




ORIGINAL ARTICLE

Analysis of mortality in Parkinson disease in China: Exploration of recent and future trends

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Abstract

Objectives: Parkinson disease (PD) is the third leading cause of mortality among middle-aged and older individuals in China. This study aimed to explore the trends and distribution features of PD mortality in China from 2013 to 2021 and make predictions for the next few decades.

Methods: Relevant data were obtained from the Chinese Center for Disease Control and Prevention Disease Surveillance Point system. The joinpoint regression model was used to evaluate trends. The R software was used to predict future trends.

Results: Age-standardized mortality rate (ASMR) of PD increased from 0.59 per 100,000 individuals to 1.22 per 100,000 individuals from 2013 to 2021, with an average annual percent change (AAPC) of 9.50 (95% CI: 8.24–10.78). The all-age ASMR of PD were higher in male individuals than in female individuals, and ASMR increased with age. The number of deaths and ASMR increased gradually from west to east and from rural to urban areas. Furthermore, ASMR is expected to increase to 2.66 per 100,000 individuals by 2040.

Conclusions: The heightened focus on the ASMR of PD among male individuals, urban areas, eastern China, and individuals aged ≥ 85 years has become a key determinant in further decreasing mortality, thereby exhibiting novel challenges to effective strategies for disease prevention and control.

KEYWORDS

aging, China, joinpoint regression model, mortality, Parkinson disease

1 | INTRODUCTION

Parkinson disease (PD), also known as “shaking palsy” or “paralysis agitans,” is a neurodegenerative disease that occurs mainly in individuals aged >50 years. It is characterized by the degeneration and loss of dopaminergic neurons in the substantia nigra and Lewy body formation. The main biochemical change in this disease is the decrease in dopamine transmitters in the striatal region. Its clinical

features include static paralysis, bradykinesia, myotonia, and postural gait abnormalities.¹

The incidence of PD increases with age, with $>80\%$ of patients aged >65 years. This is a trend toward younger age groups. Adolescent patients with PD account for 10% of all cases.²

Parkinson disease-related disorders have become the fastest-growing neurodegenerative diseases in prevalence and mortality rates.³ Experts predicted that the number of PD patients worldwide

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will reach 12–17 million by 2040.⁴ A recent study predicted that the total cost of managing PD in the United States will exceed \$79 billion by 2037.⁵ According to statistics, in 2019, there were >8.5 million patients with PD worldwide, of which over 3 million were in China.^{6,7} A Global Burden Disease study showed that the total number of PD-related mortality in China increased among the population aged >45 years from 1990 to 2019, with an estimated 76,990 deaths in 2019.⁸ Currently, the prevalence of PD among individuals aged >65 years in China is approximately 17,070 per 100,000.⁹ PD has become the third heading cause of mortality in middle-aged and older individuals worldwide (second only to tumors and cardiovascular disease).¹⁰ The socioeconomic and population structures in China have changed rapidly over the past 20 years. With an increasingly aging population, China may become the country with the largest population of patients with PD worldwide.¹¹

Parkinson disease is a progressive, chronic disease with no radical cure. Patients may rapidly progress to disability and death. Symptom progression in later stages of the disease can severely limit the independence of patients, leading to a heavy burden on their families and society.¹² Thus, monitoring the burden of PD in a rapidly changing society is essential not only for Chinese policymakers but also for other countries facing rapid demographic and economic changes to prioritize health resource allocation.⁶

Therefore, our study analyzed the deaths due to PD in China until 2021 in detail to serve as a reference for the “tertiary prevention strategy” of the disease and reduce the burden of PD.

2 | METHODS

2.1 | Data sources

This study gathered relevant data on PD from the Chinese Center for Disease Control and Prevention's Disease Surveillance Points (CDC-DSP) system between 2013 and 2021. The International Classification of Diseases 10 (ICD-10) codes for PD [ICD 10: F02.3, G20-G20.9] were used to identify cases.⁷ This system covers 605 disease surveillance sites, encompassing 208 urban and 397 rural points distributed across 31 provinces. The population under surveillance exceeds 340 million, accounting for approximately 24% of the national population. The system collects death information that occurs in each jurisdiction, including household and non-household registrations. Information on deaths was collected with layer-by-layer quality audits. Data cleaning was performed on the collected information before data analysis to ensure the high quality and credibility of the information in the monitoring system. Data from 2021 were excluded if the mortality rate was lower than 4.5 per 1000 population (5 per 1000 population in the newly added points in 2013). Crude mortality was calculated after deleting a small proportion of the DSP points. Finally, data from 74 disease surveillance sites were excluded, and 531 sites were included in the summary analysis. The CDC-DSP system has good national and provincial representations.¹³ We also extracted data on sex, age, place of residence

(urban or rural), and region (East, Central, and West China). The eastern region includes Beijing, Shanghai, Fujian, Hebei, Jiangsu, Liaoning, Shandong, Hainan, Tianjin, Guangdong, and Zhejiang, covering about 152 million individuals; the central region includes Anhui, Hubei, Hunan, Heilongjiang, Henan, Jilin, Shanxi, and Jiangxi, covering about 100 million individuals; and the western region includes Gansu, Inner Mongolia, Guangxi, Ningxia, Guizhou, Qinghai, Shaanxi, Xinjiang, Sichuan, Yunnan, Tibet, and Chongqing, accounting for about 86 million individuals. Aging subgroups were divided into <20-years, 20–39-year, and 5-year intervals from 40 to 84 years and >85 years. We obtained age-specific population data from the National Bureau of Statistics of China (<http://data.stats.gov.cn>).⁷

2.2 | Statistical analysis

The age-standardized mortality rate (ASMR) was calculated using age-specific population data. The Joinpoint Regression Program 4.3.1.0 was used to fit the trend of PD mortality and compute the average annual percentage change (AAPC) to reflect the magnitude of secular trends for the ASMR of PD. The model uses joinpoints to divide a long-term trend line into 0 to *n* segments, and each segment is described as a continuous linear. Then use the Z-test to test the hypotheses of segmentation points. If there were zero joinpoints, the model would be a straight line, and APC would be equal to AAPC. The mortality rates were log-transformed, and 95% confidence intervals (95% CIs) were set at 0.05 using the Monte Carlo permutation method. Positive AAPC values and their lower limit of 95% CI indicate an upward trend in ASMR, whereas negative AAPC values and upper limits of 95% CI suggest a downward trend. A stable trend is indicated when the AAPC or its 95% CI is zero.

We assumed that the mortality trends from 2013 to 2021 would continue to follow the linear variation obtained from the regression model for the next decades. We applied estimates of the annual change in mortality during 2013–2021 and projected ASMR until 2040.^{14,15} The “Predict” package of R 4.3.0 was used to establish a linear regression model for exploring changes in annual mortality.

3 | RESULTS

3.1 | Overall findings

In 2021, 3280 cases of PD-related mortalities were observed across 531 surveillance points, with an ASMR of 0.764 (95% CI: 0.730–0.797) per 100,000 individuals (Figure 1). In 2013, approximately 1332 cases of PD-related mortalities were recorded in the CDC-DSP system, with an ASMR of 0.511 (95% CI: 0.482–0.541) per 100,000 individuals (Figure 1). From 2013 to 2021, the absolute number of PD-related deaths and the ASMR of PD increased by 146.2% and 49.5%, respectively, with an AAPC of 9.50% (95% CI: 8.24%–10.78%). From 2013 to 2019, PD-related mortality in China demonstrated a steadily increasing trend, both in the entire

population and subgroups stratified by age, sex, and region. ASMR increased significantly from the age of 50 years. The mortality rate was significantly higher in rural areas than in urban ones (Table 1).

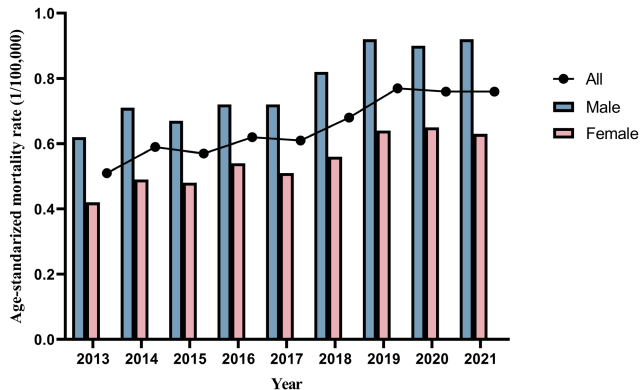


FIGURE 1 Age-standardized mortality rate of PD in China from 2013 to 2021.

The number of deaths and ASMR gradually increased from Western China to Eastern China (Table 1).

3.2 | ASMR and the trend of PD stratified by age and sex

Comparing the data from 2013 to 2021, the number of deaths across all ages presented an upward trend, except for the 20–39 age group (Table 1) and the ASMR of PD was higher in male individuals than in female individuals (Figure 2). Consistent with previous studies, the number of deaths and ASMR of PD increased with age in both sexes. The oldest age group (>85 years) exhibited the highest number of deaths, with an estimated 724 deaths in 2021. The 55–59 age group demonstrated a peak in the rate of growth of the disease. Conversely, the most obvious increase in ASMR was in the 40–44 age group, with an AAPC of 14.3% (95% CI: –6.35% to 39.5%). The 45–49 age group had an AAPC of 13.15% (95% CI: 6.37%–20.37%).

TABLE 1 Jointpoint analysis of temporal trends in PD mortalities stratified by age, sex, and regional classifications using cause of death monitoring datasets, spanning 2013–2021.

Characteristics	2013		2021		AAPC (%) (95% CI)	p-Value
	Number	Mortality rate (1/100,000)	Number	Mortality rate (1/100,000)		
Total (Crude)	1332	0.586 (0.555–0.618)	3,280	1.224 (1.182–1.266)	9.559 (8.311 to 10.821)	<0.001
Age-standardized		0.511 (0.482–0.541)		0.764 (0.730–0.797)	5.211 (3.5331 to 6.918)	<0.001
Age groups (years) (Crude)						
<20	0	0.000 (0.000–0.000)	0	0.000 (0.000–0.000)	–	–
20–39	7	0.010 (0.003–0.018)	5	0.007 (0.001–0.014)	–	–
40–44	5	0.024 (0.003–0.045)	7	0.039 (0.010–0.068)	7.823 (–10.719 to 30.216)	0.377
45–49	8	0.034 (0.010–0.057)	22	0.100 (0.058–0.141)	12.993 (7.276 to 19.015)	0.001
50–54	25	0.188 (0.114–0.262)	46	0.195 (0.139–0.252)	2.278 (–6.460 to 11.832)	0.570
55–59	46	0.279 (0.198–0.359)	102	0.512 (0.412–0.611)	7.507 (0.717 to 14.756)	0.034
60–64	95	0.790 (0.631–0.949)	159	1.058 (0.894–1.223)	4.026 (0.405 to 7.778)	0.034
65–69	146	1.868 (1.565–2.171)	368	2.383 (2.139–2.627)	2.801 (0.776 to 4.866)	0.013
70–74	186	3.126 (2.677–3.575)	533	5.160 (4.722–5.599)	6.743 (4.756 to 8.768)	<0.001
75–79	326	6.898 (6.149–7.647)	647	9.873 (9.112–10.633)	5.122 (1.323 to 9.063)	0.015
80–84	289	10.504 (9.293–11.715)	667	14.657 (13.545–15.770)	4.368 (1.831 to 6.969)	0.005
>85	199	13.267 (11.424–15.111)	724	23.670 (21.946–25.394)	7.086 (4.983 to 9.231)	<0.001
Sex (Age-standardized)						
Male	741	0.617 (0.572–0.662)	1803	0.922 (0.871–0.973)	5.239 (3.506 to 7.002)	<0.001
Female	591	0.423 (0.384–0.461)	1477	0.631 (0.589–0.674)	5.113 (3.422 to 6.832)	<0.001
Urban–rural (Age-standardized)						
Urban	676	0.778 (0.713–0.844)	1437	0.946 (0.883–1.009)	1.815 (–0.395 to 4.074)	0.094
Rural	656	0.376 (0.346–0.406)	1843	0.667 (0.629–0.705)	7.683 (6.413 to 8.969)	<0.001
Region (Age-standardized)						
Eastern	825	0.725 (0.669–0.782)	1709	0.919 (0.862–0.977)	2.650 (0.845 to 4.486)	0.010
Central	315	0.366 (0.324–0.407)	851	0.609 (0.558–0.660)	7.263 (5.126 to 9.444)	<0.001
Western	192	0.319 (0.272–0.365)	720	0.699 (0.637–0.760)	11.085 (8.692 to 13.530)	<0.001

Abbreviation: AAPC, average annual percentage change.

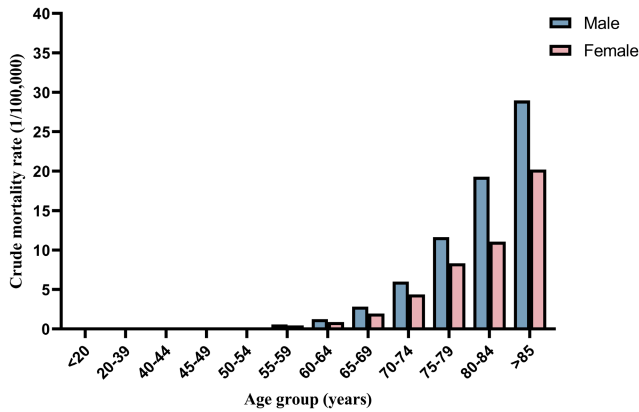


FIGURE 2 Crude mortality rate of PD stratified by age and sex in China in 2021.

This finding suggests a trend towards younger individuals experiencing PD-related mortality (Table 2).

3.3 | ASMR and the trend of PD stratified by region and sex

In terms of geographical regions, Eastern China demonstrated the highest ASMR of 0.73 (95% CI:0.67-0.78) and 0.92 (95% CI: 0.86–0.98) per 100,000 individuals in 2013 and 2019, respectively, with an AAPC of 2.65% (95% CI: 0.85%–4.49%) (Figure 3A). Notably, ASMR decreased from Eastern China to Western China, whereas the tendency of AAPCs of ASMRs in these regions was opposite to that of ASMRs. The western regions showed the most rapid change, with an AAPC of 11.08% (95% CI: 8.69%–13.53%), followed by that of the central regions with an AAPC of 7.26% (95% CI: 5.13%–9.44%). In 2016, ASMR was higher in male individuals than in female individuals across all regions, except in the western region (Figure 3). The number of deaths and ASMR of PD were remarkably higher in urban areas than in rural areas ($p < 0.0001$). In both rural and urban areas, ASMR was higher in male individuals than in female individuals. From 2013 to 2021, no significant change in ASMR was observed in urban areas, whereas ASMR in rural areas showed a steady upward trend (Figures 4).

3.4 | The projection for PD mortality in the future

The projected crude mortality rate and ASMRs of PD for 2025, 2030, and 2040 are presented in Table 3. If the trends continue, the crude mortality rate of PD in China will increase to 1.88 (95% CI: 1.71–2.05) and 2.66 (95% CI: 2.36–2.95) per 100,000 individuals by 2030 and 2040, respectively. For male individuals, the ASMR of PD would increase to 1.29 (95% CI: 1.12–1.46) and 1.69 (95% CI: 1.39–1.98) per 100,000 individuals by 2030 and 2040, respectively. Notably, ASMR would still be lower in female individuals than in male individuals, with 0.90 (95% CI: 0.79–1.01) and 1.17

TABLE 2 Regional age-standardized mortality rate and the joinpoint results in Parkinson disease stratified by sex (China, 2013–2021).

	National			Urban			Rural			Eastern			Central			Western		
	All	Male	Female	All	Male	Female	All	Male	Female	All	Male	Female	All	Male	Female	All	Male	Female
2013	0.511	0.617	0.423	0.778	0.998	0.592	0.376	0.424	0.336	0.725	0.918	0.569	0.366	0.409	0.328	0.272	0.375	0.272
2014	0.595	0.714	0.491	0.967	1.193	0.778	0.417	0.486	0.353	0.834	1.020	0.680	0.428	0.474	0.385	0.268	0.494	0.268
2015	0.565	0.671	0.481	0.856	1.048	0.705	0.425	0.487	0.374	0.811	0.956	0.698	0.393	0.486	0.318	0.313	0.428	0.313
2016	0.620	0.716	0.541	0.929	1.103	0.784	0.473	0.528	0.425	0.851	1.014	0.727	0.447	0.545	0.357	0.445	0.443	0.445
2017	0.606	0.716	0.513	0.886	1.081	0.720	0.468	0.533	0.414	0.780	0.965	0.636	0.480	0.544	0.420	0.403	0.494	0.403
2018	0.679	0.822	0.559	0.964	1.182	0.779	0.537	0.637	0.451	0.870	1.087	0.698	0.555	0.665	0.456	0.430	0.543	0.430
2019	0.770	0.920	0.640	1.070	1.310	0.860	0.610	0.710	0.530	0.970	1.160	0.810	0.610	0.760	0.490	0.550	0.730	0.550
2020	0.759	0.897	0.647	0.967	1.147	0.819	0.637	0.747	0.546	0.910	1.075	0.777	0.627	0.741	0.531	0.566	0.789	0.566
2021	0.764	0.922	0.631	0.946	1.185	0.751	0.667	0.783	0.569	0.919	1.129	0.751	0.609	0.753	0.486	0.616	0.792	0.616
AAPC (%)	5.142 (3.540 to 6.770)	5.316 (3.574 to 7.087)	5.148 (3.394 to 6.931)	1.815 (-0.395 to 4.074)	1.780 (-0.419 to 4.028)	2.258 (-0.442 to 5.031)	7.683 (6.413 to 8.969)	8.199 (6.595 to 9.827)	7.239 (5.719 to 8.781)	2.650 (0.845 to 4.486)	2.401 (0.808 to 4.019)	2.706 (0.484 to 4.976)	7.263 (5.126 to 9.444)	8.347 (6.219 to 10.517)	6.162 (3.335 to 9.066)	11.085 (8.692 to 13.530)	8.428 (1.114 to 16.271)	9.041 (1.381 to 17.280)
p to value	<0.001	<0.001	<0.001	0.094	0.098	0.089	<0.001	<0.001	<0.001	0.010	0.009	0.023	<0.001	<0.001	0.001	<0.001	0.030	0.026

Abbreviation: AAPC, average annual percentage change.

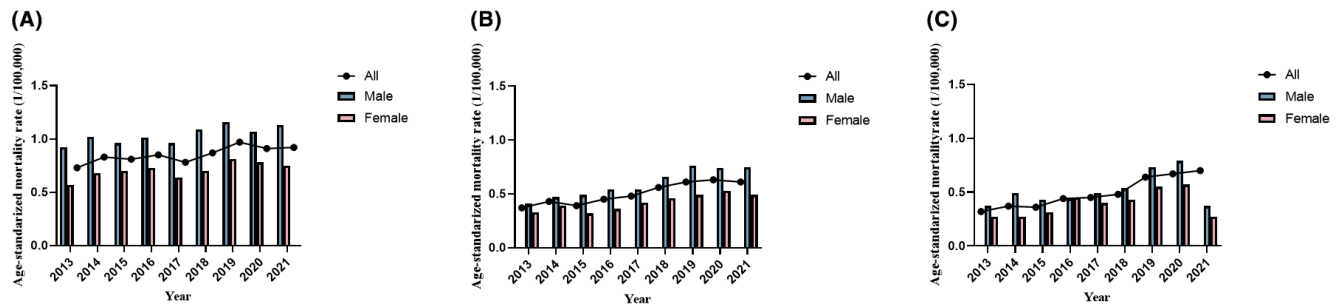


FIGURE 3 Changes in the age-standardized mortality rate of PD stratified by region and sex in China from 2013 to 2021. (A) Age-standardized mortality rate of PD in Eastern China; (B) Age-standardized mortality rate of PD in Central China; (C) Age-standardized mortality rate of PD in Western China.

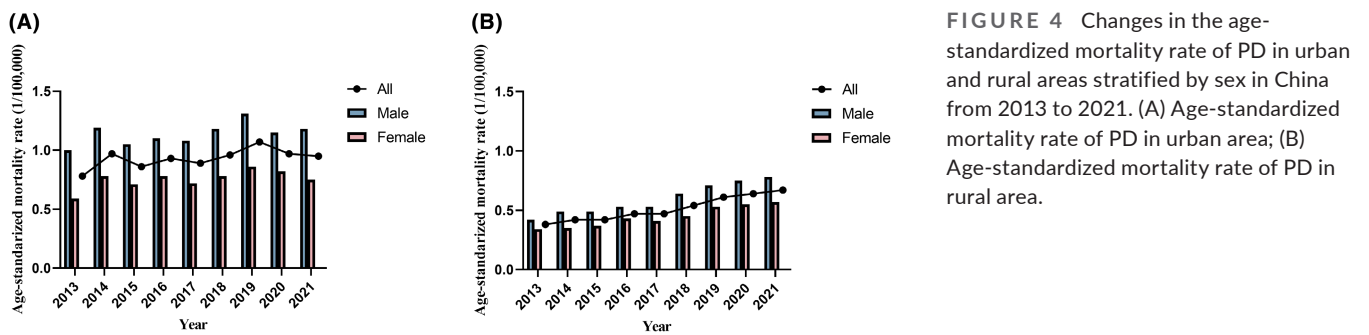


FIGURE 4 Changes in the age-standardized mortality rate of PD in urban and rural areas stratified by sex in China from 2013 to 2021. (A) Age-standardized mortality rate of PD in urban area; (B) Age-standardized mortality rate of PD in rural area.

TABLE 3 Crude mortality rate of PD projected by age groups and age-standardized mortality rate of PD projected by sex and region for 2025, 2030, and 2040 stratified in China.

Characteristics	2025		2030		2040	
	Mortality rate (1/100,000)	Ratio (2025/2021)	Mortality rate (1/100,000)	Ratio (2030/2021)	Mortality rate (1/100,000)	Ratio (2040/2021)
Total (Crude)	1.488 (1.380–1.596)	1.220	1.878 (1.707 to 2.048)	1.539	2.657 (2.360 to 2.954)	2.178
Age groups (years) (Crude)						
<20	0 (0.000–0.000)	–	0 (0.000 to 0.000)	–	0 (0.000 to 0.000)	–
20–39	0.009 (0.001–0.018)	1.000	0.009 (–0.004 to 0.022)	1.000	0.009 (–0.014 to 0.033)	1.000
40–44	0.046 (0.002–0.091)	1.150	0.057 (–0.013 to 0.128)	1.425	0.079 (–0.045 to 0.202)	1.975
45–49	0.130 (0.108–0.152)	1.300	0.170 (0.135 to 0.205)	1.700	0.250 (0.190 to 0.312)	2.500
50–54	0.254 (0.106–0.403)	1.270	0.287 (0.053 to 0.521)	1.435	0.352 (–0.056 to 0.760)	1.760
55–59	0.578 (0.377–0.778)	1.133	0.714 (0.398 to 1.029)	1.400	0.987 (0.436 to 1.538)	1.935
60–64	1.254 (0.987–1.521)	1.183	1.447 (1.026 to 1.868)	1.365	1.832 (1.098 to 2.567)	1.728
65–69	2.707 (2.360–3.053)	1.137	3.035 (2.489 to 3.582)	1.275	3.692 (2.738 to 4.647)	1.551
70–74	6.611 (6.039–7.184)	1.281	8.052 (7.150 to 8.955)	1.560	10.935 (9.358 to 12.511)	2.119
75–79	11.351 (8.799–13.902)	1.150	13.339 (9.316 to 17.362)	1.351	17.316 (10.292 to 24.341)	1.754
80–84	17.384 (14.736–20.032)	1.186	20.150 (15.976 to 24.325)	1.374	25.682 (18.393 to 32.972)	1.752
>85	30.739 (28.415–33.062)	1.299	37.778 (34.115 to 41.441)	1.596	51.856 (45.460 to 58.253)	2.191
Sex						
Male	1.094 (0.986–1.201)	1.189	1.291 (1.122 to 1.461)	1.403	1.687 (1.391 to 1.983)	1.834
Female	0.765 (0.695–0.836)	1.214	0.902 (0.790 to 1.013)	1.432	1.174 (0.980 to 1.369)	1.863
Urban–rural						
Urban	1.082 (0.909–1.255)	1.139	1.176 (0.903 to 1.449)	1.238	1.364 (0.888 to 1.841)	1.436
Rural	0.816 (0.759–0.875)	1.218	1.005 (0.911 to 1.098)	1.500	1.384 (1.221 to 1.546)	2.066
Region						
Eastern	1.031 (0.914–1.148)	1.121	1.143 (0.958 to 1.328)	1.242	1.366 (1.043 to 1.689)	1.485
Central	0.785 (0.702–0.867)	1.287	0.961 (0.831 to 1.090)	1.575	1.312 (1.086 to 1.539)	2.151
Western	0.895 (0.792–0.998)	1.279	1.147 (0.984 to 1.309)	1.639	1.650 (1.365 to 1.934)	2.357

(95% CI: 0.98–1.37) per 100,000 individuals by 2030 and 2040, respectively. In 2030, ASMR would increase to 1.14 (95% CI: 0.96–1.33), 0.96 (95% CI: 0.83–1.09), and 1.15 (95% CI: 0.98–1.31) per 100,000 individuals in the eastern, central, and western populations. Furthermore, it would be 1.37 (95% CI: 1.04–1.69), 1.31 (95% CI: 1.09–1.54), and 1.65 (95% CI: 1.37–1.93) per 100,000 individuals, respectively, by 2040. Additionally, ASMR in urban regions would increase to 1.18 (95% CI: 0.90–1.45) and 1.36 (95% CI: 0.89–1.84) per 100,000 individuals by 2030 and 2040, respectively, whereas in the rural regions, it would increase to 1.01 (95% CI: 0.91–1.10) and 1.38 (95% CI: 1.22–1.55) per 100,000 individuals by 2040, respectively.

4 | DISCUSSION

Currently, PD is the second most common neurodegenerative disease after Alzheimer's disease, exhibiting the fastest increase among all neurodegenerative diseases.¹⁶ Owing to the specificity of its symptoms, it is a substantial burden on patients, their families, and society.¹⁷

Over the past three decades, the global burden of PD has more than twice, and this trend is going on, presenting a considerable challenge to the economic sustainability of the global healthcare system.¹⁸ The increasing mortality trends for PD may be related to population growth, aging, genetic predisposition, lifestyle changes, and environmental pollution.^{19–23}

China is one of the most populous countries in the world. Based on representative data, this study suggests that mortality from PD in China showed an uptrend from 2013 to 2021. With an aging population and changes in living environments, PD has gradually become a major threat to the health and quality of life of older adults in China.²⁴

Apart from the sheer size of the population, industrial pollution and occupational exposure may contribute to the increasing trends in China.^{25,26} Many by-products of the industrial revolution, including heavy-metal-specific pesticides and solvents, have been linked to PD. Countries that have undergone rapid industrialization have seen the greatest increase in PD rates. Therefore, from 1990 to 2016, the age-standardized prevalence and ASMR of PD in China increased more than in any other country.¹⁹

Additionally, since 2019, the ASMR of PD has exhibited a clear upward trend, which may be related to the pandemic. Previous studies have shown that COVID-19 can increase the mortality rate associated with PD.^{27,28}

Although the etiology of PD is not fully clear, researchers have determined that it occurs and progresses with age.^{29,30} Studies have shown that age-related changes in the brain facilitate dopaminergic neuron vulnerability.³¹ With aging, blood vessels undergo functional and structural changes, and compromised blood flow to the brain contributes to cognitive decline and neurodegeneration.³²

There was a noticeable trend toward younger age groups for PD. This phenomenon can be attributed to advances in medical care, such as strengthening the screening for PD, enhancing people's awareness of their health, improving diagnostic methods, and

increasing clinicians' experience in managing PD.³³ However, most patients were still over 50 years old, emphasizing that PD is primarily a disease in older individuals.

A meta-analysis in China reported that PD is more prevalent in men than in women (odds ratio 1.29, 95% CI: 1.05–1.57).³⁴ De Miranda et al. observed that male rats were more susceptible to rotenone-induced neurodegeneration than female rats; this may be attributed to the preserved autograph of α -synuclein of female rats.³⁵ Additionally, a meta-analysis suggested that estrogen has potential neuroprotective effects in women. Women have higher levodopa bioavailability and lower levodopa clearance. Moreover, the more considerable burden and upward trends of ASMR in male individuals are possibly due to factors including higher occupational status and unhealthy lifestyles.^{36–38} The longer life expectancy of the female sex may explain the high prevalence of PD in older women aged >85 years. Structural and physiological changes occur as inevitable consequences of aging and are the outcomes of lifetime cumulative risk factors.

Although the global mortality rate of PD has increased significantly over the past ten years, some differences in mortality according to geographic location have been reported,³⁹ which is consistent with our results. In China, the ASMR of PD decreased from east to west, and a lower mortality rate of PD was found in rural residents than in urban residents, with generally increasing mortality trends over time. One reason for this discrepancy is public health awareness and the level of medical care in different regions. Wealthy areas have relatively higher medical standards and robust health systems than those of poor areas, and the public's concern for health and awareness of diseases is higher, resulting in a higher disease detection rate. Although the exact pathogenesis of PD is unknown, genetic and environmental factors, including exposure to agricultural and industrial occupations, are likely to play a role. Another reason for the higher mortality of PD observed in urban residents may be the exposures associated with the urban living environment, differences in lifestyle or health-system factors, or both.⁴⁰

In contrast to most diseases, whose burden decreases with improving socioeconomic status, the burden of PD is the opposite. Disability due to PD increases with sociodemographic indices (SDI).⁴⁰ Generally, the socioeconomic level is higher in the eastern region than in the western region, and the SDI of China gradually decreases from east to west, which can also explain why the ASMR of PD decreased from east to west. Furthermore, a study showed that social isolation is associated with a higher risk of developing PD.⁴¹ Areas with relatively high levels of social development have highly educated populations. Studies have shown that older adults living alone with higher education levels are at a higher risk of loneliness than that of individuals with lower education levels. This trend may be attributed to the relatively high emotional needs of well-educated older individuals, which can increase loneliness if those needs are not met.⁴² Moreover, owing to the high level of development, housing in economically developed areas is mostly in buildings, which increases the social distance between people and results in a higher number of people living alone, thereby significantly increasing the sense of isolation.⁴³

China's health system is suitable for PD management. As China's national economy grows, PD has been given substantial priority. For example, the number of PD-related publications in China ranks second only to that in the USA.⁴⁴ The economic burden of PD on families has been slightly relieved after the inclusion of PD into major disease insurance in the Chinese government insurance system since 2007 (CIRC Major disease insurance in China, 2019. Available at: <http://bxjg.circ.gov.cn/web/site47/tab4386/info196985.html>).⁴⁵ However, owing to the continual expansion of the population, the progress of the aging social structure, and increasing environmental pollution, the burden of PD in China remains at the forefront of the world. The Chinese healthcare system continues to face progressively increasing challenges.

Therefore, we can strengthen the primary prevention of PD to control its occurrence from its source and reduce its burden in China. For instance, for high-risk groups, such as those with a family history of Parkinson disease, carriers of related genes, and those exposed to toxic chemicals, we should closely monitor the disease progression, conduct regular medical checkups, and strengthen health education; strengthen environmental protection for industrial and agricultural production and reduce the emission of harmful gases, sewage, and waste²; improve drinking-water facilities in rural areas; protect water resources and reduce the pollution of potable water; increase active socialization and care for older people; and encourage the entire nation to engage in regular aerobic exercise. These measures can effectively reduce the risk of PD and death.⁴⁶

As far as we know, this is the first study to exclusively analyze trends in PD mortality in China and decompose the effects of age, sex, and region using the joinpoint regression model. However, this study has certain limitations: First, the PD-related mortality data used in this study were directly determined by the CDC-DSP system. Therefore, the reliability of the conclusion primarily depends on the accuracy of the database and data quality control of this system. Although the CDC-DSP system offers nationwide coverage and provides reliable data, it barely covers the entire nation of China, and remote areas inevitably have underreporting and other special circumstances. Second, to predict future trends in PD mortality, we assumed that the linear mortality trends obtained using the regression model from 2013 to 2021 would last for the next two decades, making it an ideal model. Many potential factors can influence mortality in the real world. Third, the analysis of the major subtypes and specific causes of death in PD would provide more valuable information for the future management of PD and distribution of health resources. However, data on the subtypes and specific causes of death from PD in China are not available in the CDC-DSP system. Thus, further studies focusing on these issues are warranted.

5 | CONCLUSION

Overall, the ASMR of PD increased from 2013 to 2019 in China, and this upward trend will continue until 2024. Although China's PD

mortality prevention and control measures have achieved some degree of success over the past few decades, considerable challenges remain. Male sex, living in areas with a high SDI, and advanced age (>55 years) were characteristics that contributed to an increased mortality in PD. Primary prevention strategies, such as close monitoring and follow-up of the disease, regular medical checkups, strengthening health education and environmental protection, performing more exercise, and decreasing isolation for high-risk groups, are encouraged to reduce the burden of PD.

AUTHOR CONTRIBUTIONS

YR, JL, and BL contributed to the conception of the study. YR, GS, LL, HZ, and BL contributed materials and experimented. JL, ML, RZ, CY, and BL performed the data analyses. YM and XZ reviewed and revised the manuscript. YR and JL contributed significantly to writing the manuscript. All authors contributed to the article and approved the submitted version.

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Not applicable.

CONFLICT OF INTEREST STATEMENT

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

DATA AVAILABILITY STATEMENT

Publicly available datasets were analyzed in the current study. The data can be found here: https://ncncd.chinacdc.cn/xzzq_1/202101/t20210111_223706.htm.

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