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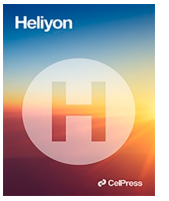

Research article

Current status, trends, and predictions in the burden of coal worker's pneumoconiosis in 204 countries and territories from 1990 to 2019

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ABSTRACT

Coal worker's pneumoconiosis (CWP), a pulmonary condition resulting from prolonged exposure to coal mining environments, not only leads to a high prevalence of morbidity and mortality among miners but also incurs substantial economic burdens and diminishes the labor force within society. In light of evolving trends in the global coal industry, the ramifications of CWP are anticipated to manifest in new patterns and variations. This study seeks to comprehensively assess the present landscape, trend dynamics, and future projections of the global CWP burden from 1990 to 2019. The objective is to provide a scientific framework for nations to develop and enhance pertinent policies and preventative strategies, thereby promoting the health and occupational safety of coal miners.

1. Introduction

CWP, otherwise known as black lung disease, is a chronic respiratory disease resulting from prolonged inhalation of coal dust in occupational settings [1,2]. The inhalation of minute coal dust particles during activities like coal extraction, processing, and transportation leads to the buildup of these particles in the lungs [3,4]. This accumulation causes inflammation, scarring, and the eventual manifestation of CWP [5–7]. Despite efforts to mitigate coal dust exposure and improve working conditions, CWP remains a significant health risk for coal miners globally [8], especially in regions with a history of coal mining [9–12]. Understanding the current prevalence and future projections of CWP is crucial for devising effective prevention measures and optimizing the allocation of healthcare resources to safeguard the well-being of miners and their communities [13–15].

The aim of this research is to conduct a comprehensive analysis of the disease burden of CWP across 204 countries and regions between 1990 and 2019. The objective is to explore changes in prevalence, incidence, mortality, DALYs, geographical variations, and potential risk factors associated with this occupational lung condition. Data sourced from the Global Burden of Disease (GBD) Study

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2019 database was utilized, alongside statistical modeling techniques, to uncover the progression of CWP burden and forecast future trends. These findings offer insights for evidence-based policies and interventions to address the complexities of this public health issue [16].

Through this investigation, we aim to tackle the following significant questions.

1) What is the current trend regarding the occurrence and impact of CWP among coal miners on a global and regional scale?
2) How do socio-economic, occupational, and environmental elements influence changes in the impact of CWP in various countries and regions?
3) What is the projected course of the impact of CWP? What implications does this projection have on healthcare systems and public health efforts worldwide?

By clarifying these crucial questions, this investigation contributes to enhancing the occupational health and overall well-being of coal workers, thus diminishing the global burden of CWP [17].

Table 1
ASRs of Prevalence, incidence, mortality, and DALYs (per 100,00 population) for CWP in all GBD regions in 2019.

Location	Prevalence(95%UI)	Incidence(95%UI)	Mortality(95%UI)	DALYs(95%UI)
Global	1.312 (1.047,1.593)	0.087 (0.072,0.105)	0.038 (0.028,0.049)	0.919 (0.684,1.173)
Africa	0.022 (0.016,0.029)	0.003 (0.002,0.004)	0.011 (0.006,0.023)	0.245 (0.140,0.510)
African Region	0.029 (0.020,0.038)	0.004 (0.003,0.005)	0.011 (0.006,0.024)	0.246 (0.134,0.544)
America	0.757 (0.632,0.896)	0.067 (0.056,0.079)	0.032 (0.027,0.038)	0.661 (0.576,0.759)
Andean Latin America	0.042 (0.027,0.061)	0.003 (0.002,0.004)	0.006 (0.004,0.009)	0.148 (0.100,0.209)
Asia	1.859 (1.474,2.284)	0.114 (0.093,0.140)	0.046 (0.026,0.065)	1.181 (0.791,1.601)
Australasia	0.214 (0.163,0.270)	0.018 (0.014,0.024)	0.003 (0.002,0.008)	0.092 (0.062,0.178)
Caribbean	0.011 (0.006,0.017)	0.001 (0.001,0.001)	0.005 (0.002,0.008)	0.129 (0.065,0.224)
Central Asia	0.076 (0.056,0.100)	0.009 (0.007,0.012)	0.018 (0.010,0.030)	0.437 (0.261,0.743)
Central Europe	1.260 (1.042,1.525)	0.107 (0.09,0.128)	0.034 (0.028,0.040)	0.807 (0.667,0.963)
Central Latin America	0.264 (0.206,0.333)	0.029 (0.023,0.037)	0.019 (0.014,0.024)	0.437 (0.339,0.537)
Central Sub-Saharan Africa	0.072 (0.050,0.095)	0.014 (0.010,0.019)	0.025 (0.007,0.076)	0.508 (0.159,1.483)
Commonwealth High Income	0.988 (0.777,1.220)	0.099 (0.078,0.122)	0.073 (0.062,0.115)	1.102 (0.946,1.616)
Commonwealth Low Income	0.041 (0.028,0.057)	0.007 (0.005,0.009)	0.013 (0.005,0.025)	0.291 (0.102,0.554)
Commonwealth Middle Income	0.041 (0.028,0.056)	0.013 (0.010,0.017)	0.020 (0.009,0.031)	0.412 (0.165,0.656)
East Asia	4.183 (3.304,5.152)	0.257 (0.210,0.313)	0.071 (0.040,0.116)	2.077 (1.413,3.059)
East Asia &Pacific -WB	2.879 (2.285,3.540)	0.178 (0.146,0.217)	0.059 (0.033,0.088)	1.601 (1.067,2.268)
Eastern Europe	0.201 (0.153,0.256)	0.032 (0.024,0.040)	0.018 (0.015,0.024)	0.410 (0.324,0.535)
Eastern Mediterranean Region	0.035 (0.024,0.047)	0.009 (0.007,0.012)	0.013 (0.007,0.019)	0.282 (0.152,0.414)
Eastern Sub-Saharan Africa	0.008 (0.005,0.011)	0.001 (0.001,0.002)	0.017 (0.006,0.042)	0.374 (0.135,0.910)
Europe	0.459 (0.385,0.550)	0.042 (0.035,0.050)	0.027 (0.023,0.035)	0.495 (0.439,0.609)
Europe &Central Asia -WB	0.446 (0.374,0.535)	0.041 (0.034,0.049)	0.027 (0.024,0.035)	0.504 (0.451,0.623)
European Region	0.442 (0.370,0.529)	0.041 (0.034,0.049)	0.027 (0.024,0.035)	0.499 (0.446,0.617)
High-income Asia Pacific	0.460 (0.364,0.579)	0.057 (0.045,0.071)	0.076 (0.036,0.095)	1.470 (0.763,1.829)
High-income North America	1.082 (0.918,1.274)	0.098 (0.083,0.115)	0.045 (0.038,0.056)	0.866 (0.748,1.024)
Latin America &Caribbean -WB	0.426 (0.332,0.539)	0.037 (0.030,0.046)	0.016 (0.013,0.019)	0.416 (0.339,0.483)
Middle East &North Africa -WB	0.021 (0.015,0.027)	0.003 (0.002,0.004)	0.008 (0.004,0.012)	0.168 (0.080,0.263)
North Africa and Middle East	0.045 (0.033,0.058)	0.005 (0.004,0.007)	0.011 (0.004,0.015)	0.224 (0.081,0.323)
North America	1.082 (0.918,1.274)	0.098 (0.083,0.115)	0.045 (0.038,0.056)	0.865 (0.748,1.024)
Oceania	0.003 (0.002,0.004)	0.001 (0.000,0.001)	0.017 (0.008,0.031)	0.355 (0.161,0.624)
Region of the Americas	0.757 (0.632,0.896)	0.067 (0.056,0.079)	0.032 (0.027,0.038)	0.661 (0.576,0.759)
South Asia	0.043 (0.029,0.059)	0.014 (0.010,0.018)	0.022 (0.009,0.035)	0.449 (0.163,0.728)
South Asia -WB	0.042 (0.029,0.058)	0.014 (0.010,0.018)	0.022 (0.009,0.034)	0.441 (0.161,0.712)
Southeast Asia	0.012 (0.007,0.018)	0.001 (0.001,0.002)	0.002 (0.001,0.004)	0.049 (0.019,0.090)
South-East Asia Region	0.100 (0.079,0.126)	0.015 (0.011,0.018)	0.019 (0.008,0.029)	0.397 (0.163,0.634)
Southern Latin America	0.039 (0.025,0.056)	0.003 (0.002,0.004)	0.003 (0.002,0.003)	0.051(0.037,0.065)
Southern Sub-Saharan Africa	0.155 (0.110,0.204)	0.019 (0.014,0.025)	0.016 (0.012,0.025)	0.367 (0.291,0.584)
Sub-Saharan Africa -WB	0.029 (0.021,0.038)	0.004 (0.003,0.006)	0.012 (0.006,0.025)	0.268 (0.139,0.582)
Tropical Latin America	0.887 (0.688,1.121)	0.073 (0.059,0.090)	0.023 (0.017,0.027)	0.640 (0.502,0.746)
Western Europe	0.406 (0.327,0.491)	0.034 (0.027,0.041)	0.028 (0.024,0.039)	0.450 (0.387,0.605)
Western Pacific Region	3.304 (2.617,4.062)	0.206 (0.168,0.251)	0.065 (0.037,0.099)	1.807 (1.213,2.582)
Western Sub-Saharan Africa	0.002 (0.001,0.003)	0.000 (0.000,0.000)	0.003 (0.001,0.005)	0.092 (0.050,0.168)
World Bank High Income	0.801 (0.681,0.948)	0.071 (0.060,0.084)	0.043 (0.036,0.049)	0.825 (0.697,0.930)
World Bank Low Income	0.384 (0.301,0.485)	0.027 (0.021,0.033)	0.025 (0.010,0.045)	0.622 (0.269,1.069)
World Bank Lower Middle Income	0.042 (0.031,0.055)	0.011 (0.008,0.014)	0.016 (0.008,0.024)	0.331(0.158,0.489)
World Bank Upper Middle Income	2.582 (2.043,3.174)	0.158 (0.129,0.193)	0.047 (0.028,0.074)	1.355 (0.955,1.981)

2. Results

2.1. Current status on global and regional levels

In 2019, statistics for CWP per 100,000 individuals worldwide were as follows: prevalence, 1.312 (95 % uncertainty interval [UI]: 1.047 to 1.593); incidence, 0.087 (95 % UI: 0.072 to 0.105); mortality, 0.038 (95 % UI: 0.028 to 0.049); and DALYs, 0.919 (95 % UI: 0.684 to 1.173), as detailed in Table 1.

As of 2019, the total number of individuals affected globally was 2,648,972.875 (95 % UI: 2,178,324.861 to 3,179,349.169); the global incidence was 138,971.030 (95 % UI: 113,564.476 to 167,464.972); the worldwide death count was 12,886.686 (95 % UI: 10,826.977 to 16,160.924); and the global DALYs amounted to 655,762.889 (95 % UI: 519,296.986 to 828,025.128). It is noteworthy that Asia, specifically East Asia, stands out as the most affected region by CWP, representing around 85 % of the total cases globally, as indicated in Table S1.

In the regional ASR rankings for 2019, East Asia exhibited the highest prevalence of CWP at 4.183 (95 % UI: 3.304 to 5.152), along with the highest incidence (0.257, 95 % UI: 0.210 to 0.313) and DALYs (2.077, 95 % UI: 1.413 to 3.059). Remarkably, even without considering income stratification criteria, East Asia's mortality (0.406, 95 % UI: 0.317 to 0.556) ranked first. The lower bound of prevalence, incidence, mortality, and DALYs of CWP in East Asia surpassed the upper bound of these indicators in most other regions, indicating a heavier burden of CWP in East Asia compared to other parts of the world, as shown in Table 1.

In 2019, the global prevalence of CWP peaked in the 75–79 age group at 7.009 cases per 100,000 individuals (95 % UI: 5.527 to 8.912). The incidence reached its peak in the 90–94 age group, with 0.589 cases per 100,000 individuals (95 % UI: 0.353 to 0.987). Similarly, the mortality peaked in the 85–89 age group, with 0.848 cases per 100,000 individuals (95 % UI: 0.675 to 1.052). Furthermore, DALYs peaked in the 80–84 age group at 8.615 per 100,000 individuals (95 % UI: 6.578 to 10.449), as shown in Fig. 1.

2.2. Current status on a national level

In 2019, Taiwan had the highest ASR for the prevalence of CWP among 204 countries and regions (6.149, 95 % UI: 4.816 to 7.778), followed by the People's Republic of China (4.146, 95 % UI: 3.272 to 5.106), the Republic of Poland (3.732, 95 % UI: 3.086 to 4.519), and the Democratic People's Republic of Korea (3.731, 95 % UI: 2.876 to 4.738), as outlined in Table S2 and Fig. 2(A). Regarding the ASR for the incidence of CWP, Taiwan maintained its top spot (0.42, 95 % UI: 0.339 to 0.528), followed by the Republic of Poland (0.315, 95 % UI: 0.264 to 0.376), the Democratic People's Republic of Korea (0.266, 95 % UI: 2.212 to 0.335), and the People's Republic of China (0.254, 95 % UI: 0.207 to 0.31), as indicated in Table S3 and Fig. 2(B). Analyzing the ASR for mortality of CWP, with

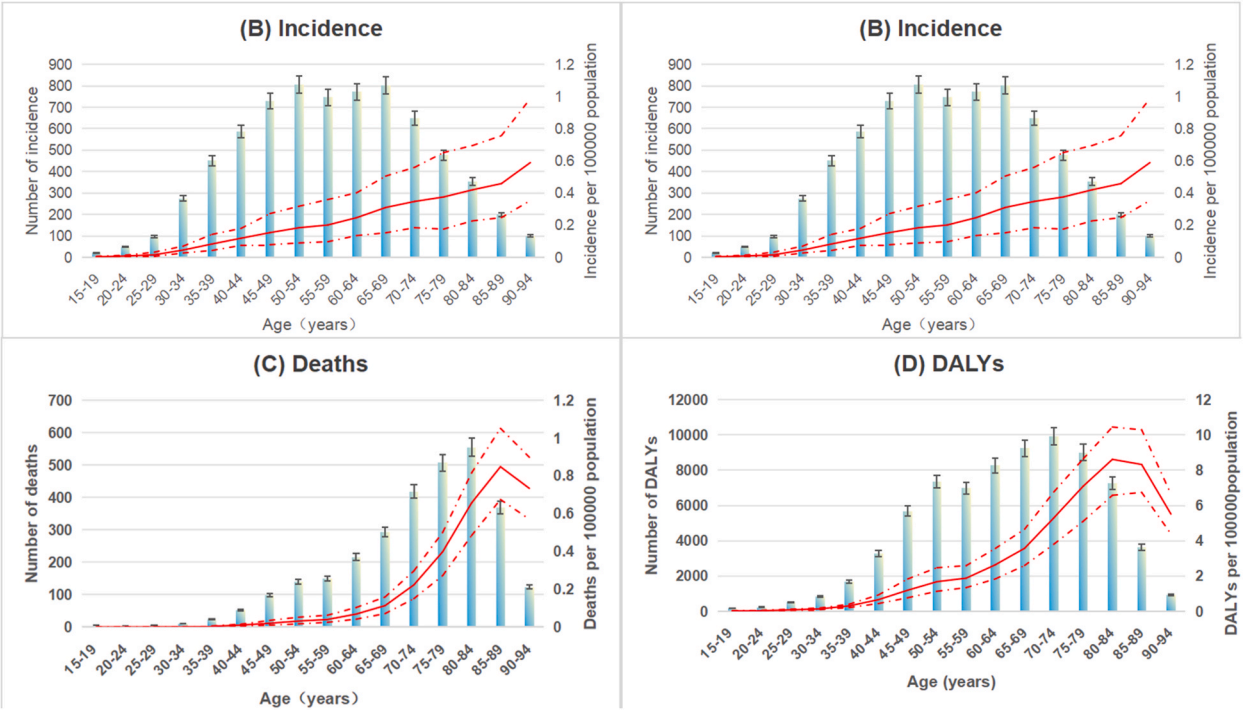


Fig. 1. The numbers and ASR of CWP by age group for prevalence (A), incidence (B), mortality (C), and DALYs (D) per 100,000 population in 2019. The gradient color columns represent the numbers, while the red lines reflect the ASR. The error bar and dash-to-dash gap present the 95 % UI. ASR, age-standardized rate; DALYs, disability-adjusted life years; UI, uncertainty intervals.

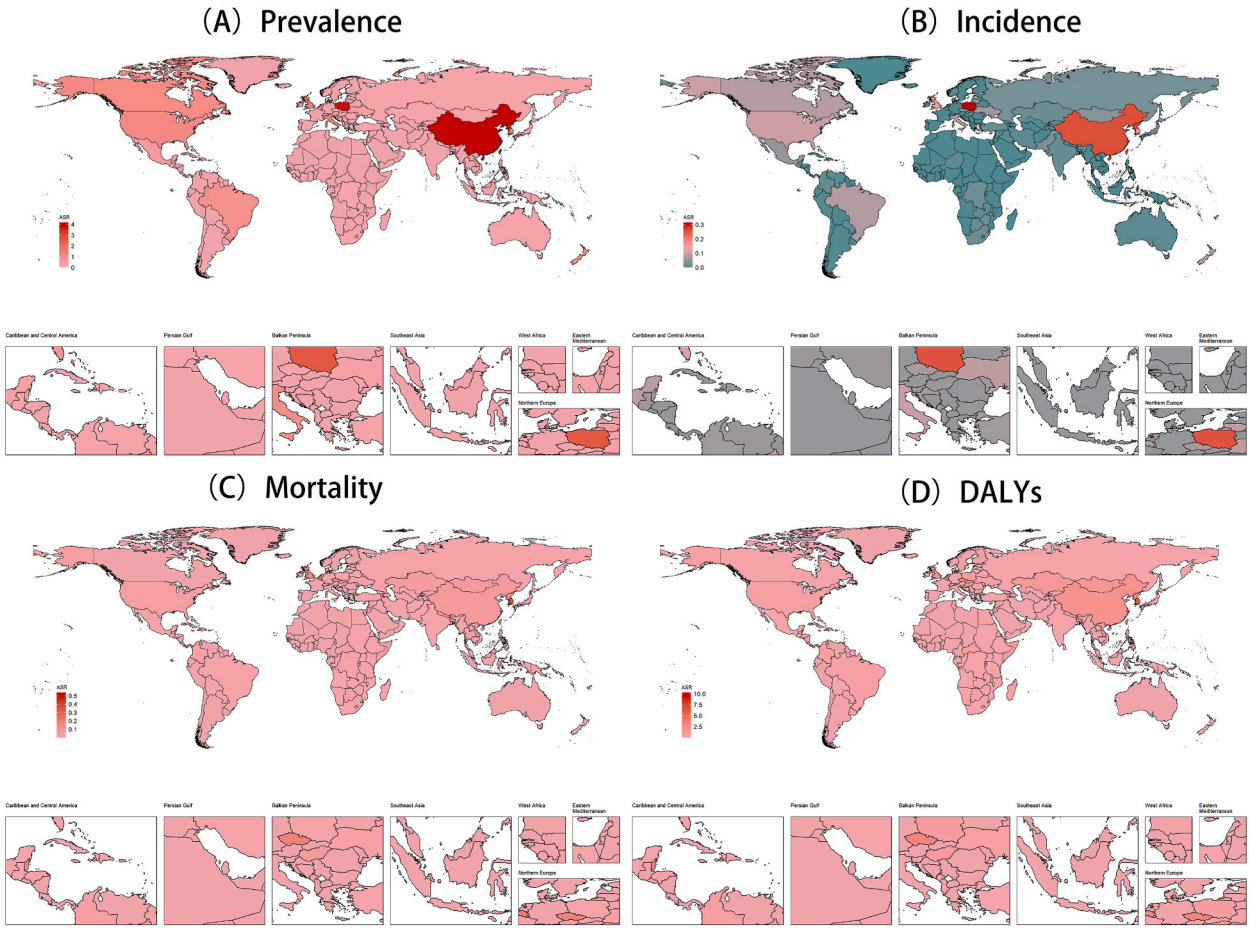


Fig. 2. The global disease burden of CWP for both sexes in 204 countries and territories in 2019. (A) ASR of prevalence for CWP per 100,000 population in 2019. (B) ASR of incidence for CWP per 100,000 population in 2019. (C) ASR of mortality for CWP per 100,000 population in 2019. (D) ASR of DALYs for CWP per 100,000 population in 2019.

Republic of Palau and Republic of Kiribati excluded due to their smaller populations and fewer deaths, the leading countries are the Republic of Korea (0.373, 95 % UI: 0.135 to 0.473), Kingdom of Belgium (0.196, 95 % UI: 0.142 to 0.259), Czech Republic (0.172, 95 % UI: 0.13 to 0.218), and United Kingdom of Great Britain and Northern Ireland (0.14, 95 % UI: 0.118 to 0.209), as shown in Table S4 and Fig. 2(C). The assessment of DALYs associated with CWP revealed that, excluding less populated areas like Republic of Palau, Belize, Republic of Kiribati, Grenada, and Principality of Monaco, the Republic of Korea (6.559, 95 % UI: 2.568 to 8.273) ranked highest, followed by Czech Republic (3.069, 95 % UI: 2.307 to 3.953), Democratic People's Republic of Korea (2.761, 95 % UI:1.146 to 5.429), Kingdom of Belgium (2.694, 95 % UI: 1.987 to 3.491), Taiwan (2.364, 95 % UI: 1.611 to 3.197), People's Republic of China (2.058, 95 % UI: 1.387 to 3.087), and United Kingdom of Great Britain and Northern Ireland (2.022, 95 % UI: 1.747 to 2.933), detailed in Table S5 and Fig. 2(D).

2.3. Trends

From 1990 to 2019, the data in Table S6 demonstrates a shifting trend showing a decline in ASR of prevalence, incidence, mortality, and DALYs in most global regions. However, some regions have exhibited an increase in ASR, while others have a 95 % UI upper limit above 0.

Throughout this period, North Africa and the Middle East showed the highest ASR increase in prevalence of CWP (0.997, 95 % UI: 0.666 to 1.443), followed by the Middle East & North Africa - WB (0.805, 95 % UI: 0.542 to 1.163), Oceania (0.469, 95 % UI: 0.155 to 0.964), Central Sub-Saharan Africa (0.369, 95 % UI: 0.192 to 0.613), Commonwealth Low Income (0.312, 95 % UI: 0.129 to 0.569), Central Asia (0.221, 95 % UI: 0.067 to 0.413), Eastern Mediterranean Region (0.212, 95 % UI: 0.109 to 0.338), Western Sub-Saharan Africa (0.207, 95 % UI: 0.081 to 0.403), Southeastern Asia (0.128, 95 % UI: 0.069 to 0.215), Eastern Sub-Saharan Africa (0.113, 95 % UI: 0.031 to 0.205), Andean Latin America (0.110, 95 % UI: 0.017 to 0.211), World Bank Low Income (0.07, 95 % UI: −0.071 to 0.249), Southern Latin America (0.018, 95 % UI: −0.06 to 0.104). In contrast, the most significant decreases were observed in World Bank Lower Middle Income (−0.712, 95 % UI: −0.776 to −0.639), Eastern Europe (−0.604, 95 % UI: −0.693 to −0.505), and East Asia

(−0.531, 95 % UI: −0.573 to −0.487).

Analyzing the ASR's changes in incidence from 1990 to 2019, Oceania witnessed the most significant increase (1.379, 95 % UI: 0.643 to 2.383), followed by the Middle East & North Africa - World Bank (0.692, 95 % UI: 0.452 to 1.031), Tropical Latin America (0.159, 95 % UI: 0.064 to 0.255), the Eastern Mediterranean Region (0.13, 95 % UI: −0.028 to 0.33), Latin America & Caribbean - World Bank (0.097, 95 % UI: 0.029 to 0.165), and World Bank Low-Income countries (0.052, 95 % UI: −0.091 to 0.221). Conversely, High-Income North America (−0.544, 95 % UI: −0.599 to −0.485), North America (−0.544, 95 % UI: −0.599 to −0.485), and Western Europe (−0.542, 95 % UI: −0.599 to −0.479) experienced the most substantial decline.

During the same period, the ASR of mortality decreased in most global regions, with Australasia showing the most notable reduction (−0.964, 95 % UI: −0.983 to −0.859). However, Tropical Latin America (0.413, 95 % UI: 0.096 to 0.695) and the Middle East & North Africa - World Bank (0.163, 95 % UI: −0.261 to 0.926) exhibited an upward trend. Similarly, the ASR of DALYs in most regions followed a decreasing pattern, with Australasia (−0.945, 95 % UI: −0.965 to −0.851) indicating the most significant decrease. Only Tropical Latin America (0.203, 95 % UI: −0.008 to 0.375) and the Middle East & North Africa - World Bank (0.125, 95 % UI: −0.283 to 0.836) showed an increasing trend.

In accordance with the data presented in Fig. 3, the Jointpoint regression analysis illustrates the turning point and path of the burden of CWP from 1990 to 2019. The Annual Average Percentage Change (AAPC) for prevalence, incidence, mortality, and DALYs were −2.342 % (95 % CI: −2.643 % to −2.039 %, $p < 0.001$), −2.290 % (95 % CI: −2.466 % to −2.114 %, $p < 0.001$), −3.918 % (95 % CI: −4.141 % to −3.695 %, $p < 0.001$), and −3.900 % (95 % CI: −4.081 % to −3.719 %, $p < 0.001$), respectively, indicating a consistent decline over the past three decades. The prevalence increased from 1990 to 1998, with an Annual Percentage Change (APC) of 1.361 % ($p < 0.05$). However, there was a decrease in prevalence from 1998 to 2019, notably during the period from 2001 to 2005 with an APC of −8.569 ($p < 0.05$) (Fig. 3(A)). The incidence pattern of CWP indicates a rise from 1990 to 1997, followed by a decline until 2019, with the most significant drop observed from 2001 to 2005 (APC of −6.614, $p < 0.05$) (Fig. 3(B)). Regarding mortality and DALYs, a consistent downward trend was observed from 1990 to 2019 (Fig. 3(C) and (D)).

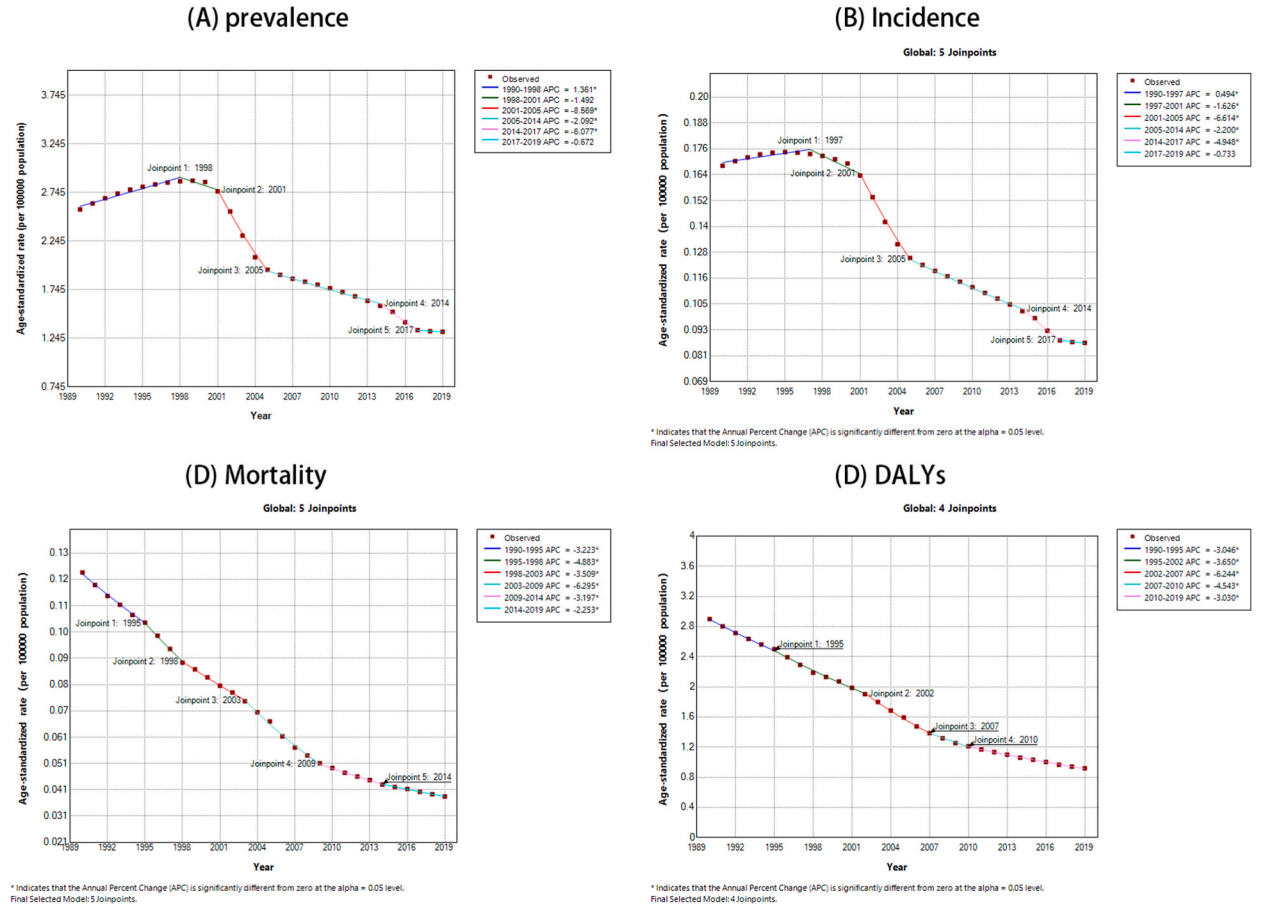
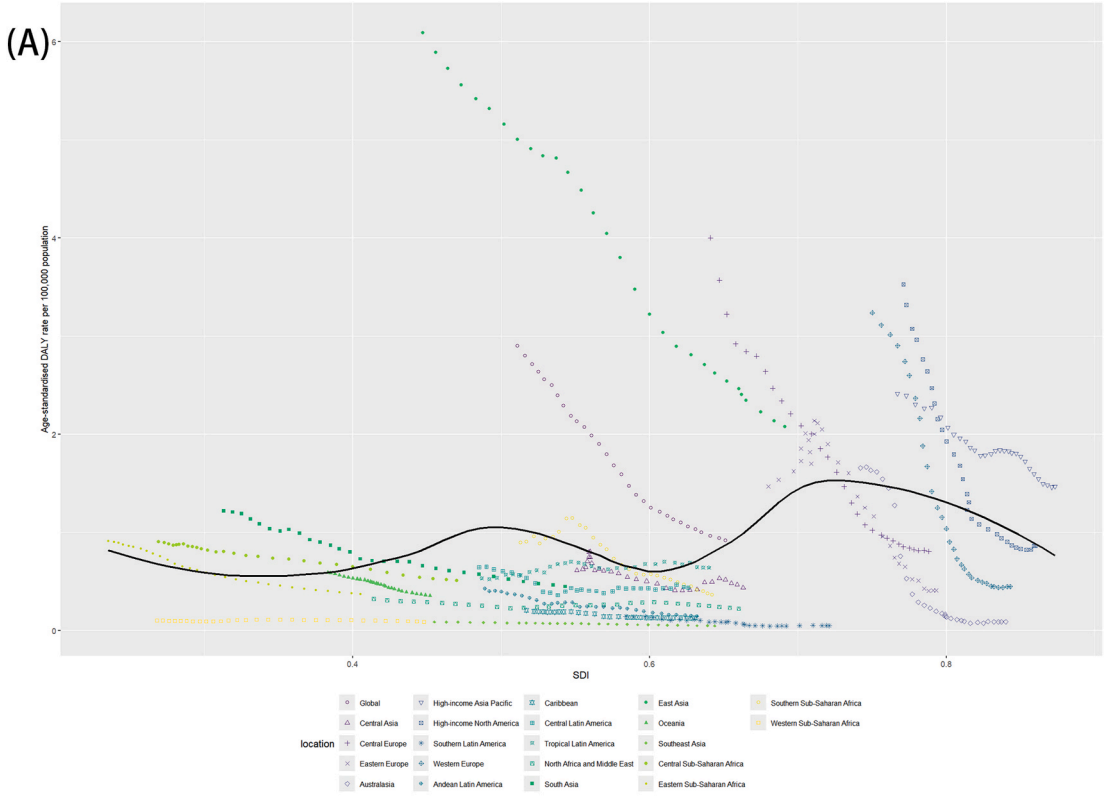


Fig. 3. Global trends of ASR, from 1990 to 2019, for prevalence (A), incidence (B), mortality (C) and DALYs (D) per 100,000 population of CWP by Jointpoint Regression analysis. The symbol * represents statistical significance at $p < 0.05$. APC, annual percentage change.



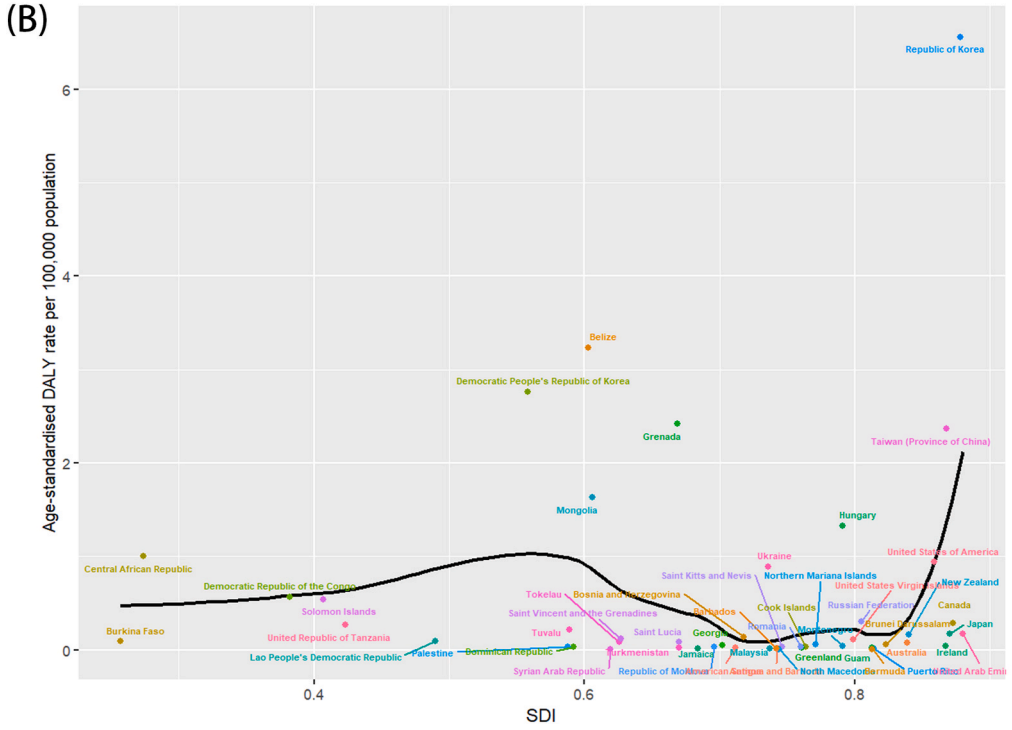


Fig. 4. The association between the age-standardized DALY rate and SDI at the regional (A) and national (B) levels.

2.4. Association between DALYs and SDI on a regional level

From 1990 to 2019, a distinctive pattern resembling the letter "M" can be observed in the correlation between the SDI and ASR of DALYs for CWP. As the SDI reaches around 0.5, there is a consistent rise in the global burden of DALYs. Within the SDI range of 0.5–0.6, DALYs show a gradual decrease. Subsequently, within the SDI range of 0.6–0.7, DALYs start to increase gradually. Once the SDI surpasses 0.7, there is a gradual decline in DALYs. During the period of 1990–2019, the ASR of DALYs for CWP in high-income regions of East Asia and the Asia Pacific exceeded the expected levels based on SDI. As shown in the findings in Fig. 4(B), the age-standardized DALYs rates of countries such as the Republic of Korea, Belize, Democratic People's Republic of Korea, Grenada, Taiwan, Mongolia, Hungary, Ukraine, and the Central African Republic all surpassed the predicted levels. These results suggest that the burden of CWP is higher than anticipated, with a more significant impact observed in low-income nations compared to high-income regions.

2.5. Predictions

Based on Nordpred's age cohort analysis, the ASR trends of prevalence, incidence, mortality, and DALYs of CWP in the globe, the People's Republic of China, the Republic of Poland, and the United States of America were estimated by sex up to 2044. The following analysis is limited to both sexes due to the nature of the work. Prior to 2019, Fig. 5(A) indicated that the ASR of prevalence of CWP in the People's Republic of China and the Republic of Poland was notably higher than the global average. From 2019 to 2044, the prevalence and ASR of CWP in the globe, the People's Republic of China, and the Republic of Poland started to decrease annually. Oppositely, the ASR of prevalence of CWP in the United States of America has been gradually rising since 2019 and is projected to surpass the global average post-2024.

In Fig. 5(B), pre-2019, the ASR of the incidence of CWP in the People's Republic of China and the Republic of Poland significantly exceeded the global average. Between 2019 and 2044, the ASR of the incidence of CWP in the globe and the People's Republic of China showed a similar pattern, exhibiting a slow downward trajectory. The Republic of Poland's ASR of incidence displayed a slight upward trend post-2019, expected to stabilize after 2028. Despite minor fluctuations, it remains relatively constant. In comparison, the ASR of the incidence of CWP in the United States of America has shown a gradual increase post-2019, consistently higher than the global

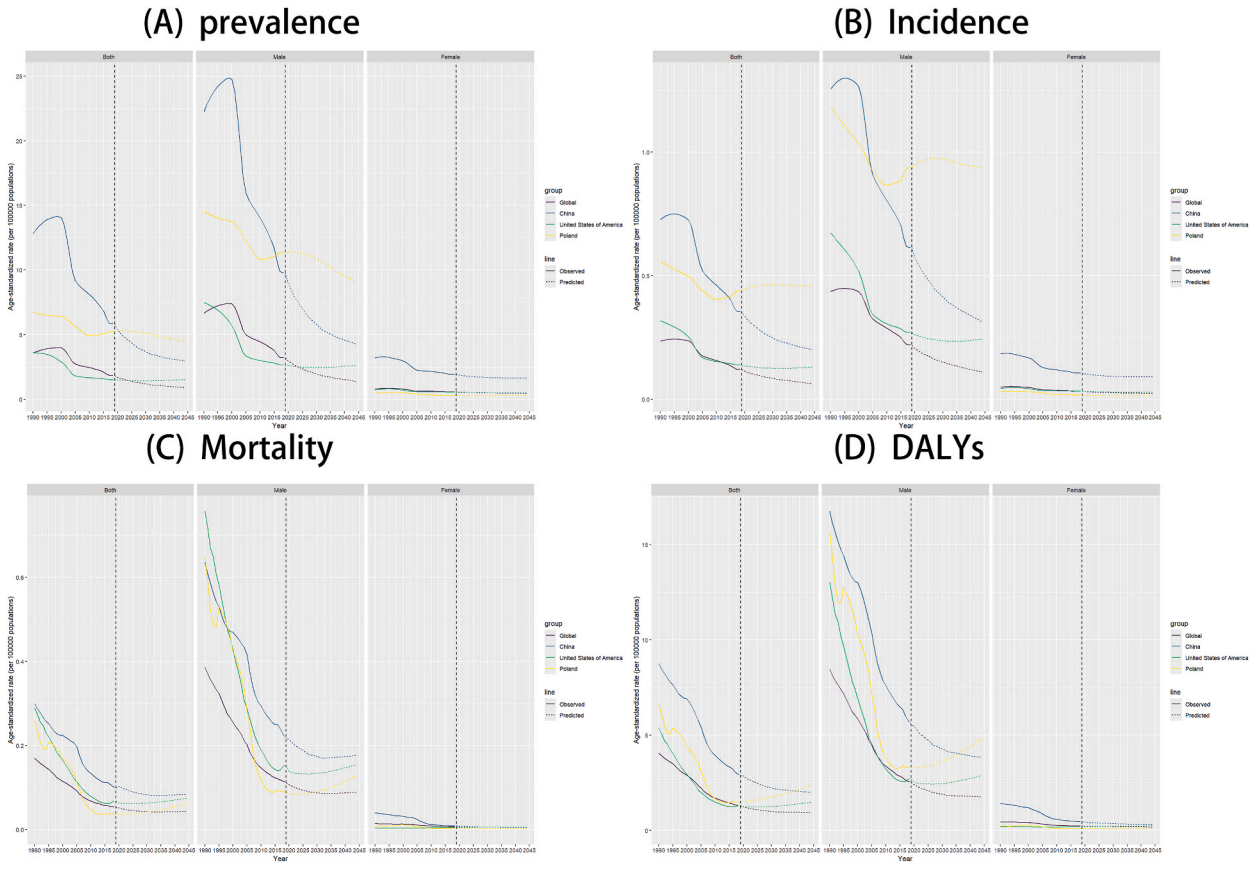


Fig. 5. Nordpred based age-period-cohort prediction of ASR of prevalence (A), incidence (B), mortality (C) and DALYs (D) per 100,000 population for CWP up to 2044 in the globe, the People's Republic of China, the United States America, the Republic of Poland. Solid lines indicate observed ASRs values while dashed lines denote the predicted.

average.

In Fig. 5(C), pre-2019, the ASR of mortality of CWP in the People's Republic of China and the United States America significantly surpassed the global average. Between 2019 and 2044, the People's Republic of China and the globe exhibited similar trends, with a slow decline followed by stability. The Republic of Poland and the United States America both displayed slight upward trends, with the Republic of Poland projected to exceed the global average after 2030, while the United States America remains elevated above the global average.

In Fig. 5(D), pre-2019, the ASR of DALYs in CWP in the People's Republic of China was notably higher than the global average. From 2019 to 2044, both the People's Republic of China and the globe showcased a similar slow decline. Alternatively, the ASR of DALYs for CWP in the United States America and the Republic of Poland continued to rise, consistently surpassing the global average, particularly in the Republic of Poland where the increase is pronounced.

3. Discussion

This study extensively investigates the current situation and trends of CWP, and provides a detailed analysis of the burden on regions and countries, as well as the future burden associated with this disease. Our main findings are as follows: Firstly, Asia was the region most severely affected by CWP, especially East Asia, which accounted for approximately 82 % of the total global cases of CWP in 2019. Taiwan, Republic of Poland, and the Democratic People's Republic of Korea have the highest ASR for CWP cases and new cases. These countries should attach great importance to and continue to strive to develop prevention strategies. Secondly, from a global perspective, individuals aged 75 to 79 have a higher risk of CWP, with an increased risk of onset as age increases. Individuals aged 85 to 89 have a higher risk of death, and individuals aged 80 to 84 have a higher risk of DALYs. These findings suggest that even after workers leave high-risk occupational positions, their health may still be continuously affected by CWP. Thirdly, from 1990 to 2019, the prevalence of ASR in North Africa and Middle East showed the most significant increase, followed by Middle East&North Africa WB, Oceania, Central Sub Saharan Africa, and Commonwealth Low Income. The area with the most significant increase in ASR of incidence is Oceania, followed by Middle East&North Africa - WB. The ASR of mortality and DALYs have decreased in most regions, with only Middle East&North Africa WB and Tropical Latin America indicating an increase. The decline is most significant in high-income regions of Central Europe, Asia Pacific, and Western Europe. Fourthly, it is gratifying to note that the global burden of CWP has significantly decreased from 1990 to 2019, and may continue to decline in the coming years.

The above research results indicate that although significant achievements have been made globally in preventing CWP, it is still a chronic disease that urgently needs to be addressed in some countries and regions [18].Nonetheless, it is encouraging to observe an "M"-shaped relationship between SDI and ASR of DALYs for CWP, indicating an overall downward trend. This observation might be linked to the initial absence of health protection initiatives; however, once socio-economic development attains a certain threshold, enhancements in workplace conditions and the establishment of preventive strategies could alleviate the disease burden on the workforce [19–21]. Nevertheless, as socio-economic development progresses, potential transformations in industrial structure may arise, potentially mitigating the issue of occupational pneumoconiosis associated with industrialization. It is crucial to note that the emergence of new industries could introduce distinct health challenges [22–25].

This study comprehensively investigates and analyzes the current situation, trends, and predictions of the global burden of CWP. Through studying data from 1990 to 2019, we found significant differences in the burden of CWP among different countries and regions, and also revealed trends over time. Governments and relevant industries in various countries should take active measures to strengthen the formulation and implementation of occupational health regulations, enhance workers' health awareness, and promote technological innovation to reduce the risk of pneumoconiosis [26–28]. Although the global total burden has declined in the past three decades, some regions are still struggling to cope with the high burden of prevalence, incidence, mortality and DALYs of CWP. In future research, we suggest further strengthening global cooperation and information sharing in order to more effectively reduce the incidence of CWP and ensure the health and safety of workers [25,29,30].

4. Conclusion

From 1990 to 2019, we observed an "M" - shaped correlation between SDI and ASR of DALYs for CWP. Our research shows that from 2019 to 2044, the ASR of prevalence, incidence, mortality and DALYs of the global have decreased. These research findings provide the latest insights into the burden of CWP for future research and emphasize the necessary strategies and interventions for effective prevention and management of the disease.

Limitations of the study

First, the GBD database utilizes health data gathered from numerous countries, and the completeness and precision of this data could be influenced by several variables. For instance, certain low- and middle-income nations may have inadequate data collection and reporting infrastructures, potentially leading to gaps or inaccuracies in their data. This disparity in data quality could have implications for the thoroughness of global burden assessments.

Second, given the retrospective nature of the analysis, there may be constraints in capturing real-time fluctuations in the burden of CWP, particularly concerning recent advancements in coal mining techniques, occupational health policies, and healthcare accessibility.

Third, the study primarily emphasizes quantitative data analysis, potentially neglecting qualitative dimensions like the socio-

economic, cultural, and environmental factors influencing the burden of CWP, consequently presenting an inadequate portrayal of the disease's intricacies.

Finally, projections regarding future trends in CWP are derived from extrapolations of historical data and assumptions regarding forthcoming scenarios, which might not fully accommodate unforeseen changes in coal mining technologies, regulatory structures, or healthcare systems.

Ethics statement

The Ethics Review Committee of Shandong Academy of Occupational Health and Occupational Medicine Affiliated to Shandong First Medical University determined that the study did not require ethical approval and consent to participate because it used publicly available data.

STAR ★methods

Key resources table

REAGENT or RESOURCE	SOURCE	IDENTIFIER
Deposited data		
Original data	**Global Health Data Exchange**	https://vizhub.healthdata.org/gbd-results/
Software and algorithms		
R 4.3.3	R	https://www.r-project.org/
Joinpoint Trend Analysis Software	The Division of Cancer Control and Population Sciences (DCCPS), USA	https://surveillance.cancer.gov/joinpoint/callable/
WPS Office	Kingsoft Office, China	https://www.wps.cn/

Resource availability

Lead contact

For additional information and resources should be directed to the lead contact, Dr. Zhongjun Du (duzj1981@163.com).

Materials availability

This study did not generate new unique reagents.

Data and code availability

- All data reported in this paper will be shared by the lead contact upon request.
- This study did not report original code.
- Any additional information required to reanalyze the data reported in this paper is available from the lead contact upon request.

Experimental model and study participant details

All data used in this study were obtained from the GBD database.

Subject details

Data sources

The data for the study originates from the GBD database, an extensive and publicly accessible epidemiological database that focuses on the prevalence, incidence, mortality, and DALYs related to diseases and injuries across different countries and regions [31,32]. This database is managed by the Institute of Health Metrics and Evaluation (IHME) and comprises information from national health surveys, vital registration systems, hospital records, and scientific literature [33,34]. Specifically, we collected information on the burden of CWP from the GBD database spanning from 1990 to 2019, covering prevalence, incidence, mortality, DALYs, and relevant risk factors at global, regional, and national scales. These data can be categorized by age, sex, and other demographic variables to facilitate detailed trend analysis. Additionally, statistical methodologies like time series analysis and predictive models were utilized to scrutinize the temporal pattern of CWP burden and devise prognostic curves for future trajectories [35–37].

Quantification and statistical analysis

We conducted an initial compilation and analysis of the quantitative data regarding the prevalence, incidence, mortality, DALYs, ASR (with a 95 % confidence interval), and percentage change in 2019 on a global scale, regionally, and nationally, spanning across 16 age brackets (ages ranging from 15 to 94 years, with five-year intervals). Furthermore, we investigated the relationship between the SDI and the impact of ASR on DALYs at a regional level [38,39]. The Jointpoint Regression analysis method was utilized to evaluate the temporal trends of estimated ASR for prevalence, incidence, mortality, and DALYs [40,41]. We employed the Monte Carlo permutation test along with its 95 % confidence interval to calculate the APC and AAPC [42,43].

Moreover, we employed the EasyGBDR software package to conduct Nordpred age cohort analysis using R software (version 4.3.3) to forecast the future trends of prevalence, incidence, mortality, and DALYs associated with CWP. This analysis encompasses a logarithmic linear age-period-cohort model tailored for predicting the number or rate of new cases, capable of adjusting for exponential growth and aligning linear trend predictions with recent data, demonstrating efficacy in forecasting future burden trends. A power function was applied to interpret the observations of the past five years to counteract the growth pattern. Additionally, adjustments to the linear trends of the prior decade were implemented in the second, third, and fourth forecasting periods, either reducing or enhancing by 25 %, 50 %, and 75 %, respectively. Lastly, the ASR of new cases in 2044 was projected by averaging the incidence rate of the last two prediction periods centered around 2044 [44,45].

CRediT authorship contribution statement

Zhuofeng Wang: Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation. **Jiaqi Zhang:** Resources, Methodology, Investigation, Formal analysis, Data curation. **Yong Yang:** Resources, Investigation, Data curation, Conceptualization. **Mao Cao:** Project administration, Methodology, Formal analysis, Data curation. **Jiazi Ma:** Software, Project administration, Methodology, Investigation. **Shumin Li:** Writing – review & editing, Methodology, Funding acquisition, Data curation. **Hua Shao:** Writing – review & editing, Supervision, Software, Methodology, Investigation, Funding acquisition, Data curation. **Zhongjun Du:** Writing – review & editing, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e37940.

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