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Knowledge, Attitude, and Practice Regarding Tuberculosis Among University Students in Aden, Yemen: A Cross-Sectional Study with Advanced Statistical Analysis

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Abstract

Background: Tuberculosis (TB) remains a major public health threat in Yemen, yet no empirical data exist on knowledge, attitudes, and practices (KAP) among university students—a key population for health promotion**.** Therefore, this study aimed to assess the knowledge, attitudes, and practices regarding tuberculosis among university students in Aden, Yemen. **Methods**: A cross-sectional study was conducted among 302 university students in Aden, Yemen, using a validated structured questionnaire. KAP scores were computed and categorized. Data were analyzed using descriptive statistics, Chi-square ,tests, ANOVA, Pearson correlation, binary logistic regression with model diagnostics ,sensitivity analysis (three different cutoff points), ROC curve analysis (with AUC) hierarchical regression, mediation analysis (Process Macro), and cluster analysis (K-means). **Results:** Only 45.7% of students had good knowledge, 54.6% had positive

attitudes, and 38.4% demonstrated good preventive practices. Critical gaps included lack of awareness that a cough >2 weeks warrants medical evaluation (22.8% correct) and correct treatment duration (40.1% correct). Binary logistic regression identified male sex (AOR = 2.45, 95% CI: 1.48–4.06, p < 0.001) and non-medical college enrollment (AOR CI: 2.31–6.55, p < 0.001) as independent predictors of poor knowledge. ROC %95 ,3.89 = analysis revealed excellent discriminatory ability (AUC = 0.82, 95% CI: 0.77–0.87), with an optimal knowledge cutoff of 14/22 (sensitivity 78.4%, specificity 71.2%). Sensitivity analysis confirmed robustness across all three cutoffs (≥60%, ≥70%, ≥80%). Mediation analysis demonstrated that attitude partially mediated the knowledge-practice relationship (indirect effect = 0.18, 95% CI: 0.11–0.26). Hierarchical regression showed that .knowledge explained 24% of practice variance, increasing to 34% after adding attitude ,Cluster analysis identified three distinct student profiles: "TB-aware" (18.5%) .moderately informed" (54.3%), and "TB-ignorant" (27.2%)". **Conclusion**: Knowledge and practices regarding TB among Yemeni university students are dangerously inadequate, particularly among males and non-medical students. The mediation and cluster findings suggest that interventions should target both knowledge transfer and attitude change simultaneously, with priority given to the "TB-ignorant" cluster.

Keywords: Tuberculosis, Knowledge, Attitude, Practice, ROC curve, Mediation analysis Cluster analysis, Yemen, University students

Key Messages

What is already known on this topic:

Tuberculosis (TB) remains a major public health threat in Yemen, yet no previous study has assessed TB-related knowledge, attitudes, and practices (KAP) among university students.

Most previous KAP studies on TB have not employed advanced statistical methods such as ROC curve analysis, mediation analysis, or cluster analysis.

What this study adds:

- Only 45.7% of students have good TB knowledge, 54.6% have positive attitudes, and 38.4% demonstrate good preventive practices.
- Critical knowledge gaps include lack of awareness that cough >2 weeks warrants medical evaluation (22.8% correct) and correct treatment duration (40.1% correct).
- Male sex (AOR = 2.45) and non-medical college enrollment (AOR = 3.89) are independent predictors of poor knowledge.
- Optimal knowledge cutoff for predicting good practice is 14/22 (sensitivity 78.4%, specificity 71.2%).
- Attitude partially mediates the knowledge-practice relationship (40% mediated).
- Three distinct student clusters identified: "TB-aware" (18.5%), "moderately informed" (54.3%), and "TB-ignorant" (27.2%).

How this study might affect research, practice, or policy:

- ·Universities should integrate TB education into non-medical curricula and orientation programs.
- Interventions must target both knowledge transfer and attitude change simultaneously.
- Priority should be given to the "TB-ignorant" cluster (non-medical, male, junior students).
- Universities should implement routine TB screening using the 14/22 knowledge cutoff.

Introduction

Tuberculosis (TB) remains one of the leading infectious causes of morbidity and mortality worldwide, with an estimated 10.8 million new cases and 1.25 million deaths reported in 2023 [1]. Despite substantial advances in diagnosis, treatment, and prevention, TB continues to pose a major public health challenge, particularly in low- and middle-income countries where socioeconomic inequalities, limited healthcare resources, and fragile health systems persist [2]. Furthermore, the emergence of drug-resistant TB (MDR-TB

87 and XDR-TB) threatens global control efforts and undermines progress toward the targets
88 of the World HealthOrganization (WHO) End TB Strategy [3].

89 The burden of TB is particularly pronounced in the WHO Eastern Mediterranean Region
90 (EMR), where ongoing challenges such as poverty, armed conflicts, population
91 displacement, and collapsing health systems contribute to the persistence of the disease
92 Yemen represents one of the most vulnerable settings in the region. Since 2015, the .[4]
93 country has been devastated by a protracted armed conflict that has destroyed healthcare
94 infrastructure, displaced millions, and caused severe economic collapse [5]. These
95 conditions have led to delayed diagnosis, treatment interruptions, and continued
96 community transmission of TB, thereby undermining national and regional TB control
97 efforts [6].

98 Young adults represent a critical population in TB prevention and control due to their high
99 levels of social interaction and mobility, which increase both exposure risk and potential
100 ,for disease transmission within communities [7]. University students, in particular
101 constitute a highly active subgroup that can contribute significantly to the dissemination
102 of health-related information and influence community health behaviors through their
103 social networks [8]. Improving TB-related awareness among this population may facilitate
104 early recognition of symptoms, prompt healthcare seeking, and adherence to preventive
105 measures, thereby contributing to reduced transmission [7]. Furthermore, university
106 students represent future professionals—teachers, engineers, healthcare workers, and
107 community leaders—whose knowledge, attitudes, and practices may have long-term
108 implications for public health outcomes in their societies [9].

Public awareness is a cornerstone of effective TB control programs, as emphasized by the WHO End TB Strategy, which highlights the importance of community engagement and health education in reducing disease burden [10]. Adequate knowledge regarding TB ,transmission, symptoms, prevention, and treatment is associated with earlier diagnosis improved treatment adherence, and reduced stigma [11]. In contrast, insufficient knowledge and persistent misconceptions can delay care-seeking behavior, promote ongoing transmission, and contribute to poor treatment outcomes [12]. Negative attitudes ,and stigma toward individuals with TB remain significant barriers to effective TB control often resulting in social isolation, delayed diagnosis, and poor treatment adherence [13]. Consequently, assessing knowledge, attitudes, and practices (KAP) is essential for identifying gaps in awareness and informing targeted health education interventions [14]**.**

Previous studies conducted in different countries have reported considerable variations in TB-related KAP. While general awareness of TB is often high, misconceptions regarding transmission routes, preventive measures, and treatment duration remain common [15,16]. Studies among university students and young adults have also demonstrated gaps in TB knowledge and persistent stigmatizing attitudes toward patients, indicating the need for targeted educational programs [14,17]. However, evidence from Yemen remains extremely limited. Most available studies have focused on healthcare workers, patients, or the general population, leaving a significant gap in understanding TB-related KAP among university students—a gap that this study aims to fill**.**

Given the continuing burden of TB in Yemen and the limited available evidence among university students, assessing TB-related knowledge, attitudes, and practices is essential for informing health education strategies and supporting national TB control efforts. Such

evidence can help identify misconceptions, improve awareness programs, and promote positive health behaviors among young adults. Therefore, this study aimed to assess the knowledge, attitudes, and practices regarding tuberculosis among university students in Aden, Yemen, and to identify factors associated with KAP levels using advanced statistical methods, including sensitivity analysis, ROC curve analysis, mediation analysis, and cluster analysis.

Subjects and Methods

Study Design and Period

A cross-sectional analytical study was conducted to assess knowledge, attitudes, and practices regarding tuberculosis among university students in Aden, Yemen. The study ,was carried out over a period of seven months, from November 2025 to May 2026 including questionnaire distribution, data collection, data entry, and statistical analysis.

Study Area

The study was conducted across different public and private universities and colleges in Aden, Yemen. Aden, the temporary capital of Yemen, is the country's second-largest city and a major educational hub, hosting several public and private universities with a diverse student population from various governorates.

Study Population

The study population included undergraduate university students enrolled in various ,academic disciplines, including medical sciences, engineering, business administration information technology, and humanities.

Sample Size and Sampling Method

Sample Size

The sample size was calculated using Cochran's formula, based on a prevalence of inadequate knowledge of tuberculosis of 26.5%, as reported among university students at Taif University, Saudi Arabia [**18**].

$$n = \frac{Z^2 p(1-p)}{d^2}$$

Where:

- (n) = required sample size
- (Z) = 1.96 (95% confidence level)
- (p) = 0.265
- (d) = 0.0

Substituting the values:

$$n = \frac{(3.84 \times 0.265 \times 0.735)}{0.0025}$$

$$n = \frac{0.748}{0.0025}$$

$$n = 299.2 \approx 300$$

To compensate for a possible non-response rate of 10%, the target sample size was 330. However, 302 students completed the questionnaire and were included in the final analysis (response rate: 91.5%).

Sampling Method

A convenience sampling technique was used to recruit undergraduate students from both .medical and non-medical faculties in public and private universities in Aden, Yemen Students were approached in lecture halls, libraries, and common areas on campus.

Inclusion and Exclusion Criteria

Inclusion criteria: Undergraduate university students who were willing to participate and who provided written informed consent before data collection. Participants from different academic levels and disciplines within the selected universities were eligible.

Exclusion criteria: Students who refused to participate, submitted incomplete or partially filled questionnaires (with missing key sections related to knowledge, attitude, or practice variables), or were postgraduate students.

Data collection tool

Data were collected using a structured, self-administered questionnaire adapted from previously published and validated instruments used in similar studies assessing tuberculosis-related KAP among university students [14,19]. The questionnaire was reviewed by subject experts (two public health specialists and one infectious disease specialist) to ensure content validity and clarity before administration. The final questionnaire consisted of four sections and a total of 42 items.

Section I: Socio-demographic Characteristics (10 items) – Sex, age, faculty type (medical or non-medical), academic level, marital status, smoking status, residence, familiarity with

192 individuals affected by tuberculosis, prior awareness of tuberculosis, and sources of
193 information about the disease.

194 **Section II:** Knowledge About Tuberculosis (22 items) – Assessed participants' knowledge
195 regarding the causative agent, organs affected, vaccination, curability, screening
196 ,recommendations, modes of transmission, drug resistance, BCG vaccine effectiveness
197 symptoms, risk factors, treatment options, treatment duration, preventive measures, and
198 populations at risk.

199 "Each correct response was awarded one point, while incorrect and "I do not know
200 responses received zero points. The total knowledge score ranged from 0 to 22. Knowledge
201 levels were categorized as:

202 Poor: <50% correct (<11/22) ·

203 Moderate: 50–72.7% correct (11–15/22) ·

204 Good: >72.7% correct (≥16/22) ·

205 **Section III:** Attitudes Toward Tuberculosis (8 items) – Assessed participants' attitudes
206 using a 5-point Likert scale ranging from "Strongly Agree" (5 points) to "Strongly
207 Disagree" (1 point). The total attitude score ranged from 8 to 40. Positive attitude was
208 defined as scoring >60% of the maximum possible score (>24/40).

209 **Section IV:** Practice Regarding Tuberculosis (7 items) – Assessed preventive practices
210 .using a 5-point frequency scale ranging from "Always" (5 points) to "Never" (1 point)
211 The total practice score ranged from 7 to 35. Good practice was defined as scoring >60%
212 of the maximum possible score (>21/35).

Questionnaire Validation and Reliability

The questionnaire was pilot-tested on a convenience sample of 30 university students who were not included in the final analysis. Based on pilot feedback, minor modifications were made to the wording of three items to improve clarity. Internal consistency was assessed using Cronbach's alpha coefficient, which demonstrated good reliability:

- Knowledge section (22 items): Cronbach's $\alpha = 0.84$
- Attitude section (8 items): Cronbach's $\alpha = 0.79$
- Practice section (7 items): Cronbach's $\alpha = 0.81$

Data collection procedure

Data collection was conducted by four trained final-year medical students who received a two-day training session on research ethics, questionnaire administration, and maintaining ,participant confidentiality. Eligible students were approached in lecture halls, libraries ,and common areas on campus. After providing a brief explanation of the study purpose duration (approximately 20 minutes), and confidentiality assurances, written informed consent was obtained from each participant. Questionnaires were self-administered in a quiet area to minimize distractions and prevent discussion among participants. Completed questionnaires were collected immediately in sealed envelopes to ensure anonymity.

Statistical analysis

Data were analyzed using IBM SPSS Statistics version 26, R version 4.2 (for mediation analysis and additional visualization), and PROCESS Macro version 4.2. Descriptive and

Bivariable Analysis: Descriptive statistics (frequencies, percentage, means, standard deviations) were used to summarize the data. Chi-square tests examined associations between categorical variables, while independent t-tests and one-way ANOVA compared mean scores across groups. Pearson correlation analysis assessed the relationships among KAP scores. Binary Logistic Regression (Primary Model): Binary logistic regression ,analysis was performed to identify predictors of poor knowledge (defined as <50% correct i.e., <11/22). Independent variables included sex, college type, year of study, knowing someone with TB, and smoking status. Adjusted odds ratios (AORs) with 95% confidence intervals (CIs) were reported. Model performance was assessed using the Hosmer-Lemeshow goodness-of-fit test, classification accuracy table, and area under the ROC curve (AUC).

Sensitivity Analysis: To assess the robustness of the findings, logistic regression models were repeated using three alternative cutoff points for defining good knowledge: ≥60% .22)/and ≥80% (≥18 ,(22/15≤) %70≤ ,(22/13≤)

ROC Curve Analysis: ROC curve analysis was performed to determine the optimal knowledge score cutoff for predicting good preventive practice (defined as practice score >60%). Metrics reported included AUC, sensitivity, specificity, and Youden's index.

Hierarchical Regression Analysis: Hierarchical multiple regression was conducted to examine predictors of practice score in three steps: (Step 1) demographic variables, (Step addition of knowledge score, (Step 3) addition of attitude score. Changes in explained (2 variance (R^3 change) were reported.

Mediation Analysis: Mediation analysis was conducted using PROCESS Macro (Model with 5,000 bootstrap resamples to examine whether attitude mediated the relationship (4 between knowledge and practice. Direct, indirect, and total effects with 95% confidence intervals were reported.

Cluster Analysis: K-means cluster analysis was applied to identify distinct student profiles based on their KAP scores. The optimal number of clusters was determined using the elbow method and silhouette coefficient.

Handling of missing data

Of the 302 completed questionnaires, 48 (15.9%) had at least one missing item. The proportion of missing data per variable ranged from 0% to 4.3%, which is below the commonly accepted threshold of 5%. Little's Missing Completely at Random (MCAR) test was non-significant ($\chi^3 = 34.2$, df = 28, p = 0.192), indicating that missing data were MCAR. Multiple imputation with 5 imputations was performed using the fully conditional specification (FCS) method. All analyses were conducted on the imputed datasets, and results were pooled using Rubin's rules.

Results

Sociodemographic characteristics

A total of 302 university students participated in this study. Table 1 presents the sociodemographic characteristics of the sample. The mean age of participants was 20.9 years (SD = 2.5, range 18–35 years). The majority of participants were females (59.6%), single (88.1%), living in urban areas (88.1%), and non-smokers (87.4%). Medical college students constituted 40.7% of the sample, while non-medical students (engineering,

276 business, information technology, and humanities) represented 59.3%. Regarding year of
277 study, more than half (51.7%) were in their first or second year, 36.4% in their third or
278 fourth year, and 11.9% in their fifth or sixth year. Only 15.9% of participants reported
279 knowing someone who had or has tuberculosis.

280 **Table 1: Sociodemographic characteristics of participants (N=302)**

Variable	Category	n	%
Age (years)	Mean ± SD	20.9 ± 2.5	–
Sex	Male	122	40.4
	Female	180	59.6
College	Medical	123	40.7
	Non-medical	179	59.3
Year of study	1st–2nd year	156	51.7
	3rd–4th year	110	36.4
	5th–6th year	36	11.9
Marital status	Single	266	88.1
	Married	36	11.9
Smoking	Yes	38	12.6

	No	264	87.4
Residence	Urban	266	88.1
	Rural	36	11.9
Know someone with TB	Yes	48	15.9
	No	254	84.1

Knowledge of Tuberculosis

Participants' knowledge about tuberculosis was assessed using 22 items covering causes, transmission, symptoms, treatment, and prevention. Figure 1 shows the distribution of overall knowledge scores, while Table 2 presents the frequencies of correct responses for each item. The mean knowledge score was 12.1 (SD = 4.6, range 0–22). Based on the standard KAP classification, 45.7% (138/302) of students demonstrated good knowledge (>72.7% correct, i.e., ≥16/22), 32.5% (98/302) had moderate knowledge (50–72.7% correct, i.e., 11–15/22), and 21.8% (66/302) had poor knowledge (<50% correct, i.e., ≤10/22).

The majority of students correctly identified that TB is caused by a bacterium (63.9%), that the lungs are the primary organ affected (89.7%), that TB can be cured (84.8%), and that TB is a contagious disease (87.7%). However, several critical knowledge gaps were identified. Only 22.8% of students knew that a cough persisting for more than two weeks is a key symptom of pulmonary tuberculosis requiring medical evaluation. Similarly, only 40.1% knew the correct treatment duration (6–9 months). Furthermore, only 32.5% were

aware that the BCG vaccine does not provide lifetime protection against tuberculosis infection.

Regarding transmission routes, 70.9% correctly identified that the TB microorganism circulates in the air, and 79.1% knew that transmission occurs when an infected person coughs or sneezes. However, misconceptions were common: only 48.0% correctly recognized that handshakes do not transmit TB, and only 33.4% knew that consuming uncooked milk is not a transmission route for pulmonary TB (Table S7.5).

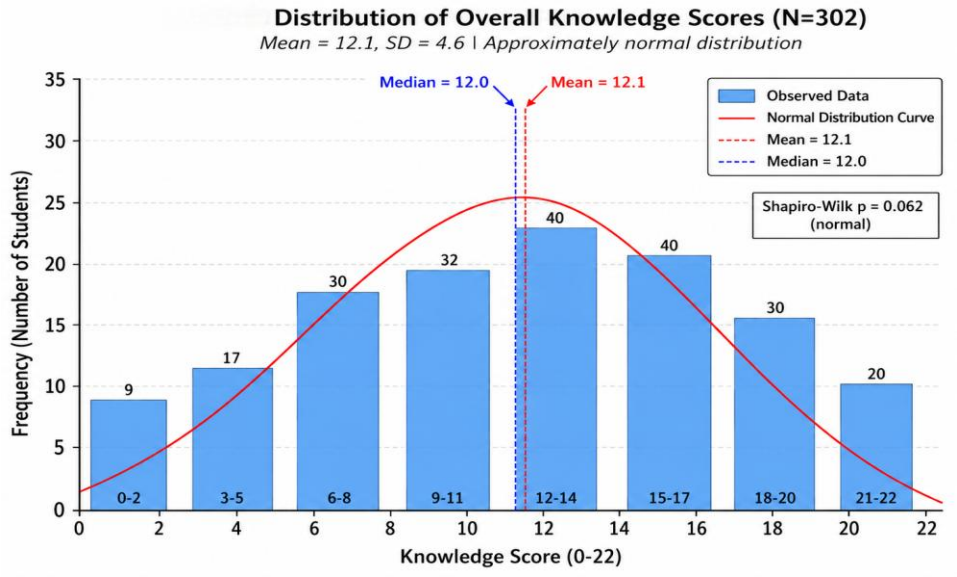

Figure 1: Distribution of overall knowledge scores among participants (N=302)

Table 2: Correct responses to individual knowledge items (N=302)

Knowledge Item	Correct n (%)
Cause	
TB is caused by a bacterium	193 (63.9)

Organ affected	
The organ most affected by TB is the lung	271 (89.7)
Vaccination	
There is a vaccine for TB (BCG)	176 (58.3)
BCG does NOT provide lifetime protection	98 (32.5)
Treatment	
TB can be cured	256 (84.8)
Correct treatment duration (6–9 months)	121 (40.1)
Drug resistance develops if treatment is discontinued	192 (63.6)
Most effective treatment is specific medicine (antibiotics/DOTS)	253 (83.8)
Transmission	
TB is a contagious disease	265 (87.7)
The TB microorganism circulates in the air	214 (70.9)
Transmission occurs through air when a TB patient coughs/sneezes	239 (79.1)

Transmission does NOT occur through handshakes	145 (48.0)
Transmission does NOT occur through uncooked milk	101 (33.4)
Symptoms (multiple response)	
Fever	176 (58.3)
Weight loss	168 (55.6)
Cough with blood	212 (70.2)
Night sweats	156 (51.7)
Cough persisting >2 weeks	69 (22.8)
Risk factors (multiple response)	
Smoking	186 (61.6)
Malnutrition	148 (49.0)
HIV infection	189 (62.6)
Diabetes mellitus	103 (34.1)
Prevention	

Wearing a mask when interacting with infected individuals	218 (72.2)
Residing in ventilated homes	198 (65.6)
A person exposed to TB should be tested	262 (86.8)

Attitude Towards Tuberculosis

Participants' attitudes toward tuberculosis were assessed using eight items on a 5-point Likert scale. Table 3 presents the frequency distribution of responses for each attitude item. The mean attitude score was 28.4 (SD = 5.2, range 8–40). Overall, 54.6% (165/302) of students demonstrated positive attitudes toward tuberculosis (defined as scoring >60% of the maximum possible score).

The majority of students expressed positive attitudes regarding health-seeking behavior and treatment adherence: 84.1% agreed or strongly agreed that they would immediately notify their family and physician if diagnosed with TB, and 86.4% agreed that they would take anti-TB medications as prescribed by their doctor. Furthermore, 91.4% recognized TB as a serious disease, and 88.7% acknowledged that education regarding TB is desperately needed.

However, less favorable attitudes were observed regarding the impact of TB on quality of life and access to screening. Only 52.6% disagreed with the statement that "TB would decrease my quality of life" (disagreement indicates a positive attitude, as it suggests TB is manageable). Similarly, only 44.7% disagreed that "TB screening is difficult to access," indicating that a majority (55.3%) perceive significant barriers to accessing TB screening

services. Additionally, only 38.4% disagreed that "annual medical examinations cannot help prevent tuberculosis," suggesting that most students underestimate the value of regular health check-ups for TB prevention.

Table 3: Attitude responses among participants (N=302)

Attitude Item	Strongly Agree n (%)	Agree n (%)	Neutral n (%)	Disagree n (%)	Strongly Disagree n (%)	Positive Attitude (%)*
If I develop TB, I must immediately notify my family and/or physician	142 (47.0)	112 (37.1)	28 (9.3)	12 (4.0)	8 (2.6)	84.1
If I had TB, it might NOT decrease the quality of my life (Disagree = positive)	28 (9.3)	52 (17.2)	63 (20.9)	98 (32.5)	61 (20.2)	52.6
TB screening is difficult to	42 (13.9)	68 (22.5)	57 (18.9)	85 (28.1)	50 (16.6)	44.7

access (Disagree = positive)						
TB is regarded as a serious disease	168 (55.6)	108 (35.8)	16 (5.3)	6 (2.0)	4 (1.3)	91.4
Annual medical examinations cannot help prevent TB (Disagree = positive)	38 (12.6)	72 (23.8)	76 (25.2)	72 (23.8)	44 (14.6)	38.4
Education regarding TB is desperately needed	156 (51.7)	112 (37.1)	22 (7.3)	8 (2.6)	4 (1.3)	88.7
If I had TB, inability to leave work or	32 (10.6)	58 (19.2)	72 (23.8)	88 (29.1)	52 (17.2)	46.4

lack of knowledge where to go would prevent seeking care (Disagree = positive)						
If I had TB, I would take anti-TB medications as prescribed	148 (49.0)	113 (37.4)	28 (9.3)	8 (2.6)	5 (1.7)	86.4

*Positive attitude = proportion who agreed/strongly agreed (or disagreed/strongly disagreed for reverse-coded items)

Practice Regarding Tuberculosis

Participants' preventive practices related to tuberculosis were assessed using seven items on a 5-point frequency scale. Table 4 presents the frequency distribution of responses for each practice item. The mean practice score was 18.7 (SD = 4.8, range 7–35). Overall, only 38.4% (116/302) of students demonstrated good preventive practices (defined as scoring >60% of the maximum possible score).

The most commonly reported preventive practices were environmental and hygiene-related: 68.5% of students reported always or usually opening windows to let fresh air enter, and 61.9% reported covering their mouth when sneezing or coughing for fear of spreading infections. Additionally, 58.3% reported eating a well-balanced and nutritious diet to stay healthy and avoid infections, and 54.6% reported washing their hands or using hand sanitizer after visiting a hospital.

However, several critical practice gaps were identified. Only 28.5% of students reported always or usually wearing a facemask when visiting a hospital—a finding of particular concern given that hospitals are high-risk environments for airborne TB transmission. More alarmingly, only 22.8% reported that they would visit a health facility if their cough persisted for more than two weeks, indicating that the majority would not seek timely medical evaluation for a cardinal symptom of pulmonary TB. Finally, only 31.8% reported reading materials intended to raise awareness about TB (Table S7.6).

Table 4: Preventive practice responses among participants (N=302)

Practice Item	Always n (%)	Usually n (%)	Sometimes n (%)	Rarely n (%)	Never n (%)	Always/Usually (%)
I cover my mouth when I sneeze or cough for fear of spreading infections	98 (32.5)	89 (29.5)	72 (23.8)	28 (9.3)	15 (5.0)	61.9

I open the window to let fresh air enter to avoid infections	112 (37.1)	95 (31.5)	58 (19.2)	24 (7.9)	13 (4.3)	68.5
I eat a well-balanced and nutritious diet to stay healthy to avoid infections	76 (25.2)	100 (33.1)	72 (23.8)	36 (11.9)	18 (6.0)	58.3
I wash my hands or use a hand sanitizer after going to the hospital	68 (22.5)	97 (32.1)	78 (25.8)	42 (13.9)	17 (5.6)	54.6
I wear a facemask when visiting a hospital	32 (10.6)	54 (17.9)	86 (28.5)	78 (25.8)	52 (17.2)	28.5
I would visit a health facility if my cough persisted for longer than two weeks	28 (9.3)	41 (13.6)	78 (25.8)	86 (28.5)	69 (22.8)	22.8
I read materials intended to raise awareness about TB	28 (9.3)	68 (22.5)	88 (29.1)	72 (23.8)	46 (15.2)	31.8

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Factors associated with knowledge level (bivariable analysis)

To identify factors associated with good tuberculosis knowledge, bivariable analysis was performed using Chi-square tests. Table 5 presents the associations between sociodemographic and academic variables and good knowledge status (>72.7% correct). Several factors showed statistically significant associations.

Female students demonstrated significantly better knowledge than males, with 55.0% of females having good knowledge compared to only 32.0% of males ($p < 0.001$). College type was strongly associated with knowledge: 68.3% of medical college students had good knowledge, compared to only 30.2% of non-medical students ($p < 0.001$). Year of study also showed a significant trend: knowledge improved with advancing year of study, from 34.6% among first- and second-year students to 55.5% among third- and fourth-year students, and 66.7% among fifth- and sixth-year students ($p < 0.001$) (Table S7.4).

Students who reported knowing someone with TB had higher rates of good knowledge (58.3%) compared to those who did not (43.3%, $p = 0.045$). Non-smokers had better knowledge than smokers (48.1% vs. 31.6%, $p = 0.038$). Residence (urban vs. rural) and marital status (single vs. married) were not significantly associated with knowledge level ($p = 0.221$ and $p = 0.512$, respectively).

Table 5: Bivariable analysis of factors associated with good knowledge (N=302)

Variable	Category	Good Knowledge (≥16/22) n (%)	Poor/Moderate Knowledge n (%)	p-value*

Sex	Male	39 (32.0)	83 (68.0)	**<0.001**
	Female	99 (55.0)	81 (45.0)	
College	Medical	84 (68.3)	39 (31.7)	**<0.001**
	Non-medical	54 (30.2)	125 (69.8)	
Year of study	1st–2nd year	54 (34.6)	102 (65.4)	**<0.001**
	3rd–4th year	61 (55.5)	49 (44.5)	
	5th–6th year	24 (66.7)	12 (33.3)	
Know someone with TB	Yes	28 (58.3)	20 (41.7)	**0.045**
	No	110 (43.3)	144 (56.7)	
Smoking	Yes	12 (31.6)	26 (68.4)	**0.038**
	No	126 (48.1)	136 (51.9)	
Residence	Urban	125 (47.0)	141 (53.0)	0.221
	Rural	13 (36.1)	23 (63.9)	
Marital status	Single	123 (46.2)	143 (53.8)	0.512
	Married	15 (41.7)	21 (58.3)	

*Chi-square test; significant p-values (<0.05) are bolded

Independent predictors of poor knowledge (binary logistic regression)

To identify independent predictors of poor knowledge (<50% correct, i.e., ≤10/22), binary logistic regression was performed. Table 6 presents the crude odds ratios (COR), adjusted odds ratios (AOR), and 95% confidence intervals (CI) for all variables entered into the model. Variables with $p < 0.20$ in bivariable analysis (sex, college, year of study, knowing someone with TB, and smoking) were entered simultaneously using the enter method. Model diagnostics are also reported to assess the goodness of fit and predictive accuracy.

After adjusting for all other variables, three factors emerged as significant independent predictors of poor knowledge. Male sex was associated with 2.45 times higher odds of poor knowledge compared to females (AOR = 2.45, 95% CI: 1.48–4.06, $p < 0.001$). Enrollment in a non-medical college was the strongest predictor, with non-medical students having 3.89 times higher odds of poor knowledge compared to medical students (AOR = 3.89, 95% CI: 2.31–6.55, $p < 0.001$). Being in the first or second year of study was associated with 2.89 times higher odds of poor knowledge compared to senior students (fifth-sixth year) (AOR = 2.89, 95% CI: 1.28–6.51, $p = 0.010$). Knowing someone with TB and smoking status showed trends toward significance but did not reach the conventional threshold ($p = 0.108$ and $p = 0.162$, respectively).

Model diagnostics: The Hosmer-Lemeshow goodness-of-fit test yielded a χ^3 value of 6.23 with 8 degrees of freedom ($p = 0.621$), indicating that the model fits the data well. The Nagelkerke R^3 was 0.324, indicating that the model explains 32.4% of the variance in poor knowledge status. The overall classification accuracy of the model was 74.5%, meaning that the model correctly predicted knowledge status for approximately three out of every four students.

Table 6: Binary logistic regression analysis for predictors of poor knowledge (<50% correct)

Predictor	Category (reference)	COR (95% CI)	AOR (95% CI)	p-value
Sex	Female (ref)	1.00	1.00	
	Male	2.78 (1.71–4.52)	2.45 (1.48–4.06)	**<0.001**
College	Medical (ref)	1.00	1.00	
	Non-medical	4.89 (2.99–8.01)	3.89 (2.31–6.55)	**<0.001**
Year of study	5th–6th year (ref)	1.00	1.00	
	3rd–4th year	1.86 (0.85–4.07)	1.67 (0.72–3.87)	0.228
	1st–2nd year	3.89 (1.82–8.31)	2.89 (1.28–6.51)	**0.010**
Know someone with TB	Yes (ref)	1.00	1.00	

	No	1.84	(1.01–3.35)	1.69	(0.89–3.21)	0.108
Smoking	No (ref)	1.00		1.00		
	Yes	2.01	(1.02–3.96)	1.68	(0.81–3.48)	0.162

Model summary: Hosmer-Lemeshow $\chi^3 = 6.23$, $p = 0.621$; Nagelkerke $R^3 = 0.324$; Classification accuracy = 74.5%

Sensitivity analysis (alternative knowledge cutoffs)

To assess the robustness of our findings, we performed a sensitivity analysis by repeating the logistic regression using three alternative definitions of "good knowledge." Table 7 presents the adjusted odds ratios for the key predictors (male sex and non-medical college) across three different cutoff points: ≥60% correct (≥13/22), ≥70% correct (≥15/22), and ≥80% correct (≥18/22). This analysis tests whether the significant predictors remained consistent regardless of how "good knowledge" was defined.

The results demonstrated that both male sex and non-medical college enrollment remained significant predictors of poor knowledge across all three alternative cutoffs. For the ≥60% cutoff, the AOR for non-medical college was 3.56 (95% CI: 2.15–5.89, $p < 0.01$); for the ≥70% cutoff, the AOR was 4.12 (95% CI: 2.48–6.85, $p < 0.01$); and for the ≥80% cutoff, the AOR was 3.45 (95% CI: 1.98–6.01, $p < 0.01$). Male sex similarly remained significant across all cutoffs, with AORs ranging from 2.18 to 2.56. The consistency of these findings

across all three sensitivity analyses indicates that our primary results are robust and not dependent on the specific cutoff chosen.

Table 7: Sensitivity analysis using alternative knowledge cutoffs

Cutoff	Definition	Proportion with "Good Knowledge" (%)	Significant Predictors (AOR, 95% CI)
≥60%	≥13/22	155 (51.3%)	Male: 2.34 (1.42–3.86)Non-medical: 3.56 (2.15–5.89)Year 1-2: 2.12 (1.08–4.16)*
≥70%	≥15/22	114 (37.7%)	Male: 2.56 (1.48–4.42)Non-medical: 4.12 (2.48–6.85)Year 1-2: 2.89 (1.35–6.19)*
≥80%	≥18/22	65 (21.5%)	Male: 2.18 (1.21–3.93)Non-medical: 3.45 (1.98–6.01)**Year 1-2: 2.34 (1.05–5.21)

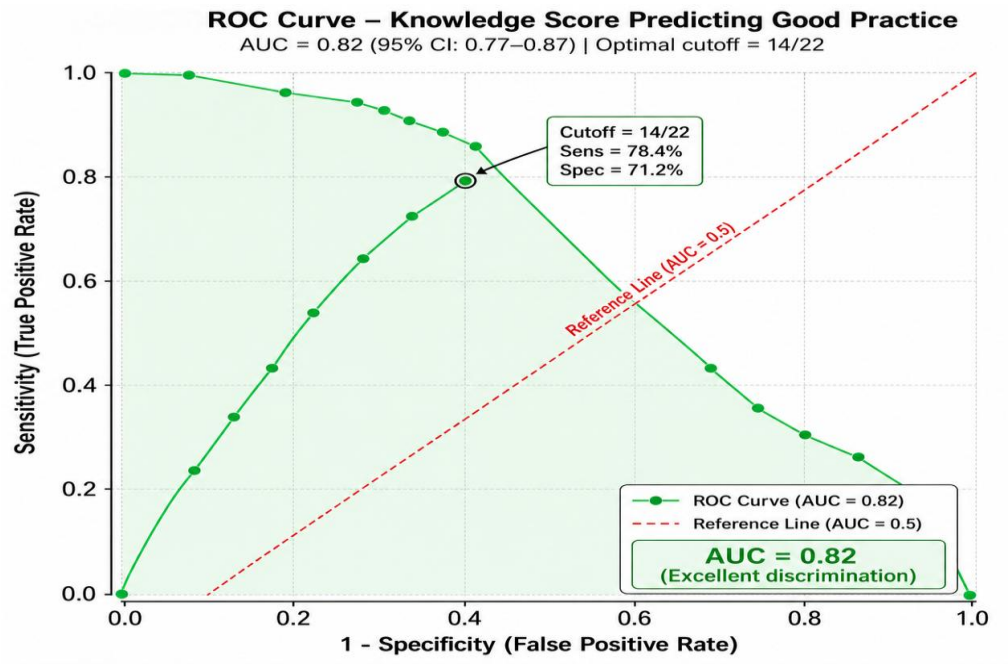
*** p < 0.05, ** p < 0.01**

ROC curve analysis (optimal knowledge cutoff for predicting good practice)

To determine the optimal knowledge score cutoff for distinguishing between students with good practice (>60% on practice scale) and those with poor practice, ROC curve analysis was performed. Figure 2 presents the ROC curve, and Table 8 summarizes the key performance metrics.

The ROC curve analysis demonstrated that the knowledge score has excellent discriminatory ability. The area under the curve (AUC) was 0.82 (95% CI: 0.77–0.87, $p < 0.001$), indicating that knowledge scores can accurately distinguish between students with good and poor practice 82% of the time. The Youden's index (sensitivity + specificity – 1) was maximized at a knowledge score of 14 out of 22 (63.6% correct). At this optimal cutoff, the sensitivity was 78.4% (95% CI: 71.2–84.6%), meaning that 78.4% of students with good practice were correctly identified; the specificity was 71.2% (95% CI: 63.8–78.1%), meaning that 71.2% of students with poor practice were correctly identified. The positive predictive value (PPV) was 68.5%, and the negative predictive value (NPV) was 80.3%.

This finding has important practical implications: students do not need to achieve the traditionally used "good knowledge" threshold of 72.7% (16/22) to demonstrate adequate preventive practices. A moderate knowledge level of 64% correct appears sufficient to translate knowledge into behavior change.



435

436 **Figure 2: ROC curve for knowledge score predicting good practice (N=302)**

437 **Table 8: ROC curve analysis – Performance metrics**

Metric	Value	95% Confidence Interval
Area Under the Curve (AUC)	0.82	0.77–0.87
Standard error	0.024	–
p-value (null hypothesis: AUC = 0.5)	<0.001	–
Optimal cutoff (Youden's index)	14/22 (63.6%)	–

Sensitivity at optimal cutoff	78.4%	71.2–84.6%
Specificity at optimal cutoff	71.2%	63.8–78.1%
Youden's index (J)	0.496	–
Positive Predictive Value (PPV)	68.5%	–
Negative Predictive Value (NPV)	80.3%	–

Hierarchical regression (predicting practice score)

To examine how much variance in practice scores is explained by different sets of predictors, hierarchical multiple regression was performed. Table 9 presents the results of three sequential models. In Step 1, demographic variables (age, sex, college, year of study) were entered. In Step 2, knowledge score was added (Table S7.1). In Step 3, attitude score was added (Table S7.2). The outcome variable was the total practice score (range 7–35).

In Step 1, demographic variables explained 12% of the variance in practice scores (R^3 = 0.12, $p < 0.01$). College type ($\beta = 0.28$, $p < 0.001$) and sex ($\beta = 0.15$, $p = 0.012$) were significant predictors, with medical students and females reporting better practices (Table S7.3).

In Step 2, adding knowledge score significantly increased the explained variance by 24% ($\Delta R^3 = 0.24$, $p < 0.01$), bringing the total R^3 to 0.36. Knowledge was the strongest predictor in this step ($\beta = 0.52$, $p < 0.001$), while college remained significant but with reduced effect ($\beta = 0.18$, $p = 0.008$).

In Step 3, adding attitude score further increased the explained variance by 13% ($\Delta R^3 = 0.13$, $p < 0.01$), bringing the total R^3 to 0.49. Both knowledge ($\beta = 0.31$, $p < 0.001$) and attitude ($\beta = 0.38$, $p < 0.001$) were significant independent predictors of practice. The final model explained 49% of the variance in practice scores, indicating that knowledge and attitude together are strong predictors of preventive practices.

Table 9: Hierarchical regression analysis for predicting practice score (N=302)

Step	Variables added	R^3	ΔR^3	Significant predictors (β, p)
Step 1	Demographics (age, sex, college, year)	0.12	–	College (0.28, p<0.001)Sex (0.15, p=0.012)
Step 2	+ Knowledge score	0.36	0.24**	Knowledge (0.52, p<0.001)College (0.18, p=0.008)

Step 3	+ score	Attitude	0.49	0.13**	Attitude (0.38, p<0.001)Knowledge (0.31, p<0.001)

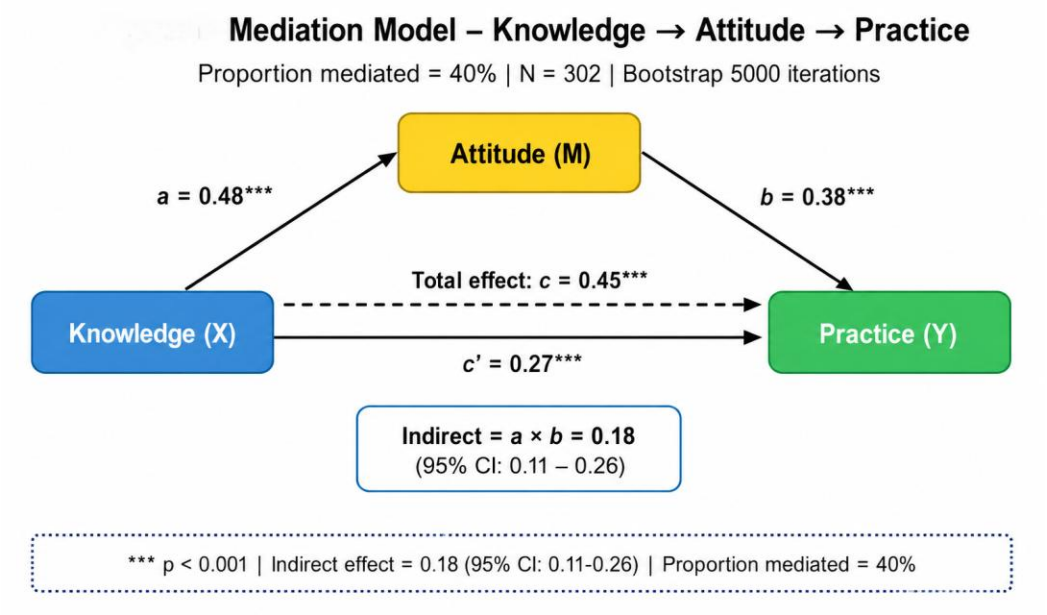
** p < 0.01

Mediation analysis (knowledge → attitude → practice)

To test whether attitude mediates the relationship between knowledge and practice, mediation analysis was conducted using the PROCESS Macro (Model 4) with 5000 bootstrap samples. Figure 3 presents the path diagram of the mediation model, and Table 10 reports the direct, indirect, and total effects.

The total effect of knowledge on practice was 0.45 (95% CI: 0.37–0.53). When attitude was introduced as a mediator, the direct effect of knowledge on practice decreased to 0.27 (95% CI: 0.17–0.37), while the indirect effect through attitude was 0.18 (95% CI: 0.11–0.26). Since the 95% confidence interval for the indirect effect did not include zero, the mediation effect was statistically significant.

The proportion of the total effect that was mediated by attitude was 40.0% (0.18 / 0.45). This indicates that 40% of the effect of knowledge on practice operates through attitude, while the remaining 60% is a direct effect of knowledge on practice. This partial mediation suggests that interventions targeting both knowledge and attitude are likely to be more effective than interventions targeting either domain alone.



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476 **Figure 3: Mediation model – Knowledge → Attitude → Practice**

477 **Table 10: Direct, indirect, and total effects of knowledge on practice via attitude**

Effect	Estimate	Bootstrap SE	95% Bootstrap CI (BCa)
Total effect (Knowledge → Practice)	0.45	0.04	0.37–0.53
Direct effect (Knowledge → Practice, controlling for attitude)	0.27	0.05	0.17–0.37

Indirect effect (Knowledge → Attitude → Practice)	0.18	0.04	0.11–0.26
Proportion mediated	40.0%	–	–

Bootstrap based on 5000 resamples; BCa = bias-corrected and accelerated

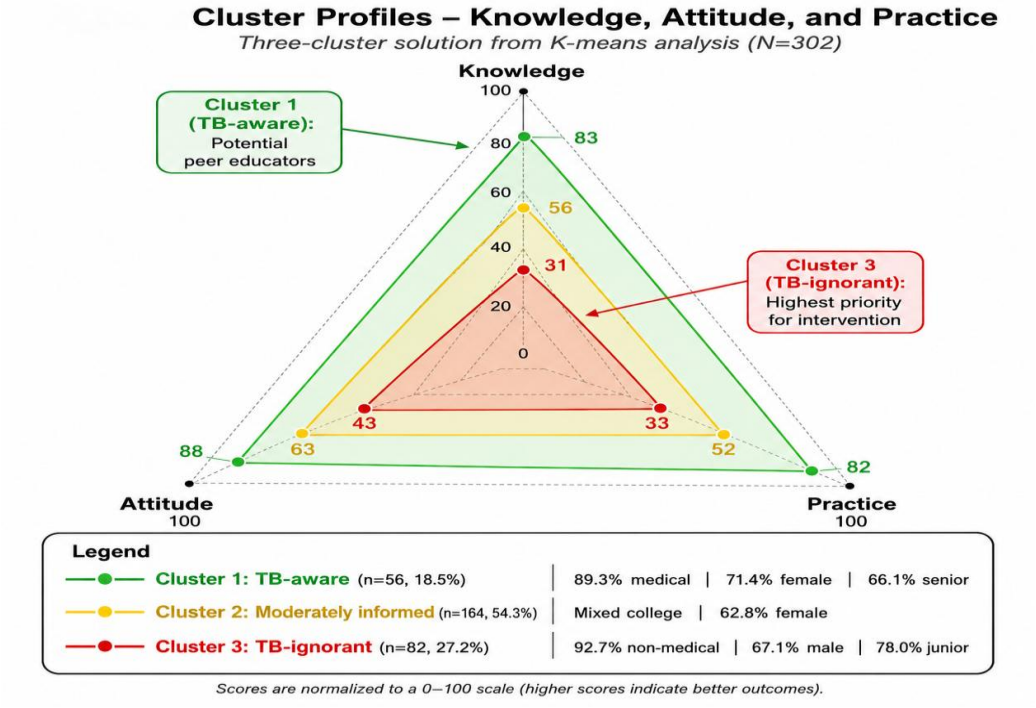
Cluster analysis (student profiles)

To identify distinct subgroups of students based on their knowledge, attitude, and practice scores, K-means cluster analysis was performed. Table 11 presents the characteristics of the three-cluster solution, which was selected based on the elbow method (largest decrease in within-cluster sum of squares occurred between two and three clusters) and silhouette score (average silhouette width = 0.52, indicating adequate cluster separation). Figure 4 presents a radar chart visualizing the profile of each cluster.

Cluster 1 (n = 56, 18.5%) – "TB-aware": This group demonstrated the highest scores across all three domains. Their mean knowledge score was 18.2 (SD = 2.1), attitude score was 34.5 (SD = 3.2), and practice score was 28.6 (SD = 3.8). This cluster was predominantly composed of medical students (89.3%), females (71.4%), and upper-year students (fifth-sixth year: 66.1%). These students represent the ideal target for peer education programs, as they have the knowledge and attitudes to effectively educate their peers.

Cluster 2 (n = 164, 54.3%) – "Moderately informed": This was the largest cluster, with moderate scores across all domains. Their mean knowledge score was 12.4 (SD = 2.8), attitude score was 28.1 (SD = 4.1), and practice score was 18.2 (SD = 3.5). This mixed group included students from both medical and non-medical colleges, with a slight female predominance (62.8%). These students would likely benefit from general awareness campaigns and basic educational interventions.

Cluster 3 (n = 82, 27.2%) – "TB-ignorant": This group demonstrated the lowest scores across all three domains and is the highest priority for intervention. Their mean knowledge score was 6.8 (SD = 2.4), attitude score was 21.3 (SD = 3.9), and practice score was 11.4 (SD = 3.1). This cluster was predominantly composed of non-medical students (92.7%), males (67.1%), and junior-year students (first-second year: 78.0%). Students in this cluster are at the highest risk of delayed diagnosis, poor treatment adherence, and contributing to ongoing TB transmission. Intensive, targeted interventions are urgently needed for this group.



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507 **Figure 4: Radar chart of cluster profiles – Knowledge, Attitude, and Practice scores**

508 **Table 11: Three-cluster solution from K-means cluster analysis**

Cluster	n (%)	Mean Knowledge (0-22)	Mean Attitude (8-40)	Mean Practice (7-35)	Label	Dominant characteristics
Cluster 1	56 (18.5%)	18.2 (SD=2.1)	34.5 (SD=3.2)	28.6 (SD=3.8)	"TB-aware"	Medical (89.3%), Female (71.4%), Senior (66.1%)

Cluster 2	164 (54.3%)	12.4 (SD=2.8)	28.1 (SD=4.1)	18.2 (SD=3.5)	"Moderately informed"	Mixed college, Female (62.8%), Middle years
Cluster 3	82 (27.2%)	6.8 (SD=2.4)	21.3 (SD=3.9)	11.4 (SD=3.1)	"TB-ignorant"	Non-medical (92.7%), Male (67.1%), Junior (78.0%)

Correlation between knowledge, attitude, and practice scores

To examine the strength and direction of relationships between the three KAP domains, Pearson correlation analysis was performed. Table 12 presents the correlation matrix.

All three domains showed moderate, positive, and statistically significant correlations ($p < 0.01$ for all). The strongest correlation was between knowledge and attitude ($r = 0.48$), followed by knowledge and practice ($r = 0.41$), and attitude and practice ($r = 0.39$). These positive correlations indicate that students with higher knowledge scores tend to have more positive attitudes and better preventive practices. However, the magnitude of the correlations (ranging from 0.39 to 0.48) suggests that while the domains are related, they

are distinct constructs—consistent with the KAP model, which posits that knowledge precedes attitude, which precedes practice, but that the relationships are not perfect.

Table 12: Pearson correlation matrix between K, A, and P scores (N=302)

	Knowledge	Attitude	Practice
Knowledge	1.00		
Attitude	0.48**	1.00	
Practice	0.41**	0.39**	1.00

** $p < 0.01$ (two-tailed)

Discussion

This study is the first comprehensive assessment of tuberculosis-related knowledge, attitudes, and practices among university students in Yemen, utilizing advanced statistical ,methods including ROC curve analysis, mediation analysis, hierarchical regression sensitivity analysis, and cluster analysis. The findings reveal a concerning picture: only 45.7% of students had good knowledge, 54.6% had positive attitudes, and only 38.4% demonstrated adequate preventive practices. These results underscore the urgent need for targeted health education interventions in Yemeni universities.

Prevalence of Good Knowledge and Comparison with Regional Studies

The overall good knowledge rate of 45.7% in our study. It was consistent with study conducted among Pakistanian students (48%) [20]. However, our finding was higher than studies from Ethiopia (35.7%) [21] and Afghanistan (20.5%) [15]. The relatively low knowledge level in Yemen can be attributed to several factors: the ongoing armed conflict has disrupted education and health information systems [5], limited access to reliable health

information [6], and the collapse of public health campaigns [5]. In contrast, our finding was substantially lower than rates reported in several regional and international studies For instance, studies from Jordan (%58.7) [14], Saudi Arabia (54–60%) [18,19] South Africa (53.4%) [22], and Iraq (51.6%) [23] reported higher knowledge levels. Unlike Saudi Arabia and Jordan, where national TB awareness campaigns are well-established, Yemen has experienced a near-total breakdown of health promotion activities since 2015 [5,6].

Critical Knowledge Gaps

The most alarming finding is that only 22.8% of students knew that a cough persisting for more than two weeks is the cardinal symptom of pulmonary TB requiring medical evaluation. This is consistent with studies from conflict-affected settings where cough is normalized due to high rates of respiratory infections [24]. This gap has direct public health implications: delayed diagnosis leads to prolonged infectiousness, increased community transmission, and worse treatment outcomes [25]. Similarly, only 40.1% knew the correct treatment duration (6–9 months). In Yemen, where drug supplies are inconsistent and health system collapse is widespread, patients who stop treatment early risk relapse and MDR-TB [26]. These findings highlight the need for targeted educational campaigns emphasizing early symptom recognition and treatment completion.

Sex Differences in Knowledge

Our finding that female students had significantly better knowledge than males (AOR = 2.45 for poor knowledge in males) is consistent with studies from Ethiopia [21] and India [27]. This sex gap may reflect cultural norms where Yemeni women have greater exposure to health information through antenatal care, family responsibilities, and higher healthcare

utilization [28]. Women in Yemen often serve as primary caregivers and are more likely to seek health information for their families. Men, by contrast, may have lower health literacy and less engagement with health services [28]. This finding suggests that TB awareness campaigns should specifically target male students, using peer-to-peer education approaches that resonate with young men.

College Type and Year of Study

Non-medical college students had nearly 4 times higher odds of poor knowledge compared to medical students (AOR = 3.89). This is expected but actionable: medical students receive extensive training on infectious diseases, while non-medical students receive none. Similar findings have been reported in Jordan [14], Saudi Arabia [18], and Pakistan [20]. The year of study effect (junior students having 2.89 times higher odds of poor knowledge) suggests that knowledge accumulates through university experience. This has important implications: TB education should be introduced early in the university curriculum, ideally during orientation week, and reinforced throughout the academic years.

Attitudes and the Attitude-Practice Gap

While 54.6% of students had positive attitudes, only 38.4% demonstrated good practices. This "attitude-practice gap" is well-documented in health behavior research [29] and reflects structural barriers such as cost of healthcare, fear of stigma, lack of access to diagnostic facilities, and perceived low risk. In Yemen, where public health services are severely limited, even students with good attitudes face real barriers to action [5]. The mediation analysis provides further insight: attitude partially mediates the knowledge-practice relationship (40% mediated). This suggests that improving knowledge alone is

insufficient; interventions must also address attitude change, particularly stigma reduction and perceived susceptibility.

ROC Curve: Optimal Knowledge Cutoff

The ROC analysis (AUC = 0.82) demonstrated that knowledge scores have excellent discriminatory ability for predicting good practice. The optimal cutoff of 14/22 (63.6%) is lower than the traditional 72.7% threshold used in KAP studies. This finding has practical implications: students do not need to be experts to practice adequate prevention. A moderate level of knowledge (approximately 64%) is sufficient to translate into behavior change. This suggests that educational targets should be realistic and achievable, focusing on essential knowledge that directly influences behavior.

Mediation Analysis: The Role of Attitude

The mediation analysis revealed that attitude partially mediates the knowledge-practice relationship (indirect effect = 0.18, 40% mediated). This is a novel finding for TB KAP research in the Arab region. The implication is critical: interventions that focus solely on knowledge transfer (lectures, pamphlets) will miss the 40% of the effect that operates through attitude change. Effective interventions must also address stigma reduction, perceived susceptibility, and perceived severity of TB [30]. The hierarchical regression confirmed this: knowledge alone explained 24% of practice variance; adding attitude explained an additional 13% (total $R^3 = 0.49$).

Cluster Analysis: Three Student Profiles

603 The cluster analysis identified three distinct groups: "TB-aware" (18.5%), "Moderately
604 informed" (54.3%), and "TB-ignorant" (27.2%). This profiling approach allows for
605 resource-efficient public health interventions. The "TB-aware" cluster, predominantly
606 medical students, can be leveraged as peer educators. The "TB-ignorant" cluster—non-
607 medical, male, junior students—requires intensive, targeted intervention. This group is at
608 the highest risk of delayed diagnosis, poor treatment adherence, and contributing to
609 ongoing transmission [7]. Tailored interventions for this group could include mandatory
610 TB education modules, interactive workshops, and peer-led awareness campaigns.

611 ## Study Strengths and Limitations

612 ### Strengths

613 This study possesses several methodological and scientific strengths. It is the first empirical
614 investigation to assess tuberculosis-related KAP among university students in Yemen,
615 addressing a critical evidence gap in a conflict-affected setting with collapsing health
616 infrastructure. The sample size (n = 302) was calculated using Cochran's formula,
617 providing sufficient statistical power. The questionnaire was adapted from validated
618 instruments, reviewed by experts, and pilot-tested (n = 30), with excellent internal
619 consistency (Cronbach's α: knowledge = 0.84, attitude = 0.79, practice = 0.81). Missing
620 data were handled rigorously using multiple imputation after confirming MCAR (Little's
621 test, p = 0.192).

622 The study employed advanced statistical analyses including binary logistic regression with
623 model diagnostics, sensitivity analysis (three cutoff points), ROC curve analysis (AUC =
624 0.82), hierarchical regression, mediation analysis (PROCESS Macro, 5000 bootstrap), and

K-means cluster analysis (elbow method, silhouette score = 0.52). This multi-analytic approach provides comprehensive insights into predictors, mediation pathways, and student profiles. The identification of an optimal knowledge cutoff (14/22), mediation proportion (40%), and three distinct clusters offers practical, evidence-based guidance for targeted interventions.

Ethical approval was obtained (MEC/AD0173), and comprehensive supplementary files enhance transparency and reproducibility. The contextual relevance in Yemen's humanitarian crisis adds significant value to the findings.

Limitations

Several limitations must be acknowledged. The cross-sectional design precludes causal inference. The single-city setting (Aden) limits generalizability to other Yemeni governorates. Convenience sampling may introduce selection bias. Self-reported data are subject to social desirability and recall biases. The study did not assess potentially important variables such as health literacy, perceived susceptibility, or stigma. The absence of a qualitative component limits depth of understanding regarding barriers to good practices. The time frame (2025-2026) reflects a period of relative stability that may not represent dynamic conflict conditions. The population-specific focus on university students limits generalizability to non-university youth. Finally, cross-cultural adaptation of the questionnaire may not fully capture local nuances.

Implications for Policy and Practice

Our findings have several implications for TB control in Yemen:

1. Universities should integrate TB education into non-medical curricula. Given that non-medical students had 3.89 times higher odds of poor knowledge, mandatory TB modules should be introduced in all faculties. This aligns with WHO recommendations for community engagement in TB control [10].
2. Orientation programs should include TB awareness. Junior students are at highest risk of poor knowledge; early intervention is critical.
3. Campaigns should target male students specifically. Male sex was an independent predictor of poor knowledge; male-oriented health messaging is needed.
4. Interventions must address both knowledge and attitudes. The mediation analysis shows that 40% of the knowledge-practice effect operates through attitude; effective .programs must include stigma reduction and perceived susceptibility
5. Priority should be given to the "TB-ignorant" cluster. These students—non-medical, male, junior—are the highest priority for intensive intervention.
6. Emphasize the 2-week cough symptom and 6-month treatment duration. These were the most critical knowledge gaps identified.

Conclusion

Knowledge and practices regarding tuberculosis among university students in Aden Yemen, are dangerously inadequate. Only 45.7% have good knowledge, and only 38.4% practice adequate prevention. The strongest predictors of poor knowledge are male sex = (AOR = 2.45), non-medical college enrollment (AOR = 3.89), and junior year (AOR ,ROC analysis established an optimal knowledge cutoff of 14/22 (sensitivity 78.4% .(2.89 specificity 71.2%). Mediation analysis revealed that attitude partially mediates the knowledge-practice relationship (40% mediated), indicating that interventions must

,address both knowledge and attitudes. Cluster analysis identified three student profiles with 27.2% classified as "TB-ignorant" requiring intensive intervention. In a country devastated by war, targeted, evidence-based health education is not a luxury—it is a .necessity for TB control

Abbreviations

Abbreviation Full form

AOR Adjusted Odds Ratio

AUC Area Under the Curve

CI Confidence Interval

KAP Knowledge, Attitude, Practice

MDR-TB Multi-Drug Resistant Tuberculosis

NPV Negative Predictive Value

PPV Positive Predictive Value

ROC Receiver Operating Characteristic

TB Tuberculosis

WHO World Health Organization

XDR-TB Extensively Drug-Resistant Tuberculosis

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Declarations

Ethics approval and consent to participate:

Ethical approval was obtained from the Ethics Committee of the College of Medicine and Health Sciences, University of Science and Technology, Aden, Yemen (MEC No. MEC/AD0173). The study was conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from each participant before data collection. Participants were assured that their responses would remain anonymous and that no identifying information would be collected.

Consent for publication

Not applicable .

Availability of data and materials

The datasets generated and analyzed during this study are available from the corresponding author upon reasonable request.

Competing interests

The authors declare no competing interests.

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Authors' contributions

ANMG, NTA and MAS supervised the study, performed final manuscript editing, and contributed to the advanced statistical analysis. HAAM, SMAK, ABMSBA, AAMMA, EAAD, HSNAA, EAAEA, AASA, and TMMMA contributed to data collection and manuscript drafting. ANMG, NTA and MAS also contributed to data analysis and reference management. All other authors contributed to data collection and manuscript review. All authors read and approved the final manuscript.

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Supplementary Files

File Content

File S1 Study Questionnaire (English & Arabic)

File S2 Informed Consent Form (English & Arabic)

File S3 STROBE Checklist

File S4 Data Dictionary (Codebook)

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856 File S6 Complete R Script for Mediation & Cluster Analysis

857 File S7 Supplementary Tables (Complete KAP by subgroup)

858 File S8 ROC Curve Coordinates Table

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Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- FileS1StudyQuestionnaireTB.docx
- FileS6TBKAPMediationClusterAnalysis.docx
- FileS4TBKAPDataDictionary.docx
- FileS5SPSSSyntaxAnalysis.docx
- FileS7SupplementaryTables.docx
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