

Student-Led Health Education Intervention Package Enhanced Tuberculosis Prevention in Colleges: A Quasi-Experimental One-Group Pre-Test/Post-Test Study

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Objective: Tuberculosis (TB) remains a major public health threat, and colleges are crucial yet challenging settings for sustainable TB control. This study evaluated a standardized, student-led, multi-component intervention package designed to improve TB-related knowledge, attitudes, and practices (KAP) among college students in Zhejiang Province, China.

Methods: Conducted across 20 colleges from March 2022 to June 2023, this quasi-experimental one-group pre-test/post-test design study implemented a novel health education intervention package that integrated five activities. KAP data were collected using an electronic questionnaire at baseline and post-intervention. Data on TB patients and delays were collected through the Tuberculosis Information Management System. The Mann-Whitney U-test was used for delay time analysis.

Results: Valid responses included 4414 pre- and 4133 post-intervention. Overall, core knowledge of TB increased from 81.6% to 83.4% ($P < 0.001$). Significant improvements were seen in symptom recognition and care-seeking intent ($P < 0.05$). Regarding beliefs, the proportion who considered TB health education in schools “very necessary” increased from 53.5% to 57.8% ($P = 0.001$), while the proportion willing to proactively share knowledge with others rose from 90.9% to 92.5% ($P = 0.007$). Regarding behaviors, the proportion of current smokers decreased from 3.3% to 2.2% ($P = 0.002$), and the proportion of students frequently resting after 11 p.m. decreased from 70.2% to 64.3% ($P < 0.001$). Voluntary care-seeking among TB patients increased from 69.1% to 76.6%, while median patient delay decreased from 3 days to 0 ($P < 0.001$).

Conclusion: This report adds to the literature by demonstrating the effectiveness of a participatory, multi-faceted health education model within the college population. The findings provide a replicable example for campus-based health promotion and offer clear implications for strengthening institutional public health strategies.

Keywords: tuberculosis, health education, college students, knowledge attitudes practices, quasi-experimental study, health promotion

Introduction

Tuberculosis (TB), a chronic respiratory infectious disease caused by *Mycobacterium tuberculosis* (MTB), has its determinants firmly rooted in social and health factors. According to the World Health Organization's (WHO) Global Tuberculosis Report 2023, an estimated 10.6 million people contracted TB in 2022, with the annual incidence declining at an alarmingly slow pace and even increasing by 3.9% during 2020–2022.¹ Particularly,

men and women aged ≥ 15 years accounted for nearly 88% of the people who developed TB,¹ highlighting adolescents and young adults as a critical demographic for targeted interventions.

China, ranking as the fourth highest TB burden country among the 30 high-burden nations worldwide, faces significant challenges in TB control. In 2022, the country reported an estimated 748,000 new TB cases, corresponding to an incidence rate of 52 cases per 100,000 population.¹ Between 2004 and 2021, a total of 908,171 student TB cases were reported nationwide in China, accounting for 5.37% of all reported TB cases in the general population. Notably, a significant upward trend in reported incidence was observed specifically during the period 2015–2019.² In recent years, the dramatic expansion of higher education enrollment in China has led to sustained growth in the college student population, making infectious disease prevention and control on college campuses a critical public health priority.^{2,3} The educational environment, characterized by prolonged close contact in classrooms, dormitories, and social gatherings, creates highly conducive conditions for TB transmission.⁴ In this context, college students (aged 18–25 years) represent one of the most vulnerable groups for TB infection and transmission.⁵ Successive outbreaks of TB in colleges across different provinces underscore the urgency of developing effective campus-based prevention and control strategies.^{6,7}

Beyond screening and treatment interventions, health promotion constitutes a critical component of comprehensive TB prevention strategies. Effective health education aims to increase awareness of disease prevalence, transmission routes, symptoms, and preventive measures, thereby enabling early detection, reducing stigma, promoting timely health-seeking behavior, and fostering protective habits.^{8,9} However, the effectiveness of traditional top-down TB health education in Chinese colleges is hampered by its typically ad-hoc nature, inconsistent delivery, and passive student participation.^{10,11} These constraints significantly undermine the potential for developing sustained student awareness and proactive prevention behaviors.

The study region, Zhejiang Province, a densely populated and economically developed region of China, exemplifies these challenges. Despite implementing measures aligned with the WHO's "End TB Strategy", the province reported over 30 school-related TB outbreaks in 2021, with approximately one-third occurring specifically within higher education institutions.¹² Colleges in this region face heightened risk due to high population density, significant student mobility, and a pre-intervention TB awareness rate of only 38% – well below the national target (above 85%).¹³ Additionally, previous campus TB education in the study province mainly relied on top-down lectures and the distribution of informational materials that failed to engage students or produce sustained behavioral change. Research indicates that the effectiveness of one-off health education diminishes over time; therefore, TB health education in schools must emphasize long-term, systematic, and continuous efforts.

Based on these lessons learned, this study developed a novel, student-led, multi-component health education intervention package. This package integrates five standardized, mandatory core activities. This approach aims to create a sustained, engaging, and student-centered ecosystem for TB prevention, moving beyond one-off campaigns to foster long-term behavioral change. Therefore, this study aimed to assess the impact of the package on TB knowledge, attitudes and practices (KAP) among undergraduates, and explore optimization strategies for campus TB prevention.

Methods

Study Design and Setting

A quasi-experimental, one-group pre-test/post-test study was conducted from March 2022 to June 2023 in Zhejiang Province, eastern China. The intervention package was delivered to the campus of the colleges. Pre-intervention data were collected at baseline (pre-intervention phase), followed by implementation of the intervention package (intervention phase), after which post-intervention data were collected (post-intervention phase).

Zhejiang Province, comprising 11 prefecture-level cities and 90 counties, stands as one of the most densely populated and economically advanced regions in China. As of the end of 2023, its resident population reached 66.27 million, marking an increase of 500,000 from the previous year. As of 2023, Zhejiang Province ranks 11th nationally in the number of higher education institutions, with a total of 109 colleges, primarily located in the southern and northern regions.

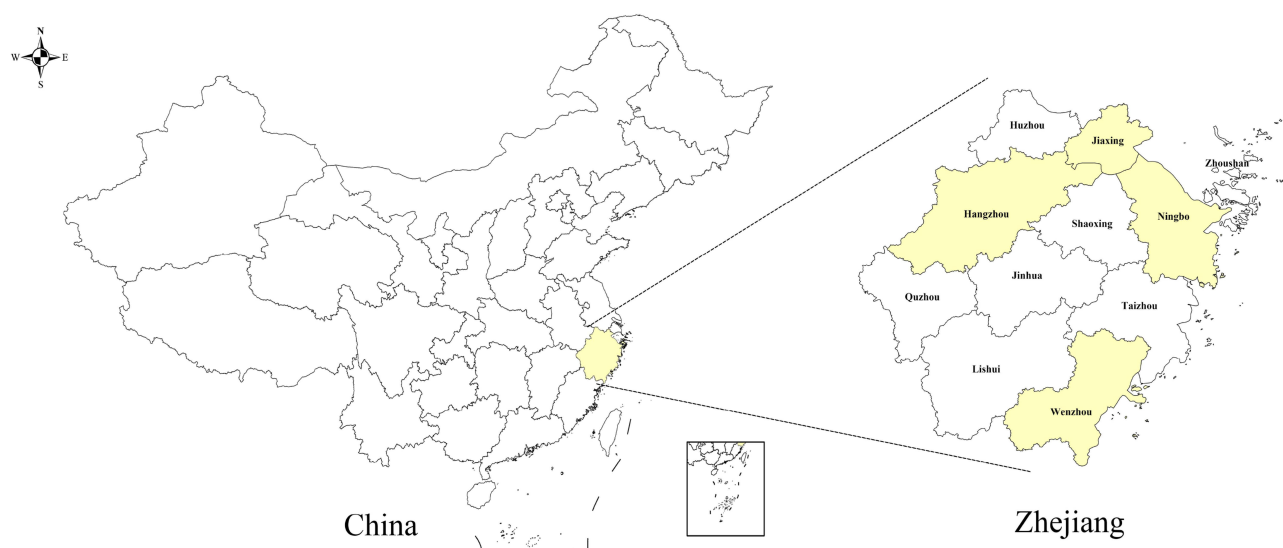


Figure 1 Geographic location of the study site.

Participants and Sampling

A multi-stage stratified cluster sampling method was employed. Sample size was calculated assuming an expected intervention effect size of 5%, $\alpha = 0.05$, and power = 0.8, and a design effect of 2.5 to account, yielding a required sample size of approximately 4000 participants per survey round. In the first stage, four prefecture-level cities were selected from the study province to ensure representativeness across geographic regions and varying TB incidence levels (Figure 1). In the second stage, from these four selected cities, a total of 20 colleges were randomly selected from the official registry of higher education institutions using a computer-generated random number sequence, stratified by institution type (comprehensive, science/engineering, medical, and arts) to reflect the diversity of the provincial student body. In the third stage, within each selected college, approximately 8 to 10 first- and second-year classes were randomly selected. Finally, following informed consent procedures, 20–25 students (balanced by gender) were randomly selected from these classes for study inclusion (Figure S1). All participants were full-time undergraduate students aged 18–25 years. Non-student individuals, students refusing to participate: students on long-term leave or exchange programs outside the province during the study period, or students unable to complete the questionnaire independently were excluded. The post-intervention survey targeted students from the same 20 colleges, using the same sampling approach to select second- and third-year students, aiming to capture the cohort exposed to the intervention during the academic year.

Procedures

During pre-intervention phase, professionals from TB department of local Center for Disease Control and Prevention (CDC) trained school health education coordinators, student volunteers, and medical staff on the purpose of the study and the intervention measures to be taken. Subsequently, a pre-designed structured electronic questionnaire was used to collect the following data from the respondents: socio-demographic data, respondent's KAP regarding TB. Data on students with TB in 2021 from each college were collected through the Tuberculosis Information Management System (TBIMS), including health-seeking behaviors, date of symptom onset, date of initial medical consultation, and date of diagnosis.

Following the baseline survey, youth volunteer groups at each participating college implemented the intervention measures. The intervention package was newly developed, drawing on national TB control guidelines and a literature review of effective campus health education strategies adapted for college contexts, and was subsequently implemented as a standardized package across all participating colleges. The selection prioritized activities with proven feasibility and scalability in Chinese college settings, which comprised the following five components: (1) themed publicity around World Tuberculosis Day; (2) regular in-campus promotion via new media platforms (one issue per month); (3) annual

campus TB prevention knowledge competition; (4) during the September back-to-school season, combine TB awareness campaigns with freshmen health check-ups; (5) special TB prevention and control activities on important disease prevention days (no less than three times).

The intervention spanned a period of fifteen months. Upon its completion, participants were asked to complete the same questionnaire used in the baseline survey to evaluate changes in their TB-related knowledge, attitudes, and health behaviors. Similarly, data on student TB cases from each college in 2022—including treatment-seeking behavior, dates of symptom onset, first medical consultation, and diagnosis—were also collected via the TBMIS.

Data Collection

This study utilized standardized electronic questionnaires to collect data before and after the intervention period, which were developed based on the Technical Specifications for Tuberculosis Prevention and Control in China (2020 Edition) and the Work Standards for Tuberculosis Prevention and Control in Schools (2017 Edition), supplemented by comprehensive literature review and expert consultation. The questionnaire encompassed three key domains: sociodemographic characteristics, assessment of core KAP regarding TB in the school setting, and the acceptance of TB health education. The assessment of TB knowledge comprised eight core questions (Table S1). The evaluation of attitudes and practices toward TB mainly encompasses the following dimensions: perceived necessity of TB education, risk perception, disease-related stigma, willingness to share knowledge, and self-reported health behaviors such as smoking, sleep habits, and hygiene practices. Each item presented in a multiple-choice format with only one correct answer per question, ensuring precise evaluation of participants' understanding.

Quality Control

The provincial CDC oversaw sampling and supervision, while the county-level CDCs managed on-site implementation and questionnaire collection. All investigators received a 2-day provincial-level training covered study purpose, study protocols, questionnaire administration, and survey norms, followed by a unified assessment to ensure consistency. Permission was obtained from the administrative office of each participating college through a formal letter from the provincial CDC. All schools provided written approval. Participants were briefed on the study purpose and required to independently complete the survey independently with a minimum response time of 5 minutes. The provincial CDC conducted daily checks of electronic responses for quantity, completeness, and logical consistency, with all data consolidated into a unified provincial database for final quality verification.

Definitions

Pre- and post-intervention knowledge levels were assessed using awareness rates, and the formula was as follows:¹⁴

$$\text{The total awareness rate (\%)} = \frac{\sum \text{The number correct responses across TB core information items}}{\text{The number of TB core information items responded by participants}} \times 100\%$$

$$\text{The entire awareness rate (\%)} = \frac{\text{The number of participants who correctly responded all TB core information items}}{\text{The number of participants}} \times 100\%$$

$$\text{The single awareness rate (\%)} = \frac{\text{The number of single TB core information item corrected responded by participants}}{\text{The number of participants}} \times 100\%$$

Changes in student health-seeking behaviors were quantitatively assessed through two primary metrics: rate of active visit for symptoms and delays. “Rate of active visit for symptoms” referred to the proportion of individuals who, upon self-recognition of TB suspicious symptoms, voluntarily sought diagnosis and treatment at local TB dispensary, among all TB cases confirmed within the year.

Delays were systematically categorized and quantified as follows: patient delay (the interval between initial symptom onset and first healthcare-seeking behavior), health facility delay (the duration between the first contact with health facility and the confirmation of the diagnosis), and total delay (the sum of both).¹⁵

Statistical Analysis

Data management was performed in Microsoft Excel 2019, followed by statistical analysis in R (version 4.3.2; R Foundation for Statistical Computing). Descriptive analysis was performed to describe the characteristics and variables based on two pre and post surveys. The package's impact on TB knowledge awareness was evaluated across demographic subgroups through pre-post intervention analysis. The delay time of student TB patients was statistically analyzed by Mann–Whitney U-test and compared before and after the intervention. P-values were 2-tailed with statistical significance set at 0.05.

Ethics Approval and Consent to Participate

This study was reviewed and approved by the Institutional Review Board of Zhejiang Provincial CDC, with approval number [AF/SC-06/01.0]. The study complies with the Declaration of Helsinki. All study methods were carried out in accordance with relevant guidelines and regulations. All participants were given a detailed explanation about the study with the emphasis that participation was completely voluntary. Data confidentiality was maintained throughout the study.

Results

Basic Information of Participants

Application of the package yielded 4427 pre-intervention and 4142 post-intervention returned questionnaires. Following quality control, 4414 (99.7%) and 4133 (99.8%) valid questionnaires were retained for analysis. The general profile of the participants in the two surveys was shown in [Table 1](#). The mean age of participants at baseline and post-intervention was 19.9 (standard deviation 1.1) years and 20.4 (standard deviation 1.5) years, respectively. Socio-demographic characteristics revealed significant differences in sex, age, grade, major, student origin, monthly living expenses, previous TB health education and self-reported contact history with TB patients between the two surveys (all $P < 0.05$). These two surveys remained homogeneous in Han ethnicity predominance (96.1% vs 96.2%), rural residency (64.4% vs 64.6%), and parental education levels (nearly 40.0% of fathers and more than 38.0% of mothers completed junior high school).

Respondents' Awareness of TB Knowledge

Pre-intervention, the mean number of correctly answered knowledge items among all participants was 6.53 (median = 7, IQR: 6–8). Post-intervention, the mean score improved to 6.67 (median = 7, IQR: 6–8). The distribution of correct responses post-intervention differed from baseline (Wilcoxon signed-rank test, $P < 0.001$) ([Figure 2](#)).

Pre-intervention, 2680 participants (60.7%) correctly answered more than 6 items, while 3 individuals (0.1%) provided incorrect responses for all core information. The entire awareness rate was 25.3%. Post-intervention, the proportion of participants responding ≤ 4 items correctly was lower, with no cases (0%) of complete misinformation. Notably, 2649 participants (64.1%) achieved > 6 correct responses, including a 29.1% full awareness rate ([Figure 3](#)).

The overall TB knowledge awareness rate increased from 81.6% pre-intervention to 83.4% post-intervention ($P < 0.001$) ([Figure 4](#)). Changes in specific knowledge items are presented in [Table S2](#). The proportion correctly identifying “coughing with sputum for ≥ 2 weeks or bloody sputum” as a TB indicator increased from 91.1% to 93.6% ($\chi^2 = 23.918$, $P < 0.001$). Participants selecting “visit a designated TB medical institution” rose from 96.2% to 97.0% ($\chi^2 = 16.679$, $P = 0.001$). Certainty about TB curability increased from 75.7% to 78.2% ($\chi^2 = 9.509$, $P = 0.023$). And correct responses to “report to school authorities without concealing symptoms” increased from 83.5% to 85.1% ($\chi^2 = 20.592$, $P < 0.001$). Awareness of “frequent ventilation” as an effective measure improved from 76.1% to 78.8% ($\chi^2 = 9.140$, $P = 0.027$). Correct identification of “balanced diet, regular sleep, and exercise” improved from 88.2% to 90.7% ($\chi^2 = 20.850$, $P < 0.001$). Regarding knowledge of TB classification, the majority of participants correctly identified TB as a chronic infectious disease both pre- (51.0%) and post-intervention (51.7%), with no statistically significant change ($\chi^2 = 0.713$, $P = 0.870$). While 90.7% (pre) and 91.7% (post) recognized respiratory transmission, confusion about bloodborne (1.4% vs 1.3%) and digestive routes (1.8% vs 2.0%) persisted ($\chi^2 = 6.284$, $P = 0.099$).

Analysis of awareness rates for TB prevention and control core information across demographic subgroups revealed heterogeneous intervention effects ([Table S3](#)). Female participants demonstrated consistently higher awareness rates

Table 1 Socio-Demographic Characteristics of the Participants

Characteristics	Pre-Intervention Survey (n, %)	Post-Intervention Survey (n, %)	Total	χ^2	P-value
Sex				38.589	<0.001
Male	2282 (51.7)	1859 (45.0)	4142		
Female	2132 (48.3)	2274 (55.0)	4405		
Age				18.625 ^a	<0.001
Mean (Standard Deviation, SD)	19.9 (1.1)	20.4 (1.5)		0.005	0.945
Nationality					
Han	4244 (96.1)	3975 (96.2)	8219		
Others	170 (3.9)	158 (3.8)	328		
Area residence				0.039	0.844
Urban	1562 (35.4)	1471 (35.6)	3033		
Rural	2852 (64.6)	2662 (64.4)	5514		
Origin of the students				4.447	0.035
This Province	3157 (71.5)	2870 (69.4)	6027		
Others	1257 (28.5)	1263 (30.6)	2520		
Grade ^b				419.222	<0.001
Low	2378 (53.9)	3105 (75.1)	5483		
High	2036 (46.1)	1028 (24.9)	3064		
Major				71.264	<0.001
Humanity Social Sciences	1367 (31.0)	1390 (33.6)	2757		
Science and Engineering	1989 (45.1)	1521 (36.8)	3510		
Medicine	675 (15.3)	718 (17.4)	1393		
Art	383 (8.7)	504 (12.2)	887		
Father's level of education				1.693	0.890
Illiterate	46 (1.0)	54 (1.3)	100		
Primary school	706 (16.0)	662 (16.0)	1368		
Junior high school	1766 (40.0)	1630 (39.4)	3396		
Senior secondary education and equivalent qualifications	935 (21.2)	890 (21.5)	1825		
Bachelor	890 (20.2)	827 (20.0)	1717		
Postgraduate	71 (1.6)	70 (1.7)	141		
Mother's level of education				1.509	0.912
Illiterate	97 (2.2)	102 (2.5)	199		
Primary school	952 (21.6)	883 (21.4)	1835		
Junior high school	1706 (38.6)	1583 (38.3)	3289		
Senior secondary education and equivalent qualifications	832 (18.8)	797 (19.3)	1629		
Bachelor	772 (17.5)	710 (17.2)	1482		
Postgraduate	55 (1.2)	58 (1.4)	113		
Monthly living expenses (RMB)				11.180	0.025
≤500	72 (1.6)	59 (1.4)	131		
501–1000	318 (7.2)	265 (6.4)	583		
1001–1500	1353 (30.7)	1167 (28.2)	2520		
1501–2000	1752 (39.7)	1755 (42.5)	3507		
≥2000	919 (20.8)	887 (21.5)	1806		
Have you ever received health education of TB?				8.145	0.004
Yes	3404	3328	6732		
No	1010	850	1860		

(Continued)

Table 1 (Continued).

Characteristics	Pre-Intervention Survey (n, %)	Post-Intervention Survey (n, %)	Total	χ^2	P-value
Have you ever had contact with a TB patient?				33.114	<0.001
Yes	197 (4.5)	202 (4.9)	399		
No	3415 (77.4)	2980 (72.1)	6395		
No idea	802 (18.2)	951 (23.0)	1753		

Notes: ^aAn independent samples t-test was used. ^bThe baseline survey sampled first- and second-year undergraduate students enrolled in 2022, while the follow-up intervention survey targeted second- and third-year undergraduates enrolled in 2023.

compared to males across multiple domains. Upper-grade participants exhibited improvements across multiple knowledge domains, such as Q2 (93.6% vs 89.9%), Q3 (95.6% vs 91.3%) and Q4 (97.3% vs 95.9%). After intervention, medical majors achieved post-intervention accuracy of 99.9% for Q4 and 89.3% of Q5, compared with 96.1% and 75.5% for humanities students, and 92.5% and 70.0% for arts students. Participants with prior TB health education maintained higher awareness rates both pre- and post-intervention compared to unexposed counterparts. Individuals with TB patient contact achieved higher post-intervention Q8 awareness (92.1% vs 90.4% in unexposed groups).

TB-Related Beliefs

Table 2 presents the distribution of TB-related beliefs among participants before and after the intervention. Following the intervention, the proportion of participants who perceived it as “highly necessary” for their college to conduct TB prevention and control publicity and education increased (57.8% vs 53.5%, $P = 0.001$). Regarding willingness to participate in university TB awareness activities, the proportion reporting they were “highly willing” rose from 45.4% to 49.9% ($P = 0.001$). Furthermore, the proportion of participants who perceived themselves as “at risk” of TB was 14.9% post-intervention, compared with 11.8% pre-intervention ($P < 0.001$). Concurrently, a greater proportion reported they would “try to keep distance” from TB patients (13.6% vs 10.4%, $P < 0.001$). In terms of knowledge dissemination, willingness to actively share acquired TB knowledge with others significantly improved (92.5% vs 90.9%, $P = 0.007$).

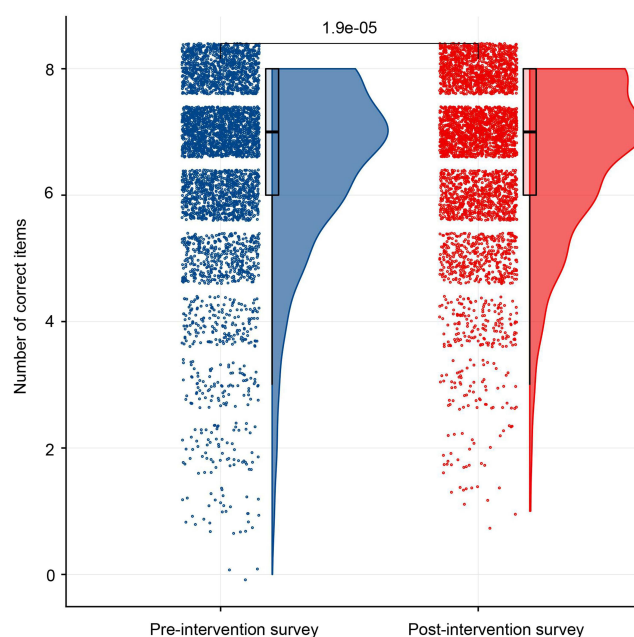


Figure 2 Distribution of correct answers before and after the intervention.

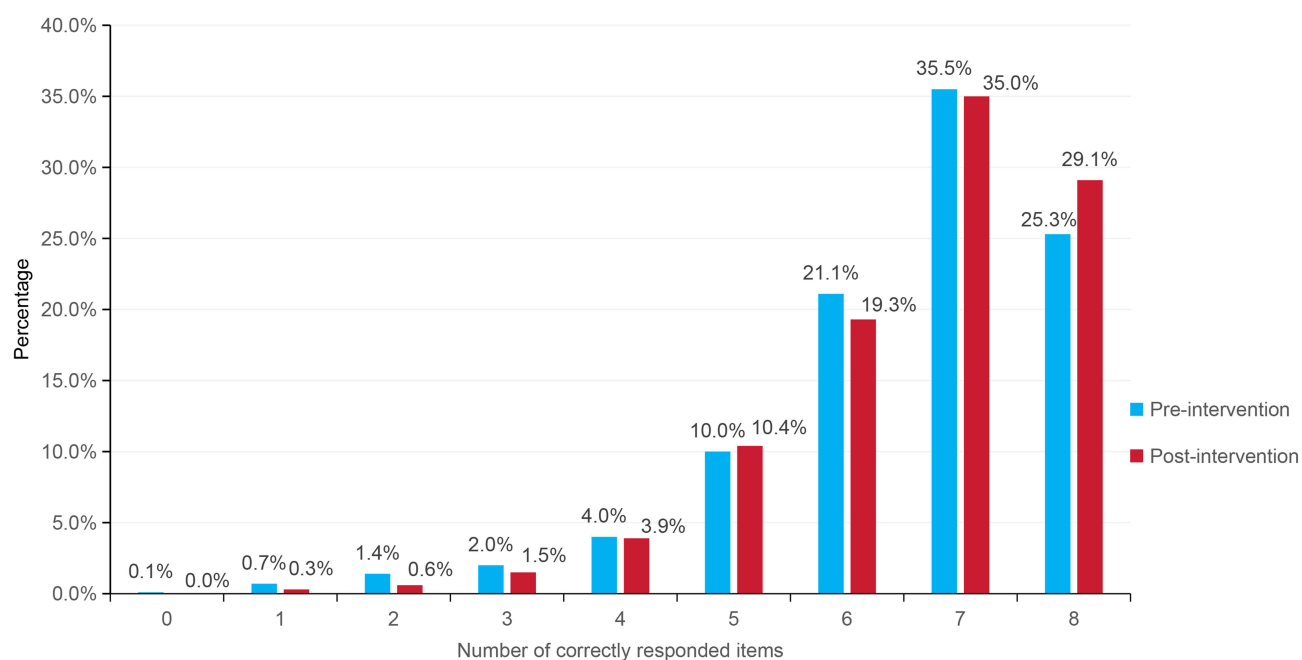


Figure 3 Percentage of correct TB knowledge items answered pre- and post-intervention.

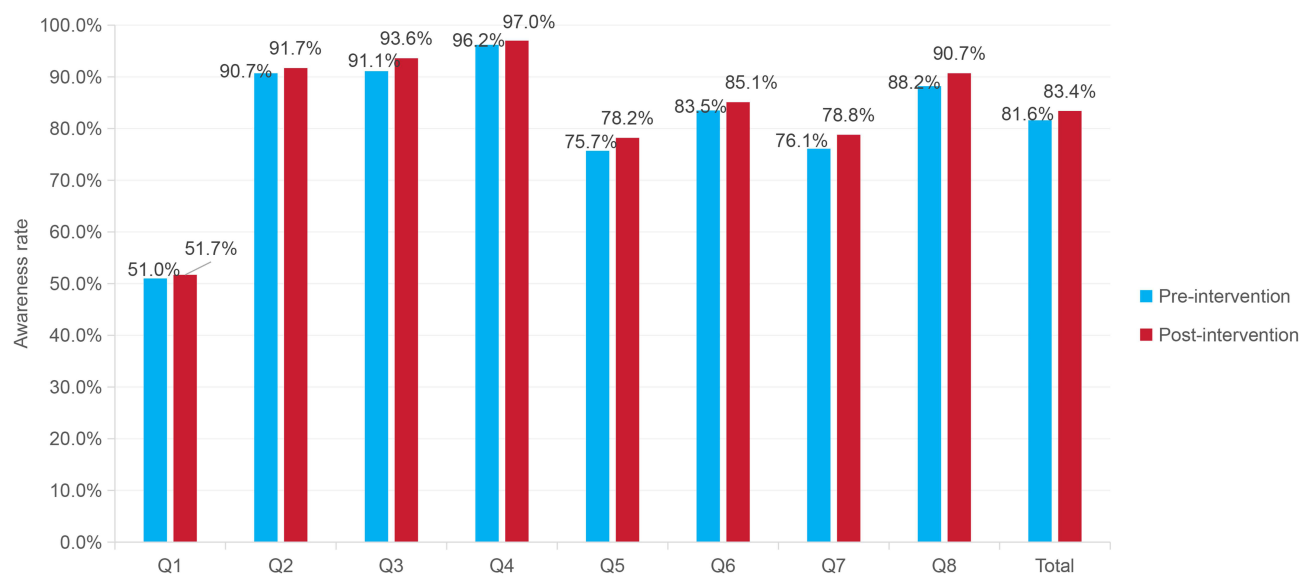


Figure 4 Awareness rates of each TB core information item pre- and post-intervention.

However, no statistically significant changes were observed in certain behavioral intentions, such as willingness to undergo “proactive annual TB screening” ($P = 0.125$), or in “volunteering willingness” ($P = 0.076$).

TB-Related Behaviors

As presented in Table 3, changes in TB-related behaviors were observed. Post-intervention, the proportion perceiving no classmates spitting indiscriminately increased from 48.8% to 50.4% ($P = 0.027$). However, the proportion reporting observing such behavior also slightly increased (20.7% vs 19.7%). A higher proportion of participants reported always covering their mouth and nose with an elbow or tissue when coughing or sneezing (61.9% vs 59.7%, $P = 0.013$), while the proportion reporting doing so only occasionally decreased (8.1% vs 10.1%). Additionally, participants demonstrated

Table 2 TB-Related Beliefs Among Participants Before and After the Intervention

TB-Related Belief Item	Pre-Intervention Survey (n, %)	Post-Intervention Survey (n, %)	χ^2	P-value
Do you think it is necessary for college students to master TB prevention knowledge?			4.019	0.250
Highly necessary	2601 (58.9)	2519 (60.9)		
Not necessary	56 (1.3)	44 (1.1)		
Neutral	115 (2.6)	99 (2.4)		
Necessary	1642 (37.2)	1471 (35.6)		
Do you think it is necessary for your college to carry out TB prevention and control publicity and education?			16.455	0.001
Highly necessary	2363 (53.5)	2390 (57.8)		
Not necessary	105 (2.4)	82 (2.0)		
Neutral	192 (4.3)	157 (3.8)		
Necessary	1754 (39.7)	1504 (36.4)		
If the college holds a TB prevention and control publicity education activity, are you willing to participate?			17.288	0.001
Unwilling	173 (3.9)	137 (3.3)		
Highly willing	2006 (45.4)	2061 (49.9)		
Neutral	383 (8.7)	331 (8.0)		
Willing	1852 (42.0)	1604 (38.8)		
Are you willing to proactively undergo an annual TB health screening?			4.166	0.125
Unwilling	137 (3.1)	155 (3.8)		
Neutral	556 (12.6)	482 (11.7)		
Willing	3721 (84.3)	3496 (84.6)		
If a classmate near you is diagnosed with TB, are you willing to cooperate with the college for TB screening?			1.375	0.503
Unwilling	57 (1.3)	59 (1.4)		
Neutral (Will do if required by school)	296 (6.7)	254 (6.1)		
Willing	4061 (92.0)	3820 (92.4)		
When relatives, classmates, or friends have a cough or expectoration lasting more than two weeks, are you willing to remind them to get checked at a designated TB hospital?			3.944	0.139
Unwilling	57 (1.3)	68 (1.6)		
Neutral	175 (4.0)	139 (3.4)		
Willing	4182 (94.7)	3926 (95.0)		
Do you think you are at risk of suffering TB?			20.720	<0.001
Do not know	773 (17.5)	661 (16.0)		
Possibly yes	1610 (36.5)	1516 (36.7)		
No	1510 (34.2)	1339 (32.4)		
Yes	521 (11.8)	617 (14.9)		
If you contracted TB, what would be your first reaction?			7.465	0.058
Active treatment	3764 (85.3)	3577 (86.5)		
Despair/Helplessness	117 (2.7)	100 (2.4)		
Low mood	402 (9.1)	316 (7.6)		
Neutral	131 (3.0)	140 (3.4)		

(Continued)

Table 2 (Continued).

TB-Related Belief Item	Pre-Intervention Survey (n, %)	Post-Intervention Survey (n, %)	χ^2	P-value
If someone near you contracted TB, what would your attitude towards them be?			23.021	<0.001
Avoid contact with them	184 (4.2)	147 (3.6)		
Encourage them to persist with treatment	3563 (80.7)	3237 (78.3)		
Treat them as usual	210 (4.8)	186 (4.5)		
Try to keep distance	457 (10.4)	563 (13.6)		
Are you willing to become a volunteer for TB prevention and control publicity education?			6.863	0.076
Unwilling	372 (8.4)	356 (8.6)		
Highly willing	1495 (33.9)	1490 (36.1)		
Neutral	846 (19.2)	801 (19.4)		
Willing	1701 (38.5)	1486 (36.0)		
After learning about TB prevention, will you proactively share the knowledge with family, friends, or classmates?			7.184	0.007
No	403 (9.1)	311 (7.5)		
Yes	4011 (90.9)	3822 (92.5)		

Table 3 TB-Related Behaviors Among Participants with Different Characteristics Before and After the Intervention

TB-Related Behavior Item	Pre-Intervention Survey (n, %)	Post-Intervention Survey (n, %)	χ^2	P-value
Have you observed classmates spitting indiscriminately?			7.207	0.027
Do not know	1390 (31.5)	1192 (28.8)		
No	2154 (48.8)	2084 (50.4)		
Yes	870 (19.7)	857 (20.7)		
When coughing or sneezing, do you cover your mouth and nose with your elbow or a tissue?			10.826	0.013
Never	104 (2.4)	93 (2.3)		
Often	1228 (27.8)	1148 (27.8)		
Every time	2637 (59.7)	2557 (61.9)		
Occasionally	445 (10.1)	335 (8.1)		
Smoking status			12.983	0.002
Never smoked	4055 (91.9)	3873 (93.7)		
Former smoker	212 (4.8)	169 (4.1)		
Current smoker	147 (3.3)	91 (2.2)		
Do you frequently stay up late? (Resting after 11 PM)			33.766	<0.001
Yes	3097 (70.2)	2656 (64.3)		
No	1317 (29.8)	1477 (35.7)		
Do you experience insufficient sleep? (Sleep duration less than 7 hours)			2.166	0.141
Yes	1666 (37.7)	1624 (39.3)		
No	2748 (62.3)	2509 (60.7)		

Table 4 Diagnostic Delays Among Student TB Patients Pre- and Post-Intervention

Delay Type	Pre-Intervention		Post-Intervention		Z	P-value
	Median	IQR	Median	IQR		
Patient delay	3 (0–142)	15.25	0 (0–181)	2	–4.177	<0.001
Health facility delay	6 (0–64)	8.5	8 (0–114)	12	–2.170	0.030
Total delay	13.5 (0–148)	22.25	11 (0–198)	21	–0.825	0.409

improvements in smoking behavior and late-night habits post-intervention. The proportion of current smokers decreased (2.2% vs 3.3%, $P = 0.002$). Concurrently, the prevalence of frequently staying up late (resting after 23:00) declined substantially (64.3% vs 70.2%, $P < 0.001$). Although the proportion reporting insufficient sleep (less than 7 hours) increased from 37.7% to 39.3%, this difference did not reach statistical significance ($P = 0.141$).

Active Seeking Care and Diagnostic Delays Among TB Patients

In the pre-intervention survey, among 94 diagnosed student TB cases, 65 (69.1%) sought treatment at designated medical institutions on their own initiative following symptom onset, 25 (26.6%) were identified after being referred from non-designated medical institutions, and 4 (4.3%) via close-contact screening; a total of 49 student TB patients were diagnosed in 20 colleges in the post-intervention survey, and voluntary presentation increased to 76.6% ($n=37$), while transfer-in accounted for 23.4% ($n=12$).

As detailed in Table 4, the median patient delay was 3 days (IQR: 0–142) pre-intervention and 0 days (IQR: 0–181) post-intervention ($P < 0.001$). However, health system delays increased by 2 days (median: 8d vs 6d, $P = 0.030$). The median total delay was 13.5 days (IQR: 0–148) pre-intervention and 11 days (IQR: 0–198) post-intervention ($P = 0.409$).

Discussion

This study evaluated a standardized, multi-component TB health education package in real-world college settings using a pre-post design. The intervention was associated with significant improvements in overall TB knowledge, several key attitudes, and health-related behaviors among students, as well as a reduction in patient care-seeking delay. The success of this approach offers valuable insights for optimizing campus-based TB control strategies.

The intervention resulted in statistically significant but modest improvements in overall TB knowledge awareness (83.4% vs 81.6%), eliminated extreme misinformation and boosted full awareness rates by 3.8%. These findings were similar to those of intervention studies conducted in Philippine, Malaysia and Tanzania.^{16–18} Specifically, recognition of TB symptoms (Q3) and proactive reporting behaviors (Q6) increased by 2.5% and 1.6%, respectively, indicating enhanced student understanding of critical prevention practices. However, limited progress was observed for certain items, such as identifying TB as a chronic communicable disease (51.7% vs 51.0%), which fell below the 2022 national survey data for the general Chinese population (75.3%).¹⁹ This suggested ineffective knowledge transfer via conventional education methods for complex concepts. Persistent gaps in foundational pathological knowledge underscore the need to refine health communication strategies to address these cognitive blind spots.

The subgroup analysis reveals significant demographic variations in TB knowledge acquisition following the package. Medical majors demonstrated near-universal mastery of critical items post-intervention, notably in healthcare-seeking behavior (Q4: 99.9% vs 97.5%) and curability knowledge (Q5: 89.3% vs 81.2%). These aligned with findings from Saudi Arabia and Indonesia that disciplinary relevance enhanced health literacy internalization.^{4,20} This may be attributed to the inclusion of infectious disease education, including TB, within medical curricula, thereby better preparing students for TB prevention.²¹ Conversely, non-medical majors showed limited improvement in complex concepts, reinforcing the need for context-adapted educational strategies. Notably, participants with prior TB health education exhibited persistently superior awareness, echoing Hassan's assertion that baseline health literacy mediates intervention efficacy.²² Prior education provides foundational schema for integrating new information. Students exposed

to TB concepts could better contextualize content of the package, reducing cognitive load during knowledge acquisition.²³ This explains their superior performance in complex items. Students with TB patient contact achieved higher post-intervention awareness, supporting Bressan et al's observation that lived experience amplifies health messaging impact.²⁴ Due to the differences in the needs of TB prevention and treatment, the role that playing, and the benefits and ability of acceptance between different groups of people, it is necessary to carry out targeted TB health education.¹⁰

Comparison of beliefs before and after the package showed significant improvements in perceived necessity of TB education (57.8% vs 53.5%) and willingness to share knowledge (92.5% vs 90.9%), reflecting enhanced engagement. However, improvements in specific behavioral compliance were limited; for instance, responses to the item "Are you willing to proactively undergo an annual TB health screening" showed only a 0.3% increase in the proportion of participants answering "willing" compared to pre-intervention rates. Similar discrepancies in beliefs and behaviors are common across virtually all fields and have been observed globally.²⁵ Moreover, heightened risk perception (14.9% vs 11.8%) paradoxically coincided with stronger social distancing tendencies (13.6% vs 10.4%), underscoring enduring stigma-related challenges. This reflected deep-seated fear of TB's infectious label, consistent with findings conducted in South Africa among healthcare workers.²⁶ The absence of change in proactive screening willingness further signaled that knowledge alone might not drive behavior. Knowledge, Attitudes and Practice (KAP) theory asserts that the accumulation of knowledge leads to the formation of attitude, subsequently influencing practice, all three factors are inseparable.²⁷ Therefore, to effect behavioral change, it is essential to initiate with enhancing health education, improving negative attitudes towards TB, and guiding positive behaviors.¹⁷

In addition, reductions in smoking (2.2% vs 3.3%) and late-night habits (64.3% vs 70.2%) demonstrate the package's benefits on TB risk factors. These findings are particularly relevant given smoking's well-established role in TB susceptibility, as evidenced by a Kelantan-based retrospective cross-sectional study demonstrating threefold higher TB infection risk among smoking youth compared to non-smokers.²⁸ Critically, the intervention's effectiveness was further substantiated by enhanced health-seeking behaviors, manifested through both increased symptom-driven care-seeking (76.6% vs 69.1%) and reduced patient delay (median reduction from 3 to 0 days). While the overall reduction in total delay (11 vs 13.5 days) did not reach statistical significance, it nevertheless represents a meaningful improvement compared to the 18-day delay reported in Quzhou's children and adolescents population.²⁹ However, the concurrent increase in health system delays (from 6 to 8 days) may reflect structural inefficiencies in diagnostic pathways, referral bottlenecks, or reduced diagnostic capacity in some facilities, suggesting that future interventions must address facility-level bottlenecks and strengthen process optimization within the health system to accelerate TB case management.

Various health education interventions for students have been implemented globally, each demonstrating unique advantages and limitations - a characteristic equally applicable to the current health education intervention package. First, the study was limited to 20 colleges across four prefecture-level cities, with public institutions comprising majority of the sample. The underrepresentation of private colleges and vocational institutions may restrict the generalizability of our findings. Second, the one-year intervention period precluded assessment of long-term outcomes, including knowledge retention rates and changes in disease incidence, while the lack of post-graduation follow-up limited our understanding of health behavior sustainability - issues warranting further investigation. Third, the absence of a control group limits causal inference, as we cannot completely rule out the influence of secular trends of national TB awareness campaigns or other concurrent public health events. Results should be interpreted as pre-post changes rather than definitive causal effects. Forth, the small number of student TB patients (94 pre-, 49 post-intervention) limits statistical power for delay analyses; these findings should be interpreted cautiously.

Regardless these limitations, our study presents several notable innovations. We pioneered the health education intervention package, systematically integrating five core activities with innovative components to create a sustainable TB prevention framework for college settings. Additionally, the student volunteer-led implementation enhanced traditional unidirectional health education into peer-to-peer knowledge dissemination, significantly enhancing engagement and outreach efficacy. Furthermore, we established a tripartite collaboration network involving CDC experts, college administrations, and student volunteer teams, optimizing resource allocation and providing a replicable organizational package for other regions.

Conclusions

The student-led health education intervention package effectively showed potential to enhance students' role in TB prevention - shifting them from passive recipients to more active agents - and demonstrated feasibility for provincial-level implementation. Traditional metrics focused solely on knowledge awareness rates (the “knowing” gap) may underestimate the value of interventions that target self-efficacy and social norms (the “doing” gap). Therefore, campus TB control programs should prioritize peer-driven, multi-component behavioral interventions over didactic, knowledge-only campaigns to achieve tangible reductions in transmission risk and delays. Future research should include long-term follow-up to assess knowledge retention and behavioral sustainability, incorporate controlled designs to strengthen causal inference, and evaluate cost-effectiveness to inform scale-up across diverse educational settings. This study provides a replicable practice for student-centric health promotion in global tertiary education settings.

Data Sharing Statement

All data generated or analyzed during this study are included in this published article and its [supplementary information files](#).

Acknowledgments

We would like to thank the staffs from all the local CDCs for the collection of the questionnaires.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Funding

This work was supported by the program of University Volunteers' TB Prevention and Control Advocacy in Promoting Patient Finding, and “Pioneer” and “Leading Goose” R&D Program of Zhejiang (grant number 2025C01134) and Disease Prevention and Control Innovation Team of Zhejiang Province (2026JKC-05).

Disclosure

The authors have no competing interests to declare for this work.

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