Nurse Media Journal of Nursing
e-ISSN: 2406-8799, p-ISSN: 2087-7811
https://medianers.undip.ac.id
15(2):265-281, August 2025
https://doi.org/10.14710/nmjn.v15i2.70345

ORIGINAL RESEARCH

# Key Predictors of Medication Adherence Among Diagnosed Pulmonary Tuberculosis Patients: A Cross-Sectional Study

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**Article Info**

Article History:
Received: 16 January 2025
Revised: 17 August 2025
Accepted: 30 August 2025
Online: 31 August 2025

Keywords:
Adherence; drug side effects; knowledge; medication; support systems; tuberculosis

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**Abstract**

**Background:** Medication adherence remains a critical challenge in tuberculosis (TB) control, particularly in Indonesia, which ranks second globally in TB incidence. Most existing studies focus on single-factor analyses rather than a comprehensive multifactorial assessment of adherence predictors among Indonesian TB patients.
**Purpose:** This study aimed to identify and quantify key predictors of medication adherence among diagnosed pulmonary tuberculosis patients with particular emphasis on sociodemographic factors, clinical variables, and psychosocial determinants.
**Methods:** A cross-sectional study was conducted involving 150 pulmonary TB patients recruited through consecutive sampling. Data were collected using validated instruments, including the 8-item Morisky Medication Adherence Scale (MMAS-8) for adherence, the Knowledge About Tuberculosis Questionnaire (KATUB-Q) for TB knowledge, a structured questionnaire for drug side effects, the Treatment Motivation Questionnaire for motivation, the Multidimensional Scale of Perceived Social Support (MSPSS) for support systems, and the TB-related Stigma Scale for stigma measurement. Statistical analyses included descriptive statistics, Chi-square tests, and ordinal logistic regression to evaluate relationships between variables and adherence levels.
**Results:** Only 20% of participants demonstrated high adherence, while 50.7% exhibited low adherence. Significant predictors of adherence included early adulthood (OR = 0.061, 95% CI 0.004–0.857, $p = 0.038$) and middle adulthood (OR = 0.052, 95% CI 0.005–0.565, $p = 0.015$), indicating lower adherence compared to late elderly. Other predictors were poor TB knowledge (OR = 0.316, 95% CI 0.154–0.650, $p = 0.002$), motivation (OR = 0.244, 95% CI 0.108–0.553, $p < 0.001$), family support (OR = 0.470, 95% CI 0.232–0.952, $p = 0.036$), healthcare worker support (OR = 0.349, 95% CI 0.204–0.840, $p = 0.015$), and drug side effects (OR = 5.294, 95% CI 2.134–13.126, $p < 0.001$). Younger adults showed lower adherence rates compared to older populations, while patients with better knowledge and stronger support systems demonstrated higher adherence.
**Conclusion:** Key predictors of medication adherence were age, TB knowledge, motivation, family support, healthcare worker support, and drug side effects. Younger patients, those with poor knowledge, moderate motivation, inadequate support systems, and severe side effects demonstrated significantly lower adherence rates. These findings highlight the need for targeted, multifactorial interventions to improve TB treatment outcomes.

**How to cite:** Sarfika, R., Martini, E., Yuliharni, S., & Saifudin, I. M. M. Y. Key predictors of medication adherence among pulmonary tuberculosis patients: A cross-sectional study. *Nurse Media Journal of Nursing, 15*(2), 265-281. https://doi.org/10.14710/nmjn.v15i2.70345



## 1. Introduction

Tuberculosis (TB) remains a formidable global health challenge, with approximately 10 million new cases and 1.5 million deaths annually, predominantly affecting low and middle-income countries (Yang et al., 2024). Asia accounts for 60% of global incident cases, with India, Indonesia, and China collectively contributing 43% of the worldwide burden (Okada, 2016). Within Southeast Asia, Indonesia ranks as the second-highest TB burden country globally,

reporting a concerning prevalence rate of 660 per 100,000 population with significant regional variations—Sumatra demonstrating elevated rates of 759 per 100,000, while Java-Bali maintains relatively lower rates at 593 per 100,000 population (Noviyani et al., 2021; Sarumpaet & Syarifah, 2019; Setiyadi et al., 2020). The burden is further complicated by substantial case notification gaps of 48% and the emergence of multidrug-resistant TB (MDR-TB), underscoring persistent challenges in TB control and management across the Indonesian archipelago (Chee et al., 2012; Yang et al., 2024).

Medication adherence in tuberculosis treatment represents a critical determinant of therapeutic success, characterized by complex interrelationships among sociodemographic, psychosocial, cognitive, and treatment-related factors (Story, 2021). Adherence patterns are significantly modulated by sociodemographic variables, with younger age, higher educational attainment, and stable economic status emerging as positive predictors (Shinde, 2024). The psychosocial domain demonstrates particular salience, where internalized stigma and consequent depression manifest as significant barriers to adherence, while robust family support systems and effective healthcare provider relationships serve as protective factors (Chen et al., 2020). Health literacy emerges as a fundamental mediator of adherence behaviors, with higher levels of tuberculosis-specific knowledge correlating positively with medication compliance (Qomariyah & Piyabanditkul, 2023)

The implications of suboptimal medication adherence in tuberculosis treatment manifest across multiple domains, encompassing both individual clinical outcomes and broader public health ramifications (Pradipta et al., 2020). A critical consequence emerges in the form of treatment failure and disease relapse, stemming from insufficient therapeutic exposure due to incomplete medication regimens (Appiah et al., 2023). Of particular concern is the development of drug-resistant tuberculosis strains, a direct sequela of inadequate adherence patterns that compromise both individual treatment efficacy and public health control measures (Bajrami et al., 2019). This antimicrobial resistance phenomenon necessitates more complex, costly, and prolonged treatment protocols, potentially straining healthcare resources and systems (Garcia-Cremades et al., 2022). Furthermore, poor adherence extends the period of bacterial infectivity, thereby amplifying transmission risk within communities and perpetuating the cycle of disease burden (Gugssa Boru et al., 2017; Munro et al., 2007). The confluence of these factors culminates in elevated mortality rates among non-adherent patients, underscoring the critical importance of adherence optimization in tuberculosis treatment protocols.

Indonesia's tuberculosis control infrastructure demonstrates a comprehensive yet complex approach to addressing the adherence-related challenges previously discussed, particularly given its position as the second-highest TB burden country globally. The National Strategy for TB Prevention and Control 2020-2024 is a multifaceted framework that incorporates evidence-based interventions such as Directly Observed Treatment Short-course (DOTS) and Public-Private Mix (PPM) initiatives (Ardian et al., 2007; Lestari et al., 2023; Mahendradhata et al., 2014). These approaches have yielded variable outcomes across different provinces, with PPM implementation showing initial improvements in case detection rates, though falling short of national targets (Jiang et al., 2022; Winardi et al., 2022). The program's evolution reflects an increasing emphasis on technological integration, exemplified by the adoption of mobile health technologies for adherence monitoring, directly addressing the adherence challenges and their consequences outlined earlier (Johns et al., 2009; Machlaurin et al., 2020; Probandari et al., 2016).

The empirical landscape of tuberculosis medication adherence in Indonesia presents a multifaceted interplay of predisposing, reinforcing, and enabling factors, with significant gaps in understanding their relative contributions and interactions. While existing literature establishes correlations between cognitive factors (knowledge, self-efficacy) and adherence behaviors, the mechanistic pathways underlying these associations remain incompletely characterized (Adima & Arini, 2025; Fuady et al., 2020; Ghozali & Murani, 2023). The reinforcing domain, particularly family and healthcare personnel support, consistently influences adherence patterns, though quantitative metrics for optimal implementation strategies require further investigation. Moreover, enabling factors such as healthcare accessibility and economic constraints emerge as critical determinants, yet comprehensive cost-effectiveness analyses of targeted interventions remain limited. The temporal dynamics of adverse drug reactions and their impact on adherence patterns represent another significant research gap, particularly within Indonesia's unique sociocultural context.

Despite extensive research on TB adherence globally, there remains a limited comprehensive understanding of how sociodemographic, clinical, and psychosocial factors simultaneously influence medication adherence in Indonesian TB patients, particularly using validated quantitative assessment tools in local settings. Therefore, this cross-sectional study aimed to identify and quantify key predictors of medication adherence among patients with pulmonary tuberculosis in Palembang, Indonesia.

## 2. Methods

### *2.1. Research design*

A cross-sectional analytical investigation was undertaken to delineate the determinants influencing medication adherence patterns among patients with pulmonary tuberculosis, adhering to the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines for cross-sectional studies (Vandenbroucke et al., 2007). The design allows assessment of multiple variables at a single point in time, facilitating exploration of relationships among patient characteristics, treatment factors, and adherence levels.

### *2.2. Setting and samples*

Participant recruitment was conducted between July and August 2024 across five strategically selected Public Healthcare Centers (PHCs) in Palembang, Indonesia. The study employed a systematic sampling framework with clearly defined eligibility criteria. Inclusion parameters encompassed: confirmed pulmonary tuberculosis diagnosis at participating PHCs, minimum age threshold of 18 years, active engagement in anti-tuberculosis treatment protocols, and demonstrated capacity for sustained study participation. Meanwhile, exclusion criteria were implemented for individuals presenting with severe mental health disorders or those unable to provide informed consent, ensuring methodological rigor and ethical compliance.

A consecutive sampling strategy was implemented, as supported by previous methodological research (Sarfika et al., 2023), to optimize participant recruitment within the constraints of available resources and temporal limitations. This approach facilitated systematic enrolment of eligible participants until the predetermined sample size was achieved. The final cohort comprised 150 participants, with sample size determined through comprehensive power analysis. Statistical power was established at 80% with a 95% confidence interval, ensuring robust detection of significant associations. Moreover, the sample size satisfied the requisite case-to-predictor ratio for multivariate analytical procedures, thereby enhancing the statistical validity of the findings.

### *2.3. Measurement and data collection*

Data collection was facilitated by six trained enumerators, recruited from nurses working at the PHCs. These enumerators underwent a standardized training program to ensure their understanding of the study's objectives, instruments, and procedures. Respondents were selected based on pre-defined inclusion and exclusion criteria to ensure the integrity and representativeness of the sample.

Data collection was executed using a structured, culturally adapted, and psychometrically validated questionnaire complemented by a demographic survey. The demographic instrument captured established predictors of medication adherence, including age, gender, educational status, employment status, duration of treatment, smoking status, and smoking duration—variables previously identified as significant correlates of adherence behavior in pulmonary TB patients (Gurusinga et al., 2024; Islam et al., 2024; Sartika et al., 2019). The study examined key variables including medication adherence, knowledge, drug side effects, treatment supervisor support, family support, healthcare worker support, motivation, and stigma. Instrument selection was guided by global recognition, psychometric rigor, and population relevance.

#### *2.3.1 Medication adherence*

Medication adherence was measured using the 8-item Morisky Medication Adherence Scale (MMAS-8), a globally recognized tool for assessing medication-taking behavior (Morisky et al., 2008). The MMAS-8 consists of dichotomous responses ("Yes"/"No") for items 1–7 and a 5-point Likert scale for item 8, with responses ranging from "Never" to "Always." Total scores classify adherence into three levels: low (<6), moderate (6 to <8), and high (>8) (Chen et al., 2020). The

MMAS-8 has been culturally adapted and validated for use in Indonesia, with a Cronbach's alpha of 0.759 and a reliability coefficient of 0.860, confirming its internal consistency and stability (Agustina et al., 2024).

*2.3.2 Knowledge*

Knowledge about TB was assessed using the Knowledge about Tuberculosis Questionnaire (KATUB-Q), developed and psychometrically validated by Kusuma et al. (2022) using Rasch Modelling for the Indonesian population. The questionnaire consists of 10 dichotomous items ("True/False" or "Yes/No") covering TB symptoms, transmission, treatment, and prevention. Correct responses were scored as 1, while incorrect or "do not know" responses were scored as 0. Total scores were categorized into knowledge levels: poor (<5) or good (≥5). The adapted version demonstrated strong validity and reliability, with a Cronbach's alpha of 0.89, confirming its suitability for assessing TB knowledge in the Indonesian context (Kaaffah et al., 2023).

*2.3.3 Motivation*

Motivation for TB treatment adherence was measured using a 20-item Likert-scale questionnaire adapted from Widianingrum (2017). Responses ranged from "Strongly Disagree" (1) to "Strongly Agree" (4). Positive items were scored 4–1, while negative items were reverse-scored. Higher total scores indicated greater motivation to adhere to treatment. The total scores were categorized into three levels: good motivation (76–100%), moderate motivation (56–75%), and low motivation (0–55%). Example items included statements such as "Taking medication regularly not only cures the disease but also improves overall health" (positive item) and "Side effects of medication make me reluctant to take it consistently" (negative item). Validity testing showed correlation coefficients ranging from 0.482 to 0.663, exceeding the r table value of 0.444, and the instrument demonstrated excellent reliability with a Cronbach's alpha of 0.908 (Salvadila et al., 2023).

*2.3.4 Family support*

Family support for TB treatment was measured using a 4-item Likert-scale questionnaire adapted from a previous study (Chen et al., 2020). The instrument evaluates various aspects of family involvement, including medication supervision, spiritual encouragement, interpersonal relationships among family members, and assistance in solving daily life problems. Responses were scored on a 3-point scale: "Often" (3), "Sometimes" (2), and "Never" (1). Higher total scores indicated greater family support. Example items included: "How often does your family supervise your medication intake?" and "How often does your family provide spiritual encouragement for TB treatment?" The instrument demonstrated excellent validity and reliability, with a Cronbach's alpha of 0.893, confirming its suitability for assessing family support in TB treatment.

*2.3.5 Healthcare worker support*

Healthcare worker support in TB treatment was measured using a 7-item Likert-scale questionnaire (Widiastutik et al., 2020). This instrument evaluates healthcare providers' attitudes and behaviors toward supporting TB patients, with responses ranging from "Strongly Agree" (5) to "Strongly Disagree" (1). The total possible score ranged from 7 to 35, with scores < 17.5 indicating low support and scores ≥ 17.5 indicating good support. Example items included: "The healthcare worker is friendly toward you during treatment" and "The healthcare worker listens to your complaints and helps address them." The instrument was validated through prior testing, demonstrating excellent internal consistency (Cronbach's alpha = 0.893), indicating its reliability for this study.

*2.3.6 Drug side effects*

Drug side effects were assessed using an 11-item Guttman scale questionnaire, designed to measure the presence and severity of side effects associated with TB medication. Each item was answered with "Yes" or "No," indicating whether specific symptoms occurred. The scale categorized side effects as mild (0–6) or severe (7–11) based on the total number of positive responses. Higher scores indicated more severe side effects. Example items included questions such as "Did you experience a loss of appetite during treatment?" and "Did you experience joint

pain during treatment?" The instrument demonstrated acceptable reliability (Cronbach's alpha = 0.719) and was validated for use in the current study.

*2.3.7 Stigma*

The Tuberculosis-Related Stigma scale (TBS), adapted from Van Rie et al. (2008), was used to assess stigma associated with tuberculosis among patients. The instrument comprises 23 items, categorized into two dimensions: Community Perspectives on TB (11 items) and Patient Perspectives on TB (12 items). The Community Perspectives dimension measures societal behaviors toward TB patients, such as discrimination and social distancing, with items like "Some people prefer not to have individuals with TB living in their community" and "Some people may not want to eat or drink with friends who have TB." The Patient Perspectives dimension reflects the emotional and psychological impact of TB on patients, including feelings of fear, guilt, and social exclusion, as seen in items like "Some people with TB feel guilty because they carry the burden of being cared for" and "Some people with TB fear telling people outside their family about their condition."

Responses are measured on a 4-point Likert scale (1 = "Strongly Disagree" to 4 = "Strongly Agree"), with higher scores indicating greater perceived or experienced stigma. A total score of <38 indicates positive stigma, while a score of ≥38 suggests negative stigma. The instrument was translated from English to Indonesian to ensure cultural and linguistic relevance, and it demonstrated good validity and reliability, with a Cronbach's alpha of 0.749. This scale is a valuable tool in both clinical and research settings for evaluating the social and psychological effects of TB-related stigma on patients.

*2.3.8 Treatment supervisor support*

Treatment supervisor support was evaluated using a 15-item questionnaire designed to assess supervisors' roles in ensuring adherence to TB treatment. The instrument measured four key domains: supervision, roles, responsibilities, and information delivery. Example items included, "Does your treatment supervisor remind you to take your medication every day?" and "Has your treatment supervisor explained the potential side effects of TB medication and how to manage them?" Responses were scored dichotomously ("Yes" = 1, "No" = 0), with total scores ranging from 0 to 15. Scores below 7.5 indicated low support, while scores of 7.5 or higher reflected good support.

The instrument's validity was confirmed through item correlation testing, with correlation coefficients (r) ranging from 0.571 to 0.895, exceeding the critical value (r table = 0.444). Reliability testing demonstrated strong internal consistency, with a Cronbach's alpha of 0.793. These findings confirm that the instrument is a reliable and valid tool for evaluating the support provided by treatment supervisors, which plays a crucial role in fostering patient adherence to TB treatment protocols and improving treatment outcomes.

*2.4. Data analysis*

Descriptive statistics were used to summarize participant characteristics and study variables, with results presented as frequencies and percentages. Chi-square tests were used to assess relationships among variables. Additionally, a multivariate analysis was conducted using ordinal logistic regression to evaluate the impact of multiple independent variables on medication adherence, categorized as low, moderate, and high. Statistical significance was set at $p < 0.05$.

*2.5. Ethical considerations*

Ethical approval for this study was obtained from the Health Research Ethics Committee at the Faculty of Nursing, Universitas Andalas, with the reference number 345.layaketik/ KEPKFKEPUNAND. All procedures adhered strictly to WHO 2011 standards and CIOMS 2016 guidelines for human subject research. Participants received detailed information about study objectives and procedures, and written informed consent was obtained prior to data collection. Confidentiality was maintained through data anonymization and secure storage protocols. Participants retained the right to withdraw from the study at any point without consequence, ensuring voluntary participation throughout the research process.

## 3. Results

### *3.1. Characteristics of respondents and their association with medication adherence*

Table 1 presents the characteristics of respondents and differences in medication adherence levels among pulmonary tuberculosis patients based on demographic and clinical factors. Age was significantly associated with medication adherence levels ($p$ = 0.047). Respondents in the early adult (26–35 years) and late adult (36–45 years) groups exhibited higher proportions of low adherence, accounting for 60.0% and 59.6%, respectively. In contrast, respondents in the early elderly (46–55 years) and late elderly (56–65 years) groups showed higher proportions of high adherence (29.7% and 28.6%, respectively). Regarding gender, males constituted the majority of respondents (64.7%), but no significant association was found between gender and adherence levels ($p$ = 0.757). Females slightly outperformed males in the high adherence category (20.0% vs. 20.6%). Educational attainment was not significantly associated with adherence levels ($p$ = 0.169). However, respondents with a Diploma 3 qualification exhibited the highest proportion of moderate adherence (44.4%), whereas those with elementary school education were exclusively categorized under moderate adherence (100.0%). Employment status approached statistical significance ($p$ = 0.065), with unemployed respondents showing a higher proportion of low adherence (61.4%) compared to their employed counterparts (46.2%). The duration of tuberculosis treatment was not significantly associated with adherence levels ($p$ = 0.437). However, respondents undergoing treatment for one month had the highest proportion of high adherence (30.0%) compared to other durations. Smoking habits and smoking duration also showed no significant association with adherence levels ($p$ = 0.220 and $p$ = 0.746, respectively). Nevertheless, non-smokers exhibited a higher proportion of high adherence (22.1%) compared to smokers (16.4%).

**Table 1**. Characteristics of respondents and group differences in medication adherence levels among pulmonary tuberculosis patients (n = 150)

| Characteristics | Total | | Adherence Levels | | | | | | *p* |
|---|---|---|---|---|---|---|---|---|---|
| | | | Low | | Moderate | | High | | |
| | n | % | f | % | f | % | f | % | |
| Age, in years | | | | | | | | | 0.047* |
| Early Adult (26-35) | 10 | 6.7 | 6 | 60.0 | 4 | 40.0 | 0 | 0 | |
| Late adult (36-45) | 52 | 34.7 | 31 | 59.6 | 17 | 32.7 | 4 | 7.7 | |
| Early Elderly (46-55) | 64 | 42.7 | 30 | 46.9 | 15 | 23.4 | 19 | 29.7 | |
| Late Elderly (56-65) | 21 | 14.0 | 9 | 42.9 | 6 | 28.6 | 6 | 28.6 | |
| Older (> 65) | 3 | 2.0 | 0 | 0 | 2 | 66.7 | 1 | 33.3 | |
| Gender | | | | | | | | | 0.757 |
| Male | 97 | 64.7 | 47 | 48.5 | 30 | 30.9 | 20 | 20.6 | |
| Female | 53 | 35.3 | 29 | 54.7 | 14 | 26.4 | 30 | 20.0 | |
| Education | | | | | | | | | 0.169 |
| Elementary School | 2 | 1.3 | 0 | 0 | 2 | 100.0 | 0 | 0 | |
| Junior high school | 24 | 16.0 | 15 | 62.5 | 4 | 16.7 | 5 | 20.8 | |
| Senior high school | 54 | 36.0 | 32 | 59.3 | 12 | 22.2 | 10 | 18.5 | |
| Diploma 3 | 9 | 6.0 | 3 | 33.3 | 4 | 44.4 | 2 | 22.2 | |
| Bachelor's Degree | 61 | 40.7 | 26 | 42.6 | 22 | 36.1 | 13 | 21.3 | |
| Employment status | | | | | | | | | 0.065 |
| Employed | 106 | 70.7 | 49 | 46.2 | 37 | 34.9 | 20 | 18.9 | |
| Unemployed | 44 | 29.3 | 27 | 61.4 | 7 | 15.9 | 10 | 22.7 | |
| Duration of Treatment | | | | | | | | | 0.437 |
| 1 Month | 20 | 13.3 | 8 | 40.0 | 6 | 30.0 | 6 | 30.0 | |
| 2 Months | 32 | 21.3 | 17 | 53.1 | 11 | 34.4 | 4 | 12.5 | |
| 3 Months | 39 | 26.0 | 19 | 48.7 | 9 | 23.1 | 11 | 28.2 | |
| 4 Months | 29 | 19.3 | 19 | 65.5 | 7 | 24.1 | 3 | 10.3 | |
| 5 Months | 24 | 16.0 | 10 | 41.7 | 10 | 41.7 | 4 | 16.7 | |
| 6 Months | 6 | 4.0 | 3 | 50.0 | 1 | 16.7 | 2 | 33.3 | |
| Smoking status | | | | | | | | | 0.220 |
| Non-smokers | 95 | 63.3 | 43 | 45.3 | 31 | 32.6 | 21 | 22.1 | |
| Smokers | 55 | 36.7 | 33 | 60.0 | 13 | 23.6 | 9 | 16.4 | |
| Duration of smoking | | | | | | | | | 0.746 |
| < 10 years | 142 | 94.7 | 73 | 51.4 | 41 | 28.9 | 28 | 19.7 | |
| > 10 years | 8 | 5.3 | 3 | 37.5 | 3 | 37.5 | 2 | 25.0 | |

*Notes:* Chi square test was performed, *$p$<0.05, **$p$<0.01, ***$p$<0.001.

*3.2. Distribution of medication adherence levels and related variables among pulmonary tuberculosis patients*

Table 2 provides an overview of medication adherence levels and related variables among pulmonary TB patients. A total of 52.7% of respondents had good knowledge of TB and its treatment, while 47.3% had poor knowledge. Regarding drug side effects, the majority of participants (83.3%) reported mild side effects, while 16.7% experienced severe side effects. Support from Medication Adherence Supervisors (MAS) was perceived as not supportive by 55.3% of respondents, while 44.7% reported it was supportive. Motivation levels showed that 47.3% of respondents had moderate motivation, followed by 31.3% with high motivation, and 21.3% with low motivation. Adequate support from healthcare workers was reported by 55.3% of respondents, while 44.7% felt unsupported. Family support was also relatively balanced, with 52.7% of respondents reporting supportive families and 47.3% reporting a lack of family support. Stigma related to TB remains a concern, as 54.0% of respondents experienced negative stigma, compared to 46.0% who reported positive or neutral stigma. Finally, medication adherence levels revealed that half of the respondents (50.7%) had low adherence, 29.3% demonstrated moderate adherence, and only 20.0% exhibited high adherence. This distribution underscores significant challenges faced by TB patients in achieving optimal adherence to their treatment regimens.

**Table 2**. Distribution of medication adherence levels and variables related among pulmonary tuberculosis patients (n = 150)

| Variables | Category | f | % |
|---|---|---|---|
| Knowledge | Poor | 71 | 47.3 |
| | Good | 79 | 52.7 |
| Drug Side Effects | Severe | 25 | 16.7 |
| | Mild | 125 | 83.3 |
| Medication Adherence Supervisor | Not Supportive | 83 | 55.3 |
| | Supportive | 67 | 44.7 |
| Motivation | Low | 32 | 21.3 |
| | Moderate | 71 | 47.3 |
| | High | 47 | 31.3 |
| Healthcare Worker Support | Poor | 67 | 44.7 |
| | Good | 83 | 55.3 |
| Family Support | Not Supportive | 71 | 47.3 |
| | Supportive | 79 | 52.7 |
| Stigma | Negative Stigma | 81 | 54.0 |
| | Positive Stigma | 69 | 46.0 |
| Medication Adherence Levels | Low | 76 | 50.7 |
| | Moderate | 44 | 29.3 |
| | High | 30 | 20.0 |

*3.3. Associations between variables and medication adherence among tuberculosis patients*

The results in Table 3 show a significant association between knowledge and medication adherence ($p$ = 0.038), with a higher proportion of patients with good knowledge exhibiting high adherence (26.6%) than those with poor knowledge (12.7%). Drug side effects were also significantly associated with adherence ($p$ = 0.023), where patients experiencing severe side effects were more likely to report high adherence (40.0%) compared to those with mild side effects (16.0%). Motivation demonstrated a significant relationship with adherence levels ($p$ = 0.035), where a higher proportion of patients with high motivation reported high adherence (23.4%) than those with low or moderate motivation. Similarly, healthcare worker support was significantly associated with adherence ($p$ = 0.028), with patients receiving good support reporting higher adherence (22.9%) than those with poor support (16.4%). Family support was another significant factor ($p$ = 0.011), as patients with supportive families were more likely to report high adherence (20.3%) compared to those without family support (19.7%). Stigma also showed a significant association with adherence ($p$ = 0.033), with patients who perceived positive stigma having a higher proportion of high adherence (24.6%) than those who experienced negative stigma (16.0%). There was no significant association between support from Medication Adherence Supervisors (MAS) and medication adherence levels ($p$ = 0.188).

**Table 3.** Relationships between knowledge, drug side effects, medication adherence supervisor, motivation, healthcare worker support, family support, and stigma with medication adherence levels in tuberculosis patients (n =150)

| Variables | Medication Adherence Levels | | | | | | *p*-value |
|---|---|---|---|---|---|---|---|
| | Low | | Moderate | | High | | |
| | f | % | f | % | f | % | |
| Knowledge | | | | | | | 0.038* |
| Poor | 43 | 60.6 | 19 | 26.8 | 9 | 12.7 | |
| Good | 33 | 41.8 | 25 | 31.6 | 21 | 26.6 | |
| Drug Side Effects | | | | | | | 0.023* |
| Severe | 9 | 36.0 | 6 | 24.0 | 10 | 40.0 | |
| Mild | 67 | 53.6 | 38 | 30.4 | 20 | 16.0 | |
| MAS | | | | | | | 0.188 |
| Not Supportive | 40 | 48.2 | 22 | 26.5 | 21 | 25.3 | |
| Supportive | 36 | 53.7 | 22 | 32.8 | 9 | 13.4 | |
| Motivation | | | | | | | 0.035* |
| Low | 13 | 40.6 | 13 | 40.6 | 6 | 18.8 | |
| Moderate | 45 | 63.4 | 13 | 18.3 | 13 | 18.3 | |
| High | 18 | 38.3 | 18 | 38.3 | 11 | 23.4 | |
| Healthcare Worker Support | | | | | | | 0.028* |
| Poor | 42 | 62.7 | 14 | 20.9 | 11 | 16.4 | |
| Good | 34 | 41.0 | 30 | 36.1 | 19 | 22.9 | |
| Family Support | | | | | | | 0.011* |
| Not Supportive | 44 | 62.0 | 13 | 18.3 | 14 | 19.7 | |
| Supportive | 32 | 40.5 | 31 | 39.2 | 16 | 20.3 | |
| Stigma | | | | | | | 0.033* |
| Negative Stigma | 49 | 60.5 | 19 | 23.5 | 13 | 16.0 | |
| Positive Stigma | 27 | 39.1 | 25 | 36.2 | 17 | 24.6 | |

*Notes*. Abbreviation: MAS = Medication Adherence Supervisor. Chi-square test was performed, **p*<0.05, ***p*<0.01, ****p*<0.001

*3.4. Predictors of medication adherence*

The ordinal logistic regression analysis presented in Table 4 identifies significant predictors of medication adherence levels in tuberculosis patients. The final model demonstrated good fit (pseudo-$R^2$ = 0.308–0.329, $p < 0.001$), indicating moderate explanatory power for the variability in medication adherence. Age was a significant predictor, with early adults (26–35 years) and late adults (36–45 years) exhibiting lower odds of low adherence than older adults (>65 years) (OR = 0.061, $p = 0.038$; OR = 0.052, $p = 0.015$, respectively). Other age groups (46–55 and 56–65 years) did not show significant associations ($p > 0.05$). Knowledge significantly influenced adherence, with individuals with poor knowledge having lower odds of adherence than those with good knowledge (OR = 0.316, $p = 0.002$). Motivation also emerged as a significant predictor, with patients with moderate motivation demonstrating significantly lower odds of adherence than those with high motivation (OR = 0.244, $p < 0.001$), whereas poor motivation was not significant ($p > 0.05$). Family support was a critical determinant: patients without supportive families had lower odds of adherence than those with supportive families (OR = 0.470, $p = 0.036$). Similarly, healthcare worker support played a significant role: patients with poor support were less likely to adhere than those with good support (OR = 0.349, $p = 0.015$). Drug side effects were positively associated with adherence. Patients experiencing mild side effects were more likely to adhere than those with severe side effects (OR = 5.294, $p < 0.001$). Conversely, stigma and support from medication adherence supervisors (MAS) did not significantly predict adherence in this model ($p > 0.05$).

**Table 4.** Predictors of medication adherence levels among tuberculosis patients (n = 150)

| Predictors | Category | Step 1 | | | Step 2 | | | Step 3 | | | OR | 95%CI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Estimate | Wald | *p* | Estimate | Wald | *p* | Estimate | Wald | *p* | | |
| Medication Adherence (Y) | Intercept [Low] | -3.654 | 7.632 | .006** | -3.793 | 8.854 | .003** | -3.896 | 9.350 | .002*** | | |
| | Intercept [Moderate] | -1.880 | 2.108 | .147 | -2.021 | 2.636 | .104 | -2.166 | 3.033 | .082 | | |
| Age (X1) | Early Adult (26-35) | -2.470 | 3.280 | .070 | -2.538 | 3.508 | .061 | -2.793 | 4.301 | .038* | .061 | .004 – .857 |
| | Late adult (36-45) | -2.405 | 3.707 | .054 | -2.466 | 3.979 | .046* | -2.949 | 5.911 | .015* | .052 | .005 – .565 |
| | Early Elderly (46-55) | -1.352 | 1.260 | .262 | -1.395 | 1.355 | .244 | -1.818 | 2.375 | .123 | .162 | .016 – 1.639 |
| | Late Elderly (56-65) | -.950 | .569 | .451 | -1.004 | .644 | .422 | -1.551 | 1.626 | .202 | .212 | .019 – 2.300 |
| | Older (>65) | 0a | . | . | 0a | . | . | 0a | | | 1.000 | Reference |
| Knowledge (X2) | Poor | -1.055 | 8.068 | .005** | -1.055 | 8.097 | .004** | -1.151 | 9.822 | .002*** | .316 | .154 - .650 |
| | Good | 0a | . | . | 0a | . | . | 0a | . | . | 1.000 | Reference |
| Motivation (X3) | Poor | -.349 | .578 | .447 | -.351 | .586 | .444 | -.392 | .742 | .389 | .676 | .277 – 1.646 |
| | Moderate | -1.376 | 10.868 | <.001*** | -1.371 | 10.819 | .001** | -1.409 | 11.433 | <.001*** | .244 | .108 - .553 |
| | Good | 0a | . | . | 0a | . | . | 0a | . | . | 1.000 | Reference |
| Family Support (X4) | Not Supportive | -.740 | 4.072 | .044* | -.757 | 4.357 | .037* | -.755 | 4.391 | .036* | .470 | .232 - .950 |
| | Supportive | 0a | . | . | 0a | . | . | 0a | | | 1.000 | Reference |
| HWS (X5) | Poor | -.924 | 6.349 | .012* | -.939 | 6.562 | .010* | -.883 | 5.961 | .015* | .414 | .204 - .840 |
| | Good | 0a | . | . | 0a | . | . | 0a | | . | 1.000 | Reference |
| Drug Side Effects (X6) | Mild | 1.603 | 11.915 | <.001*** | 1.596 | 11.846 | <.001*** | 1.667 | 12.920 | <.001*** | 5.294 | 2.134 – 13.126 |
| | Severe | 0a | . | . | 0a | . | . | 0a | | . | 1.000 | Reference |
| Stigma(X7) | Negative | -.698 | 3.782 | .052 | -.691 | 3.714 | .054 | | | | | |
| | Positive | 0a | . | . | 0a | . | | | | | | |
| MAS (X8) | Not Supportive | .139 | .154 | .694 | | | | | | | | |
| | Supportive | 0a | . | . | | | | | | | | |

*Abbreviation:* HWS = Healthcare Worker Support, MAS = Medication Adherence Supervisor, OR = Odds Ratio, CI = Confidence Interval.
*Note*. Pseudo $R^2$ (Nagelkerke) = 0.308, Model fit $p<0.001$. Ordinal logistic regression test was performed, *p<0.05, **p<0.01, ***p<0.001.
Reference = baseline category for comparison.

## 4. Discussion

This study aimed to identify and quantify key predictors of medication adherence among pulmonary TB patients in Palembang, Indonesia, with particular emphasis on sociodemographic factors, clinical variables, and psychosocial determinants. The findings reveal a complex interplay of factors influencing adherence, with only 20% of patients achieving high adherence. This study identified significant associations between adherence and several key predictors, including age, knowledge levels, motivation, support systems, and drug side effects.

This study revealed that age was a significant predictor of medication adherence, with younger adults demonstrating lower adherence than older adults. For instance, Fekadu et al. (2020) found that younger age was associated with a higher likelihood of non-adherence among pediatric patients in Ethiopia, suggesting that age-related factors may influence treatment compliance This finding is corroborated by Adiutama et al. (2018) who noted that sociodemographic factors, including age, significantly correlated with medication adherence, indicating that younger individuals may face unique challenges that affect their ability to adhere to treatment.

Furthermore, the Health Belief Model, as discussed by Azizi et al. (2018), indicates that perceived benefits and barriers to treatment can vary significantly across age groups, influencing adherence behaviors. Younger patients may not fully grasp the long-term benefits of completing a TB treatment regimen, while older patients may be more aware of the consequences of non-adherence but struggle with practical aspects of medication management. This pattern suggests age-specific vulnerabilities in treatment compliance, potentially influenced by competing life demands, employment obligations, or differing health priorities among younger adults (Chenciner et al., 2021; Leddy et al., 2022).

This study also found that the relationship between knowledge levels and medication adherence was particularly significant, with patients with good knowledge exhibiting higher adherence rates. This finding aligns with the previous research by Maifitrianti et al. (2024), which also highlighted a significant relationship between knowledge and adherence, emphasizing the need for educational interventions to enhance patients' understanding of TB. Such educational efforts are crucial, as they can empower patients to recognize the importance of their treatment, thereby improving adherence rates.

Moreover, Azizi et al. (2018) identified perceived treatment benefits as a critical factor influencing adherence, noting that patients who understood the advantages of completing their therapy were more likely to adhere to their medication regimen. This is consistent with findings from Kulkarni et al. (2013), who reported that accurate knowledge of TB and its treatment is essential for improving adherence, as patients lacking this knowledge were often non-adherent. Similarly, another study indicated that participants with poor knowledge about TB were three times more likely to be non-adherent compared to those with good knowledge, underscoring the importance of education in promoting adherence (Tirore et al., 2024).

Additionally, a relationship was observed between drug side effects and adherence patterns. The relationship between drug side effects and adherence patterns in TB treatment is a critical area of study, as adverse effects can significantly influence a patient's willingness and ability to continue their medication regimen. Numerous studies have established that the experience of side effects from anti-TB drugs is a major factor contributing to non-adherence. Yadav et al. (2020) found that patients who experienced drug side effects were more likely to discontinue their treatment, as they often perceived these side effects as a worsening of their condition rather than a normal part of the treatment process. This perception can lead to a lack of trust in the treatment, prompting patients to stop taking their medications altogether. Similarly, another study reported that the likelihood of non-adherence among TB patients experiencing side effects was as high as 90%, compared to only 16.6% among those who did not experience such effects (Gube et al., 2018). This stark contrast underscores the significant impact that side effects can have on treatment adherence.

Furthermore, a meta-analysis study highlighted that the presence of drug side effects is a common reason for treatment failure in TB patients (Ismail et al., 2023). The study indicated that patients who experience adverse drug reactions are less likely to adhere to their treatment regimens, reinforcing the need for effective management of these side effects to improve adherence rates. Another study also emphasized that the severity of drug side effects directly correlates with adherence, noting that more severe symptoms lead to higher rates of non-

adherence (Pramono et al., 2021). This finding suggests that healthcare providers must be vigilant in monitoring and addressing side effects to maintain patient adherence.

Additionally, the World Health Organization (WHO) guidelines recommend discontinuing or switching drugs in cases of severe adverse reactions, which further illustrates the importance of managing side effects to ensure adherence (Bea et al., 2021). Moreover, a systematic review also indicated that the likelihood of non-adherence is almost twice as high among patients experiencing drug side effects compared to those who do not (Zegeye et al., 2019). This finding aligns with the broader literature that identifies drug-related adverse effects as a significant barrier to effective TB treatment.

This study also demonstrated that family and healthcare worker support systems are crucial in influencing medication adherence among TB patients. Numerous previous studies have highlighted that both familial and healthcare support significantly enhance adherence to TB treatment, thereby improving health outcomes. da Silva et al. (2017) emphasized that the family is the closest social group to patients, and their support is vital for treatment adherence. The study indicates that when families are actively involved in the treatment process, patients are more likely to adhere to their medication regimens. This is further supported by Nabillah et al. (2022), who conducted a meta-analysis revealing that social support, particularly from family members, can increase medication adherence by more than twofold.

Moreover, previous research also found a strong correlation between family support and adherence behaviors among TB patients (Soleman et al., 2021). This research indicated that higher levels of family support corresponded with increased adherence to treatment, suggesting that emotional and practical support from family members can significantly impact a patient's commitment to their medication regimen (Soleman et al., 2021). This is consistent with findings from Chen et al. (2020), which highlighted that family support not only aids in adherence but also mitigates the risks associated with non-adherence, such as the development of drug-resistant TB strains. Healthcare worker support is equally important in fostering adherence. Fuadiati et al. (2024) noted that health education interventions and patient counseling provided by healthcare workers significantly enhance patients' knowledge and self-efficacy, which are critical for medication adherence.

The presence of healthcare professionals who actively engage with patients can help address concerns, manage side effects, and reinforce the importance of completing the treatment regimen. A study found that emotional support from healthcare providers can empower patients to cope with the stigma associated with TB, thereby further enhancing adherence rates (Musiimenta et al., 2024). Additionally, integrating healthcare support with family involvement has been shown to create a more robust support system for patients. Lestari et al. (2020) highlighted that both family and healthcare worker support are essential for ensuring that patients adhere to their treatment. This dual support system can provide patients with the necessary encouragement and resources to manage their treatment effectively.

This study also revealed that motivation and stigma emerged as significant psychosocial factors influencing adherence behaviors. This is in line with a previous study, which found that feeling motivated to comply with treatment, along with emotional support from family, significantly correlates with better adherence levels (Fagundez et al., 2016). This suggests that intrinsic motivation, possibly driven by personal health goals or the desire to avoid the consequences of non-adherence, can enhance a patient's commitment to their treatment plan. Additionally, another study found that social support and a sense of being cared for can bolster motivation, thereby improving adherence (Thiruvalluvan et al., 2017). When patients perceive that their social network supports their treatment, they are more likely to remain compliant.

Conversely, stigma associated with TB can severely undermine medication adherence. Research emphasized that stigma is a significant barrier to achieving effective TB control, as it can lead to delays in seeking treatment and hinder adherence (Faraade et al., 2022). Patients often internalize negative societal perceptions about TB, which can result in feelings of shame and isolation. This stigma can discourage individuals from disclosing their diagnosis or seeking necessary medical care, further complicating their treatment journey. Another study also demonstrated that stigma not only affects adherence but also mediates the relationship between depressive symptoms and quality of life in TB patients, indicating that stigma can exacerbate mental health challenges that further impede adherence (Qiu et al., 2019).

Moreover, previous research also found that both perceived and internalized stigma are associated with increased levels of depression among TB patients, which in turn negatively impacts their treatment adherence (Pradhan et al., 2022). This highlights a vicious cycle where stigma leads to psychological distress, which results in poorer adherence outcomes. Similarly, Kipp et al. (2011) noted that stigma related to TB and HIV co-infection can lead to missed doses, as patients fear that taking their medication might reveal their health status to others. The interplay between motivation and stigma is complex. While motivation can drive patients to adhere to their treatment, stigma can undermine this motivation by fostering feelings of shame and isolation. As Skinner and Claassens (2016) pointed out, psychological factors, including stigma, can significantly affect adherence behaviors, particularly in settings where both TB and HIV are prevalent.

Finally, the findings of this study demonstrate the multifaceted nature of adherence determinants, suggesting the need for comprehensive, multi-component interventions that target multiple factors simultaneously. Future interventions should consider age-specific approaches, enhanced health literacy programs, strengthened support systems, and improved protocols for managing side effects.

## 5. Implications and limitations

The findings from this study provide crucial insights for advancing tuberculosis care delivery and improving patient outcomes. Nursing practice should incorporate systematic adherence assessment tools into routine TB patient encounters, with nurses playing a pivotal role in implementing age-specific education and support interventions identified in this study. The strong association between knowledge and adherence underscores the need for nurses to develop and deliver comprehensive, culturally appropriate patient education programs that address misconceptions and enhance understanding of treatment. Nursing education curricula should integrate these findings by emphasizing the importance of family-centered care approaches and developing competencies in medication adherence assessment and counselling.

However, several methodological limitations should be considered when interpreting this study's findings. First, the cross-sectional design precludes establishing causal relationships between identified predictors and adherence outcomes. Second, the consecutive sampling approach and single-city setting may limit the generalizability of findings to other Indonesian regions or broader populations. Third, the reliance on self-reported adherence measures may introduce recall and social desirability bias, although the use of validated instruments partially mitigates these concerns. Fourth, while the study identified significant associations between various factors and adherence, it may not have captured all potential confounding variables that could influence these relationships.

## 6. Conclusion

This study provides comprehensive evidence regarding the multifaceted nature of medication adherence among pulmonary TB patients in Palembang, Indonesia. The findings demonstrate that adherence behavior is influenced by a complex interplay of sociodemographic, clinical, and psychosocial factors, including age, knowledge levels, support systems, and drug side effects. These results contribute to the existing literature by identifying specific predictors of adherence in the Indonesian context and suggesting potential intervention targets. Future research should focus on longitudinal studies to establish causality, intervention studies testing targeted adherence support strategies, and broader multi-center investigations to enhance generalizability. The implementation of evidence-based, comprehensive adherence support programs addressing multiple determinants simultaneously is crucial for improving tuberculosis treatment outcomes in Indonesia and similar settings.

## Acknowledgments

We would like to express our gratitude to the research funders from the Directorate General of Higher Education (DRTPM), Ministry of Education and Culture of the Republic of Indonesia, for their financial support in 2024 under grant contract No. 041/E5/PG.02.00.PL/2024. Additionally, we would like to extend our heartfelt thanks to the Research and Community Service Institute (LPPM) of Universitas Andalas for their facilitation and support throughout this research. We also appreciate all participants who generously shared their time and experiences,

making this study possible. Their contributions were invaluable in enhancing our understanding of medication adherence in patients with pulmonary tuberculosis.

**Author contribution**

Conceptualization: RS, SY, EM; Methodology: RS, EY, EM; Investigation: EM; Data curation: SY, EM; Formal Analysis: RS, EM; Visualization: RS; Writing-Original draft: RS, EM; Writing-Review and Editing: RS, IMMYS; Project Administration: EM.

**Conflict of interest**

The authors declare that there are no conflicts of interest regarding the publication of this manuscript. All authors have disclosed any potential conflicts of interest, financial or otherwise, that could influence the results or interpretation of the study.

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