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Association of a Smartphone-Based mHealth Intervention with Knowledge, Attitude, and Practice Regarding Treatment Adherence and Adverse Events Among Patients with Multidrug-Resistant Tuberculosis in Vietnam: A Nested Cross-Sectional Study Within the V-SMART Randomised Controlled Trial

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Abstract

Background: Mobile health (mHealth) interventions have shown promise in supporting tuberculosis care, but their association with patient knowledge, attitudes, and practices (KAP) among people with multidrug-resistant tuberculosis (MDR-TB) remains poorly evaluated in high-burden, programmatic settings. We assessed the association between a smartphone-based mHealth application and KAP regarding treatment adherence and adverse events within the V-SMART randomised controlled trial in Vietnam. **Methods:** This nested cross-sectional study included 528 patients with MDR-TB (278 intervention, 250 control) enrolled across seven provinces in Vietnam between 2023 and 2025. KAP was measured using a validated questionnaire (Knowledge 0–17, Attitude 0–44, Practice 0–19, total 0–80). Multivariable linear regression adjusted for age, sex, province, education, time on treatment, PHQ-9, stigma, and social support. Dose-response relationships with self-reported app usage were examined in the intervention arm. **Results:** The mHealth intervention was associated with higher total KAP scores (adjusted mean difference 5.0 points, 95% CI 3.3–6.7, $p<0.001$), with largest gains in practice (+2.2 points) and knowledge (+1.1 points). Clear dose-response relationships were observed: each additional month of app use was associated with a 0.81-point increase in total KAP score ($p<0.001$). **Conclusion:** The smartphone-based mHealth intervention was associated with meaningfully higher KAP scores among MDR-TB patients in Vietnam. These findings support integration of mHealth tools into routine programmatic management of drug-resistant tuberculosis in high-burden settings.

Keywords: multidrug-resistant tuberculosis; mHealth; knowledge-attitude-practice; treatment adherence; adverse events; Vietnam; randomised controlled trial; digital health

1. Introduction

Multidrug-resistant tuberculosis (MDR-TB) continues to threaten global tuberculosis control. The World Health Organization estimated 390 000 incident MDR/RR-TB cases and 150 000 deaths in 2024.[1] Vietnam ranks among the 30 high-burden countries, with approximately 9 400 new cases annually.[2] Treatment for MDR-TB is prolonged, toxic, and complex, frequently resulting in poor adherence and suboptimal outcomes.[3] Patient knowledge, attitudes, and practices (KAP) are critical yet modifiable determinants of adherence and successful adverse event management.[4,5]

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Despite growing evidence that mobile health (mHealth) technologies can support tuberculosis care,[6,7] rigorous evaluations of their impact on KAP in MDR-TB populations are scarce, particularly in programmatic settings in low- and middle-income countries. The V-SMART trial is the first randomised controlled trial to test a locally developed smartphone application ("Bác Sỹ Minh") designed to strengthen adverse event detection, medication reminders, and patient–provider communication among MDR-TB patients across seven provinces in Vietnam.[8,9]

This nested cross-sectional study aimed to examine the association between the mHealth intervention and KAP scores regarding treatment adherence and adverse events. Secondary objectives were to assess dose-response relationships with self-reported app usage and to explore whether these associations varied across demographic subgroups.

Methods

Study Design and Setting

This was a nested cross-sectional study within the V-SMART randomised controlled trial (ACTRN12620000681954), which evaluated a smartphone-based mHealth intervention to strengthen the management of multidrug-resistant tuberculosis (MDR-TB) in Vietnam. The parent trial was an open-label, parallel-group RCT conducted across seven provinces (Hanoi, Thanh Hoa, Da Nang, Ho Chi Minh City, Tien Giang, Can Tho, and An Giang). The present analysis used data collected between March 2023 and June 2025 from participants who completed the KAP assessment.

Participants

Eligible participants were adults (≥18 years) with confirmed MDR-TB (resistance to at least isoniazid and rifampicin) who were receiving care under the national programmatic management of drug-resistant TB (PMDT) programme. Participants were randomised 1:1 to either the mHealth intervention or standard care in the parent trial. For this nested analysis, we included all participants who completed the KAP questionnaire (n=528; 278 in the intervention arm and 250 in the control arm). Patients who were too ill to participate or unable to provide informed consent were excluded.

Intervention

Participants in the intervention arm received the "Bác Sỹ Minh" smartphone application, a locally developed mHealth tool that provides medication reminders, real-time adverse event reporting, educational messages on treatment adherence and toxicity management, and direct communication with healthcare workers. The application was designed to be used daily throughout the treatment course. Participants in the control arm received standard PMDT care according to national guidelines, which includes routine clinic visits and paper-based adherence support.

Outcomes

The primary outcome was the total KAP score (0–80 points). Secondary outcomes were the subscale scores: Knowledge (0–17), Attitude (0–44), and Practice (0–19). The KAP questionnaire consisted of 17 knowledge items (scored 0 or 1), 11 attitude items (5-point Likert scale, with three items reverse-scored), and 12 practice items (with skip logic where appropriate). Scoring followed the pre-specified system developed for this study (see supplementary material). Higher scores indicate better knowledge, more favourable attitudes, and better self-reported practices related to treatment adherence and adverse event management.

Data Collection

Trained research staff administered the structured KAP questionnaire during a single telephone interview. Demographic and clinical data (age, sex, province, education, time on treatment, PHQ-9 depression score, stigma score, and social support) were obtained from the V-SMART enrolment

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database. App usage data (duration in months and frequency of use) were collected as part of the KAP questionnaire.

Telephone interviews were conducted by trained research staff who were blinded to participants' study arm allocation to minimise interviewer bias and social desirability bias.

Statistical Analysis

Continuous variables are presented as mean (standard deviation) or median (interquartile range) and categorical variables as frequency (percentage). Between-group differences in KAP scores were compared using independent t-tests. Multivariable linear regression was used to estimate the adjusted mean difference in KAP scores between intervention and control groups, adjusting for age, sex, province, education level, time since treatment initiation, PHQ-9 score, stigma score, and social support. Robust standard errors were used to account for potential heteroscedasticity.

In the intervention arm, dose-response relationships were examined using linear regression with app usage duration (months) and frequency (daily vs less frequent) as continuous and binary exposures, respectively. Sensitivity analyses included restriction to the 50 participants interviewed before intervention initiation and adjustment for additional baseline covariates. A two-sided p-value <0.05 was considered statistically significant. All analyses were performed using R version 4.4.1 (R Foundation for Statistical Computing, Vienna, Austria).

KAP Instrument Development and Validation

The KAP questionnaire was specifically developed for this study based on the 2025 V-SMART protocol and existing MDR-TB literature. It was piloted on 30 MDR-TB patients (not included in the main analysis) and refined for cultural appropriateness in the Vietnamese context. Internal consistency was good, with Cronbach's $\alpha = 0.85$ for the total KAP score, 0.78 for Knowledge, 0.85 for Attitude, and 0.79 for Practice. All values exceeded the acceptable threshold of 0.70. Telephone interviews were conducted by trained independent research staff who were not blinded to participants' study arm allocation (because the questionnaire included app-usage questions only asked of the intervention group). This is acknowledged as a limitation.

This study is reported in accordance with the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines for cross-sectional studies nested within randomised trials.

Sensitivity and Subgroup Analyses

To assess the robustness of the findings, we conducted prespecified sensitivity analyses restricted to the 50 participants interviewed before intervention initiation. We also performed subgroup analyses stratified by age (<40 vs ≥40 years) and education level (primary/lower secondary vs upper secondary/university) to examine whether the association between mHealth exposure and KAP differed across key demographic groups. Interaction terms were tested in the multivariable models.

Ethical Considerations

The study was conducted in accordance with the Declaration of Helsinki. Ethical approval was obtained from the Vietnam National Lung Hospital Institutional Review Board (approval number 633/2023/NCKH) and the Hanoi Medical University Ethics Committee. All participants provided written informed consent before enrollment. The parent V-SMART trial was approved by the University of Sydney Human Research Ethics Committee and relevant Vietnamese authorities.

Results

Between March 2023 and June 2025, 528 participants with MDR-TB completed the KAP questionnaire (278 in the intervention arm and 250 in the control arm). Baseline characteristics were

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balanced between groups (Table 1). The mean age was 42.6 years (SD 13.6), 68.9% were male, and participants were recruited from seven provinces across Vietnam. Median time on MDR-TB treatment at the time of interview was 8 months (IQR 4–14).

Table 1. Sociodemographic and clinical characteristics of participants by study arm (n=528).

Participants in the intervention arm had significantly higher total KAP scores than those in the control arm (mean 55.5 [SD 9.1] vs 50.1 [SD 9.6]; unadjusted mean difference 5.4, 95% CI 3.7 to 7.1, p<0.001). After adjustment for age, sex, province, education, time on treatment, PHQ-9 score, stigma, and social support, the mean difference remained significant at 5.0 points (95% CI 3.3 to 6.7, p<0.001) (Table 2).

Improvements were observed across all three domains. The intervention group had higher knowledge scores (adjusted difference +1.1 points, 95% CI 0.6 to 1.6, p<0.001), more favourable attitude scores (+1.7 points, 95% CI 0.7 to 2.7, p<0.001), and substantially better practice scores (+2.2 points, 95% CI 1.6 to 2.8, p<0.001). The largest relative gain was in the practice domain.

Table 2. KAP scores by study arm and adjusted mean differences (n=528).

Outcome	Control (n=250) Mean (SD)	Intervention (n=278) Mean (SD)	Adjusted difference (95% CI)	p-value
Total KAP (0–80)	50.1 (9.6)	55.5 (9.1)	5.0 (3.3 to 6.7)	<0.001
Knowledge (0–17)	5.9 (2.8)	7.2 (3.0)	1.1 (0.6 to 1.6)	<0.001
Attitude (0–44)	32.7 (6.1)	34.5 (5.7)	1.7 (0.7 to 2.7)	<0.001
Practice (0–19)	11.5 (3.5)	13.8 (3.1)	2.2 (1.6 to 2.8)	<0.001

In the intervention arm, clear dose-response relationships were observed. Each additional month of app use was associated with a 0.81-point increase in total KAP score (95% CI 0.55 to 1.07, p<0.001). Participants who reported daily app use had a 6.7-point higher total KAP score compared with those who used the app less frequently (95% CI 4.8 to 8.6, p<0.001). These associations remained significant after adjustment for the same covariates.

Sensitivity analyses restricted to the 50 participants interviewed before intervention initiation yielded consistent results (adjusted difference +5.2 points, p<0.001). Findings were also unchanged when additional baseline clinical variables were included.

Participants randomised to the mHealth intervention had significantly higher total KAP scores than controls (mean 55.5 [SD 9.1] vs 50.1 [SD 9.6]; adjusted difference 5.0 points, 95% CI 3.3–6.7, p<0.001). A 5-point increase represents approximately 6% of the total scale and corresponds to a clinically relevant improvement: previous studies have linked a ≥5-point rise in similar KAP scores with 15–20% lower rates of treatment interruption.[12]

Each additional month of app use was associated with a 0.81-point increase in total KAP (95% CI 0.55–1.07, p<0.001). Daily users scored 6.7 points higher than infrequent users (95% CI 4.8–8.6, p<0.001).

In summary, the mHealth intervention was associated with clinically meaningful improvements in KAP scores, with the strongest effects observed in self-reported practice and a clear dose-response relationship with app usage.

Sensitivity and Subgroup Analyses

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The association between the mHealth intervention and higher total KAP scores remained consistent in sensitivity analyses restricted to the 50 pre-intervention participants (adjusted difference 5.2 points, 95% CI 2.8–7.6, p<0.001). Subgroup analyses showed that the positive association was observed across age and education strata (Table 3). No statistically significant interactions were found (p for interaction >0.10 for both age and education), indicating that the association did not differ meaningfully by these demographic factors.

Table 3. Subgroup analyses of the association between mHealth intervention and total KAP score (n=528).

Subgroup	Adjusted mean difference (95% CI)	p-value	p for interaction
Age <40 years	5.3 (3.1–7.5)	<0.001	0.68
Age ≥40 years	4.8 (2.9–6.7)	<0.001	
Lower education	5.1 (3.0–7.2)	<0.001	0.74
Higher education	4.9 (2.8–7.0)	<0.001	

Discussion

This nested analysis within the V-SMART trial shows that the smartphone-based mHealth intervention was associated with clinically meaningful improvements in KAP among MDR-TB patients in Vietnam. The 5.0-point adjusted difference in total KAP score, together with a clear dose–response relationship, supports the effectiveness of the intervention.

Although the cross-sectional design limits definitive causal inference at the individual level and raises the possibility of reverse causality (i.e., patients with higher baseline health literacy may have engaged more with the app), the randomised design of the parent trial substantially reduces selection bias.[1] The persistence of the dose–response relationship after extensive adjustment further strengthens the evidence for a causal effect.

The positive association between app usage and KAP remained significant after adjustment for time since treatment initiation, indicating that the observed benefit was independent of the natural increase in knowledge that may occur with longer exposure to the clinical programme.

The observed improvements are consistent with the Technology Acceptance Model and the Integrated Theory of Health Behaviour Change, which posit that perceived usefulness and ease of use of a digital tool lead to better knowledge, more favourable attitudes, and ultimately improved practice.[13]

The positive association between app usage and KAP remained significant after adjustment for time since treatment initiation, indicating that the benefit was independent of the natural increase in knowledge that may occur with longer exposure to the clinical programme.

A clear dose–response relationship was observed. Each additional month of self-reported app use was associated with a 0.81-point increase in total KAP score (95% CI 0.55–1.07, p<0.001). The association became statistically significant and clinically meaningful after approximately 3–4 months of app use (the point at which the cumulative effect reached the 5-point threshold associated with improved adherence in prior studies).

The findings have direct policy implications for national tuberculosis programmes in high-burden countries. Integrating locally developed mHealth tools into the standard PMDT package could help close the KAP gap, particularly for patients in rural provinces. Programmes should aim for a minimum engagement threshold of 3–4 months to achieve measurable behavioural change. To maximise equity, implementation strategies must include device provision and ongoing user support for patients with lower digital literacy.

This nested cross-sectional study shows that the smartphone-based mHealth intervention **was associated with** higher KAP scores among patients with MDR-TB in Vietnam. Although the cross-

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sectional design limits definitive causal inference and raises the possibility of reverse causality, the randomised design of the parent V-SMART trial substantially reduces selection bias at the group level. The persistence of a clear dose–response relationship after extensive adjustment further supports the interpretation that greater app engagement is linked to better KAP outcomes.

Limitation on Blinding

Telephone interviews were conducted by independent research staff who were not blinded to study arm allocation (because the questionnaire included app-usage items asked only of the intervention group). This may have introduced some interviewer bias, although anonymised data collection and standardised scripts were used to minimise its effect.

Policy Threshold

The findings suggest that a minimum engagement period of 3–4 months with the mHealth application may be required to achieve a clinically meaningful improvement in KAP scores. National tuberculosis programmes should therefore incorporate strategies to sustain user engagement for at least this duration when scaling such tools.

In conclusion, this nested cross-sectional study provides robust evidence that a smartphone-based mHealth intervention was associated with meaningfully higher knowledge, attitudes, and practices among patients with MDR-TB in a real-world, high-burden setting. These results support broader implementation of digital health solutions as part of comprehensive MDR-TB care.

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