Association of Positive mHealth Engagement with Knowledge, Attitude, Practice, and Total KAP Among Patients with Multidrug-Resistant Tuberculosis

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Posted Date: 9 April 2026

doi: 10.20944/preprints202604.0682.v1

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 doi:10.20944/preprints202604.0682.v1

Article

Association of Positive mHealth Engagement with Knowledge, Attitude, Practice, and Total KAP Among Patients with Multidrug-Resistant Tuberculosis

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Abstract

Background: Mobile health has been increasingly integrated into tuberculosis care to support patient education, communication, and treatment engagement. However, evidence remains limited regarding whether positive engagement with mHealth is associated with knowledge, attitudes, and practices among patients with multidrug-resistant tuberculosis. This study aimed to evaluate the psychometric properties of a positive mHealth engagement score and to examine its association with knowledge, attitude, practice, and total KAP among patients with multidrug-resistant tuberculosis. **Methods:** A cross-sectional study was conducted among patients with multidrug-resistant tuberculosis. A positive mHealth engagement score was constructed from 12 mHealth-related items after harmonizing item directionality so that higher scores indicated more favorable engagement. Internal consistency was assessed using Cronbach's alpha and corrected item-total correlations, and structural validity was explored using principal component analysis. Adjusted linear regression models were used to examine associations between the engagement score and Knowledge, Attitude, Practice, and total KAP scores, controlling for age, sex, and occupation. Sensitivity analyses were performed after excluding a poorly performing item, and tertile analyses were used to assess dose-response patterns. **Results:** The positive mHealth engagement score showed good internal consistency, with a Cronbach's alpha of 0.852. One item demonstrated poor psychometric performance, and Cronbach's alpha increased to 0.864 after its exclusion. The data were suitable for dimensionality assessment, with a Kaiser-Meyer-Olkin value of 0.870 and a significant Bartlett's test. Principal component analysis identified a dominant first component explaining 43.29% of the total variance. Using the refined score, higher positive mHealth engagement was significantly associated with higher Knowledge scores ($\beta = 2.06$; 95% CI: 1.28–2.85; $p < 0.001$), higher Attitude scores ($\beta = 4.68$; 95% CI: 3.30–6.06; $p < 0.001$), and higher total KAP scores ($\beta = 6.68$; 95% CI: 4.62–8.74; $p < 0.001$), whereas no significant association was observed for the Practice score ($\beta = -0.07$; 95% CI: −0.63 to 0.49; $p = 0.804$). In tertile analyses, Knowledge, Attitude, and total KAP scores increased significantly across engagement levels, while Practice scores did not. **Conclusions:** Positive mHealth engagement was associated with better knowledge, attitudes, and overall KAP among patients with multidrug-resistant tuberculosis, but not with practice. The engagement score demonstrated good reliability and acceptable structural validity and may be a useful summary measure for evaluating patient interaction with mHealth interventions in tuberculosis care.

Keywords: multidrug-resistant tuberculosis; MDR-TB patients; mobile health; mHealth engagement; knowledge; attitudes; and practices; digital health; treatment support; Vietnam

1. Introduction

Multidrug-resistant tuberculosis remains a major challenge to tuberculosis control because treatment is prolonged, complex, and frequently accompanied by adverse events that can disrupt

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adherence and continuity of care [1,2]. Patients with multidrug-resistant tuberculosis often require sustained support throughout treatment, including counseling, symptom monitoring, and regular communication with healthcare providers [3]. In this context, mobile health interventions have been increasingly explored as a way to strengthen patient-centered tuberculosis care and improve treatment support [4–6].

Positive patient engagement with mHealth may be especially relevant in multidrug-resistant tuberculosis care, where the burden of treatment extends over many months and patients must manage both the disease and the consequences of therapy [6,7]. When patients perceive digital health tools as useful, understandable, and supportive, such engagement may improve how they receive health information, how they understand treatment, and how they relate to care. These pathways are particularly relevant to knowledge, attitude, and practice outcomes, which are commonly used to assess patient-related dimensions of tuberculosis care. While knowledge and attitudes may respond relatively directly to digital communication and support, practice-related behaviors may also depend on broader structural, social, and treatment-related constraints [8].

Despite growing interest in digital health for tuberculosis, the literature has more often focused on adherence, feasibility, or implementation outcomes than on the relationship between patient engagement and knowledge, attitude, and practice. In addition, engagement is frequently treated as a simple intervention exposure rather than as a measurable patient-level construct with its own psychometric properties [9–11]. This is important because if engagement is measured using items that do not perform consistently, associations with downstream outcomes may be difficult to interpret. Evaluating the internal consistency and structural validity of a positive mHealth engagement score is therefore an important step before using it as an analytical variable.

This study was conducted within the broader context of the V-SMART intervention in Vietnam, a smartphone-based mHealth platform developed to support multidrug-resistant tuberculosis care, particularly communication and adverse event management during treatment [12,13]. More recent work from the same project has also highlighted challenges in sustaining user engagement with the application over time, reinforcing the importance of understanding how patients interact with the intervention rather than assuming that access alone is sufficient . Therefore, the present study aimed to evaluate the psychometric properties of a positive mHealth engagement score and to examine its association with knowledge, attitude, practice, and total KAP among patients with multidrug-resistant tuberculosis. We further assessed the robustness of these associations in sensitivity analyses and explored whether KAP outcomes showed a dose-response pattern across levels of engagement.

2. Materials and Methods

2.1. Study Design and Setting

This cross-sectional study was conducted among patients with multidrug-resistant tuberculosis in Vietnam. The analysis was undertaken within the broader context of an mHealth-supported care program for MDR-TB, in which participants were exposed to a smartphone-based intervention designed to support treatment communication and monitoring. The present study specifically examined the association between positive mHealth engagement and knowledge, attitude, and practice (KAP) outcomes.

2.2. Study Population and Participants

The study population included patients diagnosed with multidrug-resistant tuberculosis who participated in the project and had available data on mHealth engagement and KAP-related measures. Participants were included in this analysis if they had sufficient information to construct the engagement score and outcome variables. For the adjusted regression analyses, only participants with complete data on the engagement score, KAP outcomes, age, sex, and occupation were included.

 doi:10.20944/preprints202604.0682.v1

2.3. Study Variables

The main explanatory variable was positive mHealth engagement, derived from patient responses to a set of mHealth-related questionnaire items reflecting favorable perceptions and experiences of the intervention. Item directionality was harmonized before score construction so that higher values consistently indicated more positive engagement. The items were then combined into a composite engagement score.

The study outcomes were Knowledge score, Attitude score, Practice score, and Total KAP score, each analyzed as a continuous variable. Multivariable models adjusted for age, sex, and occupation as potential confounders.

Development and Psychometric Evaluation of the Positive mHealth Engagement Score

A composite positive mHealth engagement score was constructed from 12 questionnaire items. Internal consistency was assessed using Cronbach's alpha and corrected item-total correlations. Items with poor psychometric contribution were identified based on low or negative item-total correlations and by examining changes in Cronbach's alpha after item deletion.

To explore structural validity, principal component analysis (PCA) was performed after confirming the suitability of the data. Sampling adequacy was evaluated using the Kaiser-Meyer-Olkin statistic, and the correlation structure was assessed using Bartlett's test of sphericity. Because one item demonstrated poor psychometric performance, a sensitivity analysis was conducted using a refined engagement score that excluded this item.

2.4. Statistical Analysis

Descriptive and inferential analyses were performed to examine the association between positive mHealth engagement and KAP outcomes. The engagement score was first analyzed as a continuous variable in multivariable linear regression models, with Knowledge, Attitude, Practice, and Total KAP entered separately as dependent variables. All models adjusted for age, sex, and occupation.

To assess robustness, the adjusted regression analyses were repeated using the refined engagement score after exclusion of the poorly performing item. Regression coefficients, 95% confidence intervals, and p-values were reported.

To evaluate dose-response patterns, the refined engagement score was categorized into tertiles representing low, moderate, and high engagement. Mean KAP scores were compared across tertiles, and trend analyses were used to assess linear patterns across engagement levels. A two-sided p value of <0.05 was considered statistically significant.

2.5. Ethical Considerations

Ethical approval for this study was granted by the University of Sydney Human Research Ethics Committee (2019/676), the Scientific Committee of the Ministry of Science and Technology, Vietnam (08/QD-HDQL-NAFOSTED), and the Institutional Review Board of the National Lung Hospital, Vietnam (13/19/CT-HDDD). Additional approval was obtained from the Vietnam National Lung Hospital Ethics Committee (VNLH-2023-01). All participants provided informed consent prior to enrollment, and the study analyzed de-identified patient data to ensure strict confidentiality and adherence to the approved research protocol.

3. Results

The participants had a mean age of 42.96 years with a standard deviation of 13.64 years, and the median age was 41.0 years with an interquartile range of 32.0 to 54.0 years. Most participants were male (66.2%), while 33.8% were female. In terms of occupation, the largest group was freelance or informal laborers (55.0%), followed by other occupations (26.3%), retired participants (12.2%), and office workers (6.5%). Regarding treatment history, 78.4% were in their first MDR-TB treatment course, 20.5% were in their second treatment course, and 1.1% were in their third treatment course.

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A total of 278 patients with multidrug-resistant tuberculosis were included in the analysis. The mean age of participants was 42.96 ± 13.64 years. . Most participants were male (66.2%). More than half of the participants were engaged in freelance or informal labor (55.0%), while 26.3% were classified in other occupations, 12.2% were retired, and 6.5% were office workers. Most participants were undergoing their first MDR-TB treatment course (78.4%), whereas 20.5% were in their second course and 1.1% were in their third course.

3.1. Psychometric Properties of the Positive mHealth Engagement Score

The positive mHealth engagement scale demonstrated good internal consistency. The 12-item scale had a Cronbach's alpha of 0.852, based on 231 complete cases, indicating that the items showed acceptable to strong coherence as a composite measure of positive engagement.

The data were also suitable for dimensionality assessment. The Kaiser-Meyer-Olkin value was 0.870, suggesting good sampling adequacy, and Bartlett's test of sphericity supported sufficient inter-item correlation for factor-based assessment

(χ2=1351.31,*df*=66). Together, these findings support the use of the engagement items as a meaningful scale for subsequent analysis.

3.2. Association Between Positive mHealth Engagement and KAP Outcomes

In the multivariable linear regression analyses, positive mHealth engagement was significantly associated with knowledge, attitude, and total KAP, but not with practice. Interpreting the score in the positive direction, higher engagement was associated with better KAP performance.

For each one-standard-deviation increase in positive mHealth engagement, the Knowledge score increased by 2.75 points (95%*CI*:2.01*to*3.50, p<0.001), the Attitude score increased by 4.33 points (95%CI:2.79to5.86, p<0.001), and the Total KAP score increased by 7.50 points (95%CI:5.52to9.48, p<0.001). In contrast, the association with Practice score was smaller and not statistically significant(β=0.42, 95%CI:−0.12to0.96, p=0.126).

These findings suggest that more positive engagement with the mHealth intervention was related mainly to improvements in knowledge and attitudes, while behavioral practice appeared less responsive.

A clear gradient was observed when participants were categorized into tertiles of positive mHealth engagement. Mean Knowledge scores increased from 8.42 in the low-engagement group to 10.67 in the moderate-engagement group and 11.69 in the high-engagement group (p<0.001). A similar pattern was found for Attitude scores, which rose from 32.53 to 35.67 and 39.21, respectively(p<0.001). Total KAP scores also increased steadily across tertiles, from 59.38 to 64.67 and 69.13 (p<0.001).

By contrast, Practice scores remained relatively stable across engagement levels, with mean values of 18.42, 18.33, and 18.23 in the low-, moderate-, and high-engagement groups, respectively (p=0.847).

Adjusted trend analyses confirmed these dose-response findings. Each increase in engagement tertile was associated with a 1.58-point increase in Knowledge score(p<0.001), a 3.17-point increase in Attitude score (p<0.001), and a 4.71-point increase in Total KAP score (p<0.001). No significant linear trend was observed for Practice score (β=−0.045, p=0.792).

Table 2. Descriptive statistics of KAP outcomes and positive mHealth engagement.

Variable	n	Mean ± SD	Median (IQR)	Min-Max
Knowledge score	278	9.95 ± 3.39	11.0 (8.0-13.0)	0-16
Attitude score	278	35.63 ± 5.99	35.5 (31.0-41.0)	22-44

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Practice score	278	18.25 ± 2.37	19.0 (18.0-20.0)	8-21
Total KAP score	278	63.83 ± 8.40	64.0 (57.0-71.0)	42-78
Positive mHealth engagement score	231	0.11 ± 0.50	0.03 (-0.31-0.55)	-1.39-1.47

Table 2 presents the distribution of the main study variables. The mean Knowledge score was 9.95 ± 3.39, with a median of 11.0 (*IQR*:8.0–13.0). The mean Attitude score was 35.63 ± 5.99, and the median was 35.5 (*IQR*:31.0–41.0). The mean Practice score was 18.25 ± 2.37, with a median of 19.0 (*IQR*:18.0–20.0). The mean Total KAP score was 63.83 ± 8.40, and the median was 64.0 (*IQR*:57.0–71.0). Among the 231 participants with complete engagement data, the mean positive mHealth engagement score was 0.11 ± 0.50, with a median of 0.03 (IQR:−0.31to0.55)

Table 3. Psychometric properties of the positive mHealth engagement scale.KMO, Kaiser-Meyer-Olkin measure of sampling adequacy. Bartlett's test was significant, indicating that the inter-item correlation matrix was suitable for dimensionality assessment.

Measure	Value
Number of items	12
Complete cases used for analysis	231
Cronbach's alpha	0.852
Kaiser-Meyer-Olkin (KMO)	0.870
Bartlett's test of sphericity, $\chi 2$	1351.31
Degrees of freedom	66
Bartlett's test p-value	<0.001

Table 3 shows the psychometric properties of the 12-item positive mHealth engagement scale. The scale demonstrated good internal consistency, with a Cronbach's alpha of 0.852 based on 231 complete cases. Sampling adequacy was also good, as indicated by a KMO value of 0.870. In addition, Bartlett's test of sphericity was statistically significant ($\chi 2$ =1351.31, df=66, p<0.001), supporting the suitability of the inter-item correlation structure for dimensionality assessment.

Table 4. Association between positive mHealth engagement and knowledge, attitude, practice, and total KAP scores.

Outcome	β	95% CI	p-value
Knowledge score	2.06	1.28 to 2.85	<0.001
Attitude score	4.68	3.30 to 6.06	<0.001
Practice score	-0.07	-0.63 to 0.49	0.804
Total KAP score	6.68	4.62 to 8.74	<0.001

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After confirming the psychometric adequacy of the positive mHealth engagement scale, regression analyses were conducted to assess its association with KAP outcomes. As shown in Table 4, higher positive mHealth engagement was significantly associated with higher Knowledge, Attitude, and Total KAP scores. Specifically, each one-unit increase in the positive mHealth engagement score was associated with a 2.06-point increase in Knowledge score (95%*CI*:1.28 *to* 2.85, $p<0.001$), a 4.68-point increase in Attitude score (95%*CI*:3.30 *to* 6.06, $p<0.001$), and a 6.68-point increase in Total KAP score (95%*CI*:4.62 *to* 8.74, $p<0.001$). In contrast, no significant association was observed between positive mHealth engagement and Practice score ($\beta=-0.07$, 95%*CI*:−0.63 *to* 0.49, $p=0.804$).

These findings indicate that positive engagement with mHealth was more strongly related to knowledge and attitudes than to behavioral practice.

Table 5. Comparison of KAP scores across tertiles of positive mHealth engagement.

Outcome	Low tertile	Moderate tertile	High tertile	p-value
Knowledge score	8.42	10.67	11.69	<0.001
Attitude score	32.53	35.67	39.21	<0.001
Practice score	18.42	18.33	18.23	0.847
Total KAP score	59.37	64.67	69.13	<0.001

To facilitate interpretation of the regression findings, participants were categorized into low, moderate, and high tertiles of positive mHealth engagement. As presented in Table 5, mean Knowledge, Attitude, and Total KAP scores increased progressively across engagement tertiles. Mean Knowledge scores rose from 8.42 in the low-engagement group to 10.67 in the moderate-engagement group and 11.69 in the high-engagement group. Mean Attitude scores similarly increased from 32.53 to 35.67 and 39.21, respectively. Mean Total KAP scores increased from 59.37 to 64.67 and 69.13 across the three tertiles.

In contrast, Practice scores showed minimal variation across groups, with means of 18.42, 18.33, and 18.23 in the low-, moderate-, and high-engagement tertiles, respectively, and the between-group difference was not statistically significant ($p=0.847$).

Overall, the tertile-based analysis was consistent with the regression results, showing a clear positive gradient for knowledge and attitudes, but not for practice.

4. Discussion

This study evaluated the psychometric performance of the positive mHealth engagement scale and examined its association with knowledge, attitudes, and practices among patients with multidrug-resistant tuberculosis who were using an mHealth application designed to support medication adherence and adverse event reporting [6,12]. Two main findings emerged. First, the positive mHealth engagement scale demonstrated good internal consistency and acceptable psychometric adequacy, supporting its use in this study population. Second, higher positive mHealth engagement was significantly associated with better knowledge and more favorable attitudes, whereas no statistically significant association was observed for practice. This pattern was consistent across both regression and tertile-based analyses.

The psychometric findings are important because they support the validity of using the engagement score as a meaningful exposure variable in this setting. The 12-item scale showed good reliability, with a Cronbach's alpha of 0.852, and the sampling adequacy statistics also supported its

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internal coherence. In practical terms, this suggests that the scale captured a reasonably stable construct reflecting how positively and actively patients engaged with the mHealth application. This is particularly relevant in MDR-TB care, where digital tools are increasingly used not only to deliver information, but also to support long-term treatment monitoring, adherence, and communication about adverse events [14,15].

A key finding of this study was the positive association between mHealth engagement and knowledge. Patients with higher engagement scores had better knowledge scores, and this gradient was clearly observed across engagement tertiles. This is plausible given the role of mHealth applications in reinforcing treatment-related information, reminding patients about medication schedules, and providing accessible guidance on disease management [16,17]. For patients with MDR-TB, who often undergo prolonged and demanding treatment regimens, repeated access to clear and structured information may improve understanding of treatment importance, medication use, and recognition of treatment-related issues, including adverse events.

A similarly strong relationship was observed for attitudes. Patients with greater positive engagement with the application had more favorable attitudes, which may reflect increased confidence in treatment, greater trust in the usefulness of the digital tool, and stronger perceived value of staying connected to care [10]. In the context of MDR-TB, attitudes are highly relevant because treatment is lengthy, burdensome, and frequently accompanied by uncertainty, fatigue, and treatment-related discomfort. An mHealth application may therefore contribute not only to knowledge acquisition, but also to motivation, reassurance, and the perception that treatment is manageable with support [18–20].

In contrast, practice was not significantly associated with positive mHealth engagement. This finding is noteworthy and should not be interpreted as meaning that the application lacks value. Rather, it suggests that behavioral practice in MDR-TB care is shaped by a broader set of influences that may not be fully modifiable through digital engagement alone. While an application may improve awareness and attitudes, actual practice related to adherence and response to adverse events may still be constrained by medication side effects, treatment fatigue, social stigma, limited family support, financial barriers, competing life demands, or difficulties accessing health services. In this sense, the absence of a significant association with practice may reflect the complexity of behavioral implementation rather than the absence of benefit from mHealth engagement [21,22].

This interpretation is consistent with the broader logic of the KAP framework. Knowledge is often the most immediate domain influenced by educational exposure, and attitudes may shift as patients repeatedly encounter supportive and persuasive information [23,24]. Practice, however, usually represents the most distal domain, requiring not only awareness and motivation but also sufficient opportunity, support, and capacity to act. In MDR-TB treatment, where adherence is demanding and adverse events can be severe, behavior may remain difficult to sustain even when patients understand the importance of treatment and hold favorable views toward it. The present findings therefore suggest that mHealth may be effective as a tool for improving treatment-related understanding and attitudes, but that it should be embedded within broader clinical and social support strategies if the goal is to change practice more substantially.

From a clinical and programmatic perspective, these findings have several implications. First, the results support the continued use of mHealth as a component of MDR-TB care, particularly for patient education, engagement, and reinforcement of treatment-related beliefs. Second, the lack of an observed association with practice suggests that digital platforms should not be expected to function as stand-alone adherence interventions. Instead, they may be most effective when integrated with provider follow-up, counseling, adverse event management pathways, and individualized support for barriers to adherence. Third, the engagement scale itself may be useful in future implementation studies as a way to identify patients with lower levels of digital engagement who may require additional assistance to benefit fully from app-based care.

Several limitations should be acknowledged. First, the cross-sectional nature of the analysis limits causal inference. It cannot be determined whether stronger engagement led to better

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knowledge and attitudes, or whether patients with better knowledge and more positive attitudes were more likely to engage actively with the application [25]. Second, the engagement score was available only for participants with complete item responses, resulting in a smaller analytic sample for that measure. Third, KAP variables may be influenced by self-report and social desirability bias. Fourth, the study population consisted specifically of MDR-TB patients already using an mHealth application, which may limit generalizability to other TB populations, to patients not using digital tools, or to other health system contexts. Finally, although the psychometric findings were encouraging, additional validation of the engagement scale in independent MDR-TB samples would strengthen confidence in its broader applicability.

Despite these limitations, the study has notable strengths. It addresses a highly relevant topic in TB care by linking digital engagement with patient-centered outcomes in a population facing prolonged and complex treatment. The analysis also proceeds in a coherent sequence, from psychometric assessment of the engagement scale to examination of its associations with KAP outcomes and comparison across tertiles. In addition, the separation of knowledge, attitudes, and practices provides a more nuanced interpretation than would be possible from a single combined outcome alone. This is especially valuable in MDR-TB care, where improvement in knowledge or attitudes may represent meaningful progress even before measurable changes in behavior are observed.

In summary, among MDR-TB patients using an mHealth application for treatment support and adverse event management, higher positive mHealth engagement was associated with better knowledge and more favorable attitudes, but not with significantly different practice scores. The positive mHealth engagement scale also demonstrated good reliability and acceptable psychometric performance in this study population. These findings suggest that mHealth may be a useful tool for strengthening informational and attitudinal readiness in MDR-TB care, but that behavioral practice likely depends on broader structural, clinical, and social factors. Future research should assess these relationships longitudinally and examine whether integrating mHealth engagement with more intensive adherence and adverse event support can lead to stronger behavioral effects.

5. Conclusion

Among MDR-TB patients using an mHealth application for medication adherence support and adverse event reporting, higher positive mHealth engagement was significantly associated with better knowledge and more favorable attitudes, whereas no significant association was observed for practice. The positive mHealth engagement scale demonstrated good internal consistency and acceptable psychometric adequacy, supporting its use in this setting. These findings highlight the potential of mHealth to improve patient understanding and attitudinal engagement during MDR-TB treatment, but also suggest that digital engagement alone may be insufficient to change behavior. Integrated strategies combining mHealth with clinical follow-up, adherence counseling, and adverse event management may be needed to translate these gains into practice.

Author Contributions: Conceptualization, H.N.L. and L.V.D.; methodology, H.N.L. and G.M.L.; formal analysis, H.N.L.; investigation, H.N.L. and G.M.L.; writing—original draft preparation, H.N.L., H.B.N. and L.V.D.; writing—review and editing, H.N.L., G.M.L., H.B.N. and L.V.D.; supervision, H.B.N. and L.V.D.; project administration, H.B.N. and L.V.D.; funding acquisition, L.V.D. All authors have read and agreed to the published version of the manuscript.

Funding: The VSMART parent trial was jointly funded by the National Health and Medical Research Council (NHMRC), grant number APP 1157643, and the National Foundation for Science and Technology Development (NAFOSTED), grant number NHMRC.108.02–2018.0. This research also received support from Global Fund Vietnam and the National Tuberculosis Program (NTP), Vietnam.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the University of Sydney Human Research Ethics Committee (protocol code 2019/676,

 doi:10.20944/preprints202604.0682.v1

approved date: 4 October 2019), the Scientific Committee of the Ministry of Science and Technology, Vietnam (protocol code 08/QD-HDQL-NAFOSTED), the Institutional Review Board of the National Lung Hospital, Vietnam (protocol code 13/19/CT-HDDD, date 22 August 2019), and the Vietnam National Lung Hospital Ethics Committee (protocol code VNLH-2023-01, date: 24 April 2023).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy and ethical restrictions, as the dataset contains sensitive information related to patients within the National Tuberculosis Program and is subject to the data protection policies of the collaborating institutions.

Acknowledgments: The authors would like to express their sincere gratitude to Greg Fox and Anh Nguyen from the Woolcock Institute of Medical Research and the University of Sydney, Australia, for their invaluable technical support and guidance throughout this research. We would also like to thank the VSMART study team for their dedicated efforts in data collection, data entry, and conducting the participant interviews.

Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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 doi:10.20944/preprints202604.0682.v1