Citation: ZHANG Hui, CHENG Jun, YU Yan-ling, SHEN Xin, LU Wei, WANG Xiao-meng, YAO Yu-xia, HOU Shuang-yi, LI Jian-wei, ZHAO Jin-ming, XIA Lan, XU Lin, ZHANG Can-you, ZHAO Fei, XIA Yin-yin, CHEN Hui, WANG Li-xia. Evaluation of the effectiveness of community-based pulmonary tuberculosis active case-finding among key populations: a multicenter prospective cohort study [J], Chinese Journal of Antituberculosis, 2021 (12).

Evaluation of the effectiveness of community-based pulmonary tuberculosis active case-finding among key populations: a multicenter prospective cohort study

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13. Chinese Journal of Antituberculosis

Abstract: Objective: To evaluate the implementation effectiveness of community-based pulmonary tuberculosis (PTB) active case-finding (ACF) interventions among key populations. Methods: A multi-center prospective cohort study was conducted in 2013–2015 among five key populations of tuberculosis (1. residents aged 65 and above; 2. residents with diabetes mellitus; 3. residents with HIV/AIDS; 4. residents with a history of TB; and 5. close contacts of active PTB patients) in selected 27 townships/communities in 10 provincial-level regions located in eastern, central and western regions of China. TB health promotion and education, TB symptom screening, and chest X-ray examination were carried out annually. The sensitivity and specificity of different screening approaches, the effectiveness of ACF among different key populations, and factors that influenced ACF contributions were analyzed. Results: During 2013–2015, the intervention coverage of health education and TB symptom screening were 97.8% (42,684/43,654), 91.2% (41,732/45,768), and 88.1% (42,441/48,178), respectively; the intervention coverage of chest X-ray examination were 86.0% (37,538/43 654), 81.0% (37,070/45,768), and 75.7% (36,483/48,178), respectively. The TB key message awareness rate increased from 34.2% (73,066/213,420) in 2013 to 67.2% (142,629/212,205) in 2015, showing an upward trend year by year (Z_{trend} = 215.568, P < 0.01). The sensitivities of symptom screening only were low which could find 11.6% (69/596) of TB cases by using national TB control program defining symptoms and 11.7% (70/596) by using symptoms defined by this study, while specificities were quite high (99.1% (125,123/126,261) and 99.0% (125,008/126,261) respectively). The sensitivities of only using chest X-ray examination and study-defined symptom screening plus chest X-ray were both 90.7% (594/655), and the specificities were 94.2% (104 004/110 436) and 93.3% (103 062/110 436), respectively. Among all diagnosed PTB cases, 84.9% (556/655) were detected through ACF. The contribution rates of ACF in 2013, 2014, and 2015 were 95.7% (244/255), 81.0% (200/247), and 73.2% (112/153), respectively, showing a downward trend year by year (Z_{trend} = –6.403, P < 0.01). The results of multi-variable analysis showed that compared with age group 15–24, the contribution rates of ACF in age group 55–64 (*OR* = 7.18; 95%*CI*: 1.59 – 32.39) and age group ≥ 65(*OR* = 13.52; 95%*CI*: 3.31–55.16) were higher; compared with the eastern region, the contribution rate of ACF in the western region (*OR* = 2.44; 95%*CI*: 1.38–4.29) was higher. Conclusion: Carrying out an annual community-based ACF activity among key populations could significantly increase PTB case detection. The contribution rates of ACF were significantly higher in older people and western regions. However, they showed decreasing trends year by year in the three years' implementation phase. Therefore, whether to take ACF activities every year for the same group of people should be considered under this group's specific ACF contribution rate.

Received: 2021-09-10

Keywords: Tuberculosis, pulmonary; Population surveillance; Community-based participatory research; Intervention studies

Tuberculosis (TB) is an important public health and social issue of concern in China and globally. Back in 2013, there were 9 million new cases of TB globally each year, and China accounted for 10.9% of the global number of new cases each year [1]. In that year, 1/3 of TB patients worldwide were not detected and registered for reporting [1]. Early detection of TB patients is an essential tool in the control of the TB epidemic. Pulmonary tuberculosis active case-finding means systematic TB screening using rapid tests for people at high risk of TB who do not present to a health care facility for active consultation [2]. Compared with traditional passive patient detection measures, active detection allows for the timely diagnosis of patients at the early stages of the disease and reduces the spread of TB [2–4]. This measure has been adopted by the World Health Organization (WHO) as one of the patient-centered measures in its strategy to end the TB epidemic [5]. WHO strongly recommends systematic active TB screening for close contact with TB patients, people with HIV/AIDS and people with current or previous silica dust exposure, and recommends active screening for elderly people, diabetic patients and patients with previous TB as a high TB prevalence group in countries/regions that are in a position to do so [3]. Due to limited resources, the detection of tuberculosis patients at the community level in China is mainly a passive detection strategy led by consultation for symptoms, and active screening of key populations with TB incidence has not been fully implemented [6]. The fifth national TB epidemiological sample survey conducted in 2010 showed that the proportion of TB patients with no suspicious symptoms reached 43.1%, while the proportion of those with symptoms who did not seek timely medical care reached 53.2% [7]. Therefore, a certain percentage of patients will not be detected in time under the current strategy. This poses great difficulties for early detection, diagnosis and treatment of TB and the reduction of new infections. To improve the level of TB patient detection, this study used a prospective cohort study design to select representative areas in high-, medium-, and low-prevalence TB regions in China to conduct an intervention study aimed at improving patient detection from 2013 to 2015, so as to systematically evaluate the effectiveness of implementing community-based interventions for active patient detection in key populations with TB incidence.

1 Materials and methods

1.1 Study sites

A multicenter prospective cohort study design was adopted. Taking into account different economic conditions and TB epidemics, we used a stratified cluster sampling method to select 10 provinces (municipalities and autonomous regions) from the eastern, central and western regions of China, including Shanghai, Jiangsu, Zhejiang, Guangdong, Heilongjiang, Henan, Hubei, Sichuan, Yunnan, and Guangxi. In each province (municipality and autonomous region), one county (district) was selected based on the number of the resident population, TB registration rate, and the status of medical and health resources; in each county (district), 1–3 townships/communities were selected as study sites based on the number of population, the status of basic public health service programs, the setting of TB prevention and control network, and the situation of TB prevention and control work. The 10 provinces (municipalities and autonomous regions) selected a total of 27 study sites, including 10 townships and 17 communities.

1.2 Study subjects

The priority population with TB incidence in the resident population of the study site was used as the study population. The resident population was defined as those who had lived, worked or studied in the study site continuously for six months or more, including the registered and non-registered population.

1.2.1 Key population

(1) Elderly people aged 65 years old and above: those who reached the age of 65 years old as of September 30, 2013. (2) Known diabetic patients: those who are registered in the personal health records of the community health service center/station (village health office) or who have been previously diagnosed with diabetes upon inquiry during the on-site case survey. (3) HIV/AIDS patients: those registered with HIV/AIDS by the county (district) Center for Disease Control and Prevention. (4) Previous TB patients: all TB patients registered in the TB Management Information System from 2005 to 2012. (5) Close contacts of patients with active TB: all close contacts of patients with active TB who were under treatment or newly diagnosed during the baseline survey.

1.2.2 Inclusion criteria

(1) No active TB during the survey period; (2) No relocation plan during the follow-up observation period (within three years); and (3) Voluntary participation in this study with informed consent.

This study was reviewed and approved by the Ethics Committee of the Chinese Center for Disease Control and Prevention (No. 201322). All study subjects signed an informed consent form before the survey.

1.3 Intervention implementation

A task force consisting of standardized trained provincial, prefectural (city) and county (district) level CDC staff and doctors from township health centers, village health offices

or community health service centers (stations) conducted an annual TB active detection from 2013 to 2015. In this study, community-level active TB patient detection was based on the passive detection of regular TB patients as follows.

1.3.1 Health education

Person-to-person face-to-face health education was adopted, and verbal education was given to each study subject, and "health leaflets" and "TB prevention and control knowledge leaflets" were distributed to our subjects. The main content of the health promotion covered the TB prevention and treatment key messages, such as the transmission route of TB, major symptoms, medical facilities after the onset of symptoms, treatment and prognosis, and the national treatment and exemption policies.

1.3.2 Symptom screening and physical examination

Screening for suspicious symptoms of TB and questionnaires were administered to each study participant.

Suspicious symptoms of TB included: (1) cough and expectoration; (2) hemoptysis or bloody sputum; (3) fever; (4) chest pain; (5) night sweats; (6) loss of appetite; (7) fatigue; and (8) loss of body mass.

The questionnaire survey mainly included gender, age, occupation, education, smoking status, alcohol consumption, and history of TB exposure; and the physical examination included height and body mass measurements.

1.3.3 Chest imaging

A chest X-ray examination was performed for each study subject. The purified protein derivative (PPD) test was first performed in the priority group of <15 years old and a chest X-ray was performed for hard nodules ≥10 mm in average diameter on the PPD test or in the presence of blisters/suspicious symptoms of TB.

1.3.4 Sputum specimen examination

Three sputum specimens (morning sputum, nocturnal sputum and immediate sputum) were collected for sputum smear examination from those who met the study suspicious symptoms and abnormal chest X-ray examination, among which two sputum specimens with good properties were selected for sputum culture examination. If the study subjects had no sputum, they were subjected to an ultrasonic nebulized aspiration method to induce aspiration.

Suspicious symptoms were defined as those meeting any of the following 3 conditions within 1 month before the date of investigation: (1) cough and expectoration for ≥2 weeks; (2) hemoptysis or bloody sputum; (3) cough and expectoration for more than 1 week and less than 2 weeks with any of the following symptoms: fever, chest pain, night sweats, loss of appetite, malaise, and loss of body mass (>3 kg).

1.4 Diagnosis of TB

The diagnosis would be made by the doctor of the designated medical institution for TB at the county (district) level according to the examination results and by the Diagnostic Standards for Pulmonary Tuberculosis WS 288-2008. As for patients with suspected TB who cannot exclude inflammation, the diagnosis team would make a comprehensive judgment based on medical history, clinical manifestations, examination results and diagnostic anti-infection and anti-TB treatment. All patients with locally diagnosed pulmonary TB and suspected pulmonary TB were diagnosed by a national expert team for confirmation.

1.5 Quality control

The national-level subject group had formulated unified subject implementation plans and rules and conducted standardized training for site researchers. Before the survey, we first selected one village (about 1500–2000 study subjects) in each study site to conduct a pre-survey. The study invited a third-party agency, Westat USA, to monitor the site implementation for quality control. Members of the national-level subject team regularly visited the sites for data verification and conducted random checks on 5% of the site data.

1.6 Main analysis indicators

1.6.1 Sensitivity and specificity of different interventions

Using data from active findings in 2013, 2014 and 2015, the sensitivity and specificity of using only a national TB control program defining symptoms, symptoms defined by this study, and chest X-rays, and performing both symptoms defined by this study screening and chest X-rays were respectively analyzed based on the actual number of patients found.

1.6.2 Contribution rate of active detection

The contribution rate of active detection interventions was calculated for each year based on the sum of the number of patients passively detected at the study site during that year and the number of patients actively detected during that year.

1.7 Statistical analysis

The study data were recorded through the online data collection system Information Management System for Research on Tuberculosis Incidence and Intervention Patterns of Major Special Projects designed by the project, and the data were double recorded by dedicated personnel. SAS9.3 software was used to analyze the data and "percentages (%)" were used to describe the demographic characteristics, the awareness rate in key messages of TB prevention and control, and the contribution rate of active detection interventions. The effect of active detection strategy in the key TB population and the effect of consecutive interventions were analyzed by χ^2-test or Fisher's exact probability test and Cochran-Armitage trend test. All hypothesis tests were two-sided and $\alpha = 0.05$.

2 Results

2.1 Implementation of interventions

From 2013 to 2015, the intervention completion rates of health education and TB symptom screening were 97.8% (42,684/43,654), 91.2% (41,732/45,768) and 88.1% (42,441/48,178), respectively; and the intervention completion rates of chest X-ray were 86.0% (37,538/43,654), 81.0% (37,070/45,768) and 75.7% (36,483/48,178), respectively, as shown in Fig. 1.

2.2 Basic information on intervention subjects

In 2013, there were 320,590 resident population in the study site, of which 43,543 (13.6%) were the key populations with five types of TB incidence. Among the 42,684 key populations receiving the intervention, 37,989 (89.0%) were elderly people, 5642 (13.2%) were known diabetics, 83 (0.2%) were HIV/AIDS patients, 1684 (4.0%) were previous TB patients and 593 (1.4%) were close contacts of TB patients. The composition of the five priority population categories was essentially the same in 2014 and 2015. More details were shown in Table 1.

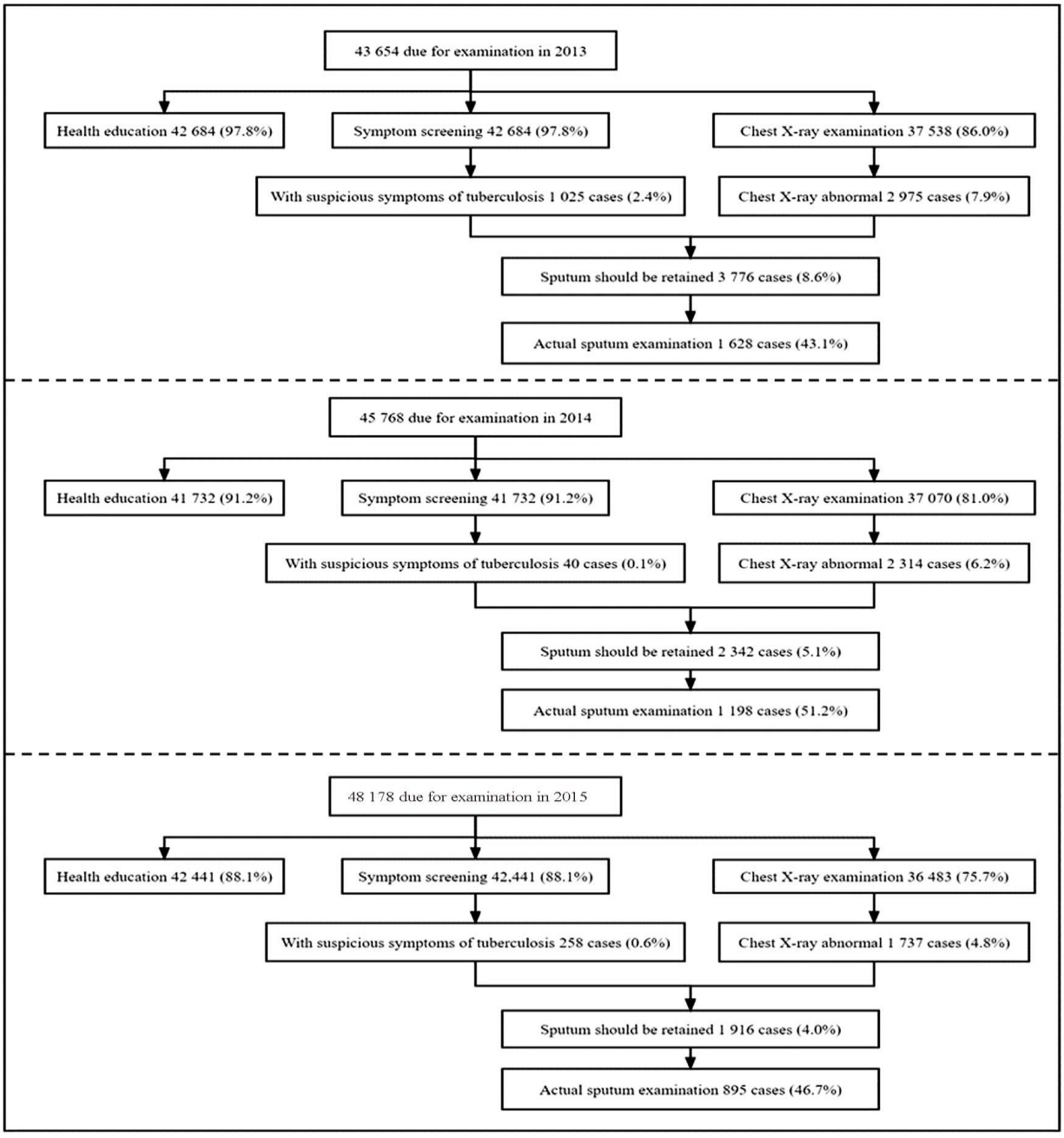

Fig. 1 Flow chart of the implementation of active TB detection interventions in key populations from 2013 to 2015

Table 1 Basic information on key populations receiving active TB detection interventions from 2013 to 2015

Characteristic	2013 (42684)	2014 (41732)	2015 (42441)
Gender			
Male	19930 (46.7)	19582 (46.9)	20020 (47.2)
Female	22754 (53.3)	22150 (53.1)	22421 (52.8)
Age group			
0–14	108 (0.3)	115 (0.3)	169 (0.4)
15–24	124 (0.3)	103 (0.3)	122 (0.3)
25–34	207 (0.5)	213 (0.5)	249 (0.6)
35–44	524 (1.2)	463 (1.1)	490 (1.2)
45–54	1326 (3.1)	1312 (3.1)	1337 (3.1)
55–64	2406 (5.6)	2313 (5.5)	2331 (5.5)
≥65	37989 (89.0)	37213 (89.2)	37743 (88.9)
Occupations			
Children, students	242 (0.6)	277 (0.7)	3519 (0.8)
Teachers	208 (0.5)	205 (0.5)	244 (0.6)
Service staff	251 (0.6)	283 (0.7)	298 (0.7)
Medical staff	88 (0.2)	95 (0.2)	105 (0.3)
Workers	1024 (2.4)	1091 (2.6)	1148 (2.7)
Farmers, herdsmen and fishermen	24468 (54.7)	24572 (58.9)	25716 (60.6)
Cadre staff	337 (0.8)	358 (0.9)	370 (0.9)
Retirees	10146 (23.8)	9911 (23.7)	9311 (21.9)
Domestic and non-working	3507 (8.2)	3441 (8.2)	3383 (8.0)
Others	1009 (2.4)	987 (2.4)	999 (2.3)
Unknown	2504 (5.8)	512 (1.2)	516 (1.2)
Education			
Illiterate or semi-literate	14306 (33.5)	14267 (34.2)	13922 (32.8)
Primary school	15006 (35.2)	15340 (36.8)	15765 (37.2)
Junior high school	6607 (15.5)	6838 (16.4)	7132 (16.8)
Senior high school or technical secondary school	3421 (8.0)	3359 (8.0)	3565 (8.4)
Junior college and above	1501 (3.5)	1535 (3.7)	1620 (3.8)
Unknown	1843 (4.3)	393 (0.9)	437 (1.0)

Continued

Characteristic	2013 (42684)	2014 (41732)	2015 (42441)
Urban orrural			
Urban	15148 (35.5)	15191 (36.4)	14648 (34.5)
Rural	27536 (64.5)	26541 (63.6)	27793 (65.5)
Region			
East	16185 (37.9)	15526 (37.2)	16451 (38.7)
Central	9479 (22.2)	9347 (22.4)	9366 (22.1)
West	17020 (39.9)	16859 (40.4)	16624 (39.2)
Smoking history			
Never smoke	34051 (79.8)	32803 (78.6)	32445 (76.4)
Past smoker	2024 (4.7)	1920 (4.6)	1889 (4.5)
Current smoking	6490 (15.2)	6449 (15.5)	6823 (16.1)
Absence	119 (0.3)	560 (1.3)	1284 (3.0)
History of alcohol consumption			
Never drank alcohol	34282 (80.3)	32854 (78.7)	32540 (76.7)
Used to drink	1556 (3.7)	1472 (3.5)	1467 (3.5)
Currently drinking	6671 (15.6)	6786 (16.3)	7095 (16.7)
Absence	175 (0.4)	620 (1.5)	1339 (3.1)
Body mass index			
<18.5	4561 (10.7)	4620 (11.1)	5153 (12.1)
18.5–23.9	25722 (60.3)	24962 (59.8)	24832 (58.5)
≥24.0	12401 (29.0)	12150 (29.1)	12456 (29.4)

Note: values outside the brackets in the table are "number of people" and the values inside the brackets are "constituent ratio (%)".

2.3 Awareness rate in key messages of TB prevention and control

Through the face-to-face health education, the overall awareness rate in key messages of TB prevention and treatment among the five key populations increased from 34.2% in 2013 to 67.2% in 2015, which showed an increasing trend year by year by Cochran-Armitage trend test (Z_{trend} = 215.568, $P < 0.01$). Compared with 2013, the awareness rates of elderly, known diabetics, previous TB patients, close contacts of TB patients and HIV/AIDS patients increased by 102.5%, 72.1%, 43.8%, 110.7% and 77.1%, respectively, as shown in Table 2.

Table 2 Awareness of key messages of TB prevention and control among different key populations from 2013 to 2015

Key populations	Number of people	Total number of key messages known	Total awareness rate(%)
In 2013			
All key populations	42684	73066	34.2
Elderly people aged 65 and above	37989	61723	32.5
Known diabetic patients	5642	12340	43.7
Previous TB patients	1684	4633	55.0
Close contact of TB patients	593	992	33.5
People with HIV/AIDS	83	199	48.0
In 2014			
All key populations	41732	119416	57.2
Elderly people aged 65 and above	37219	104072	55.9
Known diabetic patients	5855	19387	66.2
Previous TB patients	1620	5575	68.8
Close contact of TB patients	756	2278	60.3
People with HIV/AIDS	82	307	74.9
In 2015			
All key populations	42441	142629	67.2
Elderly people aged 65 and above	37771	124315	65.8
Known diabetic patients	6002	22580	75.2
Previous TB patients	1488	5885	79.1
Close contact of TB patients	1126	3972	70.6
People with HIV/AIDS	76	323	85.0

Note: Total awareness rate (%) = number of messages answered correctly / (number of respondents × 5) × 100%

2.4 Suspicious symptoms of TB and chest X-ray

At the time of the first screening in 2013, the incidence of any symptoms of pulmonary TB in the five key groups was 4.3%, the incidence of national TB control program defining symptoms with coughing and expectoration for 2 weeks or more, hemoptysis or bloody sputum was 2.2%, and the incidence of study-defined suspicious symptoms was 2.4%. The incidence of TB symptoms was higher in all patients with previous TB disease. From 2013 to 2015, the incidence of any TB symptom, suspicious symptoms defined by national TB control program and suspicious symptoms defined by this study in the key populations showed a decreasing trend year by year (Z_{trend} = −35.258, $P < 0.01$; Z_{trend} = –24.456, $P < 0.01$; Z_{trend} = –25.792, $P < 0.01$) as shown in Table 3.

In 2013, 2014, and 2015, the proportion of the key populations with TB or suspected TB lesions by chest X-ray was 3.3%, 3.0%, and 2.9%, respectively, with a decreasing trend by the Cochran-Armitage trend test (Z_{trend} = –58.318, $P <$

0.01). Among the five priority groups, the highest proportion of TB or suspected TB lesions was found in patients with previous TB, reaching about 30%, followed by those with HIV/AIDS, as shown in Table 4.

2.5 Sensitivity and specificity of different active detection interventions

The sensitivity (11.6% and 11.7%, respectively) was lower and the specificity was higher for the analysis of TB detection by screening using only the suspicious symptoms defined by the national TB control program and suspicious symptoms defined by this study; the sensitivity and specificity of chest X-ray only and screening with study-defined symptoms and chest X-ray at the same time reached over 90%. All four screening methods had low positive predictive values and high negative predictive values, as shown in Table 5.

2.6 Contribution rate of active detection and its influencing factors

2.6.1 Contribution rate

Among the patients with bacillary pulmonary tuberculosis, active detection accounted for 80.5% of all patients found (the sum of passive and active detection in each study site in that year), and the contribution rate of active detection was 91.7%, 75.9% and 67.9% in 2013, 2014 and 2015, respectively. The contribution rate was tested to show a decreasing trend year by year ($Z_{trend} = -3.524$, $p < 0.01$). Among active TB patients, active detection accounted for 84.9% of all patients, and the contribution rate of active detection was 95.7%, 81.0% and 73.2% in 2013, 2014 and 2015, respectively. The contribution rate was tested to show a decreasing trend year by year ($Z_{trend} = -6.403$, $P < 0.01$), as shown in Table 6.

2.6.2 Factors influencing the contribution of active detection

Univariate analysis showed that the contribution of active detection was higher in the detection of TB patients in the age group of 55 years old and above, among those with low education level and in the western region, and the differences were all statistically significant, as shown in Table 7. Among the 1211 TB patients detected by passive and active detection measures in 3 years, only 11.2% of patients reported suspicious symptoms of TB, and the contribution of active detection was higher among those with suspicious symptoms of TB, with a statistically significant difference.

Table 3 Screening results for TB symptoms in different key populations from 2013 to 2015

Key populations	Number of screenings (N)	Any symptom [N (incidence, %)]	Suspicious symptoms defined by the National TB Control program [N(incidence, %)]	Suspicious symptoms defined by this study [N(incidence, %)]
In 2013				
All key populations	42684	1831（4.3）	932（2.2）	1025（2.4）
Elderly people aged 65 and above	37989	1509（4.0）	731（1.9）	798（2.1）
Known diabetic patients	5642	268（4.8）	152（2.7）	167（3.0）
Previous TB patients	1684	281（16.7）	178（10.6）	207（12.3）
Close contact of TB patients	593	23（3.9）	14（2.4）	14（2.4）
People with HIV/AIDS	83	3（3.6）	0（0.0）	0（0.0）
In 2014				
All key populations	41732	491（1.2）	38（0.1）	40（0.1）
Elderly people aged 65 and above	37219	423（1.1）	30（0.1）	32（0.1）
Known diabetic patients	5855	99（1.7）	14（0.2）	14（0.2）
Previous TB patients	1620	53（3.3）	7（0.4）	7（0.4）
Close contact of TB patients	756	3（0.4）	0（0.0）	0（0.0）
People with HIV/AIDS	82	0（0.0）	0（0.0）	0（0.0）

Continued

Key populations	Number of screenings (N)	Any symptom [N (incidence, %)]	Suspicious symptoms defined by the National TB Control program [N(incidence, %)]	Suspicious symptoms defined by this study [N(incidence, %)]
In 2015				
All key populations	42441	349（0.8）	237（0.6）	258（0.6）
Elderly people aged 65 and above	37771	307（0.8）	204（0.5）	221（0.6）
Known diabetic patients	6002	62（1.0）	36（0.6）	43（0.7）
Previous TB patients	1488	34（2.3）	27（1.8）	28（1.9）
Close contact of TB patients	1126	7（0.6）	7（0.6）	7（0.6）
People with HIV/AIDS	76	0（0.0）	0（0.0）	0（0.0）

Note: suspicious symptoms defined by the national TB control program refer to cough and expectoration for 2 weeks or more, hemoptysis or bloody sputum.

Table 4 Chest X-ray findings in different key populations from 2013 to 2015

Key populations	Number of screenings (N)	TB or suspected TB lesions [N(constituent ratio,%)]	Other lesions [N(constituent ratio,%)]
In 2013			
All key populations	37 538	1 289（3.3）	1 736（4.6）
Elderly people aged 65 and above	33 717	913（2.7）	1 652（4.9）
Known diabetic patients	5 018	87（1.7）	103（2.1）
Previous TB patients	1 505	462（30.7）	116（7.7）
Close contact of TB patients	344	18（5.2）	6（1.7）
People with HIV/AIDS	59	5（8.5）	1（1.7）
In 2014			
All key populations	37 070	1 109（3.0）	1 205（3.3）
Elderly people aged 65 and above	33 686	872（2.6）	1 153（3.4）
Known diabetic patients	5 037	100（2.0）	128（2.5）
Previous TB patients	1 305	40（30.7）	63（4.8）
Close contact of TB patients	489	9（1.8）	8（1.6）
People with HIV/AIDS	62	4（6.5）	0（0.0）
In 2015			
All key populations	36 483	1 047（2.9）	690（1.9）
Elderly people aged 65 and above	33 268	842（2.5）	655（2.0）
Known diabetic patients	5 121	78（1.5）	63（1.2）
Previous TB patients	1 185	338（28.5）	60（5.1）
Close contact of TB patients	626	16（2.6）	4（0.6）
People with HIV/AIDS	68	2（2.9）	0（0.0）

The 14 variables (see Table 8 for variable assignment) that were analyzed univariately were included in a multifactorial logistic regression model, and the final variables included in the model were gender, age, region, knowledge of symptoms and consultation, and TB symptoms defined by national TB control program. The results showed that relative to the age group of 15–24 years old, the contribution of active detection was high in the age group of 55-64 years old and age group of ≥65 years old; and compared with the eastern region, the contribution of active detection was high in the western region. The contribution of active detection was lower among those who knew only one of the symptoms and consultation knowledge and among those who knew none of the symptoms and consultation knowledge compared with those who knew all of the symptoms and consultation knowledge, as well as among those who had no symptoms defined by national TB control program, as shown in Table 9.

3 Discussion

Active detection of TB patients is critical for early detection of patients, reduction of transmission, improvement of treatment success and reduction of patients' economic burden [2–3]. This study conducted the largest multicenter prospective cohort intervention study in the community population of 320,000 in 27 communities (townships) in 10 provincial-level regions in the eastern, central, and western regions of China. It systematically evaluated the intervention effects of TB active detection measures at the community level in five key populations of TB incidence, including people aged 65 years old and above, people with known diabetes, people with HIV/AIDS, people with a history of TB, and close contacts of active PTB patients, and may provide a scientific basis for developing active TB detection strategies at the community level in China.

The results of the fifth national TB epidemiological sample survey show that the prevalence of TB in China is higher in rural areas than in urban areas, and higher in the western region than in the eastern region [7]. And this study suggests that after excluding the effect of different key populations on the contribution of TB active detection, it is more meaningful to adopt active detection measures for TB patients in areas with high TB epidemic prevalence in China (western region) and in older age groups (age ≥55 years old), which have higher contribution rate and better detection effect than the previous passive detection, which is consistent with the

Table 5 Sensitivity and specificity analysis of different screening methods

Screening methods	Tuberculosis (N)		Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)
	Yes	No				
Symptoms defined by the National TB Control program			11.6	99.1	5.7	99.6
Yes	69	1138				
No	1138	125123				
Symptoms defined by this study			11.7	99.0	5.3	99.6
Yes	70	1253				
No	526	125008				
Chest X-Ray			90.7	94.2	8.5	99.9
Abnormal	594	6432				
No abnormalities seen	61	104004				
Study-defined symptoms+ Chest X-Ray						
Abnormal	594	7374	90.7	93.3	7.5	99.9
No abnormalities seen	61	103062				

Note: the diagnosis of PTB patients was calculated based on the actual number of people screened by different screening instruments.

findings of other national and regional studies [8–10]. The main reason is that these populations and these regions have relatively high incidence rates of TB [11]. At the same time, natural conditions, economic conditions and their awareness determine that patients in these regions and with these characteristics are not sufficiently aware or strong enough to seek active medical care, resulting in a higher number of undetected patients. Therefore, if active detection measures are taken against them, these scattered but undetected patients in society can be diagnosed as soon as possible and the further spread of TB can be reduced. This is significant for interrupting the spread of TB and reducing TB incidence. For those without TB suspicious symptoms and those who do not know much about TB and for whom active detection measures are taken, the patient detection effect is not as good as for those who have symptoms and know something about TB. The main reason is that the incidence rate of people without suspicious symptoms of TB is low [12], and active detection measures for them are not particularly effective. The above findings provide crucial clues about the areas and populations where active detection is implemented in China and are important guidelines for the improvement of the current active detection strategies in China.

The results of the study also suggest that if an annual active detection measure is carried out continuously in a priority population with TB incidence, its contribution to patient detection will decrease year by year [13], with the annual decline rate exceeding the annual decline rate of TB incidence in China [14]. Under limited conditions, even in areas with high TB epidemics, it is not advisable to conduct active detection measures for the same population every year, as patient detection decreases and the contribution of active detection becomes smaller each year.

The data from this study showed a low sensitivity to TB detection through symptom screening and a high specificity in five key populations. The sensitivity and specificity of chest X-rays were strong, which is consistent with findings in other countries and regions [3,15–16]. The incidence of suspi

Table 6 Contribution of active TB detection interventions in different priority populations from 2013 to 2015

Key populations	Bacillary pulmonary tuberculosis			Active tuberculosis		
	All patients (N)	Actively detected patients(N)	Contribution rate (%)	All patients (N)	Actively detected patients (N)	Contribution rate (%)
In 2013						
All key populations	84	77	91.7	255	244	95.7
Elderly people aged 65 and above	56	52	92.9	174	167	96.0
Known diabetic patients	11	11	100.0	24	23	95.8
Previous TB patients	31	28	90.3	90	84	93.3
Close contact of TB patients	2	2	2/2	9	9	9/9
People with HIV/AIDS	1	0	0.0	3	2	2/3
In 2014						
All key populations	58	44	75.9	247	200	81.0
Elderly people aged 65 and above	42	35	83.3	186	162	87.1
Known diabetic patients	2	1	1/2	18	17	94.4
Previous TB patients	23	18	78.3	90	69	76.7
Close contact of TB patients	1	0	0.0	2	0	0.0
People with HIV/AIDS	0	0	0.0	1	1	1/1
In 2015						
All key populations	53	36	67.9	153	112	73.2
Elderly people aged 65 and above	39	29	74.4	122	96	78.7
Known diabetic patients	5	1	1/5	11	6	54.6
Previous TB patients	7	5	5/7	20	12	60.0
Close contact of TB patients	1	1	1/1	6	5	5/6
People with HIV/AIDS	1	0	0.0	1	0	0.0
Total						
All key populations	195	157	80.5	655	556	84.9
Elderly people aged 65 and above	137	116	84.7	482	425	88.2
Known diabetic patients	18	13	72.2	53	46	86.8
Previous TB patients	61	51	83.6	200	165	82.5
Close contact of TB patients	4	3	3/4	17	14	82.4
People with HIV/AIDS	2	0	0.0	5	3	3/5

Table 7 Univariate analysis of factors influencing the contribution of active TB detection strategy from 2013 to 2015

Influencing factors	Number of patients (N)	Actively detected		χ^2	*P* value	*OR* (95%*CI*)
		Number of patients (N)	Contribution rate (%)			
Gender				0.025	0.875	
Male	474	403	85.0			1.04 (0.65-1.67)
Female	181	153	84.5			—
Age groups				28.574	<0.01	
15-24	12	7	58.3			—
25-34	15	8	53.3			0.82 (0.18-3.78)
35-44	22	17	77.3			2.43 (0.53-11.11)
45-54	53	39	73.6			1.99 (0.54-7.30)
55-64	71	60	84.5			3.90 (1.05-14.52)
≥65	482	425	88.2			5.33 (1.64-17.34)
Education				25.008	<0.01	
Illiterate or semi-literate	216	191	88.4			6.37 (1.81-22.40)
Primary school	267	236	88.4			6.34 (1.83-22.02)
Junior high school	125	92	73.6			2.32 (0.66-8.12)
Senior high school or technical secondary school	36	31	86.1			5.17 (1.13-23.55)
Juniorcollege and above	11	6	54.5			—
Urban orrural						
Urban	132	105	79.5			—
Rural	523	451	86.2			1.61 (0.99-2.63)
Region				6.974	0.031	
East	146	118	80.8			—
Central	171	139	81.3			1.03 (0.59-1.81)
West	338	299	88.5			1.82 (1.07-3.09)
Smoking history				1.370	0.242	
Yes	198	173	87.4			—
No	457	383	83.8			0.75 (0.46-1.22)
History of alcohol consumption				0.324	0.569	
Yes	183	153	83.6			
No	472	403	85.4			1.15 (0.72-1.83)
Body mass index				0.465	0.793	
<18.5	107	93	86.9			1.29 (0.59-2.85)
18.5-23.9	456	386	84.6			1.070 (0.58-1.97)
≥ 24. 0	92	77	83.7			—
Knowledge of symptoms and consultation				2.062	0.357	
Know all	269	234	87.0			—
Know one of them	119	97	81.5			0.66 (0.37-1.18)
Don't know	267	225	84.3			0.80 (0.49-1.30)

Continued

Influencing factors	Number of patients (N)	Actively detected		χ^2	*P* value	*OR* (95%*CI*)
		Number of patients (N)	Contribution rate (%)			
National TB control program defining symptoms				5.219	0.022	
Yes	69	65	94.2			—
No	586	491	83.8			0.32 (0.11-0.89)
Diabetes				0.163	0.686	
Yes	53	46	86.8			—
No	602	510	84.7			0.84 (0.37-1.93)
History of TB				1.277	0.259	
Yes	200	165	82.5			—
No	455	391	85.9			1.30 (0.83-2.03)
Close contact of active PTB patients				—	0.732[a]	
Yes	17	14	82.4			—
No	638	542	85.0			1.21 (0.34-4.29)
HIV/AIDS				—	0.166[a]	
Yes	5	3	3/5			—
No	650	553	85.1			3.80 (0.63-23.04)

Note: [a]: Fisher exact probability test; and "–" is the reference group.

Table 8 Multi-factor logistic regression variable assignment

Variables	Assignments	Variables	Assignments
Actively detected or not	Yes = 1; No = 0	Drinking history	Yes = 1; No = 0
Gender	Male = 1; Female = 2	Body mass index	< 18.5=1; 18.5-23.9=2; ≥24.0=3
Age groups	15-24=1; 25-34=2; 35-44=3; 45-54=4; 55-64=5; ≥65=6	Knowledge of symptoms and consultation	Know all=1; Know one of them=2; Don't know=3
Education level	Illiterate or semi-literate=1; Elementary school=2; Junior high school=3;Senior high school or technical secondary school=4; Junior college and above=5	National TB control program defining symptoms	Yes = 1; No = 0
Urban or rural	Urban =1; Rural=2	Diabetes	Yes = 1; No = 0
Region	East=1; Central=2; West=3	History of TB	Yes = 1; No = 0
Smoking history	Yes = 1; No = 0	Close contact of active PTB patients	Yes = 1; No = 0
		HIV/AIDS	Yes = 1; No = 0

Table 9 Multi-factor logistic regression analysis of factors influencing the contribution of active TB detection strategy from 2013 to 2015

Influencing factors	β	$s_{\bar{x}}$	*Wald* χ^2	*P*	Adjusted *OR*（95%*CI*）
Gender（Using“Female”as a reference）					
Male	1.056	0.860	0.526	0.468	1.20（0.73-1.99）
Age groups（Using“15-24 years old”as a reference）					
25-34	−0.255	0.895	0.063	0.802	0.80（0.14-4.62）
35-44	1.472	0.873	2.840	0.092	4.36（0.79-24.14）
45-54	1.104	0.710	2.104	0.147	3.02（0.68-13.40）
55-64	1.972	0.769	6.580	0.010	7.18（1.59-32.39）
≥65	2.604	0.718	13.167	0.000	13.52（3.31-55.16）
Region（Using“East”as a reference）					
Central	0.345	0.309	1.245	0.265	1.41（0.77-2.59）
West	0.891	0.289	9.530	0.002	2.44（1.38-4.29）
Knowledge of symptoms and consultation（Using“Know all”as a reference）					
Know one of them	−0.829	0.326	6.462	0.011	0.44（0.23-0.83）
Don't know	−0.540	0.274	3.885	0.049	0.58（0.34-1.00）
National TB control program defining symptoms（Using“Yes”as a reference）					
No	−1.884	0.589	10.223	0.001	0.15（0.05-0.48）

cious symptoms of TB and the abnormality rate of chest X-ray examination tended to decrease in the five priority groups after continuous active detection. This suggests that continuous active detection measures have led to the detection of people with more severe symptoms; with annual screening, only a few patients with mild symptoms remain. In addition, active detection measures based on symptom screening have a corresponding reduction in patient detection.

In the present study, face-to-face health education was conducted to promote knowledge of TB prevention and control among key populations. The results show a significant annual increase in awareness rate of the key messages in TB prevention and control. As awareness of TB increased, there was inevitably also an increased awareness of active consultation among the study population, resulting in a yearly increase in the contribution of passive detection of TB patients [17–18] and a yearly decrease in the contribution of active detection during the study period. This indicates that education has increased awareness of TB among key populations and increased the awareness among study participants to seek active medical care, thus increasing the rate of passive detection.

This study was a population-based cohort study, and the

results of the study provided directional guidance for screening areas and populations in key TB endemic areas in China. Several approaches were taken to ensure the quality of the study. While the sample size of this study allowed for a stratified analysis across different populations and characteristics, as with other large cohort studies, some unavoidable missing values accompany these findings with a small amount of uncontrollable information bias.

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