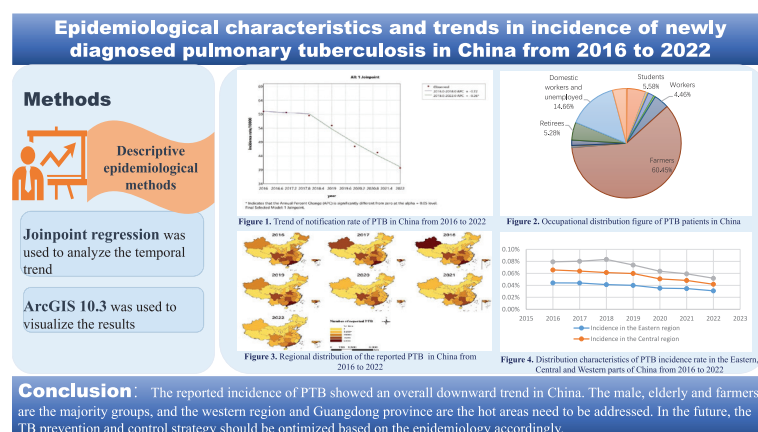




ORIGINAL ARTICLE

Epidemiological Characteristics and Trends in the Incidence of Newly Diagnosed Pulmonary Tuberculosis in China from 2016 to 2022

Graphical Abstract



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Brief Statement

The notification rate of PTB showed an overall downward trend. Men, older people, and farmers are the majority groups. The western region and Guangdong province are the hot areas that need to be addressed.

Highlights

The article explored the epidemiological characteristics and trends of pulmonary tuberculosis in China from 2016 to 2022. Descriptive epidemiological methods were used to analyze three-dimensional distribution in epidemiology. The chi-square test was used for comparison between groups. Joinpoint regression was used to analyze the temporal trend, and ArcGIS 10.3 software was used to visualize the results. The notification rate of PTB showed an overall downward trend in China. Men, older people, and farmers are the majority groups. The western region and Guangdong province are the hot areas that need to be addressed. The research will provide evidence for optimizing strategies and measures for tuberculosis prevention and control.

Epidemiological Characteristics and Trends in the Incidence of Newly Diagnosed Pulmonary Tuberculosis in China from 2016 to 2022

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Abstract

Objective: This study was aimed at exploring pulmonary tuberculosis (PTB) epidemiological characteristics and trends in China from 2016 to 2022, to provide evidence for optimizing strategies and measures for tuberculosis prevention and control.

Methods: Data on PTB in China reported from 2016 to 2022 were obtained from the Chinese Disease Prevention and Control Information System. Descriptive epidemiological methods were used to analyze the population distribution, and temporal and spatial distribution (also known as the three-dimensional distribution in epidemiology). The chi-square test was used for comparisons between groups. Joinpoint regression was used to analyze the temporal trends in PTB notification rates, and ArcGIS 10.3 software was used to visualize the results.

Results: In total, 5,141,468 cases of PTB were reported in China from 2016 to 2022, among which 39.89% were bacteriologically positive. Joinpoint regression analysis indicated that the PTB notification rate showed an overall downward trend from 2016 to 2022, with 2018 as the inflection point. The annual percentage change (APC) was -0.72% (95% CI: -4.78% to 2.96% , $P < 0.001$) from 2016 to 2018, and -9.26% (95% CI: -11.76% to -8.08% , $P < 0.001$) from 2018 to 2022; the overall average annual percentage change (AAPC) was -6.50% (95% CI: -7.56% to -5.51% , $P < 0.001$). The population distribution indicated that the male to female ratio was 2.19:1.00. Individuals older than 65 years accounted for 25.93%. Occupation distribution analysis indicated that farmers accounted for more than 60%. The PTB notification rate showed the following spatial distribution: western region > central region > eastern region. Guangdong province had the highest number of reported PTB cases.

Conclusion: From 2016 to 2022, the PTB notification rate showed an overall downward trend in China. Men, older people, and farmers were the majority groups. The western region and Guangdong province were hotspots that must be addressed. In the future, the Tuberculosis prevention and control strategies should be optimized according to epidemiological characteristics.

Key words: Tuberculosis, pulmonary, Incidence, Epidemiology

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INTRODUCTION

Tuberculosis is a global public health problem: approximately one-quarter of the world's population is infected with *Mycobacterium tuberculosis*, and more than 10 million new cases occur per year. Tuberculosis is the leading cause of death due to a single infectious agent worldwide, and is responsible for almost twice as many deaths as HIV/AIDS [1]. China has a tuberculosis high burden, and is the country with the second highest numbers of reported cases and deaths due to category A and B infectious diseases for which reporting is legally required. Tuberculosis continues to be a major health threat.

Tuberculosis was classified as a category B infectious disease in China in 1996. Subsequently, remarkable progress in tuberculosis prevention and control was made through continued optimization of tuberculosis prevention and control strategies. The recording and reporting mechanism and system were also enhanced. The pulmonary tuberculosis (PTB) notification rate initially increased but has declined since 1997 in China [2]. However, in recent years, as a result of the coronavirus disease 2019 (COVID-19) pandemic, tuberculosis notification has been affected to varying degrees among areas. Consequently, tuberculosis notification and reporting have attracted substantial attention.

This article is aimed at providing information regarding case notification and reporting in recent years, as well as further evidence to support upgrading and modifying tuberculosis strategies in China. This article analyzed the epidemiological characteristics and trends in PTB in 31 provincial-level administrative divisions in China from 2016 to 2022, to identify high-risk areas and populations, and analyze the possible reasons for the high prevalence, to aid in improving strategies and measures for PTB prevention and control. The novelty of this study lies in its focus on recent data, thus enabling more timely and pertinent analysis of changes in PTB prevalence.

METHODS

Data sources

The notification data for PTB came from the information system of the Chinese Center for Disease Control and Prevention, accessible at <https://10.249.6.18:8881/cdc/login>. The population data were derived from the 2023 statistical yearbook of the China Bureau of Statistics, accessible at <https://www.stats.gov.cn/sj/ndsj/2023/indexch.htm>.

Data analysis

Descriptive epidemiological methods were used to analyze the PTB notification rate in 31 provinces in China. Excel 2021 was used to summarize the PTB notification rates in China from 2016 to 2022 and establish a database. SPSS 27 was used for data analysis, and the chi-square test was used for comparisons between groups. The standardized notification rate of each year was calculated on the

basis of the total population in 2022, and the significance level was $\alpha=0.05$. Joinpoint 5.2.0 software was used to analyze the annual change trends in notification rates, with time (year) as the independent variable and notification rate as the dependent variable. Annual percentage change (APC), average annual percentage change (AAPC), and 95% confidence intervals (CIs) were calculated. ArcGIS 10.3 was used to visualize the distribution of PTB in China.

Classification of pulmonary tuberculosis

From 2015 to 2016, according to the Infectious Disease Reporting Information Management System of China, PTB was divided into smear positivity, clinical diagnosis, no sputum test, and sputum culture positivity only. In 2017, according to the Notice of the General Office of the National Health and Family Planning Commission of China on Adjusting the Classification of Tuberculosis Infectious Disease Reports [3], the classification was revised to rifampicin resistance, smear positivity, clinical diagnosis, no sputum test, and sputum culture positivity only. In 2018, on the basis of the new Diagnosis of PTB (WS288-2017) [4] and Tuberculosis Classification (WS196-2017) [5], according to the Notice of the National Health Commission of the People's Republic of China on Adjusting the Classification of Tuberculosis Infectious Disease Reports [6], the classification of PTB reporting was revised again to rifampicin resistance, bacteriological confirmation, clinical diagnosis, and no bacteriological results, and tuberculous pleurisy was included in the classification of PTB. After revision the historical data before 2019 remained unchanged, the classification of infectious disease report cards generated in 2019 was uniformly revised by the system, and the previously produced statistical reports were recalculated in accordance with the new statistical rules [7].

Regional classification

The eastern region includes 11 provinces: Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan. The central region includes eight provinces: Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, and Hunan. The western region includes 12 provinces: Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shanxi, Gansu, Qinghai, Ningxia, and Xinjiang [8].

RESULTS

Reported types of PTB

A total of 5,141,468 cases of PTB were reported in China from 2016 to 2022, and a downward trend was observed each year. Among the four patient types, the number of bacteriologically confirmed patients increased 31.23%, from 237,942 in 2016 to 312,257 in 2022. The bacteriologically confirmed rate of PTB in patients showed an overall upward trend, from 28.45% in 2016 to 57.68% in 2022,

representing an approximately twofold increase. The number of rifampicin resistant patients increased 47.48%, from 7,607 in 2016 to 11,219 in 2022. The number of patients without bacteriological results decreased 67.47%, from 114,429 in 2016 to 37,223 in 2022 (Table 1).

Epidemiological characteristics

Time distribution

From 2016 to 2022, the PTB notification rate in China showed an overall downward trend, with a notification rate of 60.06/100,000 in 2016 and 39.73/100,000 in 2022; the largest decline was observed in 2019–2020. The chi-square test indicated a statistically significant difference in

the PTB notification rate each year. According to Joinpoint regression analysis, the PTB notification rate in China from 2016 to 2022 had an inflection point in 2018. The APCs of the corresponding two intervals were $APC_{2016-2018} = -0.72\%$ (95% CI: -4.78% to 2.96% , $P < 0.001$) and $APC_{2018-2022} = -9.26\%$ (95% CI: -11.76% to -8.08% , $P < 0.001$), and the overall AAPC was -6.50% (95% CI: -7.56% to -5.51% , $P < 0.001$). Thus, the PTB notification rate in China decreased by an average of 6.50% per year from 2016 to 2022, the average annual decrease was 0.72% during 2016–2018, and the decline increased from 2018 to 2022, with an average annual decline of 9.26% (Fig 1 and Table 2).

TABLE 1 | Reported cases by PTB type in China from 2016 to 2022.

Year	Total	Patients with PTB				Bacteriologically confirmed rate
		Bacteriologically confirmed	Clinically diagnosed	No Bacteriological results	Rifampicin resistance	
2016	836,236	237,942	523,941	114,429	-	28.45%
2017	835,193	236,695	516,967	116,635	7,607	29.25%
2018	823,342	262,411	486,826	104,788	15,028	33.70%
2019	775,764	332,697	351,599	74,858	16,610	45.03%
2020	670,538	332,121	269,472	53,456	15,489	51.84%
2021	639,548	336,671	236,284	50,883	15,710	55.10%
2022	560,847	312,257	200,148	37,223	11,219	57.68%
Total	5,141,468	2,050,794	2,585,237	552,272	81,663	41.48%

Note: Before 2017, no statistics regarding rifampicin-resistant pulmonary tuberculosis patients were available in China's infectious disease reporting system. **PTB**: pulmonary tuberculosis.

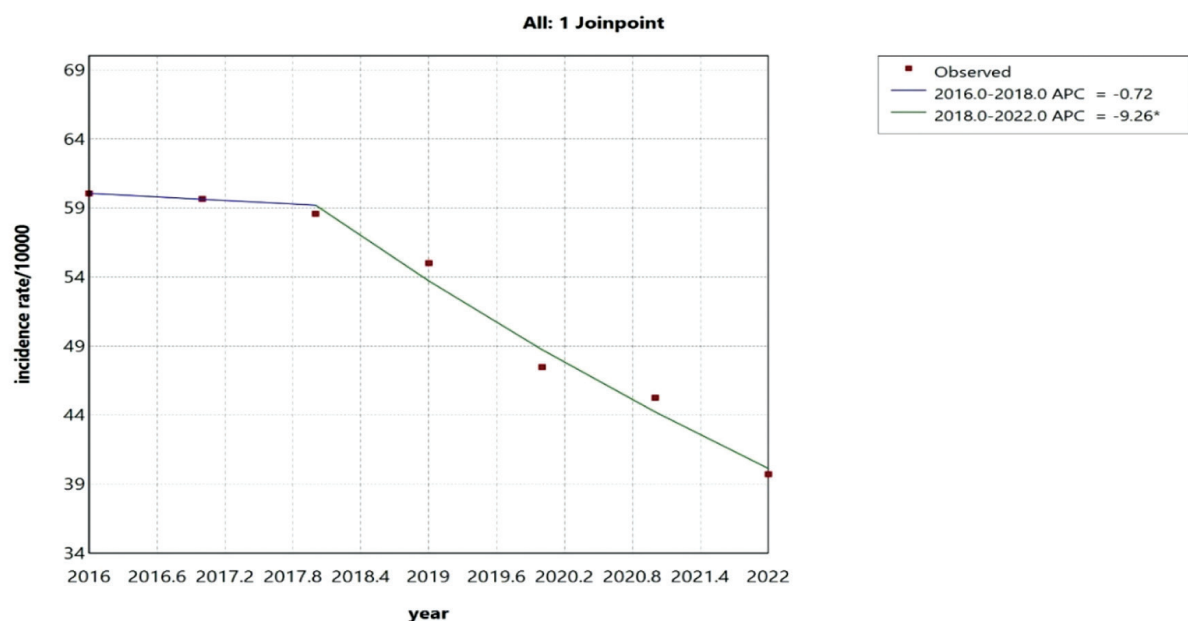


FIGURE 1 | Trends in PTB notification rates in China from 2016 to 2022. *Indicates that the APC is significantly different from zero at the $\alpha=0.05$ level. Final selected model: 1 Joinpoint.

TABLE 2 | PTB notification rate in China from 2016 to 2022.

Years	Number of population (10,000)	Number of reported patients with PTB	PTB notification rate (1/10,000)	Standardized PTB notification rate (1/10,000)	P value	APC (95% CI)	AAPC (95% CI)
2016	139,232	836,236	60.06	59.23	<0.001	−0.72% (−4.78% to 2.96%)	−6.50% (−7.56% to −5.51%)
2017	140,011	835,193	59.65	59.16			
2018	140,541	823,342	58.58	58.32			
2019	141,008	775,764	55.02	54.95			
2020	141,212	670,538	47.48	47.50			
2021	141,260	639,548	45.27	45.30			
2022	141,175	560,847	39.73	39.73			

Notes: **PTB**: pulmonary tuberculosis; **APC**: annual percentage change; **AAPC**: average annual percentage change.

TABLE 3 | Sex and age distribution of patients with PTB in China from 2016 to 2022.

	Number of reported patients	2016	2017	2018	2019	2020	2021	2022	P value
Sex									0.001
Male	3,531,981 (68.70%)	576,430 (68.93%)	578,047 (69.21%)	565,366 (68.67%)	533,981 (68.83%)	458,272 (68.34%)	436,518 (68.25%)	383,367 (68.36%)	
Female	1,609,487 (31.30%)	259,806 (31.07%)	257,146 (30.79%)	257,976 (31.33%)	241,783 (31.17%)	212,266 (31.66%)	203,030 (31.75%)	177,480 (31.64%)	
Age (years)									<0.001
<15	52,526 (1.02%)	6,769 (0.81%)	7,037 (0.84%)	7,591 (0.92%)	8,116 (1.05%)	8,057 (1.20%)	7,966 (1.25%)	6,990 (1.25%)	
15 to <25	670,695 (13.04%)	118,178 (14.13%)	115,996 (13.89%)	111,678 (13.56%)	104,967 (13.53%)	91,198 (13.60%)	73,847 (11.55%)	54,831 (9.78%)	
25 to <35	719,632 (14.00%)	120,873 (14.45%)	118,534 (14.19%)	114,558 (13.91%)	112,417 (14.49%)	98,762 (14.73%)	86,092 (13.46%)	68,396 (12.20%)	
35 to <45	567,439 (11.04%)	101,444 (12.13%)	96,839 (11.59%)	91,006 (11.05%)	83,509 (10.76%)	71,037 (10.59%)	66,516 (10.40%)	57,088 (10.18%)	
45 to <55	892,520 (17.36%)	149,851 (22.35%)	151,619 (18.15%)	144,963 (17.61%)	133,772 (17.24%)	113,022 (16.86%)	107,260 (16.77%)	92,033 (16.41%)	
55 to <65	905,320 (17.61%)	144,709 (17.30%)	142,907 (17.11%)	145,538 (17.68%)	135,253 (17.43%)	114,903 (17.14%)	116,508 (18.22%)	105,502 (18.81%)	
≥65	1,333,336 (25.93%)	194,412 (23.25%)	202,261 (24.22%)	208,008 (25.26%)	197,730 (25.49%)	173,559 (25.88)	181,359 (28.36%)	176,007 (31.38%)	

Population distribution

Sex and age distribution

During 2016–2022, most patients with PTB were male (more than 68% in each year), and the male to female ratio was 2.19:1. Patients older than 65 years accounted for 25.93%, and were followed by patients 55–65 years old (17.61%) and 45–55 years old (17.36%). The chi-square test indicated statistically significant differences among sex and age groups in each year (Table 3).

Occupational distribution

According to the chi-square test, a statistically significant difference in the total number of reported cases was

observed among occupational groups during 2016–2022 ($P<0.001$). Of the reported cases, the largest numbers of patients were farmers (60.45%), followed by domestic workers and unemployed individuals (14.66%), students (5.58%), retirees (5.28%), and workers (4.46%) (Fig 2).

Regional distribution

Across provinces, the number of reported PTB cases in Guangdong province exceeded 60,000 per year from 2016 to 2019, and the number of reported PTB cases in Xinjiang in 2018 also exceeded 60,000 per year. From 2020 to 2022, the number of reported PTB cases in all regions declined to fewer than 60,000 per year. By 2022,

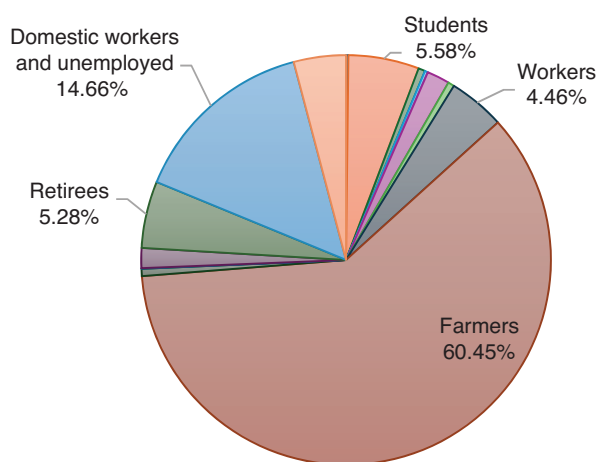


FIGURE 2 | Occupational distribution of patients with PTB in China from 2016 to 2022.

the number of reported PTB cases in all regions except Guangdong province was less than 45,000 per year, and the notification rates in 14 provinces were below 15,000 per year (Fig 3).

Analyses by region indicated the highest number of reported cases in the western region, and that more cases were reported in the central region than the eastern region. In 2018, the PTB notification rate in the western region peaked and far exceeded that of other regions. From 2018 to 2022, the PTB notification rate in all regions continued to decline, and by 2022, the gap between regions had markedly decreased (Fig 4).

DISCUSSION

This article analyzed the PTB reporting information in 31 provinces from 2016 to 2022, to explore the epidemiological characteristics and trends in PTB in China. The reported PTB numbers showed an overall downward trend while the bacteriologically positive rate showed an upward trend, and the number of rifampicin resistant patients also increased each year in China. These trends were due primarily to the implementation of the Stop tuberculosis strategy and robust measures, including continued increases in funding and scaling up of new diagnostic techniques for PTB and RR/MDR-TB.

Analysis of time trends indicated that the PTB notification rate in China from 2016 to 2022 declined, and the rate of decline accelerated over time. In 2022, the national PTB notification rate was 39.73/100,000, thus achieving the target of a national PTB incidence below 55/100,000 by 2022 in the Stop tuberculosis Action Plan [9]. The PTB incidence decreased dramatic in the past 7 years. The notification rate in 2019–2020 showed the largest decrease, possibly as a result of public health measures during the COVID-19 prevention and control period, such as decreased travel and gathering activities, and increased mask wearing, which somewhat decreased PTB risk

transmission [10]. In contrast, some PTB designated medical institutions were requisitioned for epidemic prevention and control during COVID-19, thus resulting in a decline in the diagnostic capacity for patients with PTB.

Examination of the population distribution revealed that men, older people, and farmers were the key PTB groups. From 2016 to 2022, the PTB notification rate was higher in males than females, in agreement with the epidemiological characteristics of PTB in China and worldwide. This finding might have been because the main labor force comprises men, who perform a larger range of activities and have more contact with people than women, thus increasing PTB risk infection. Simultaneously, unhealthful lifestyles, such as long-term smoking, alcohol consumption, and high labor intensity might also lead to higher PTB incidence in males than females [11]. More than one-quarter of patients were older than 65 years. The proportion of PTB among people older than 65 years increased from 23.25% in 2016 to 31.38% in 2022, thereby suggesting that PTB risk increases with age. Immunity decreases with age, and older people are often affected by chronic diseases, such as diabetes and heart diseases [12], thus resulting in a higher incidence of tuberculosis than observed in other populations. The occupational distribution was dominated by farmers; this occupation accounted for more than half the cases. This finding might have been because China is a large agricultural country with a large rural population base. The 2023 China statistical year-book indicated that China's rural population accounted for 34.78% of the total. Another explanation might be that low rural economic development, poor living conditions, and a lack of equipment and medical resources for PTB prevention and control led to insufficient PTB prevention and control capacity [13]. A third explanation might pertain to poor PTB knowledge and insufficient awareness of health prevention and control among farmers [7]. The relatively large proportion of people who were domestic workers or unemployed might potentially have been associated with cramped working environments, poor stability, and low economic income [14]. The third largest group was students, who spend most of their time in a relatively closed environment and have developing immune systems; therefore, students are a key group for PTB prevention and control [15].

The regional distribution indicated that the numbers of reported PTB cases from 2016 to 2022 were higher in Guangdong, which has many migrant workers. Because of poor health and nutrition, the floating population is not only susceptible to PTB but also can easily become a bridge population facilitating the dynamic transmission of PTB; this aspect is an important reason for the high PTB notification rate in Guangdong [16]. The large numbers of reported PTB cases in Xinjiang in 2018 might have been due to the comprehensive implementation of measures such as large-scale active screening for PTB [17], which have greatly promoted the identification of patients with PTB in Xinjiang. Overall, PTB incidence in China was

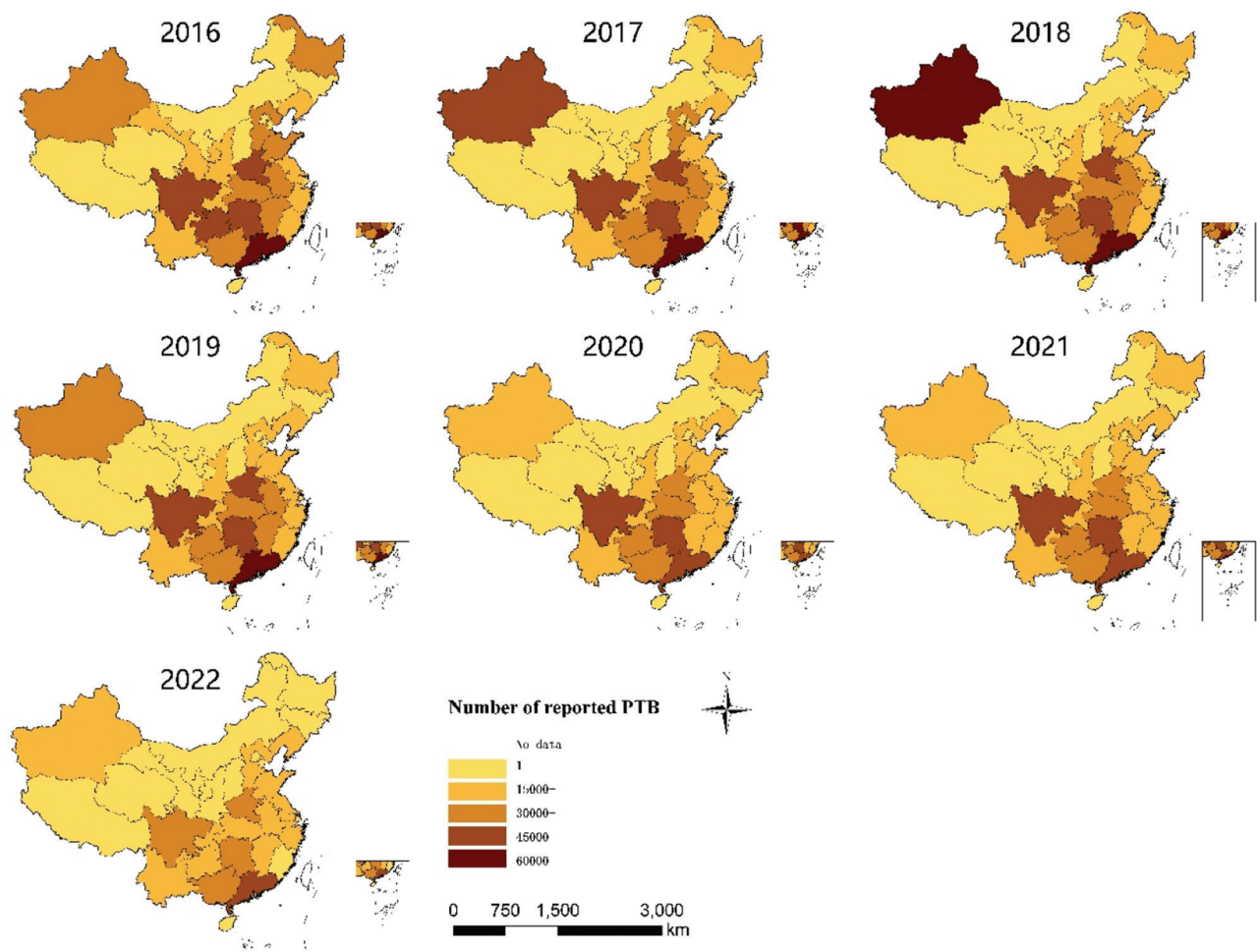


FIGURE 3 | Regional distribution of reported PTB cases in China from 2016 to 2022.
Note: This map is based on the standard map No. GS (2020) 4619 from the standard map service website of the Ministry of Natural Resources, and the boundary of the base map has not been modified.

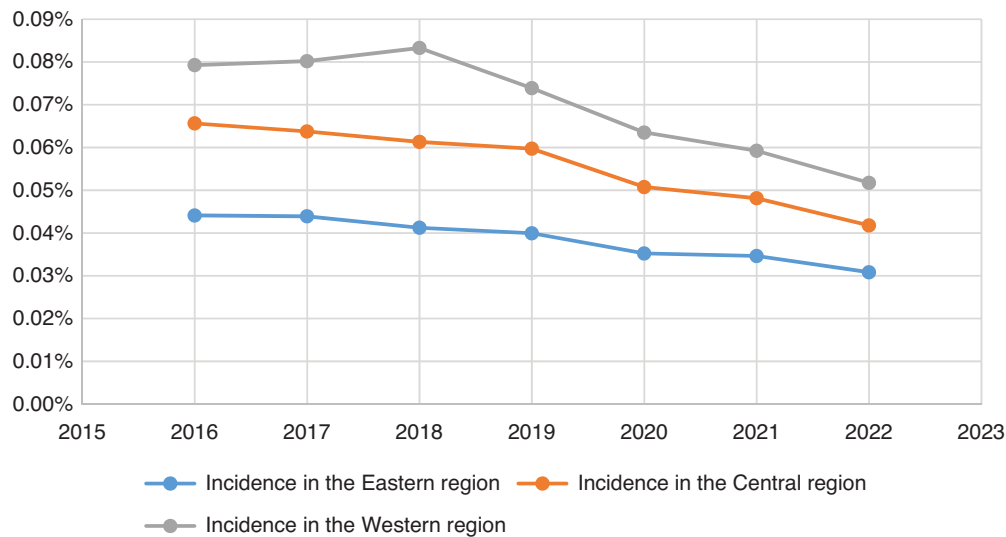


FIGURE 4 | Distribution characteristics of PTB incidence rates in the eastern, central, and western parts of China from 2016 to 2022.

found to be unevenly distributed and generally higher in the western region than the central and eastern regions; in contrast, the incidence in the central region was stable and low. The reasons for these findings might include that the western region has overall low economic development, relatively scarce medical resources, largely inadequate medical and health systems, and poor PTB awareness among residents. According to data from the fifth tuberculosis epidemiology sampling survey in China, the rate of awareness of core tuberculosis knowledge in the western region was 3.10%, and the total awareness rate was 48.50%, both of which were below national averages [18]. The low notification rate in the eastern region suggested that governmental prevention and control measures, as well as good economic conditions, are crucial for achieving low prevalence of PTB.

CONCLUSION

The PTB notification rate showed an overall downward trend in China from 2016 to 2022. The distribution of PTB cases in China was uneven, and men, older people, and farmers were found to be the key groups. The western region and Guangdong province were the areas with high PTB incidence. In the future, prevention and control strategies for tuberculosis must be optimized and upgraded, according to the epidemiological characteristics of various populations and regions.

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None.

CONFLICTS OF INTEREST

The authors have no conflicts of interest to disclose.

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