PARAMETRIC AND NON-PARAMETRIC APPROACHES TO THE ANALYSIS OF ADOLESCENTS' KNOWLEDGE AND ATTITUDES ON TUBERCULOSIS

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ABSTRACT

Pulmonary tuberculosis (TB) remains a major public health problem in Indonesia. Improving adolescents' knowledge and attitudes through school-based health education is essential to support TB prevention efforts. This study aimed to assess changes in knowledge and attitudes toward pulmonary tuberculosis following an audiovisual-based health education intervention. A quantitative pre-experimental one-group pretest–posttest design was conducted among 103 Grade XI students in a senior high school in Kudus Regency, Central Java. Data were collected using structured questionnaires. Normality was assessed prior to analysis; as most variables violated the normality assumption ($p < 0.05$), the Wilcoxon Signed-Rank Test was used as the primary statistical method, while the paired t-test was performed as a supplementary comparison analysis. The results showed a significant increase in knowledge scores from a median of 26 to 28 ($Z = –4.865$, $p < 0.001$, $r = 0.48$) and a significant improvement in attitude scores ($Z = –7.383$, $p < 0.001$, $r = 0.73$). The paired t-test produced consistent results, with a mean increase of 1.835 points in knowledge (95% CI: 1.177–2.493; Cohen's $d = 0.545$) and 3.417 points in attitudes (95% CI: 2.717–4.118; Cohen's $d = 0.954$). Normalized gain analysis indicated that improvement in knowledge was categorized as low, whereas improvement in attitudes reached the medium category. In conclusion, audiovisual-based health education was associated with positive changes in adolescents' knowledge and attitudes regarding pulmonary tuberculosis. However, because the study was conducted in a single school using a pre-experimental design, the findings should be generalized with caution. Further controlled studies involving more diverse populations are recommended.

Keywords: adolescents, health education, pre-experimental design, pulmonary tuberculosis, Wilcoxon signed-rank test.

INTRODUCTION

One of the major public health problems that remains a serious global concern is pulmonary tuberculosis (TB). Pulmonary tuberculosis is a contagious disease caused by infection with Mycobacterium tuberculosis. Although the lungs constitute the primary site of infection, the pathogen is capable of disseminating to other organs of the body. Transmission primarily occurs through inhalation of airborne droplet nuclei expelled when an infected individual coughs, sneezes, or speaks, thereby facilitating the spread of the disease within the community (World Health Organization, 2022).

According to the Global Tuberculosis Report published by World Health Organization (World Health Organization, 2022), an estimated 10 million people developed tuberculosis globally in 2019, resulting in approximately 1.45 million deaths. The global burden of tuberculosis remained high in subsequent years. The Global Tuberculosis Report (World Health Organization, 2023) estimated that approximately 10.6 million new TB cases occurred worldwide in 2021, indicating a

slight increase compared to previous estimates. However, only 60.3% of cases were successfully detected and treated, while 39.7% remained unreported, reflecting persistent gaps in case detection and surveillance systems that may contribute to continued transmission and delayed treatment. Furthermore, among the estimated 500,000 cases of multidrug-resistant tuberculosis (MDR-TB), only about 57% received appropriate treatment (Tiberi et al., 2021).

In Indonesia, 420,994 new TB cases were reported in 2017, with incidence among men reported to be 1.4 times higher than among women (Dewi, 2019). Data from the Tuberculosis Pocket Book and Infodatin published by the Indonesian Ministry of Health indicate that Indonesia contributes approximately 4.8% of global TB cases, placing the country among the five countries with the highest TB burden worldwide (Kementerian Kesehatan Republik Indonesia, 2018).

Recent official data from the Badan Pusat Statistik (BPS) of Central Java indicate that in Kudus District, the incidence of pulmonary tuberculosis reached 163.70 per 100,000 population in 2022, placing Kudus among the four districts with the highest TB burden in the province (BPS, 2022, 2023). Although TB is preventable and treatable, its persistently high prevalence may partly reflect, among other factors, limitations in public awareness and preventive practices, which have been recognized as important components of TB control efforts. One of the key factors in improving public awareness of TB is health education.

Research evidence indicates that pulmonary tuberculosis incidence is influenced by multiple interrelated determinants, including poor nutritional status, household exposure to tuberculosis, and smoking behavior (Findasari & Himayati, 2023). Beyond these biomedical and behavioral risk factors, cognitive determinants such as knowledge and attitudes toward tuberculosis have also been identified as important components in TB prevention efforts (World Health Organization, 2023).

Adolescents represent an important target group for tuberculosis education because this developmental stage is closely associated with the formation of long-term health behaviors and social attitudes. School-based tuberculosis education programs have been reported to improve adolescents' knowledge and reduce TB-related stigma (Idris et al., 2020). However, the same study found no significant improvement in attitudes and preventive practices, suggesting that increased knowledge does not necessarily translate into behavioral or attitudinal change. Similar inconsistencies have also been reported in other educational intervention studies, where improvements in cognitive outcomes were not always accompanied by corresponding behavior change (Datiko et al., 2019). In addition, cross-sectional evidence from Ethiopia showed that substantial gaps in tuberculosis knowledge and attitudinal differences persist within the community despite widespread awareness of the disease, highlighting the continuing need for targeted health education interventions (Datiko et al., 2019).

These findings indicate that the effectiveness of educational interventions across different learning domains remains inconclusive. Furthermore, the available evidence discussed in this study is largely derived from settings outside Indonesia, making it difficult to determine whether similar effects would be observed among Indonesian adolescents. Consequently, experimental studies examining simultaneous changes in knowledge and attitudes among Indonesian adolescents remain limited. Therefore, further investigation is needed to evaluate the effectiveness of school-based health education interventions for tuberculosis prevention in the Indonesian context.

In intervention-based educational research, pretest-posttest data frequently exhibit non-normal distributions due to limited score ranges, ceiling effects, and clustered responses. The paired t-test is commonly applied to analyze mean differences when the assumption of normality is satisfied. However, when this assumption is violated, the Wilcoxon signed-rank test is recommended as a non-parametric alternative that does not rely on distributional normality

assumptions. Despite the widespread use of both methods, many applied studies rely on a single statistical approach without evaluating whether conclusions remain consistent across parametric and non-parametric frameworks. From a methodological perspective, examining the robustness and consistency of statistical inferences under different analytical assumptions is essential, particularly in educational intervention research.

Strengthening health education on pulmonary tuberculosis, particularly among adolescents, is therefore essential. Promoting early knowledge of the disease and its associated risk factors may foster more positive attitudes and preventive behaviors. Building upon this rationale, the present study aimed to assess changes in adolescents' knowledge and attitudes regarding pulmonary tuberculosis following an audiovisual-based health education intervention. In addition, the study compared the results obtained from the paired t-test and the Wilcoxon signed-rank test to evaluate the consistency of statistical conclusion across parametric and non-parametric analytical approaches. The findings are expected to inform both tuberculosis health education strategies and methodological decisions in intervention-based educational research.

METHOD

The study was conducted using a quantitative pre-experimental research design, specifically a one-group pretest–posttest model, in which no control group was incorporated (Swarjana, 2015). This design was selected due to practical and administrative considerations within the school setting, where random assignment and the establishment of a control group were not feasible. Additionally, the study aimed to conduct a preliminary evaluation of the effectiveness of audiovisual-based health education before considering more rigorous experimental designs. The one-group pretest–posttest approach allowed for the measurement of changes in knowledge and attitudes before and after the intervention within the same group of participants.

The study was carried out in one senior high school in Kudus Regency, Central Java, Indonesia. The accessible population consisted of all 11th-grade students enrolled at the school, totalling 112 students. A total sampling approach was applied, in which all accessible students were invited to participate in the study. Of these, 103 students participated, while nine students did not participate due to absence on the day of data collection or refusal to provide consent. The response rate was 92.0%, indicating high participant involvement.

The respondents were distributed across four 11th-grade classes within the same school (XI F1 = 27; XI F2 = 26; XI F3 = 26; XI F4 = 24). In terms of gender, 69 students (67%) were female and 34 students (33%) were male. Data collection was conducted in October 2024. The study was conducted with permission from the school administration. Participation was voluntary, and only students who agreed to participate were included in the analysis. All data were anonymized prior to statistical processing. Nevertheless, students who were absent or declined participation may have differed systematically from those who participated, which may introduce potential selection bias.

The study employed a non-probability sampling approach using total sampling of the accessible population. This approach was considered appropriate because the intervention was conducted in a school setting involving intact 11th-grade classes, making random sampling impractical. In addition, the primary objective of the study was to evaluate changes in knowledge and attitudes before and after the intervention within the participating group rather than to make population-level generalization. Therefore, all accessible students who met the study criteria and agreed to participate were included in the analysis.

The minimum required sample size was calculated using the Lemeshow formula (Riyanto & Hatmawan, 2020), resulting in a minimum requirement of 96 participants. The final sample consisted of 103 students, thereby exceeding the minimum required sample size. Ethical approval

and permission to conduct the study were obtained from the relevant authorities and the school administration prior to data collection. Written informed consent was obtained from all participants before their involvement in the study.

The research instruments consisted of a demographic questionnaire (age and gender), a knowledge questionnaire, and an attitude questionnaire. The knowledge instrument comprised 16 multiple-choice items and 20 true-false statements. For the knowledge questionnaire, each correct answer was scored as 1 and each incorrect answer as 0, resulting in a total possible score ranging from 0 to 36, with higher scores indicating better knowledge regarding pulmonary tuberculosis.

The multiple-choice questionnaire had previously undergone construct validity testing using item-total correlation (Pearson product moment), with validity coefficients ranging from 0.573 to 0.964. Reliability testing using Cronbach's alpha yielded a coefficient of 0.970, indicating excellent internal consistency (Siagian, 2021). The 20 true-false items were adapted from a previously validated instrument. Content validity had been assessed through expert review, and reliability testing using Cronbach's alpha demonstrated acceptable internal consistency (Dewi, 2019).

To measure adolescents' attitudes toward pulmonary tuberculosis, a 10-item questionnaire was used with four response options (never, sometimes, often, always). Responses were scored on a four-point Likert scale ranging from 1 to 4, resulting in a total possible score between 10 and 40. Higher scores reflected more positive attitudes toward pulmonary tuberculosis prevention and awareness. No categorical classification (e.g., low, moderate, or high levels) was applied to either knowledge or attitude scores. Instead, both variables were analyzed as continuous measures in all statistical analyses.

Construct validity was evaluated using item-total correlation, with coefficients ranging from 0.493 to 0.819. Reliability testing using Cronbach's alpha produced a coefficient of 0.865, indicating good internal consistency (Pamungkas, 2023).

Comparative analysis of adolescents' knowledge and attitudes before and after the audiovisual health education intervention was primarily conducted using the nonparametric Wilcoxon signed-rank test. Prior to selecting the appropriate statistical procedure, the assumption of normality was assessed using the Shapiro-Wilk test for the pre- and post-intervention knowledge and attitude scores. The normality tests results indicated that the data were not normally distributed ($p < 0.05$). Therefore, the Wilcoxon signed-rank test was employed as the main non-parametric method for paired data analysis (Maiyanti et al., 2023). In addition, paired sample t-tests were performed as supplementary parametric analyses to compare the consistency of the inferential results obtained from both approaches. Effect sizes were calculated to assess the magnitude of the observed changes, and 95% confidence intervals were reported for the paired t-test analyses to provide information regarding the precision of the estimated mean differences. A significance level of $\alpha = 0.05$ was applied for all statistical analyses.

The hypotheses were formulated to examine whether the central tendency of the paired differences deviates significantly from zero:

$$H_0 : \tilde{d} = 0, \quad H_1 : \tilde{d} \neq 0,$$

where $\tilde{d}$ denotes the population median of the paired differences.

Let $d_i = X_{i,post} - X_{i,pre}$, $i = 1,2, \ldots, n$, represent the paired differences assumed to be independent observation. The paired t-test assumes that d_i are drawn from a normally distributed population with mean μ_d and finite variance σ_d^2. The corresponding test statistic is given by

$$t = \frac{\bar{d}}{s_d/\sqrt{n}}\ , \tag{1}$$

where

$$\bar{d} = \frac{1}{n}\sum_{i=1}^{n} d_i \tag{2}$$

denotes the sample mean of the differences and

$$s_d = \sqrt{\frac{\sum_{i=1}^{n}\left(d_i - \bar{d}\right)^2}{n-1}} \tag{3}$$

is the sample standard deviation of the paired differences. Under the null hypothesis, the statistic follows a *t*-distribution with $(n-1)$ degrees of freedom.

When the normality assumption is violated, the Wilcoxon signed-rank test provides a non-parametric alternative under the assumption that the distribution of d_i is continuous and symmetric about its median. The test statistic is based on the sum of signed ranks, denoted by T.

For large sample (n > 15), the standardized statistic is approximated by the normal distribution:

$$Z = \frac{T - \mu_T}{\sigma_T}, \tag{4}$$

with

$$\mu_T = \frac{n(n+1)}{4}, \qquad \sigma_T = \sqrt{\frac{n(n+1)(2n+1)}{24}}, \tag{5}$$

where adjustments to the variance are applied in the presence of tied ranks. The null hypothesis is rejected when $|Z| \geq Z_{(\alpha/2)}$ (Maiyanti et al., 2023).

After the comparative analysis, the normalized gain (N-Gain) analysis was further conducted to evaluate the magnitude of improvement in adolescents' knowledge and attitudes following the audiovisual health education intervention. While hypothesis testing determines whether statistically significant differences exist between pretest and posttest score, the N-Gain analysis was used to assess the effectiveness of the intervention in terms of learning improvement. The N-Gain score for each student was calculated using the following formula (Windi et al., 2022):

$$N_{Gain} = \frac{N_{Posttest} - N_{Pretest}}{N_{Maximum} - N_{Pretest}} \tag{6}$$

where N_{Gain} denotes the normalized gain score, $N_{Posttest}$ represents the posttest score, $N_{Pretest}$ represents the pretest score, and $N_{Maximum}$ denotes the maximum possible score. The N-Gain values were calculated individually for each respondent and subsequently averaged to obtain the overall improvement score.

The results N-Gain score were classified into four categories, as presented in Table 1:

Table 1. N-Gain Score Categories

N-Gain Score	Level
$N_{Gain} > 0.70$	High
$0.30 \leq N_{Gain} \leq 0.70$	Medium
$0 < N_{Gain} < 0.30$	Low
$N_{Gain} \leq 0$	Decline

RESULTS AND DISCUSSION

Descriptive Statistics

The study involved 103 Grade XI students from four classes in a senior high school, representing 92.0% of the accessible Grade XI population (N = 112). The remaining nine students did not participate due to absence during data collection or refusal to provide consent. The research procedure consisted of administering a pretest via Google Forms, followed by an audiovisual-based health education intervention, and subsequently a posttest administered through the same platform.

Table 2. Distribution of Grade XI Students by Class and Gender

No	Class	Total Students	Female	Male
1	XI F1	27	15	12
2	XI F2	26	18	8
3	XI F3	26	18	8
4	XI F4	24	18	6

From Table 2, it can be seen that the total number of respondents was 103 students, drawn from four classes (F1–F4). The data of respondents are presented in Table 3.

Table 3. Respondent Data

No	Pretest Knowledge	Posttest Knowledge	Pretest Attitude	Posttest Attitude
1	27	28	31	36
2	28	30	38	40
3	24	22	26	30
4	27	30	35	38
5	26	30	26	29
6	28	31	25	28
7	20	25	25	29
…	…	…	…	…
102	18	24	28	35
103	31	29	26	29

From the data presented in Table 3, the descriptive statistics can be obtained as shown in the Table 4 below:

Table 4. Descriptive Statistics

Data Type	Median	IQR	Min	Max
Knowledge Pretest Score	26.00	5	17	34
Knowledge Posttest Score	28.00	5	17	34
Attitude Pretest Score	28.00	8	19	38
Attitude Posttest Score	32.00	9	19	40

The results presented in Table 4 summarize the descriptive statistics using the median and interquartile range (IQR). The median knowledge score increased from 26.00 (IQR = 5) at pretest to 28.00 (IQR = 5) at posttest, with scores ranging from 17 to 34 in both assessments. This finding indicates an increase in the central tendency of knowledge scores following the intervention.

For attitudes, the median score increased from 28.00 (IQR = 8) at pretest to 32.00 (IQR = 9) at posttest. The scores range also increased from 19-38 to 19-40. Although score variability increased slightly, as reflected by the larger IQR, the higher median score suggests an overall improvement in adolescents' attitudes toward pulmonary tuberculosis following the intervention.

Overall, the descriptive statistics indicate improvements in both knowledge and attitude scores after the audiovisual-based health education intervention. Statistical significance was subsequently evaluated using inferential analyses.

Normality Test

Prior to conducting comparative analyses, the assumption of normality was evaluated to determine the appropriate statistical methodology. The Shapiro–Wilk test was used to assess the normality assumption because it is considered one of the most powerful test for detecting departures from normality, particularly in small to moderate sample sizes (DEMİR, 2022). The results are presented in Table 5.

Table 5. Results of Shapiro-Wilk Normality Test

Data	α	p-value
Knowledge before intervention	5%	0.070
Knowledge after intervention		< 0.001
Attitude before intervention		0.008
Attitude after intervention		<0.001

The normality assumption was assessed using the Shapiro-Wilk test at a significance level of 0.05. As shown in Table 5, the knowledge pretest scores did not significantly deviate from normality ($p = 0.070$). In contrast, the knowledge posttest scores were not normally distributed ($p < 0.001$). Similarly, both pretest and posttest attitude scores significantly deviate from normality ($p = 0.008$ and $p < 0.001$, respectively).

Because most variables violated the normality assumption required for parametric analysis, the Wilcoxon signed-rank test was considered the more appropriate inferential procedure for paired comparisons. Nevertheless, paired sample t-tests were also conducted to evaluate the consistency

of conclusions obtained from parametric and non-parametric approaches, in accordance with the methodological objective of this study.

Comparative Test of Adolescents' Knowledge Level

Wilcoxon Signed-Rank Test

The normality test indicated that the data were not normally distributed; therefore, the Wilcoxon signed-rank test, a non-parametric paired-sample test, was applied to examine differences in adolescents' pretest and posttest knowledge scores regarding pulmonary tuberculosis. The hypotheses were formulated as follows:

H_0 : There is no difference in adolescents' knowledge scores before and after the intervention.

H_1 : There is a difference in adolescents' knowledge scores before and after the intervention.

The null hypothesis is rejected if p < 0.05.

Table 6. Calculation of Adolescents' Knowledge Level

No	Pretest	Posttest	D	| D |	Rank | D |	D Sign	
						Positive	Negative
1	27	28	1	1	14	14	
2	28	30	2	2	37.5	37.5	
3	24	22	-2	2	37.5		-37.5
4	27	30	3	3	54.5	54.5	
5	26	30	4	4	67	67	
6	28	31	3	3	54.5	54.5	
7	20	25	5	5	73.5	73.5	
…	…	…	…	…	…	…	…
101	18	24	6	6	77	77	
102	31	29	-2	2	37.5		-37.5
103	31	34	3	3	54.5	54.5	
Total						3250	-845

Based on the calculations presented in Table 6, the results are as follows:

$T^+ =$ D Sign (+) = 61

$T^- =$ D Sign (–) = 29

D Sign (0) = 13

$T = T_{smallest} = 845$

$n =$ Total respondent – D Sign (0) = 103 – 13 = 90

The mean and standard deviation of the signed ranks were calculated as follows:

$$\mu_T = \frac{n(n+1)}{4} = \frac{90(90+1)}{4} = 2047.5$$

$$\sigma_T = \sqrt{\frac{n(n+1)(2n+1)}{24}} = \sqrt{\frac{90(90+1)(2(90)+1)}{24}} \approx 248.5$$

$$Z = \frac{T - \mu_T}{\sigma_T} = \frac{845 - 2048}{248{,}5} \approx -4.84$$

A standardized test statistic of Z = –4.84 was obtained, corresponding to p < 0.001. Since the p-value was below the significance level of 0.05, the null hypothesis was rejected. These results indicate a statistically significant difference between pretest and posttest knowledge scores, suggesting that the audiovisual-based health education intervention was associated with improved knowledge regarding pulmonary tuberculosis.

The explanation above refers to the Wilcoxon test conducted manually. Data processing using SPSS software produces the following output (Table 7):

Table 7. Ranking of Adolescents' Knowledge Level Data

Group	*n*	Mean Rank	Sum of Ranks
Negative Ranks	29	29.14	845.00
Positive Ranks	61	53.28	3250.00
Ties	13		
Total	103		

Based on the SPSS output, 61 students showed increased knowledge scores after the intervention, 29 students showed decreased scores, and 13 students exhibited no change. The predominance of positive rank over negative ranks suggests that knowledge scores generally improved following the audiovisual-based health education intervention.

For hypothesis testing using SPSS software, the results are presented in Table 8.

Table 8. Hypothesis Test Results of Adolescents' Knowledge Levels

	Posttest Knowledge Score – Pretest Knowledge Score
Z	-4.865
Asymp. Sig. (2-tailed)	0.000

As shown in Table 8, the Wilcoxon signed-rank test yielded a Z value of –4.865 with a corresponding p-value < 0.001. Since the p-value was below the significance level of 0.05, the null hypothesis was rejected, indicating a statistically significant difference between pretest and posttest knowledge scores. The corresponding effect size was r = 0.48, indicating a moderate-to-large magnitude of change. These findings suggest that adolescents' knowledge regarding pulmonary tuberculosis improved following the audiovisual-based health education intervention.

Paired T-test

To provide a comparison with the non-parametric analysis, a paired sample t-test (paired t-test) was conducted, disregarding the normality test result. The calculation are presented in Table 9.

The sample standard deviation of the differences (s_d) was calculated as:

$$s_d = \sqrt{\frac{\sum d^2 - \frac{(\sum d)^2}{n}}{n-1}} = \sqrt{\frac{1503 - \frac{(189)^2}{103}}{103-1}} \approx 3.367$$

thus, the obtained t-value is:

$$t = \frac{\bar{d}}{s_d/\sqrt{n}} = \frac{1.83}{3.367/\sqrt{103}} \approx 5.531$$

Table 9. Paired T-test Calculation of Adolescents' Knowledge Levels

No	Pretest	Posttest	d_i	d_i^2
1	27	28	1	1
2	28	30	2	4
3	24	22	-2	4
…	…	…	…	…
26	23	32	9	81
27	30	31	1	1
…	…	…	…	…
99	32	32	0	0
100	25	25	0	0
101	18	24	6	36
102	31	29	-2	4
103	31	34	3	9
Total	2652	2714	189	1503

At a significance level of $\alpha = 0.05$ with 102 degrees of freedom (df = 103 – 1), the critical t-value was 1.983. Since the obtained t-value (|t| = 5.531) exceeded the critical t-value, the null hypothesis was rejected. This indicates a statistically significant difference in adolescents' knowledge about pulmonary tuberculosis before and after the intervention. The mean difference between pretest and posttest scores was 1.835 points (95% CI: 1.177–2.493; $p < 0.001$), indicating higher knowledge scores following the audiovisual-based health education intervention. The paired-samples effect size analysis yielded a Cohen's d of 0.545, indicating a moderate effect of the intervention on knowledge improvement.

Overall, the results from the paired t-test (parametric) and Wilcoxon signed-rank test (non-parametric) are consistent: both indicate an improvement in knowledge following the health education program. However, this agreement should not be generalized to all datasets because the two methods are based on different statistical assumptions.

Comparative Test of Adolescent Attitudes

Following the analysis of adolescent knowledge, the same statistical framework was applied to the attitude data to ensure methodological consistency. Both the Wilcoxon signed-rank test and the paired t-test were computed using identical analytical formulations, differing only in the observed values of the differences. To avoid redundancy, only the essential computational steps are presented in this section. This structure allows a direct methodological comparison while maintaining coherence with the previous analysis.

Wilcoxon Paired Test

After conducting a comparative test on adolescents' knowledge using health education as the intervention, the next step was to examine differences in adolescents' attitudes before and after the intervention. The hypotheses for this test were formulated as follows:

H_0 : There is no difference in adolescents' attitudes toward pulmonary tuberculosis before and after the test.
H_1 : There is a difference in adolescents' attitudes toward pulmonary tuberculosis before and after the test.
The decision rule was that the null hypothesis (H_0) would be rejected if the *p-value* < *0.05*.

Table 10. Calculation of Adolescent Attitudes

Statistic	Value
Total observations	103
Zero differences	10
n (non-zero differences)	93
T^+	4108
T^-	263
$T_{smallest}$	263

From Table 10, a total of 103 paired observations were analyzed. Among them, 10 observations yielded zero differences and were therefore excluded from the ranking procedure, resulting in $n = 93$ non-zero differences used in the Wilcoxon computation.

The sum of positive ranks was $T^+ = 4108$, while the sum of negative ranks was $T^- = 263$. The test statistic was defined as the smaller of the two sums, thus $T = 263$. The theoretical mean and standard deviation of the Wilcoxon statistic were calculated as:

$$\mu_T = \frac{n(n+1)}{4} = \frac{93(93+1)}{4} = 2185.5$$

$$\sigma_T = \sqrt{\frac{n(n+1)(2n+1)}{24}} \approx 261$$

The standardized test statistic was then obtained as:

$$Z = \frac{T - \mu_T}{\sigma_T} \approx -7.37$$

The Z-value corresponds to p < 0.001, leading to the rejection of the null hypothesis. Therefore, a statistically significant difference was observed between pretest and posttest attitude score.

The results of the Wilcoxon signed-rank test using SPSS are presented in Table 11.

Table 11. Ranking of Adolescent Attitude Data

Group	n	Mean Rank	Sum of Ranks
Negative Ranks	9	29.22	263.00
Positive Ranks	84	48.90	4108.00
Ties	10		
Total	103		

Table 11 indicates a clear predominance of positive ranks over negative ranks, showing that most adolescents experienced higher posttest attitude scores after the intervention. The consistency between the SPSS output and the manual computation further confirms the accuracy of the ranking procedure used in this study.

The predominance of positive ranks indicates that posttest scores were generally higher than pretest scores. This distribution of ranks is consistent with the direction of the calculated Wilcoxon test statistic.

The SPSS output also reports the mean ranks for the positive and negative groups; however, the inferential decision is determined by the sum of ranks and the standardized test statistic rather than the mean rank values.

For hypothesis testing using SPSS, the results are presented in Table 12.

Table 12. Results of the Wilcoxon Signed-Rank Test of Adolescent Attitude

	Posttest Attitude–Pretest Attitude
Z	-7.383
Asymp. Sig. (2-tailed)	0.000

Based on Table 12, the SPSS output yielded a standardized test statistic of *Z* = –7.383 with an asymptotic two-tailed significance value of p < 0.001. Since the p-value is below the 0.05 significance level, the null hypothesis was rejected, indicating a statistically difference between pretest and posttest attitude scores. The corresponding effect size was r = 0.73, indicating a large effect. These findings suggest that adolescents' attitudes toward pulmonary tuberculosis improved following the audiovisual-based health education intervention.

The Z-value obtained from SPSS is highly consistent with the manually computed result ($Z \approx -7.37$). The minor numerical difference is attributable to rounding and the continuity correction applied in the software computation. Both approaches lead to the same inferential conclusion, thereby confirming the accuracy of the manual Wilcoxon calculation.

Paired T-test

For comparison purposes, a paired sample t-test was also conducted, irrespective of the normality assumption. The manual computation of the paired t-test is summarized in Table 13.

Table 13. Summary Statistics for Paired T-test of Adolescent Attitudes

	Pretest	**Posttest**	$\boldsymbol{d_i}$	$\boldsymbol{d_i}^2$
Total	2985	3337	352	2512
Mean	28.981	32.398	3.417	-

The paired t-test for adolescent attitudes was calculated using the same computational procedure as previously applied to adolescent knowledge. Only the summary statistics are presented here to avoid redundancy.

The sample standard deviation of the differences (s_d) was calculated as:

$$s_d = \sqrt{\frac{\sum d^2 - \frac{(\sum d)^2}{n}}{n-1}} = \sqrt{\frac{2512 - \frac{(352)^2}{103}}{103-1}} \approx 3.582$$

The t-statistic was then obtained as:

$$t = \frac{\bar{d}}{s_d/\sqrt{n}} = \frac{3.417}{3.582/\sqrt{103}} \approx 9.682$$

with a significance level of α = 0.05 and degrees of freedom df = 102, the critical t-value was 1.983. Since the computed t-value (|t| = 9.682) exceeded the critical value, the null hypothesis was rejected. This indicates a statistically significant difference between pretest and posttest attitude scores. The mean difference between pretest and posttest scores was 3.417 points (95% CI: 2.717–4.118; p < 0.001), indicating higher attitude scores following the audiovisual-based health education intervention. The paired-sample effect size analysis yielded a Cohen's d of 0.954, indicating a large effect of the intervention on attitude improvement.

Both the paired t-test and the Wilcoxon signed-rank test yielded consistent results, supporting the conclusion that adolescents' attitudes toward pulmonary tuberculosis improved following the audiovisual-based health education intervention.

Normalized Gain Analysis

To evaluate the magnitude of improvement in adolescents' knowledge and attitudes following the intervention, normalized gain (N-gain) score were calculated. The mean N-gain scores are presented in Table 14.

Table 14. Mean Normalized Gain Scores

Variable	Mean N-Gain	Category
Knowledge	0.12	Low
Attitude	0.37	Medium

The average N-gain score for adolescents' knowledge was 0.12, which falls into the low category. Although statistically significant improvements were observed, the low N-gain value suggests that the magnitude of knowledge improvement was relatively limited. In contrast, the average N-gain score for adolescents' attitudes was 0.37, categorized as medium, indicating a moderate practical improvement in the affective domain.

The greater improvement observed in attitudes compared to knowledge may be associated with the characteristics of audiovisual health education, which combines informational content with visual and auditory stimulation. Such media may influence students' perceptions and emotional responses more effectively, thereby contributing more strongly to attitudinal change than to cognitive gain.

Previous studies on educational interventions have similarly reported that statistically significant results do not always correspond to high normalized gain values, particularly when initial pretest scores are already moderate or high. Therefore, the low knowledge N-gain in this study may reflect a ceiling effect rather than the absence of instructional impact.

Overall, the normalized gain analysis complements the inferential findings by providing information on the magnitude of improvement. Consistent with the effect size estimates obtained from the Wilcoxon analysis, the intervention produced a greater improvement in attitudes than in knowledge. While knowledge gains remained low, attitude gains reached the medium category, suggesting that the audiovisual-based intervention was more effective in influencing the affective domain than the cognitive domain.

This study has several limitations. The use of a one-group pretest–posttest design without a control group may introduce threats to internal validity, such as maturation and testing effects. Therefore, the findings should be interpreted with caution, and future studies employing randomized controlled designs are recommended to strengthen causal inference.

CONCLUSION

This study demonstrated that audiovisual-based health education significantly improved adolescents' knowledge and attitude regarding pulmonary tuberculosis. Both the paired t-test and the Wilcoxon signed-rank test produced consistent conclusions, indicating statistically significant differences between pretest and posttest scores. The normalized gain analysis further showed that the magnitude of improvement was greater for attitudes, which reached the medium category, whereas knowledge improvement remained in the low category.

The findings suggest that audiovisual-based health education may be useful for strengthening tuberculosis awareness and promoting positive attitudes among adolescents. From a methodological perspective, the consistency of results obtained from both parametric and non-parametric approaches indicates that the study conclusions were robust across different analytical assumptions. Future studies are recommended to employ larger and more diverse samples and to incorporate control groups in order to strengthen the evidence and further evaluate the performance of alternative statistical approaches in educational intervention research.

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