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Disease burden of tuberculosis and post-tuberculosis in Inner Mongolia, China, 2016–2018 — based on the disease burden of post-TB caused by COPD

Caimei Jing[1†], Huiqiu Zheng[2†], Xuemei Wang[3*], Yanling Wang[2], Yifan Zhao[3], Sijia Liu[1], Jing Zhao[1] and Qianqian Du[1]

Abstract

Background Tuberculosis (TB) remains one of the most serious infectious diseases worldwide. China has the second highest TB burden globally, but existing studies have mostly neglected the post-tuberculosis (post-TB) disease burden. This study estimated the disease burden of TB and post-TB in Inner Mongolia, China, from 2016 to 2018.

Methods Population data were collected from TB Information Management System. Post-TB disease burden was defined as the burden caused by Chronic Obstructive Pulmonary Disease (COPD) occurring after patients with TB were cured. To estimate the incidence rate of TB, standardized mortality rate, life expectancy, and cause eliminated life expectancy, using descriptive epidemiological, abridged life table and cause eliminated life table. On this basis, the Disability-Adjusted Life Years (DALY), Years Lived with Disability (YLD) and Years of Life Lost (YLL) due to TB were further be estimated. The data were analyzed using Excel 2016 and SPSS 26.0. Joinpoint regression models were used to estimate the time and age trends of the disease burden of TB and post-TB.

Results The TB incidence in 2016, 2017, and 2018 was 41.65, 44.30, and 55.63/100,000, respectively. The standardized mortality in the same period was 0.58, 0.65, and 1.08/100,000, respectively. From 2016 to 2018, the total DALYs of TB and post-TB were 5923.33, 6258.03, and 8194.38 person-years, and the DALYs of post-TB from 2016 to 2018 were 1555.89, 1663.33, and 2042.43 person-years. Joinpoint regression showed that the DALYs rate increased yearly from 2016 to 2018, and the rate of males was higher than that of females. TB and post-TB DALYs rates showed a rising tendency with increasing age (AAPC values were 149.6% and 157.0%, respectively, $P < 0.05$), which was higher in the working-age population and elderly.

Conclusion The disease burden of TB and post-TB was heavy and increased year by year in Inner Mongolia from 2016 to 2018. Compared with the youngster and females, working-age population and the elderly and males had a higher disease burden. Policymakers should be paid more attention to the patients' sustained lung injury after TB cured. There is a pressing need to identify more effective measures for reducing the burden of TB and post-TB of people, to improve their health and well-being.

[†]Caimei Jing and Huiqiu Zheng contributed equally to this work.

*Correspondence:
Xuemei Wang
wangxm_zsu@163.com
Full list of author information is available at the end of the article

Keywords Tuberculosis, Post-tuberculosis, Burden of disease, Inner Mongolia

Background

Tuberculosis (TB) is a relatively severe infectious disease caused by *M. tuberculosis*. In 2022, approximately 10.60 million TB-related cases and 1.4 million TB deaths were reported globally, with the mortality of TB being 15%. In China, there were 780,000 new cases of TB, and the number of multiple-drug-resistant TB was 33,000 in 2021 [1]. Although the incidence of TB in China has shown a decreasing trend in recent years, the number of incidences and deaths of TB ranked 2nd among infectious diseases in China in 2021 [2]. What's more, with rapidly ageing populations in China, the high incidence of TB in the elderly have impacts on all aspects of economies and societies [3]. In addition, a part of the working-age population died due to TB [4]. As the prevalence of infectious diseases increases globally, the World Bank has proposed the use of Disability-Adjusted Life Years (DALY) to assess the severity of the burden of disease, which measures the total number of healthy years lost from illness onset to death. It includes two parts: Years of Life Lost (YLL) due to early death and Years Lived with Disability (YLD) due to disease. Considering the loss of life at the onset of a disease and the loss of life at the time of death, the actual impact of a disease on population health can be comprehensively evaluated. In 2019, about 122 million DALYs were attributable to TB globally [5]. Among the 30 countries with a high disease burden of TB, China ranked 2nd after India [1].

After treatment, people with TB had a high risk of COPD [6]. Studies showed that the risk of COPD was three times higher in patients over 40 years with TB than that in those without TB [7]. Most patients with TB had poor nutritional status and medication compliance and were prone to complications such as COPD after TB infection [8]. About half of the patients with TB developed clinical symptoms of post-tuberculosis (post-TB) lung disease [9, 10]. In 2019, the first internal post tuberculosis symposium presented post-TB lung disease was a heterogenous condition. Post-tuberculosis lung disease is evidence of chronic respiratory abnormality, with or without symptoms, attributable at least in part to previous tuberculosis [11]. A study on the global lifetime burden of disease due to TB showed that the disease burden of TB should include post-TB sequelae, and 58 million DALYs were attributed to post-TB, with about one-third of these DALYs occurring 15 years or more after the first occurrence of TB. In 2019, China had 2.86 million DALYs attributable to post-TB, ranking 6th among the 30 countries with a high TB burden, just behind countries such as India, the Philippines, and South Africa [5]. The result might be related to the fact that previous studies focused only on TB treatment outcomes and ignored the long-term health problems of patients with TB after cure [12]. Over 60% of patients with TB in China live in rural areas. However, rural healthcare workers always lack professional TB diagnosis and treatment capabilities, and patients with TB had lower awareness of prevention and treatment compliance. Therefore, patients were more prone to irregular treatment and even medication interruption, leading to TB recurrence and post-TB lung injury [13, 14].

Inner Mongolia, is an underdeveloped region located in northern China, is economically backward and lacks medical resources. The incidence of TB decreased from 67.5/100,000 to 35.4/100,000 during 2011–2020 [15, 16]. However, there were still 13,000 new cases of TB reported each year. In 2020, the TB incidence in 6 of 12 Inner Mongolia leagues/cities was over 55/100,000. There were more than 100,000 cases of TB in Inner Mongolia from 2011 to 2020. The burden of TB was heavy in Inner Mongolia, but most of the existing studies focused on the prevalence characteristics of TB, such as incidence. There was a lack of studies related to TB and post-TB disease burden are important but neglected. This study aimed to estimate TB and post-TB disease burden by DALYs and to provide a basis for further prevention and control of TB in Inner Mongolia.

Methods

Data source

The TB case data were obtained from the TB Information Management System from 2016 to 2018, which collected information on patients with TB in 101 banners/counties in 12 leagues/cities in Inner Mongolia. Population data were from the National Bureau of Statistics and the Inner Mongolia Statistical Yearbook.

Variable definition

TB

Patients were diagnosed according to the Diagnosis for Pulmonary Tuberculosis (WS 288–2017) [17].

Disease burden of TB

The burden of disease in this study was caused by TB and post-TB. Increasing evidence suggested that lung injury persists in patients despite TB treatment, leading to chronic lung diseases such as COPD. Previous TB can lead to pathological changes in the lungs leading to airflow limitation,

and COPD is a lung disease characterized by airflow limitation. Although COPD is not the most common post-tuberculosis disease, it has the most serious consequences once it occurs. In this study, the disease burden of post-TB was estimated based on the risk weights of COPD. Due to the lack of data on patients with TB who died from COPD after cured, post-TB YLD was used to represent post-TB DALYs. This study estimated the disease burden for each year from 2016 to 2018 by calculating YLD, YLL, and DALYs. YLL is disability adjusted life years, which refers to the years of life lost due to premature death. YLD is years lived with disability, which refers to years of life lost due to disability caused by illness. Based on the risk weight of COPD after tuberculosis in studies, this study estimated the post-tuberculosis YLD of tuberculosis patients from 2016 to 2018. Due to the lack of data on COPD deaths after tuberculosis patients were cured, we only used YLD to represent post-tuberculosis DALY. The burden of post-TB disease may be underestimated. The calculation formulas are as follows:

(1) DALYs = YLL + YLD
(2) YLL = D × L, D was the number of TB deaths by age group and sex, and L is the value of life lost by age group and sex.
(3) YLD = I × Dw × L, where I was the number of TB incidences; Dw was the disability weight, reflecting the severity of disability due to the disease, and the value ranges from 0 to 1 (the higher value of disability weight indicates the higher degree of disability); L was the duration of TB disease in patients. In this study, the disability weight for TB was 0.333, and the disease duration was 1.1 years; the disability weight value for COPD was 0.036, and the duration of COPD was 4.3 years [5, 18].

Reported TB incidence rate

The incidence of TB was calculated based on the number of patients registered in the TB reporting system in Inner Mongolia from 2016 to 2018 and the population in the corresponding period. The calculation formula was as follows:

$$\text{Reported TB incidence rate} = \text{reported TB cases in a certain period of time} / \text{the average population of the area at that time} * 100,000$$

TB Standardized Mortality Rate

The TB Standardized Mortality Rate for each year was as follow:

$$\text{Standardized Mortality Rate} = \Sigma(N_i/N)p_i$$

where p_i is the crude mortality rate for each age group (i), N_i/N is the composition ratio of each age group (i) in the standard population. The sixth census data of China in 2010 was used as the standard population.

Life expectancy and cause-eliminated life expectancy

The life expectancy of the 0-year-old population from 2016 to 2018 was estimated by preparing an abridged life table. Cause-eliminated life expectancy in Inner Mongolia from 2016 to 2018 was calculated by compiling an abridged life table method to reflect the extent of the impact of TB on the life of the population.

Age

The age division was based on the sixth census data released by the National Bureau of Statistics of China in 2010, and the population was divided into 19 age groups, which were 0, 1–4, 5–9, 10–14, 15–19, 20–24, 25–29, 30–34, 35–39, 40–44, 45–49, 50–54, 55–59, 60–64, 65–69, 70–74, 75–79, 80–84, and ≥ 85 years old [19].

Statistical analysis

The disease burden of TB was estimated by reported incidence, mortality, DALYs, and DALYs rate. Rates were standardized using standard population (Sixth Nationwide Population Census). Data were cleaned and analyzed using Excel 2016 and SPSS 26.0. The annual percent change (APC) and average annual percentage change (AAPC) in TB were estimated during 2016–2018 to descript TB DALYs rate trends using Joinpoint 4.9.0. $P < 0.05$ was considered statistically significant. TB reported incidence spatial characteristics of 101 banners/counties in Inner Mongolia was performed by ArcGIS 10.8.

Results

Reported incidence and mortality of TB

Age-specific incidence of TB

TB reported incidence was at a low level from 0 to 10 years old, increasing gradually with age after 15 years old, rapidly rising after 35 years old, with the first peak at 65–69 years old and the highest peak in the 80–84 years group, with a slight decrease in incidence in the 85 years old and above group. The reported incidence of TB was higher in males than females (Fig. 1a). In 2016–2018, the reported incidence of TB in Inner Mongolia was 47.21/100,000, increased year by year

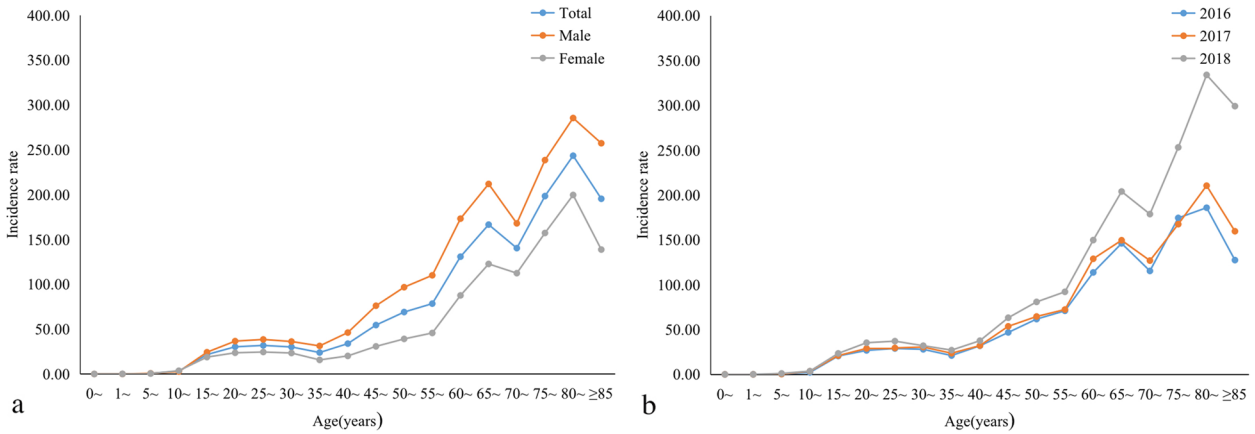

Fig. 1 Reported incidence of TB by age in Inner Mongolia, 2016–2018 **a** Age-specific reported incidence by sex **b** Age-specific reported incidence by year. The TB case data were obtained from the TB Information Management System. TB reported incidence was at a low level from 0 to 10 years old, increasing gradually with age after 15 years old. The reported incidence of TB was higher in males than females (Fig. 1a). The highest reported incidence of tuberculosis in 2018

in 2016, 2017, and 2018, which was 41.65, 44.30, and 55.63/100,000, respectively (Fig. 1b).

Distribution of TB reported incidence

The reported incidences in eastern Inner Mongolia were higher than those in the central and western regions. Among the 101 banners/counties in Inner Mongolia, the highest reported incidence in 2016 was 137.21/100,000 in Naiman Banner (Fig. 2a). In 2017, Xin Barag Zuoqi had the highest reported incidence of 178.57/100,000 (Fig. 2b). In 2018, Jalaid Banner had the highest reported incidence of 943.44/100,000 (Fig. 2c).

Standardized mortality of TB

All-cause mortality and TB cause-of-death mortality showed an increasing trend year by year, and the highest rate in 2018 was 1.08 and 0.17/100,000, respectively (Table 1). In 2016–2018, all-cause mortality and TB cause-of-death mortality were higher for males than females ($P < 0.001$).

Life expectancy and cause-eliminated life expectancy

The life expectancy in 2016, 2017, and 2018 was 78.78, 78.53, and 78.57 years, respectively (Table S1). The life expectancy after the elimination of TB increased 0.53, 0.48, and 0.46 years, respectively, and the life span loss rate was 0.67%, 0.61%, and 0.58%, respectively (Table 2).

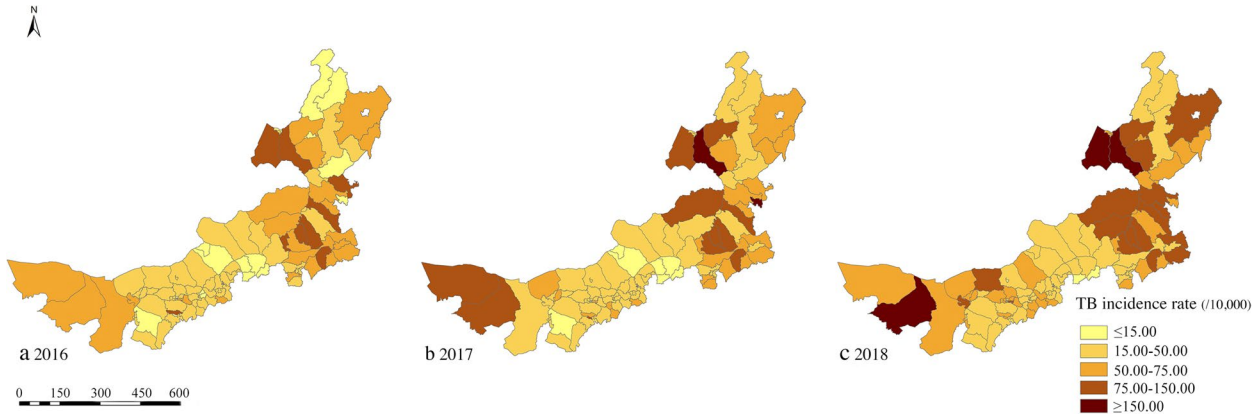

Fig. 2 Spatial distribution of TB incidence in Inner Mongolia, 2016–2018 **a** Reported incidence of TB in 2016 **b** Reported incidence of TB in 2017 **c** Reported incidence of TB in 2018. (The digital maps were obtained from the Resource and Environmental Science and Data Center, https://www.resdc.cn/). The TB case data were obtained from the TB Information Management System. Darkest color indicates highest reported incidence rate. The reported incidences in eastern Inner Mongolia were higher than those in the central and western regions

Table 1 TB standardized mortality in Inner Mongolia, 2016–2018 (1/100,000)

Years	Total		Male		Female	
	All cause of death[a]	TB causes of death	All cause of death	TB causes of death	All cause of death	TB causes of death
2016	0.58	0.09	0.75	0.13	0.33	0.04
2017	0.65	0.10	0.84	0.14	0.38	0.03
2018	1.08	0.17	1.36	0.20	0.59	0.11
Total	0.77	0.12	0.99	0.16	0.44	0.06

[a] All cause of death refers all-cause standardized mortality in patients with tuberculosis. Total refers the total population, regardless of sex. All-cause mortality and TB cause-of-death mortality showed an increasing trend year by year, and the highest rate in 2018

Table 2 Life expectancy of TB eliminated in Inner Mongolia, 2016–2018

Age	2016			2017			2018		
	Total[a]	Male	Female	Total[a]	Male	Female	Total[a]	Male	Female
0 ~	79.31	76.71	82.34	79.01	76.34	82.07	79.03	76.62	81.79
1 ~	78.61	76.01	81.63	78.28	75.64	81.30	78.25	75.86	81.01
5 ~	74.69	72.10	77.72	74.38	71.74	77.39	74.35	71.96	77.10
10 ~	69.75	67.16	72.76	69.43	66.80	72.44	69.40	67.01	72.16
15 ~	64.80	62.22	67.80	64.49	61.87	67.49	64.46	62.08	67.21
20 ~	59.87	57.32	62.85	59.56	56.96	62.54	59.51	57.15	62.24
25 ~	54.95	52.43	57.90	54.63	52.06	57.58	54.57	52.23	57.28
30 ~	50.09	47.62	52.98	49.75	47.22	52.64	49.67	47.35	52.35
35 ~	45.29	42.88	48.10	44.93	42.47	47.74	44.85	42.59	47.45
40 ~	40.47	38.13	43.19	40.11	37.73	42.85	40.02	37.84	42.53
45 ~	35.78	33.56	38.34	35.40	33.12	38.00	35.29	33.19	37.67
50 ~	31.19	29.12	33.56	30.82	28.70	33.22	30.69	28.74	32.91
55 ~	26.85	25.00	28.95	26.52	24.62	28.63	26.36	24.62	28.29
60 ~	22.58	20.96	24.41	22.22	20.55	24.05	22.08	20.59	23.73
65 ~	18.76	17.39	20.28	18.46	17.12	19.93	18.37	17.19	19.63
70 ~	15.31	14.29	16.47	15.05	14.11	16.10	14.97	14.16	15.85
75 ~	11.81	10.94	12.81	11.51	10.72	12.39	11.40	10.77	12.09
80 ~	9.08	8.34	9.92	8.58	7.90	9.34	8.29	7.75	8.89
≥ 85	7.79	6.98	8.67	7.21	6.48	8.00	6.20	7.42	6.79

[a] Total refers to life expectancy of TB eliminated for the total population, regardless of sex. This study estimated the life expectancy of TB eliminated in Inner Mongolia by compiling abridged life table. To reflect the extent to which TB affects people's lives. The life expectancy of TB eliminated in 2016, 2017, and 2018 was 79.31, 79.01, and 79.03 years, respectively

Life expectancy and life expectancy after the elimination of TB were higher for females than for males in 2016–2018.

Disease burden of TB and post-TB

Disease burden of TB

DALYs of TB from 2016–2018 were 15,114.09 person-years, including 2041.94 person-years of YLL and 13,072.16 person-years of YLD. The YLL of 2016–2018 were 536.68, 505.69, and 999.57, respectively. The YLD of 2016–2018 were 3830.77, 4089.01, and 5152.38, respectively. The highest DALYs, YLL, and YLD of TB were in 2018 (Fig. 3). The disease burden of TB was concentrated in the working-age population. DALYs, YLL, and YLD were higher in males than females in all three years (Table 3).

Age-specific DALYs rates of TB were shown in Fig. 4. DALYs rates increased with age ($AAPC_{total} = 149.6\%$, 95% CI: 84.7–237.2, $P < 0.001$). The DALYs rate increased steeply in males and increased steadily in females, and the DALYs rate was higher for males than for females

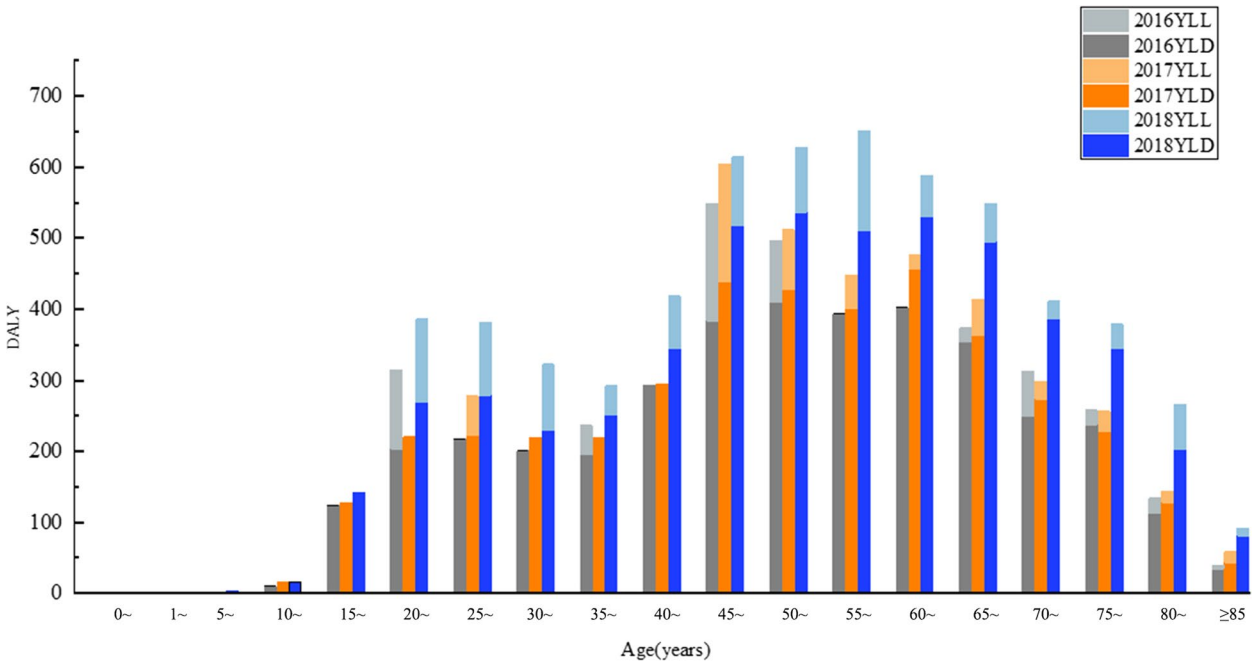

Fig. 3 Age-specific disease burden due to TB in Inner Mongolia, 2016–2018. Described using column stacking diagram, the height of each column represents the superimposed value of YLD and YLL, which is DALY. The highest DALYs, YLL, and YLD of TB were in 2018. Abbreviations: YLL, years of life lost; YLD, years lived with disability; DALY, disability-adjusted life years

($AAPC_{males}$ = 196.7%, 95% CI: 104.3–330.8, $P < 0.001$; $AAPC_{females}$ = 182.8%, 95% CI: 93.7–312.9, $P < 0.001$).

Disease burden of post-TB

The DALYs of post-TB from 2016 to 2018 were 1555.89, 1663.33, and 2042.43 person-years, respectively, with the highest DALYs in 2018. The age-specific post-TB DALYs were mainly concentrated in the 40–79 age group. The DALYs in males were higher than those in females in three years, with males post-TB DALYs being 1.98 times higher than females (Fig. 5 and Table 4).

Figure 6 showed the age-specific DALYs rates of post-TB. Post-TB DALYs rates increased with age ($AAPC_{total}$ = 157.0%, 95% CI: 124.6–194.0, $P < 0.001$). DALYs rates were lower in males than females before age 20 and increased steeply in males after age 20 ($AAPC_{males}$ = 160.4%, 95% CI: 128.4–196.9, $P < 0.001$; $AAPC_{females}$ = 205.1%, 95% CI: 94.4–378.6, $P < 0.001$).

Total disease burden of TB and post-TB

Total DALYs of TB and post-TB were 5923.33, 6258.03, and 8194.38 person-years from 2016 to 2018, respectively, with the highest DALYs in 2018. The proportion of DALYs of males was 2.07, 2.15, and 2.03 times that of females in the three years, respectively. DALYs in post-TB accounted for 25.82% of the total DALYs of TB and post-TB in 2016–2018 (Fig. 7).

DALYs rate was 0.24, 0.25, and 0.33/1,000 from 2016–2018, respectively. Total TB and post-TB disease burden increased with years (APC_{total} = 17.3%, 95% CI: -50.8–179.5). The males three-year DALYs rates were 0.31, 0.33, and 0.43/1,000, respectively, and the females were 0.16, 0.17, and 0.23/1,000, respectively (APC_{males} = 17.8%, 95% CI: -43.9–147.2, $APC_{females}$ = 19.9%, 95% CI: -50.6–190.9). DALYs rates of males were consistently higher than that of females (Fig. 8).

Discussion

China has one of the highest new TB cases globally each year [20]. According to the China National Epidemiological Profile of Statutory Infectious Diseases, TB reported incidence and mortality are the highest among infectious diseases in recent years [2]. In Inner Mongolia, the reported incidence of TB was 47.21/100,000 in 2016–2018, higher than that in Beijing (30.43/100,000) [21]. And the reported incidence rate of tuberculosis in males. Similar to our study, Pereira A et al. showed that the incidence rate of TB was higher in males than in females, and the incidence of TB in males was higher than in the overall rate, and females had the lowest reported incidence rate of TB [22]. We found the standardized mortality was

Table 3 Disease burden of TB by gender and age

Age	2016				2017				2018			
	Male DALY	Male DALY rate	Female DALY	Female DALY rate	Male DALY	Male DALY rate	Female DALY	Female DALY rate	Male DALY	Male DALY rate	Female DALY	Female DALY rate
0 ~	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1 ~	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 ~	0.73	0.00	0.73	0.00	0.73	0.00	0.73	0.00	2.93	0.00	1.47	0.00
10 ~	3.66	0.01	6.59	0.01	8.42	0.02	7.69	0.02	6.96	0.01	9.89	0.02
15 ~	72.16	0.10	52.75	0.08	76.56	0.11	51.28	0.07	80.59	0.11	62.27	0.09
20 ~	247.74	0.24	68.13	0.07	135.53	0.13	85.35	0.09	217.09	0.21	169.45	0.17
25 ~	139.19	0.13	78.75	0.08	143.22	0.13	135.59	0.13	276.13	0.25	105.86	0.10
30 ~	129.67	0.15	71.79	0.09	146.52	0.16	73.26	0.09	230.72	0.26	92.67	0.12
35 ~	176.37	0.14	60.81	0.05	149.82	0.12	69.96	0.06	216.30	0.18	76.92	0.07
40 ~	208.06	0.17	84.98	0.08	211.72	0.17	83.15	0.07	325.35	0.26	93.77	0.08
45 ~	407.31	0.31	142.13	0.12	454.56	0.34	150.56	0.12	473.98	0.35	141.03	0.11
50 ~	344.26	0.35	153.19	0.17	398.81	0.41	113.55	0.12	424.88	0.43	203.81	0.22
55 ~	266.30	0.30	127.11	0.15	342.40	0.39	105.86	0.12	511.81	0.58	140.66	0.16
60 ~	268.50	0.47	134.80	0.24	332.58	0.58	143.96	0.25	406.52	0.71	182.78	0.32
65 ~	223.81	0.62	150.11	0.38	259.97	0.69	153.77	0.37	323.39	0.82	225.50	0.53
70 ~	204.54	0.60	109.66	0.31	186.88	0.53	112.45	0.30	256.12	0.69	155.31	0.40
75 ~	151.27	0.60	107.59	0.42	174.32	0.67	82.78	0.30	206.96	0.75	172.21	0.61
80 ~	94.54	0.80	39.93	0.34	86.09	0.70	57.65	0.47	135.20	1.05	130.74	1.02
≥ 85	27.46	0.55	12.45	0.22	42.1	0.81	16.85	0.28	56.77	1.04	35.92	0.59

The disease burden of TB was concentrated in the working-age population. DALY and DALY rate of TB were higher in males than females in all three years

Abbreviations: DALY Disability-adjusted life years

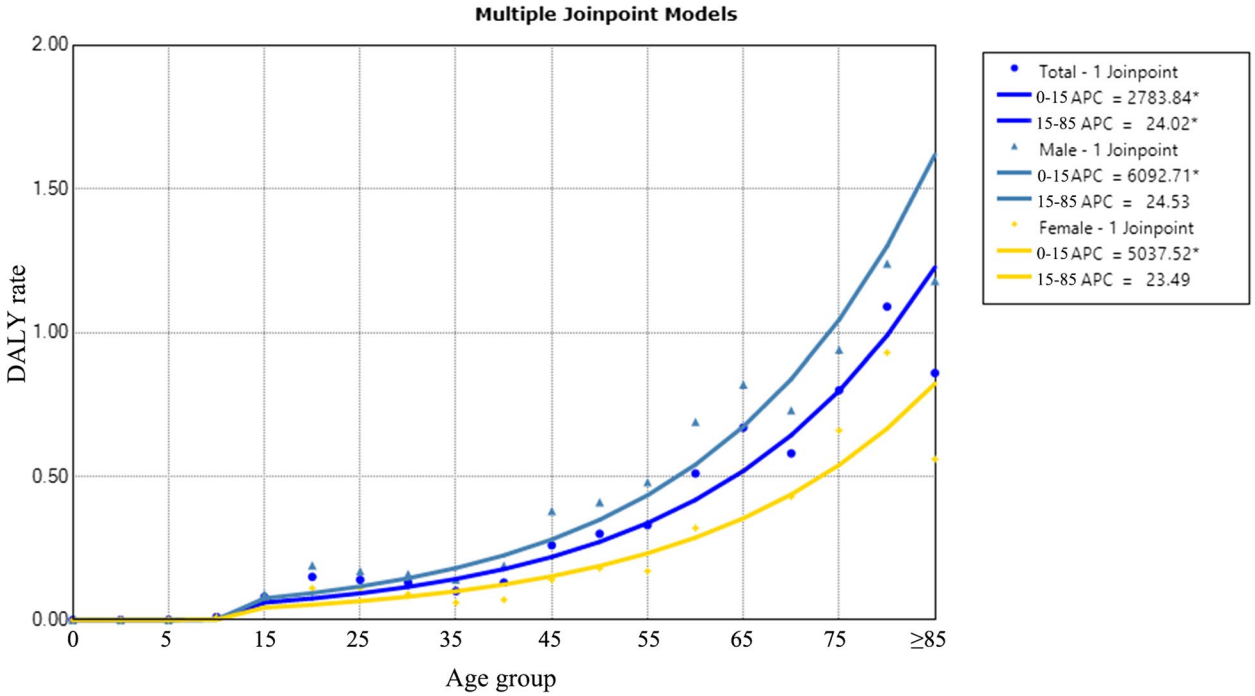

Fig. 4 Age-specific trends in TB DALYs rates in Inner Mongolia, 2016–2018. *Indicates $p < 0.05$. Total refers to life expectancy of TB eliminated for the total population, regardless of sex. The solid dot indicates a joinpoint (turning point demarking significance). DALYs rates increased with age. Abbreviations: APC, annual percentage change; DALY, disability-adjusted life years

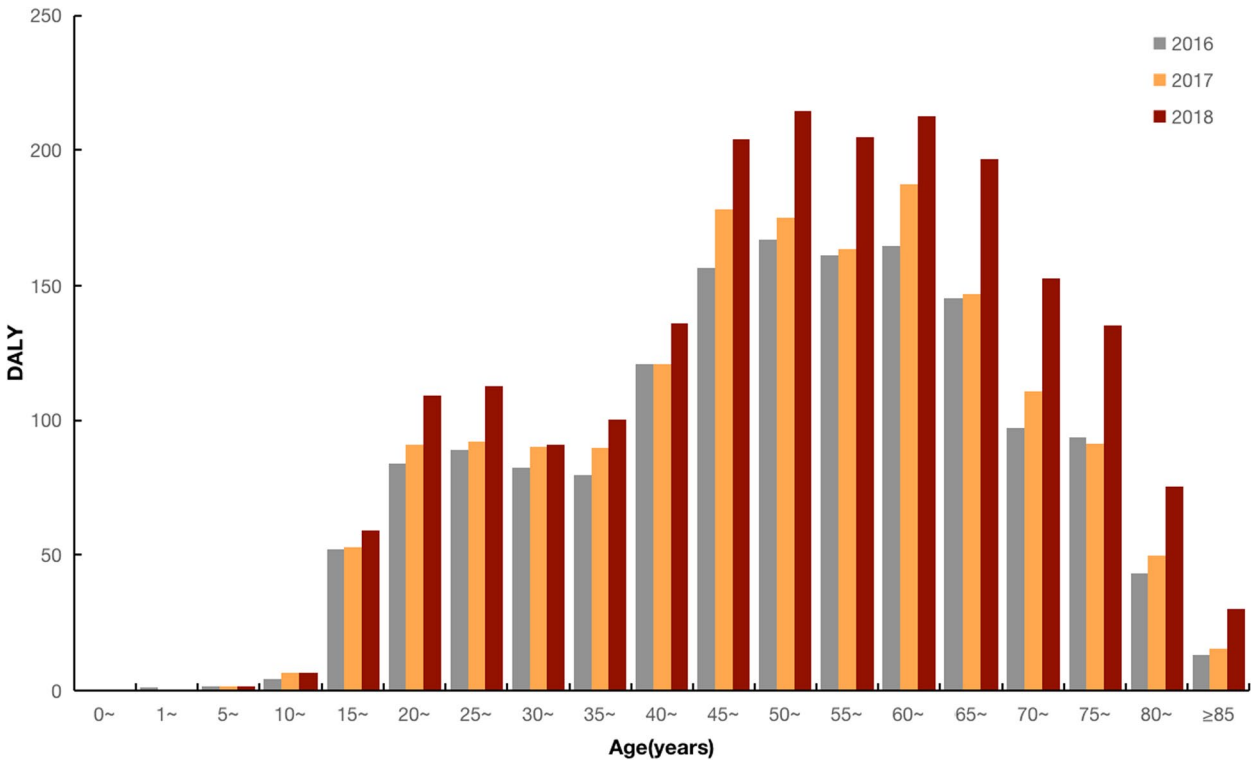

Fig. 5 Post-TB disease burden in Inner Mongolia, 2016–2018. The histogram was used to describe, different colors represent different years. The DALYs in males were higher than those in females in three years. Abbreviations: DALY, disability-adjusted life years

Table 4 Disease burden of post-TB

Age	2016				2017				2018			
	Male DALY	Male DALY rate	Female DALY	Female DALY rate	Male DALY	Male DALY rate	Female DALY	Female DALY rate	Male DALY	Male DALY rate	Female DALY	Female DALY rate
0 ~	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1 ~	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 ~	0.31	0.00	0.31	0.00	0.31	0.00	0.31	0.00	1.08	0.00	0.62	0.00
10 ~	1.55	0.00	2.79	0.00	3.41	0.01	3.10	0.01	2.79	0.00	3.72	0.01
15 ~	30.19	0.04	21.98	0.03	32.35	0.04	20.59	0.03	33.44	0.04	25.70	0.03
20 ~	55.88	0.05	28.17	0.03	56.04	0.05	34.83	0.03	65.94	0.06	43.34	0.04
25 ~	56.66	0.05	32.20	0.03	58.98	0.05	32.97	0.03	69.97	0.06	42.88	0.04
30 ~	52.32	0.05	30.19	0.03	59.60	0.06	30.50	0.03	54.49	0.05	36.38	0.04
35 ~	54.64	0.04	25.08	0.02	60.37	0.05	29.57	0.02	69.81	0.05	30.65	0.03
40 ~	85.76	0.06	35.29	0.03	86.84	0.07	34.06	0.03	99.38	0.08	36.53	0.03
45 ~	113.31	0.10	43.19	0.04	131.27	0.11	46.90	0.04	147.99	0.13	55.88	0.05
50 ~	117.34	0.12	49.85	0.06	128.02	0.14	47.21	0.05	158.21	0.17	56.35	0.06
55 ~	108.67	0.14	52.63	0.07	120.43	0.16	43.19	0.06	147.68	0.19	56.97	0.08
60 ~	109.44	0.22	55.42	0.12	128.02	0.26	59.75	0.12	138.55	0.28	73.84	0.15
65 ~	91.18	0.28	54.03	0.16	91.80	0.28	55.26	0.16	121.52	0.37	74.92	0.22
70 ~	59.44	0.20	37.93	0.13	65.17	0.22	45.67	0.16	90.71	0.31	62.07	0.21
75 ~	55.73	0.30	37.77	0.21	58.51	0.31	32.97	0.18	80.50	0.43	54.80	0.30
80 ~	28.02	0.33	15.17	0.19	30.96	0.36	18.73	0.23	41.02	0.48	34.21	0.42
≥ 85	8.51	0.24	4.80	0.12	9.60	0.27	6.04	0.16	19.66	0.55	10.84	0.28

The age-specific post-TB DALYs were mainly concentrated in the 40–79 age group. DALY and DALY rate of post-TB were higher in males than females in all three years

Abbreviations: DALY Disability-adjusted life years

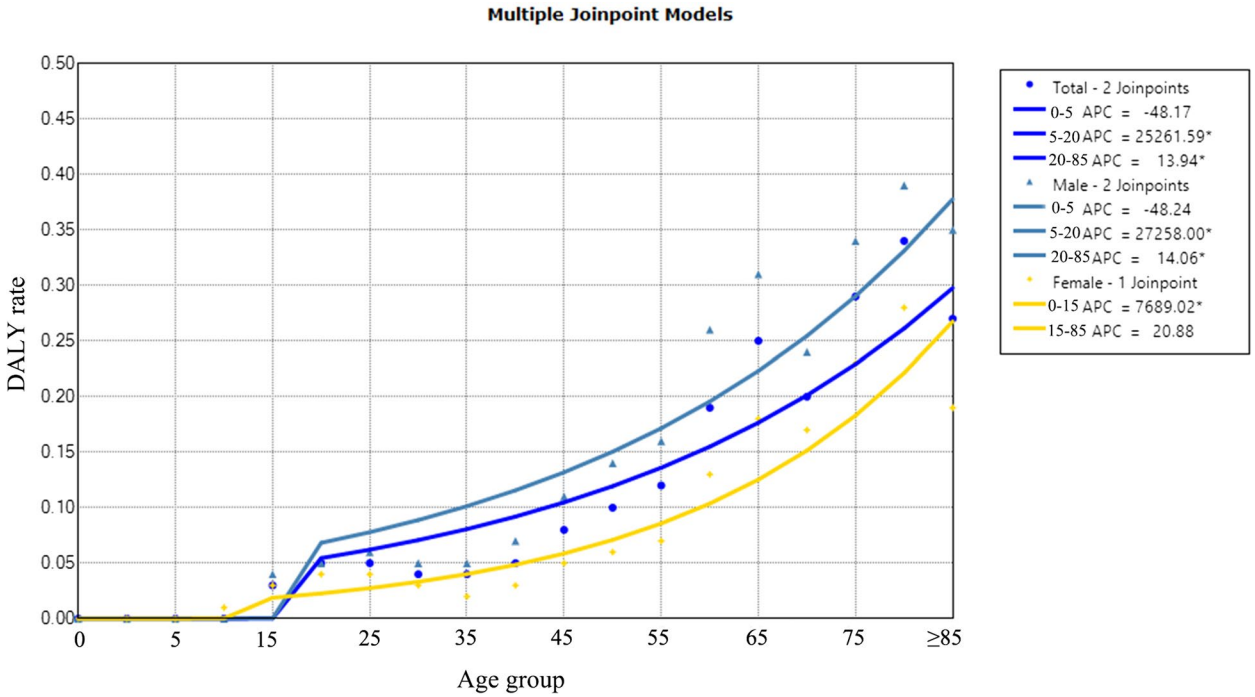

Fig. 6 Age-specific trends in post-TB DALYs rates in Inner Mongolia, 2016–2018. *Indicates $p < 0.05$. Total refers to life expectancy of TB eliminated for the total population, regardless of sex. Post-TB DALYs rates increased with age, DALYs rates were lower in males than females before age 20 and increased steeply in males after age 20. The solid dot indicates a joinpoint (turning point demarking significance). Abbreviations: APC, annual percentage change; DALY, disability-adjusted life years

0.77/100,000 in 2016–2018, higher than that in Zhejiang province (0.19/100,000) [23]. During the same period, the TB incidence in China showed a decreasing trend [24], but our results showed an increasing trend in Inner Mongolia, and the reported incidence of TB was higher in the eastern regions than in the central and western regions. The phenomenon may be related to the lack of knowledge about the transmission and symptoms of TB among the population in Inner Mongolia. The eastern region of Inner Mongolia is agricultural and pastoral area with relatively poor health care resources, where the residents had an insufficient understanding of TB and poor prevention abilities. Furthermore, there was a lack of health care resources. Therefore, it is difficult for people to get treatment in early infection stage [25–27]. In our study, life expectancy after the elimination of TB from 2016 to 2018 increased 0.53, 0.48, and 0.46 years, respectively. Wang et al. reported that the combined loss of life expectancy due to TB in China was 0.11 years [28]. Our study results were higher than those reported by Wang et al., indicating that TB prevention and control in Inner Mongolia was severe.

The total DALYs due to TB in our study consisted of two components: TB and post-TB DALYs. Our study showed that from 2016 to 2018, there were 5923.33, 6258.03, and 8194.38 person-years of DALYs caused by TB and post-TB, with the burden increasing year by year. Moreover, the burden of males was higher than that of females. Poor behavioral habits, such as smoking and drinking more, are prevalent in male patients with TB, and biological gender and high tolerance lead to delayed access to treatment [29–31].

What's more, we found that YLD of TB accounted for 86.49% of DALYs from 2016 to 2018, and YLD was the major source of the TB disease burden, consistent with Hunan Province and Korea [32, 33]. YLD represents the loss of life due to disease. In our study, YLD meant that patients survived with disability due to TB and lost part of their healthy life. Chinese immunization planning policy requires Bacillus Calmette Guerin (BCG) vaccination during the first 24 h of the neonatal [34]. The duration of protection of the BCG vaccine is usually less than 20 years, and the effectiveness of protection decreased with age [35, 36]. The age-specific analysis in our study showed that the DALYs rate of TB increased from the age of 15 years in this study, which may associate with the immunization program policy. Our results showed that the population above 15 years, the working-age population, and the elderly were the major part of the whole population for TB DALYs. The seventh census

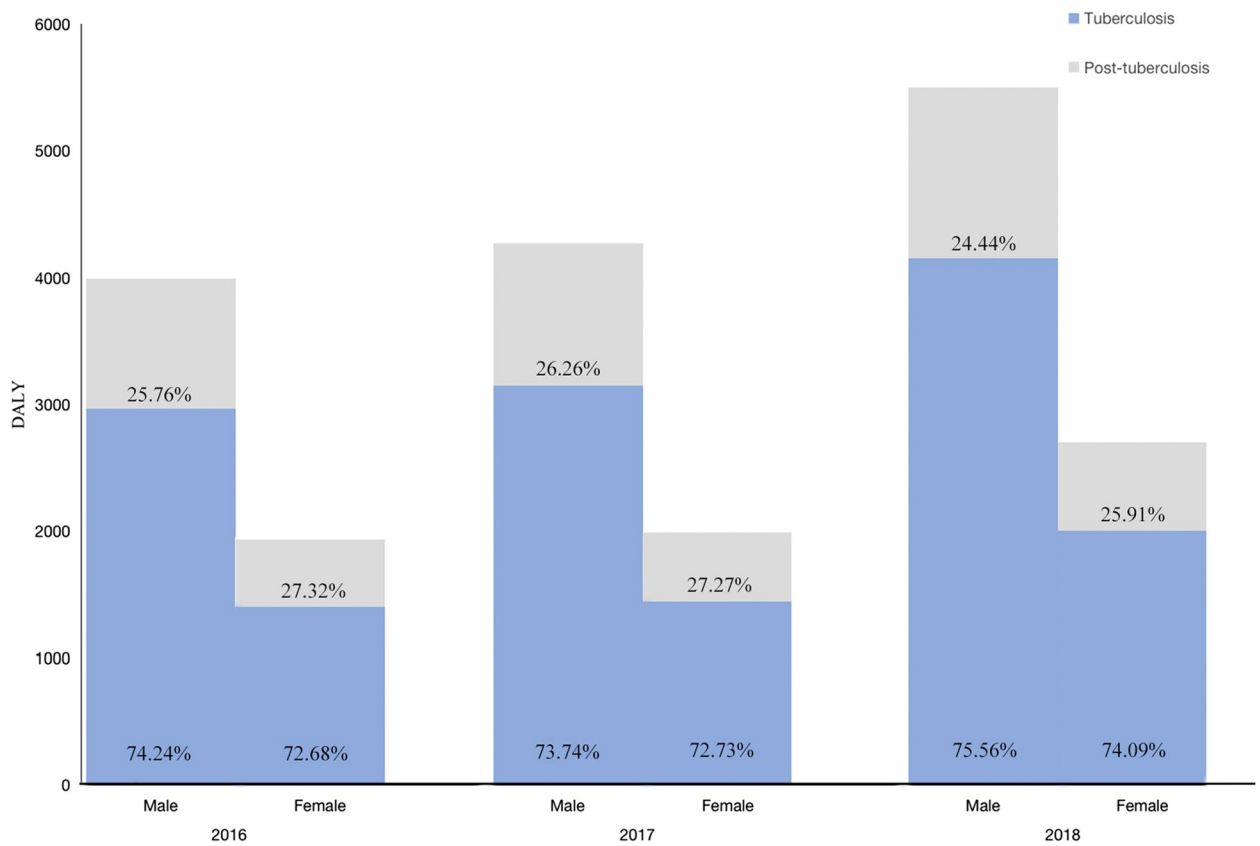

Fig. 7 DALYs in TB and post-TB in Inner Mongolia, 2016–2018. Total DALYs with the highest DALYs in 2018. DALYs in post-TB accounted for 25.82% of the total DALYs of TB and post-TB in 2016–2018. Abbreviations: DALY, disability-adjusted life years

of China showed that the population over 65 years old accounted for 13.5% of the total population [37, 38]. The elderly is prone to TB than the younger due to weakened immune system, insufficient nutrient intake, high incidence of chronic diseases, and high prevalence of bad habits (such as smoking and alcohol consumption) [3, 39]. Once infected with TB, the elderly is prone to respiratory complications (e.g., pulmonary infections and COPD) and pathological changes (e.g., lung tissue injury and bronchial dilatation), making TB treatment more difficult [40, 41]. An aging society leads to a decline in the working-age population. When the working-age population infected with TB, the TB symptoms are untypical attributed to strong immune system. Therefore, most young patients with TB fail to receive formal treatment in early infection stage [42]. Previous studies focused on deaths caused by nutrition-deficiency diseases, non-communicable diseases, and injury in the working-age population while neglecting the burden caused by TB [43–45]. However, the working-age population is a major component of social development. When suffering from TB, the work capacities immunity of them would decrease significantly, which would increase the burden on economy and society [46]. Elderly patients with TB always accompanied by low nutrition and poor immunity, leading to delayed lung tissue and airway repair, aggravated lung injury, and increased disease burden due to post-TB [47, 48]. Therefore, it is necessary to focus on the incidence and treatment of TB, and the occurrence of post-TB diseases in TB-curing patients in the working-age and elderly population.

Prior to our study, an Indian study showed that if the impact of post-TB was considered, the disease burden of TB in India would increase by 6.1 million DALYs in 2018 [49]. Menzies NA et.al also pointed out that the disease burden of post-TB accounted for 47% of the total burden, including post-TB [5]. A study pointed out that the global disease burden due to COPD caused by TB was 5.91 million person-years [50], and the global TB disease burden was 45 million person-years during the same period [51], which meant that the disease burden due to COPD caused by TB accounted for 11.8% of the TB disease burden. Although our study only estimated the disease burden of post-TB caused by COPD, the results showed that the disease burden of post-TB accounted for 26.86% of the total disease burden due to TB, higher

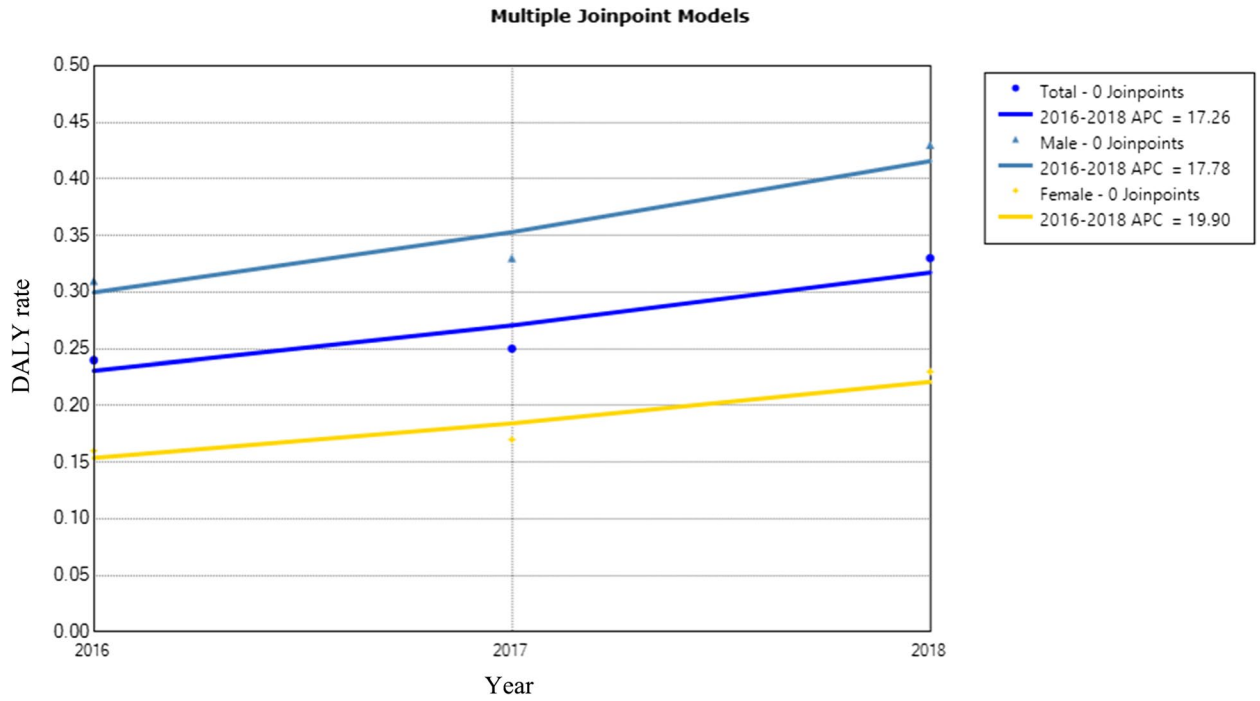

Fig. 8 Disease burden of TB and post-TB in Inner Mongolia, 2016–2018. *Indicates $p < 0.05$. Total TB and post-TB disease burden increased with years, DALYs rates of males were consistently higher than that of females. Total refers to life expectancy of TB eliminated for the total population, regardless of sex. The solid dot indicates a joinpoint (turning point demarking significance). Abbreviations: APC, annual percentage change

than the results of the above study. The comparison indicates that the burden of post-TB in Inner Mongolia was heavy. China has increased its efforts to screen for TB [52], but the focus is still on prevention and treatment while neglecting the follow-up of cured patients with TB. Although TB control focused on cutting off the transmission and curing patients, the completion of TB treatment might be the beginning of the chronic respiratory disease [53]. In addition to respiratory symptoms, there was an increased morbidity and mortality of cardiovascular disease in post-patients with TB [54]. These studies suggested that, among those who have been cure of TB, except for COPD, other respiratory diseases, cardiovascular diseases, and neurological damage were also related to the disease burden of post-TB [55]. Therefore, when other systemic diseases caused by post-TB were considered, the burden of post-TB in Inner Mongolia might be significantly heavier than our results. Given the high cost and long treatment period of post-TB, International Union Against Tuberculosis and Lung Disease recommends that patients with TB be evaluated for lung as early as possible and followed up to reduce the possibility of post-TB in patients [56].

Our study was the first to estimate the burden of post-TB in remote China. In recent years, studies on the disease burden associated with TB in China have mostly focused on the economic burden perspective, neglecting the losses due to death, organic disability, and post-TB sequelae in patients with TB, resulting in an underestimation of the disease burden of TB [57–59]. In this study, the disease burden due to post-TB was considered to estimate the health loss of patients caused by TB. However, this study still has some limitations. Firstly, only the disease burden of COPD in post-TB diseases was estimated, and data on mortality of COPD in patients with TB after cure were lacking, leading to possible underestimation of post-TB burden. Furthermore, WHO has reported that about 4 million cases of TB are underreported each year globally, and the number and characteristics of underreported cases in high TB burden countries are still unclear, indicating that underreporting still exists in China. This study did not investigate the underreporting of tuberculosis, which may lead to a certain degree of TB prevalence is undervalued and the burden of TB may be further underestimated [1, 60].

Conclusion

The disease burden of TB and post-TB was heavy and increased year by year in Inner Mongolia from 2016 to 2018. The disease burden of TB increases gradually with age. Working-age and older populations, especially males,

need more attention. Policymakers should pay attention to the burden of post-TB, such as lung injury like COPD, et al. There is a pressing need to establish appropriate assessment measures and standardized follow-up to reduce the risk of TB and post-TB in remote regions with relatively poor medical resources, like Inner Mongolia.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12879-023-08375-w.

Additional file 1: Supplementary Table 1. Life expectancy in Inner Mongolia, 2016-2018.

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Authors' contributions
CJ, HZ and XW designed the study. CJ and HZ conducted the data analysis and drafted the manuscript. XW contributed to discussion and extensively reviewed and edited the manuscript. All authors (CJ, HZ, XW, YW, YZ, SL, JZ and QD) contributed to the interpretation of data and were involved revising the manuscript critically for important intellectual content. All authors have reviewed and approved the manuscript.

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Availability of data and materials
The data that support the findings of this study are available from Inner Mongolia Center for Comprehensive Disease Control and Prevention, monitoring data are credible, but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data may however be available from the authors upon reasonable request and with permission of the Inner Mongolia Center for Comprehensive Disease Control and Prevention.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

Author details
[1]Department of Health Statistics, School of Public Health, Inner Mongolia Medical University, Jinshan Development District, Hohhot, Inner Mongolia 010110, China. [2]Department of Child and Adolescent Health and Health Education, School of Public Health, Inner Mongolia Medical University, Hohhot, Inner Mongolia 010110, China. [3]Center for Data Science in Health and Medicine, School of Public Health, Inner Mongolia Medical University, Jinshan Development District, Hohhot, Inner Mongolia 010110, China.

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