Heliyon 10 (2024) e24507

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Prospective cohort study on tuberculosis incidence and risk factors in the elderly population of eastern China

Hui Jiang[a,1], Xiu Chen[b,1], Jie Lv[c], Bing Dai[a], Qiao Liu[d], Xiaoyan Ding[d], Jingjing Pan[d], Hui Ding[d], Wei Lu[d], Limei Zhu[d], Peng Lu[d,*]

[a] Department of Chronic Communicable Disease, Disease Control and Prevention of Zhenjiang City, Zhenjiang, Jiangsu Province, PR China
[b] The First Affiliated People's Hospital with Nanjing Medical University, Nanjing, Jiangsu Province, PR China
[c] Department of Chronic Communicable Disease, Disease Control and Prevention of Yangzhong City, Zhenjiang, Jiangsu Province, PR China
[d] Department of Chronic Communicable Disease, Jiangsu Provincial Center for Disease Control and Prevention, Nanjing, Jiangsu Province, PR China

ARTICLE INFO

Keywords:
Tuberculosis
Elderly tuberculosis
Incidence
Risk factor
Follow up

ABSTRACT

Background: Tuberculosis continues to be a significant public health concern in China, particularly among the elderly population. This study aimed to assess the risk factors of tuberculosis among elderly individuals in China through a cohort study, focusing on this high-risk population.
Methods: The population-based census was strategically designed to cover diverse regions and demographics across the city. The survey captured demographic and lifestyle information, as well as a clinical examination. Participants were prospectively followed up over a specified duration to monitor the incidence of tuberculosis cases.
Results: After a follow-up period of more than 7 years, 246 individuals developed tuberculosis, resulting in an incidence rate of 92.21 per 100,000 person-years (95 % CI 81.2–104.3). In multivariate analysis, the following factors were found to have significant associations with active tuberculosis. Increasing age correlated with a higher risk of active tuberculosis (AHR = 1.03 per 1-year increase in age, 95%CI: 1.01, 1.04, $P < 0.001$). Males continued to have a higher risk compared to females (HR = 2.73, 95%CI: 2.08, 3.58, $P < 0.001$). Individuals with a normal Body Mass Index (BMI) faced nearly three times higher risk compared to their obese counterparts (HR = 2.87, 95 % CI: 1.51, 5.46, $P = 0.001$). Conversely, those with an underweight BMI had a ten-fold higher risk compared to the obese group (HR = 9.89, 95 % CI: 4.92, 19.85, $P < 0.001$). Elderly individuals who quit smoking had a 1.35-fold increased risk compared to non-smokers (HR = 1.35, 95%CI: 1.12, 1.64, $P < 0.001$).
Conclusions: Tuberculosis incidence among the elderly population in China remained alarmingly high. This finding emphasizes the urgent need for implementing proactive case detection measures specifically tailored to address the specific needs of this vulnerable demographic, particularly in individuals who are male, have a history of former or current smoking, and have a low BMI. Moreover, we must not underestimate the influence of former smoking on tuberculosis risk.

* Corresponding author.
E-mail address: lpjscdc@163.com (P. Lu).
[1] Hui Jiang and Xiu Chen contributed equally to this article.

https://doi.org/10.1016/j.heliyon.2024.e24507
Received 8 August 2023; Received in revised form 4 January 2024; Accepted 10 January 2024
Available online 19 January 2024

1. Introduction

World Health Organization (WHO) estimated that around 10.6 million new tuberculosis cases were reported globally in 2021, and approximately 1.4 million people who were HIV-negative died from tuberculosis [1]. Tuberculosis continues to pose a substantial burden, and its prevalence has been decreasing slowly. Regarding tuberculosis incidence based on age, the age group between 25 and 54 years has the highest proportion of tuberculosis cases. Nevertheless, in the WHO regions of the Eastern Mediterranean, South-East Asia, and Western Pacific, the prevalence of the tuberculosis epidemic is predominantly observed among the elderly population, showing a steady rise in the notification rate with advancing age. The highest peak of tuberculosis cases occurs among individuals aged 65 years or older [2].

According to WHO's estimation, the proportion of individuals aged 60 years or older in China is projected to experience a significant rise, increasing from 12.4 % (equivalent to 168 million people) in 2010 to 28.0 % (corresponding to 402 million people) by the year 2040 [3]. Numerous studies conducted both internationally and in China have demonstrated that the risk of tuberculosis escalates with age [4–7]. In the Fifth National Prevalence Survey of tuberculosis, a significant proportion of elderly individuals were included, with 39.8 % of them being asymptomatic, and 53.2 % choosing not to seek any medical care [8]. Bele et al. identified population aging as a critical challenge in tuberculosis control in rural China. To address this issue effectively, additional tuberculosis control efforts should be targeted towards reaching the most vulnerable populations with a high priority focus [9].

In the elderly population, multiple factors contribute to making tuberculosis a distinct concern. These include age-related immunodeficiency, the possibility of compounded immunosuppression due to other coexisting age-related conditions, and potential interactions between antituberculosis drugs and other medications used to manage additional health issues. The systematic screening of high-risk groups for early tuberculosis diagnosis has demonstrated effectiveness in contributing towards the global efforts to end the tuberculosis epidemic [10]. China has implemented active screening strategies among the elderly population, which involve the use of various methods such as symptom assessment and Chest X-rays(CXR), among others, to identify cases of tuberculosis, however, due to the large population numbers in China, it is not practical to screen all elderly individuals. Nonetheless, combining age with one or more tuberculosis risk factors could help identify a higher prevalence of tuberculosis in a more targeted and concentrated population. This study presents the findings of a prospective cohort investigation aimed at examining the incidence of tuberculosis and identifying the associated risk factors in this vulnerable age group. The research provides crucial insights into tailored prevention and intervention strategies to alleviate the burden of tuberculosis among the elderly in China.

2. Materials and methods

2.1. Study population

This study was based on the utilization of basic public health services for individuals aged ≥65 years in Zhenjiang City, Jiangsu Province, during the period from January to December 2016. The government provided this service once a year, free of charge, exclusively for elderly individuals. The service included a comprehensive survey capturing demographic and lifestyle information, as well as a clinical examination that encompassed symptom inquiry, blood glucose test, lipid profile test, electrocardiogram (ECG), complete blood count (CBC), urinalysis, abdominal ultrasound examination, and other relevant tests. Moreover, individuals displaying symptoms suggestive of tuberculosis, such as persistent cough lasting for more than two weeks, coughing up blood or bloody sputum, unexplained weight loss, loss of appetite, fatigue and weakness, fever (especially in the afternoon or evening), night sweats, chest pain or discomfort, shortness of breath or difficulty breathing, and swollen lymph nodes, were also offered CXR as part of the evaluation.

In China, tuberculosis is a notifiable infectious disease, and it is mandatory to register all tuberculosis patients in the Tuberculosis Management Information System [11]. We compared two systems of service, the Tuberculosis Management Information System and the National Basic Public Health Services Information System, in Zhenjiang City to identify active tuberculosis cases. We used identification numbers to link the participants with the Tuberculosis Management Information System, and verified by consulting with a physician at the designated tuberculosis hospital in the local area. Individuals who had current tuberculosis during the screening period were excluded from the study.

2.2. Definitions

Bacteriologically diagnosed patients are those who have tested positive via methods such as sputum smear, culture, GeneXpert MTB/RIF (Xpert, Cepheid, USA), or have received a pathological diagnosis of pulmonary lesions. Clinically diagnosed cases apply to individuals who meet three of the following criteria: 1) negative sputum smear, culture, or GeneXpert MTB/RIF results, and without a pathological diagnosis of pulmonary lesions. 2) examination of CXR showing pathological changes consistent with active tuberculosis. 3) experiencing a cough and expectoration for ≥2 weeks, hemoptysis, and other suspected symptoms of tuberculosis, or having a tuberculin skin test (TST) measurement ≥10 mm, or testing positive for interferon-gamma release assay (IGRA), or positive for antituberculosis antibodies. Body mass index (BMI) is categorized as follows: 1) Underweight: BMI less than 18.5; Normal weight: BMI greater than or equal to 18.5 to 24.0; Overweight: BMI greater than or equal to 24.0 to 28.0; Obese: BMI greater than or equal to 28.0 [12]. Diabetics with well control are referred to as patients with diabetes whose Fasting Plasma Glucose (FPG) is below 7.0 mmol/L. Diabetics with worse control are referred to as patients with diabetes whose FPG is above or equal to 7.0 mmol/L. Abnormal physical examination evaluation refers to any abnormal results from physical examinations.

2.3. Statistical analysis

Categorical variables were summarized using standard 2 × 2 contingency tables, while continuous variables were summarized using the interquartile range (IQR). To compare the frequencies of categorical variables, the appropriate statistical tests, such as the Pearson Chi-square test or Fisher's exact test, were employed. Additionally, the time to incident tuberculosis among different diabetes groups was compared using Kaplan-Meier curves. The risk of active tuberculosis was assessed through binary univariable Cox proportional hazards analysis. Age was included in the model as a continuous variable. All measured characteristics were incorporated into this analysis, and hazard ratios (HR) along with 95 % confidence intervals (CIs) were calculated. Variables that showed a suggestive relationship with tuberculosis ($P < 0.1$) in the univariable analysis were individually included in the multivariable model building process.

The tuberculosis incidence was calculated as the number of cases per 100,000 person-years for the study participants. Person-years of follow-up for each individual were determined starting from the date of active tuberculosis diagnosis, death, loss to follow-up, or June 25, 2023, whichever came first. The 95 % Poisson confidence intervals were calculated around these incidence estimates, and two-sample Poisson tests were utilized to compare tuberculosis incidence rates. A p-value of less than 0.05 was considered statistically significant. The data analysis was performed using IBM SPSS Statistics software version 23.0 (IBM Corp., Armonk, NY, USA).

The population attributable fraction (PAF) is commonly defined as the reduction in the overall disease risk in a population that would occur if the specific exposure(s) of interest were completely eliminated, while keeping the distribution of other risk factors unchanged over a specified time interval [13,14]. Mathematically, the PAF can be defined as:

$$\mathrm{PAF} = (\mathrm{Pe}\ \times (\mathrm{RR}\ -\ 1))\mathrm{RR}\ -\ 1))\mathrm{Pe} \times / \ (1 + (\mathrm{Pe}\ \times (\mathrm{RR}\ -\ 1)))$$

Pe represents the proportion of the population that is exposed to the specific risk factor. RR stands for the relative risk, also known as the risk ratio, which quantifies the association between exposure to the risk factor and the likelihood of developing the disease.

2.4. Ethical approval and participant consent

The study underwent review and approval by the ethics committee at the Zhenjiang City Center for Disease Control and Prevention. Informed consent in written form was obtained from all eligible subjects. (Reference Number: Zhenjiang City Center for Disease

Table 1
Demographic characteristics of the 39,122participants, overall and by tuberculosis status.

Characteristics	All participants	Participants with tuberculosis	Participants without tuberculosis
N	39,122 (100.0)		
Median age, years (IQR)	75 (71.0, 81.0)	78 (74.0, 83.0)	75 (71.0, 81.0)
Sex			
Female	21,102 (53.9)	74 (30.1)	21,028 (54.1)
Male	1802 (46.1)	172 (69.9)	17,848 (45.9)
Median Body mass index (IQR)	23.9 (21.8, 26.0)	21.6 (19.3, 28.4)	21.8 (20.0, 23.9)
Body mass index, kg/m2			
Underweight	1521 (3.9)	40 (16.3)	1492 (3.8)
Normal	18,624 (47.6)	136 (55.3)	18,488 (47.6)
Overweight	14,689 (37.5)	60 (24.4)	14,629 (37.5)
Obese	4277 (10.9)	10 (4.1)	4267 (10.9)
Smoking status			
Non-smoker	32,780 (83.8)	182 (74.0)	32,589 (83.9)
Former smoker	457 (1.2)	10 (4.1)	447 (1.1)
Current smoker	5885 (15.0)	54 (22.0)	5831 (15.0)
Drinking status			
Non-drinker	32,905 (84.1)	191 (77.6)	32,714 (84.1)
Former drinker	90 (0.2)	1 (0.4)	89 (0.2)
Current drinker	6127 (15.7)	54 (22.0)	6073 (15.6)
Fasting Plasma Glucose	5.3 (4.8, 6.0)	5.2 (4.7, 6.0)	5.3 (4.8, 6.0)
Diabetic status			
Nondiabetics	32,825 (83.9)	204 (84.6)	32,621 (87.3)
Diabetics with well control	518 (1.3)	4 (1.6)	514 (1.4)
Diabetics with worse control	4268 (10.9)	33 (13.4)	4235 (11.3)
Exercise			
Never exercise	31,148 (79.6)	199 (80.9)	30,949 (79.6)
Exercise occasionally	2968 (7.6)	10 (4.1)	2958 (7.6)
Exercise regularly	5006 (12.8)	54 (22.0)	4969 (12.8)
Tuberculosis symptom			
No	38,777 (99.1)	241 (98.0)	38,536 (99.1)
Yes	345 (0.9)	5 (2.0)	340 (0.9)
Physical examination evaluation			
Normal	13,603 (34.8)	78 (31.7)	13,525 (34.9)
Abnormal	25,395 (65.2)	168 (68.3)	25,217 (65.1)

Control and Prevention [2023] No. 005).

3. Result

3.1. Demographic characteristics

After excluding 10 current tuberculosis patients, a total of 39,122 elders aged ≥65 years participated in the screening. Approximately half of them were males (46.1 %). 3.9 % were classified as underweight, 47.6 % fell into the normal weight range, 37.5 % were overweight, and 10.9 % were considered obese. Among the participants, 16.2 % were smokers, with 7.2 % having successfully quit smoking. Additionally, 15.9 % reported having consumed alcohol either in the past or currently. The prevalence of diabetes was found to be 12.2 % among the elderly individuals. Around one-fifth of the participants reported engaging in regular exercise. Furthermore, 0.9 % exhibited symptoms suggestive of tuberculosis. Notably, 65.2 % of the individuals' health examinations showed abnormal results (Table 1).

3.2. Development of active tuberculosis

After a follow-up period of more than 7 years, 246 individuals developed tuberculosis, resulting in an incidence rate of 92.21 per 100,000 person-years (95 % CI 81.2–104.3). Among them, 126 (51.2 %) individuals tested positive for the tuberculosis pathogen, and 10 (4.1 %) were diagnosed with tuberculous pleurisy.

The incidence rate was significantly higher among males at 140.2 per 100,000 person-years compared to females, whose rate was 51.4 per 100,000 person-years. Moreover, individuals with underweight exhibited the highest incidence rate at 390.3 per 100,000 person-years, whereas those with obese had a significantly lower rate of 34.1 per 100,000 person-years.

Additionally, elders who quit smoking showed a fourfold higher risk of developing tuberculosis compared to those who never smoked, and a nearly three-fold higher risk compared to those who continued smoking (390.3 versus 134.4 versus 81.4 per 100,000 person-years) (Table 2).

3.3. Risk factors for developing active tuberculosis among the elderly include

In univariate analysis, several factors were found to be associated with the development of active tuberculosis among the elderly. Advanced age (HR = 1.04, 95%CI: 1.02, 1.05, $P < 0.001$) was linked to an increased risk of developing active tuberculosis. Male gender (HR = 2.73, 95%CI: 2.08, 3.58, P < 0.001) were found to have a higher risk compared to females. Individuals with a normal BMI (HR = 11.67, 95%CI: 5.84, 23.34, $P < 0.001$) had a significantly elevated risk of active tuberculosis. Those with an underweight BMI (HR = 3.18, 95%CI:1.67, 6.05, $P < 0.001$) also showed a substantially increased risk. Elderly individuals who quit smoking had a higher risk compared to non-smokers (HR = 3.97, 95%CI: 2.10, 7.50, $P < 0.001$) and those who continued smoking also had an elevated risk (HR = 1.64, 95%CI: 1.21, 2.23, $P = 0.001$). Engaging in occasional exercise was associated with a reduced risk (HR = 0.53,95%CI: 0.28, 0.99, $P = 0.047$), and Having symptoms of tuberculosis showed a trend towards an increased risk (HR = 2.37, 95%CI: 0.98, 5.75, $P = 0.056$).

In multivariate analysis, the following factors were found to have significant associations with active tuberculosis. Increasing age correlated with a higher risk of active tuberculosis (AHR = 1.03 per 1-year increase in age, 95%CI: 1.01, 1.04, $P < 0.001$). Males continued to have a higher risk compared to females (HR = 2.73, 95%CI: 2.08, 3.58, $P < 0.001$) (Table 3 and Fig. 1).

Individuals with a normal BMI faced nearly three times higher risk compared to their obese counterparts (AHR = 2.87, 95 % CI: 1.51, 5.46, $P = 0.001$). Conversely, those with an underweight BMI had a ten-fold higher risk compared to the obese group (AHR = 9.89, 95 % CI: 4.92, 19.85, $P < 0.001$). Elderly individuals who quit smoking had a 1.35-fold increased risk compared to non-smokers

Table 2
Tuberculosis incidence among participants according to baseline.

Character	Events (n)	Observation Time Person-Years	Rate per 100 Thousand Person-years	95 % Confidence Interval
All Participants	246	266,782	92.2	81.2, 104.3
Sex				
Female	74	144,099	51.4	40.6, 64.1
Male	172	122,684	140.2	120.4, 162.4
Body mass index, kg/m2				
Underweight	40	10,249	390.3	182.6, 526.2
Normal	136	126,773	107.3	90.4, 126.5
Overweight	60	100,407	59.8	46.0, 76.4
Obese	10	29,352	34.1	17.3, 60.7
Smoking status				
Non-smoker	182	223,507	81.4	70.2, 93.9
Former smoker	10	3088	323.8	164.5, 677.2
Current smoker	54	40,187	134.4	101.9, 174.0

Table 3
Risk factors for developing active tuberculosis among the 39,122participants.

Characteristics	Crude Hazard Rates	Adjusted Hazard Rates	Population attributable fraction (%)
	95 % CI, *P*-value	95 % CI, *P*-value	
Age	1.04 (1.02, 1.05), 0.001	1.03 (1.01, 1.04), 0.003	
Sex rowhead			
Female			
Male	2.73 (2.08, 3.58), 0.001	2.63 (1.95, 3.55), <0.001	42.90 %
Body mass index, kg/m2 rowhead			
Underweight	11.67 (5.84, 23.34), 0.001	9.89 (4.92, 19.85), <0.001	25.74 %
Normal	3.18 (1.67, 6.05), 0.001	2.87 (1.51, 5.46), 0.001	47.09 %
Overweight	1.76 (0.90, 3.45), 0.097	1.64 (0.84, 3.21), 0.147	
Obese			
Smoking status rowhead			
Non-smoker			
Former smoker	3.97 (2.10, 7.50), 0.001	2.35 (1.21, 4.58), 0.012	1.59 %
Current smoker	1.64 (1.21, 2.23), 0.001	1.00 (0.70, 1.42), 0.985	
Drinking statusrowhead			
Non-drinker			
Former drinker	1.94 (0.27, 13.80), 0.510	0.72 (0.10, 5.30), 0.745	
Current drinker	1.50 (1.11, 2.03), 0.009	0.97 (0.69, 1.38), 0.875	
Fasting Plasma Glucose	1.00 (0.99, 1.01), 0.848		
Diabetic status rowhead			
Nondiabetics			
Diabetics with well control	1.26 (0.47, 3.38), 0.651		
Diabetics with worse control	1.22 (0.84, 1.76), 0.298		
Exercise rowhead			
Never exercise			
Exercise occasionally	0.53 (0.28, 0.99), 0.047	0.56 (0.30, 1.06), 0.074	
Exercise regularly	1.17 (0.83, 1.67), 0.371	1.17 (0.82, 1.66), 0.386	
Tuberculosis symptom rowhead			
No			
Yes	2.37 (0.98, 5.75), 0.056	1.98 (0.82, 4.82), 0.131	
Physical examination evaluation rowhead			
Normal			
Abnormal	1.11 (0.85, 1.45), 0.453		

(HR = 1.35, 95%CI: 1.12, 1.64, $P < 0.001$) (Table 3 and Fig. 1). After conducting a dose-response analysis on smoking, we identified the smoking amount as a risk factor for active tuberculosis. However, no statistically significant difference was observed (AHR = 1.00, 95 % CI: 0.99, 1.02, $P = 0.742$) (Supplement Table).

Population attributable factors to tuberculosis incidence among elderlies followed up.

PAFs were calculated for four risk factors, as presented in Table 3. Among the risk factors analyzed, BMI with normal showed the highest PAF at 47.1 %, followed by male gender at 43.0 %, BMI with underweight at 25.7 %, and quitting smoking at 1.6 %(Table 3).

4. Discussion

In our extensive population cohort study, we made a crucial observation regarding tuberculosis incidence among the elderly population in China – it remained alarmingly high. This finding further emphasizes the utmost importance of implementing proactive case detection measures specifically tailored to address the needs of this vulnerable demographic. In addition to the concerning high incidence of tuberculosis among the elderly in China, our study revealed several key risk factors associated with developing tuberculosis disease in this population. Specifically, being male, having a history of former or current smoking, and having a low BMI emerged as significant risk factors. These findings underscore the importance of targeted interventions and preventive strategies for individuals with these risk factors to curb the impact of tuberculosis in the elderly community.

Tuberculosis incidence serves as a crucial epidemiological metric to evaluate the impact of tuberculosis within a specific region or country and monitor temporal variations in disease occurrence. Elevated tuberculosis incidence rates serve as a compelling indicator of the substantial public health burden, necessitating focused efforts and interventions to effectively control and prevent the transmission of the disease. Tuberculosis incidence is not only a vital epidemiological measure but also a critical gauge of the effectiveness of control strategies implemented at the country level, as outlined in the End Tuberculosis Strategy by the WHO [10,15]. Monitoring tuberculosis incidence allows for the assessment of progress towards achieving the ambitious goals set by the End Tuberculosis Strategy, aiding in the evaluation of the success of interventions aimed at reducing tuberculosis transmission, improving diagnosis, and enhancing access to appropriate treatment and care. The incidence rates of tuberculosis among elderly populations varied significantly between countries with high and low tuberculosis burden. For individuals aged 65 years and above, the reported average annual incidence rate of tuberculosis disease was 10.9 per 100,000 in the United States and 11.2 per 100,000 in Germany, as found in the reviewed literature [16,17]. In India, the tuberculosis notification rates for females and males were 81 and 305 per 100,000, respectively, as reported in the reviewed literature [18]. In South Africa, the reviewed literature reported an incidence rate of tuberculosis among individuals aged

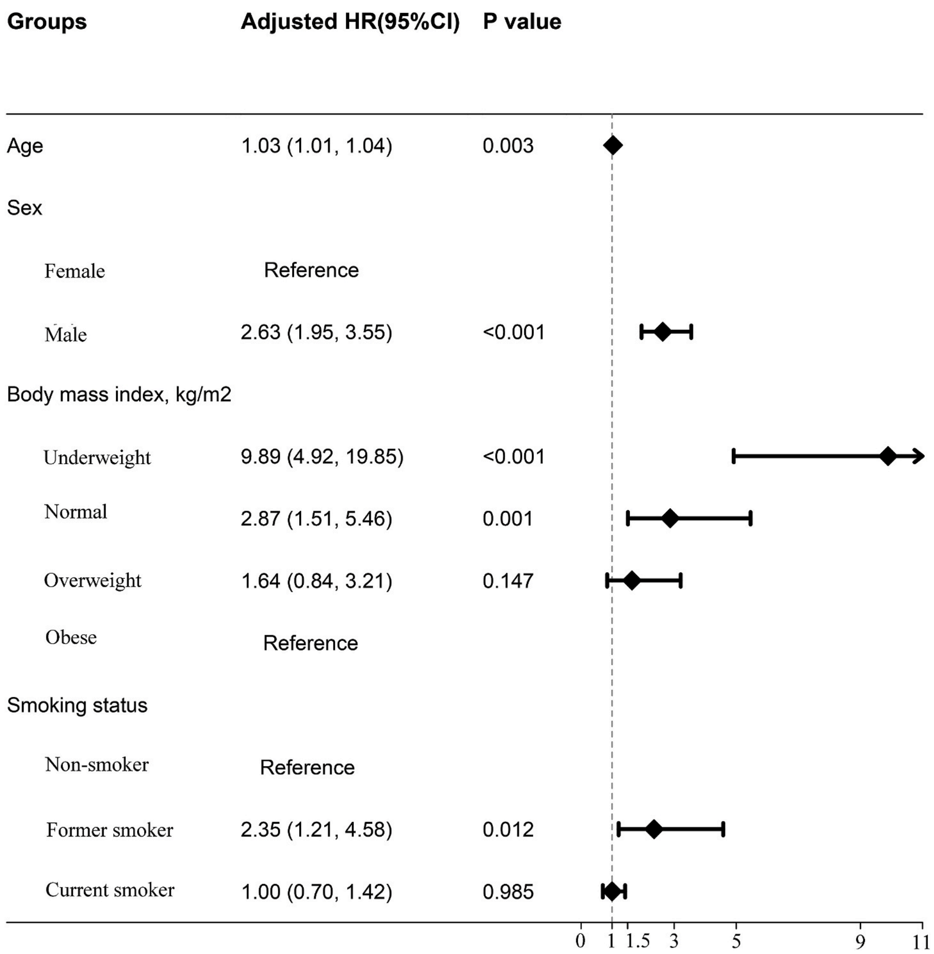

Fig. 1. Forest plot of risk factors for developing active tuberculosis among the 39,122 participants.

65 years and older, ranging from 518 to 684 per 100,000 for males and from 193 to 314 per 100,000 for females [19]. In our study, the tuberculosis incidence rate among the elderly population was found to be 92.21 per 100,000 person-years. Interestingly, this rate was lower compared to an eight-year follow-up study conducted in Taiwan, which reported an incidence rate of 175.5 [20]. Furthermore, our study's tuberculosis incidence rate among the elderly population, which stood at 92.21 per 100,000 person-years, was notably lower than the rate reported in the study conducted by Jun Cheng et al., in 2013. Their two-year follow-up study recorded an incidence rate of 481.8 per 100,000, indicating a significant disparity between the two findings [21]. One contributing factor to the lower tuberculosis incidence in our study was the significant advancement in tuberculosis control achieved in China, resulting in a rapid decrease in incidence rates. Additionally, the tuberculosis incidence in Jiangsu Province, where our study was conducted, was notably lower at approximately 30 per 100,000 compared to the national average in China. Furthermore, our study's use of the Tuberculosis Management Information System to identify active tuberculosis cases might have led to an underestimation of the true incidence rate. This is because the information system may not capture all cases, especially those in remote or underserved areas, potentially resulting in an incomplete representation of the actual tuberculosis burden among the elderly population [12]. These figures highlight the significant gender disparity in tuberculosis incidence within this age group.

In our study, we identified several robust risk factors for tuberculosis disease, which were consistent with findings from previous research. Male sex [22,23], low BMI [21,24,25] and a history of former or current smoking [26,27] were among the significant risk factors associated with tuberculosis incidence.

Notably, we observed that males had a considerably higher tuberculosis risk compared to females, with a risk that ranged from 2 to 5 times greater. This gender disparity aligns with the findings of previous studies and emphasizes the need for targeted interventions to address the specific vulnerabilities faced by man in relation to tuberculosis. Another interesting finding is that it's obvious that smoking increased the risk of tuberculosis, however former smoker showed higher RR value. There are several possible reasons that might have influenced the results in our study. Firstly, the relatively small sample size could have led to an overestimation of the factors associated with tuberculosis disease. A larger sample size would provide more precise estimates and reduce the potential for bias. Secondly, some participants who were currently smoking might have mistakenly provided information indicating that they had quit smoking. This misclassification could have affected the accuracy of the smoking-related risk factor analysis. Thirdly, we observed that the former smoker group had a higher proportion of participants who underwent physical examinations. This differential in evaluation could introduce bias in the analysis of tuberculosis risk factors, as individuals with more health concerns may have been more likely to report their smoking history accurately. Taking these factors into consideration, we acknowledge the need for cautious interpretation of the results and recommend that future studies address these limitations to obtain more robust and accurate insights into tuberculosis risk factors among the elderly population.

Our study had several notable limitations that should be acknowledged. Firstly, all the factors we considered were derived solely from the baseline survey, and we did not assess the potential influence of dynamic changes over time. This lack of longitudinal data may have limited our ability to capture changes in risk factors and their impact on tuberculosis incidence among the elderly population.

Additionally, the method we employed for data collection relied solely on referring to the Center for Disease Control and Prevention databases from Zhenjiang City. Consequently, individuals who participated in our study but later moved out of Zhenjiang City and developed tuberculosis might not have been identified in the follow-up period. This could have led to an underestimation of the true tuberculosis incidence and potential misrepresentation of the overall risk factor associations.

Additionally, certain individual characteristics such as exercise, drinking status, and smoking status were self-reported, potentially influencing the direction of the hazard ratio. However, it's important to note that these errors are more likely to result in non-differential misclassification, tending to nullify the association between factors and active tuberculosis. In light of these limitations, it is essential to interpret our findings with caution and recognize the need for more comprehensive approaches in future research to account for dynamic changes over time and track participants even if they relocate. By addressing these limitations, we can improve the validity and generalizability of our study results and contribute to a better understanding of tuberculosis risk factors in the elderly population.

5. Conclusions

In summary, our study made a crucial and concerning observation regarding tuberculosis incidence among the elderly population in China – it remains alarmingly high. This finding emphasizes the urgent need for implementing proactive case detection measures specifically tailored to address the specific needs of this vulnerable demographic, particularly in individuals who are male, have a history of former or current smoking, and have a low BMI. Moreover, we must not underestimate the influence of ex-smoking on tuberculosis risk.

Addressing these identified risk factors is essential for effective tuberculosis control among the elderly in China. By implementing targeted interventions and raising awareness about the importance of early detection and timely treatment, we can work towards reducing the burden of tuberculosis and improving the overall health and well-being of the elderly population. Our study underscores the significance of continued efforts in tuberculosis prevention and management, especially in this high-risk group, to ensure a healthier future for all.

Data availability statement

Data will be made available on request.

Funding

The work was supported by "National Natural Science Foundation of China" [grant numbers: 82003516] and "Jiangsu Provincial Medical Key Discipline" [grant numbers: ZDXK202250].

CRediT authorship contribution statement

Hui Jiang: Methodology, Investigation, Data curation, Conceptualization. **Xiu Chen:** Writing – review & editing, Methodology, Formal analysis, Conceptualization. **Jie Lv:** Investigation, Data curation, Conceptualization. **Bing Dai:** Investigation. **Qiao Liu:** Supervision, Investigation, Funding acquisition. **Xiaoyan Ding:** Investigation. **Jingjing Pan:** Investigation. **Hui Ding:** Investigation. **Wei Lu:** Validation, Supervision, Project administration, Investigation, Conceptualization. **Limei Zhu:** Supervision, Project administration, Methodology, Conceptualization. **Peng Lu:** Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

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.

Acknowledgments

The authors thank all investigators from the Jiangsu Provincial Center for Disease.

Control and Prevention, Center for Disease Control and Prevention Zhenjiang City and the First Affiliated People's Hospital with

Nanjing Medical University.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e24507.

References

[1] World Health Organization, Global tuberculosis report. https://www.who.int/publications/i/item/9789240061729, 2022.
[2] P. Caraux-Paz, et al., Tuberculosis in the elderly, J. Clin. Med. (24) (2021) 10.
[3] Organization, WHO, *World Health Organization China country assessment report on ageing and health*.https://www.who.int/publications-detail-redirect/9789241509312.
[4] V.K. Chadha, et al., Prevalence of pulmonary tuberculosis among adults in a rural sub-district of South India, PLoS One 7 (8) (2012) e42625.
[5] N.B. Hoa, et al., National survey of tuberculosis prevalence in Viet Nam, Bull. World Health Organ. 88 (4) (2010) 273–280.
[6] I. Law, et al., The first national tuberculosis prevalence survey of Lao PDR (2010-2011), Trop. Med. Int. Health 20 (9) (2015) 1146–1154.
[7] L. Wang, et al., Tuberculosis prevalence in China, 1990-2010 a longitudinal analysis of national survey data, Lancet 383 (9934) (2014) 2057–2064.
[8] Y. Wang, et al., Data compilation of the fifth national tuberculosis epidemiological sampling survey. Beijing, Military Medical Science Publishing House (2011) 31–32.
[9] S. Bele, et al., Population aging and migrant workers: bottlenecks in tuberculosis control in rural China, PLoS One 9 (2) (2014) e88290.
[10] M. Uplekar, et al., WHO's new end TB strategy, Lancet 385 (9979) (2015) 1799–1801.
[11] Q. Liu, et al., Yield and efficiency of a population-based mass tuberculosis screening intervention among persons with diabetes in Jiangsu Province, China, Clin. Infect. Dis. 77 (1) (2023) 103–111.
[12] P. Lu, et al., Predictors of discordant tuberculin skin test and QuantiFERON-TB gold in-tube results in eastern China: a population-based, cohort study, Clin. Infect. Dis. 72 (11) (2021) 2006–2015.
[13] B. Rockhill, B. Newman, C. Weinberg, Use and misuse of population attributable fractions, Am. J. Publ. Health 88 (1) (1998) 15–19.
[14] C. Poole, A history of the population attributable fraction and related measures, Ann. Epidemiol. 25 (3) (2015) 147–154.
[15] K. Avilov, et al., An approach to estimating tuberculosis incidence and case detection rate from routine notification data. The International Journal of Tuberculosis and Lung Disease 19 (3) (2015) 288–294.
[16] N.S. Hochberg, C.R. Horsburgh Jr., Prevention of tuberculosis in older adults in the United States: obstacles and opportunities, Clin. Infect. Dis. 56 (9) (2013) 1240–1247.
[17] B. Hauer, et al., Tuberculosis in the elderly in Germany, Eur. Respir. J. 38 (2) (2011) 467–470.
[18] W.W. Yew, et al., Epidemiological, clinical and mechanistic perspectives of tuberculosis in older people, Respirology 23 (6) (2018) 567–575.
[19] A. Nanoo, et al., Nationwide and regional incidence of microbiologically confirmed pulmonary tuberculosis in South Africa, 2004–12: a time series analysis, Lancet Infect. Dis. 15 (9) (2015) 1066–1076.
[20] Y.-F. Yen, et al., Influenza vaccination and incident tuberculosis among elderly persons, Taiwan, Emerg. Infect. Dis. 24 (3) (2018) 498.
[21] J. Cheng, et al., Incidence and risk factors of tuberculosis among the elderly population in China: a prospective cohort study, Infectious Diseases of Poverty 9 (1) (2020) 64–76.
[22] K.C. Horton, et al., Sex differences in tuberculosis burden and notifications in low- and middle-income countries: a systematic review and meta-analysis, PLoS Med. 13 (9) (2016) e1002119.
[23] N.S. Hochberg, C.R. Horsburgh Jr., Prevention of tuberculosis in older adults in the United States: obstacles and opportunities, Clin. Infect. Dis. 56 (9) (2013) 1240–1247.
[24] K. Lönnroth, et al., A consistent log-linear relationship between tuberculosis incidence and body mass index, Int. J. Epidemiol. 39 (1) (2010) 149–155.
[25] A. Tverdal, Body mass index and incidence of tuberculosis, Eur. J. Respir. Dis. 69 (5) (1986) 355–362.
[26] K. Slama, et al., Tobacco and tuberculosis: a qualitative systematic review and meta-analysis, Int. J. Tubercul. Lung Dis. 11 (10) (2007) 1049–1061.
[27] H.H. Lin, M. Ezzati, M. Murray, Tobacco smoke, indoor air pollution and tuberculosis: a systematic review and meta-analysis, PLoS Med. 4 (1) (2007) e20.