fuels, thereby contributing to a decrease in pollutant emissions.[41] When formulating energy transition policies, it is crucial to prioritize addressing disparities in clean energy access and flexibility in goal-setting and policy implementation.[34,40,41]

Our study is a detailed analysis of trends in IAP-related cataracts across 17 low- and middle-income countries by using GBD data. Our study used the APC model, and to our knowledge, detailed analysis of the APC model of IAP-related DALYs is still lacking. The model allows us to understand the epidemiology of IAP-related cataracts in each country and capture important

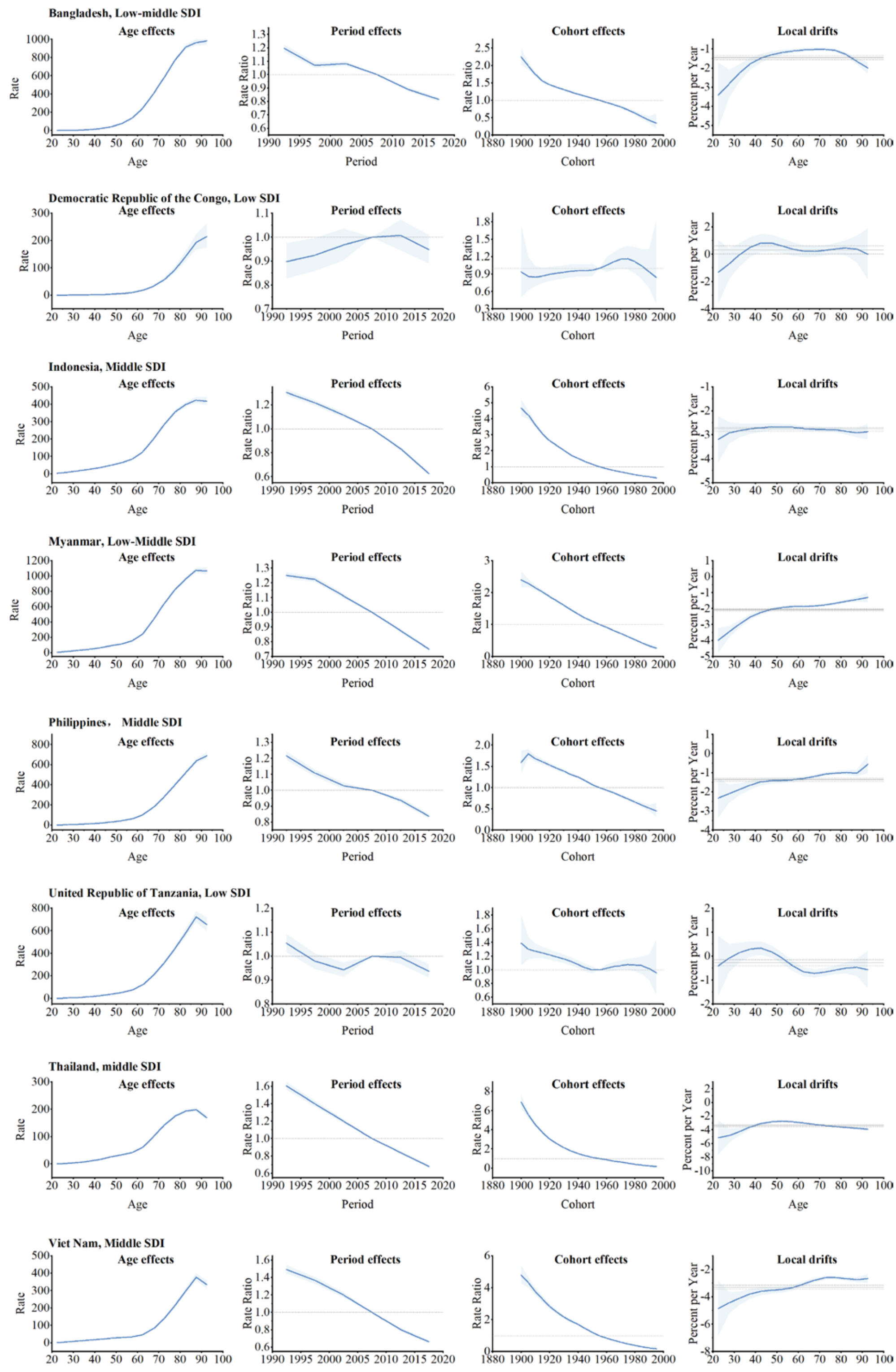

Figure 3. Continued

trends in specific populations to provide targeted recommendations through time, period and cohort effect.[42] The application of the APC model to the analysis of disease trends by age, period, and cohort is beneficial to each country to make more effective countermeasures according to different effect trends. There were several limitations. Firstly, the main limitation of GBD database analysis of disease burden is the availability of raw data, which is inevitable.[43] While GBD 2021 has improved the accuracy of existing data estimates by adjusting the methods used to collect and evaluate data,[43,44] there is still a need for more and better raw data to improve the quality of assessments.[43] However, it is widely acknowledged that potential biases in the current study have been significantly mitigated compared to studies utilizing unadjusted raw data.[45] Second, our analysis uses country-level DALYs estimates to incorporate the APC model. Since almost all countries, including developed countries such as the United

States,[46,47] have differences in energy use, those conclusions apply solely at the national level and local circumstances within countries require separate consideration and discussion. Thirdly, because the APC model mandates a 5-year interval per age group, individuals aged 95 years and older were excluded from the analysis due to the lack of age division for this group in the GBD2021 data.[27] Finally, because GBD 2021 do not include data on the prevalence and incidence of cataracts, the description of the disease burden related to IAP-induced cataracts remains incomplete.

5. Conclusion

Although the DALYs rate of cataract caused by IAP has decreased in 17 low- and middle-income countries, IAP remains a significant risk factor for cataract disease burden. Ethiopia and Nigeria have seen no significant improvement in the disease burden of cataracts due to IAP the past 32 years. The situation varies across countries and necessitates tailored public health strategies and interventions. The IAP comes mainly from heating and cooking activities, so reducing the utilization of these activities is a priority. In particular, countries with high current levels of pollution can reduce IAP pollution through regulatory policies, the use of modern energy-efficient stoves and heating systems, and the transition from solid fuels as the main source of cooking energy to cleaner energy sources.[40] In addition, the burden of cataract disease should be concentrated in areas that have been or are currently exposed to IAP contamination, where public strategies for cataract screening, treatment, and management need to be prioritized.

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Writing – review & editing: Yanrong Wang, Yueping Wu, Yongbin Zhu, Liping Shi, Xian Sun, Ping Chen, Jiangping Li.

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