Tuberculosis treatment success and its determinants among healthcare workers with tuberculosis in Selangor: A retrospective cross-sectional study

Nooreen Farzana Mustapha, MPH[1], Kamarulzaman Muzaini, DrPH[1], Siti Sara Yaacob, DrPH[1], Siti Hasmah Ilias, DrPH[2], Annabella Ruth Edwin, MD[2], Mariam Mohamad, M.Comm.Hlth[1]

[1]Department of Public Health Medicine, Faculty of Medicine, Universiti Teknologi MARA, Sungai Buloh, Selangor, Malaysia, [2]TB/Leprosy Unit, Public Health Division, Selangor State Health Department, Malaysia

ABSTRACT

Introduction: Tuberculosis (TB) remains a major occupational risk for healthcare workers (HCWs), who face higher exposure and potential challenges in achieving optimal treatment outcomes. Despite extensive national TB control strategies in Malaysia, evidence on treatment success and its determinants among HCWs is limited. This study aimed to determine the proportion of TB treatment success and identify associated factors among HCWs with active TB in Selangor from 2014 to 2023 using the National Tuberculosis Registry (NTBR) system.

Materials and Methods: A retrospective cross-sectional study was conducted using registry data from NTBR involving all HCWs diagnosed with active TB and registered in Selangor between 2014 and 2023. Universal sampling was applied to include all eligible cases with complete data. Variables were extracted across sociodemographic, occupational, sociocultural, and clinical domains. TB treatment success was defined as "cured" or "treatment completed", while unsuccessful outcomes included death, treatment failure, and not evaluated. Data were cleaned, de-identified, and analysed using SPSS version 29. Simple logistic regression identified variables with p<0.25 for inclusion in multiple logistic regression Adjusted odds ratios (AOR) and 95% confidence intervals (CI) were reported. Model diagnostics included the Hosmer–Lemeshow test, ROC (Receiver Operating Characteristic) analysis, multicollinearity checks, interaction terms, and Cook's distance.

Results: A total of 313 HCWs with active TB were included. The TB treatment success rate was 86.9%, with 51.5% cured and 48.5% completing treatment. In multivariable analysis, three factors remained significantly associated with treatment success. HCWs aged <34 years had higher odds of treatment success (AOR=5.071; 95% CI: 2.009–12.801). Conversely, doctors (AOR=0.024; 95% CI: 0.003–0.218) and supporting staff (AOR=0.366; 95% CI: 0.143–0.936) showed significantly lower success compared to paramedics. Advanced chest X-ray (CXR) findings demonstrated strong positive associations: moderate (AOR=14.686; 95% CI: 5.873 – 36.724) and far advanced disease (AOR=10.783; 95% CI: 1.909–60.904). Commonly reported risk factors such as HIV, diabetes, smoking, BCG (Bacillus Calmette-Guérin) status, and comorbidities were not significantly associated. Model performance was robust (ROC: 88.3%; Hosmer–Lemeshow p=0.858).

Conclusion: TB treatment is successful among HCWs in Selangor (86.9%), which is near to the WHO (World Health Organization) End TB Strategy. The odds of treatment success were much higher among younger HCWs, whereas doctors and other supporting staff reported had lower adjusted odds in comparison with paramedics. Moderate and far advanced CXR findings at diagnosis were independently associated with higher treatment success; however, this finding should be interpreted cautiously because of the small number of far advanced cases and the possibility of estimate instability and residual confounding. Conventional risk factors like human immunodeficiency virus infection, diabetes mellitus, smoking, and BCG status were found not associated significantly and may be due to the small subgroups and the nature of this registry data limitation. These conclusions indicate the fact that occupational role and clinical presentation are significant factors defining TB treatment outcomes among HCWs. Role-specific and targeted adherence support enhanced psychosocial interventions, and better NTBR data coverage can further improve the outcome of treatment and support the TB control in the Malaysian healthcare labour force.

KEYWORDS:
Tuberculosis, healthcare workers, treatment outcomes

INTRODUCTION

Tuberculosis (TB) remains a critical global public health challenge, ranking among the top ten causes of death worldwide. Despite significant efforts and strategic goals by the World Health Organization (WHO) under "End-TB Strategy", which aims for a TB treatment success rate of more than 90% by 2025, global targets are not yet being met.[1] In 2024, the Western Pacific region achieved only a 74% treatment success rate, while the global average was reported to be 75%.[2] In Malaysia, the number of reported TB cases rose to 26,781 in 2023, up from 21,727 in 2021 with Selangor accounts for an estimated 20-22% of total TB cases in Malaysia.[3] A similar proportion is observed for cases among healthcare workers (HCWs). This high concentration of cases

This article was accepted: 09 August 2026
Corresponding Author: Kamarulzaman Muzaini
Email: kamarulzaman@uitm.edu.my

in Selangor presents a significant public health challenge at the regional level; therefore, low-level treatment success may impair productivity and increase the burden on the country's health system.

HCWs face approximately three times higher risk of TB compared to the general population due to its occupational hazards.[4] While HCWs are expected to achieve higher treatment success rates, evidence from existing studies is inconsistent. Some global papers report high success rates, even up to 100%,[5] while others show rates between 57.9% and 84.0%.[6] This variability highlights an important knowledge gap in understanding the specific factors and hinders the development of effective strategies to improve treatment success.

Based on literature review, some studies on sociodemographic factors indicate that males and older age groups are associated with lower TB treatment success.[7] Other factors, like lower education levels and foreign nationalities, have also been linked to less favourable outcomes. Similar impact is also seen on human immunodeficiency virus (HIV) co-infection, alcohol consumption and smoking habits.[8-10] Workplace exposure in certain specialities and duration of employment may link to chronic stress and long working hours, potentially leading to lower success rates. Doctors might also tend to self-treat or adjust their regimens, contributing to inconsistent adherence. Furthermore, TB-related stigma may negatively affect treatment completion.[11-12] Clinical factors such as HIV co-infection and diabetes mellitus (DM) can prolong TB treatment, while other chronic diseases show no significant influence after adjustment.[10,13] The severity of the disease, often assessed by Chest X-ray (CXR) findings, as well as the history of previous TB and BCG (Bacillus Calmette-Guérin) vaccination status, are also considered contributing factors to the treatment outcome.[14]

Therefore, by understanding the determinants will provide evidence-based recommendations to the Ministry of Health (MOH) at both the state and national levels, enabling more targeted interventions, efficient resource allocation, and a tailored support system; and it will also support Malaysia's commitment to the global "End-TB Strategy". To achieve these aims, this study pursues two specific objectives: to describe the proportion and characteristics of TB as well as identify the determinants for TB treatment success among HCWs with TB in Selangor from 2014 to 2023.

MATERIALS AND METHODS

Study Design and Sample Size Calculation

A retrospective cross-sectional study using secondary data from the National Tuberculosis Registry (NTBR) was conducted. Treatment outcomes were assessed at a single point of analysis without considering changes over time, and information from the registry was analyzed prior to treatment completion. This study involved HCWs who were diagnosed with active TB and subsequently registered in Selangor during 2014 to 2023. The study population only involved HCWs working in government healthcare facilities in Selangor who had a confirmed diagnosis of active TB and had a final TB treatment outcome documented in the NTBR. Cases with ongoing treatment or a subsequent change in diagnosis were excluded.

As TB case registration within the NTBR is primarily based on the patient's residential address, HCWs working in Selangor but residing outside the state may not be comprehensively captured within the Selangor registry. The study was limited to HCWs who resided in Selangor and were accessed and managed by the Selangor NTBR system to ensure consistency in the ascertainment of cases and the accurate collection of treatment outcome data.

HCWs were defined as individuals engaged in activities primarily intended to improve health, including doctors, nurses, midwives, public health professionals, laboratory personnel, health technicians, support staff, and other occupations involved in health-related services.[15] Detailed sample size calculation was carried out based on a previously published paper that reported the success rate of 81.7% and 84.0% by using Open-epi software (single proportion formula), alpha 0.05 and power of 80%. With accounting for a conventional 20% attrition rate, the minimum sample size is set at 177. However, a universal sampling approach was used, where all eligible healthcare workers with complete data in the NTBR registry during the study period were included.

Data Collection and Management

The NTBR system is a web-based database designed to capture comprehensive information on disease surveillance, treatment, contact tracing, and reporting. It captures details on case notifications, investigation findings, treatment regimens and subsequent follow-up care, including treatment outcomes.[16] Treatment outcomes were determined based on the final treatment outcome recorded in the NTBR upon completion of the treatment episode. According to the Malaysian clinical practice guidelines (CPG) for TB, standard treatment duration is generally six months for drug-susceptible TB, although treatment duration may be extended depending on clinical response, disease severity, or other medical indications. The outcome recorded in the NTBR was used to determine the success or failure of treatment in this study.

All variables relevant to the study objectives were clearly defined. Age was categorised into <34 years and ≥34 years based on the median age of the study population to achieve balanced group sizes and facilitate logistic regression analysis. The "TB treatment success" is defined as the combination of two specific outcomes: 'cured' or 'treatment completed' at the end of the treatment period. According to the Malaysia CPG Management of TB (4th Edition) 2021, 'cured' is define when "a patient with bacteriologically confirmed TB at the beginning of treatment who is smear- or culture-negative in the final month of treatment and at least one before that". Conversely, 'completed treatment' applied to "a TB patient who completed treatment without evidence of failure but with no record to show that sputum smear or culture results in the final month of treatment and at least one previous occasion is negative, either because tests are not done or because results are unavailable."

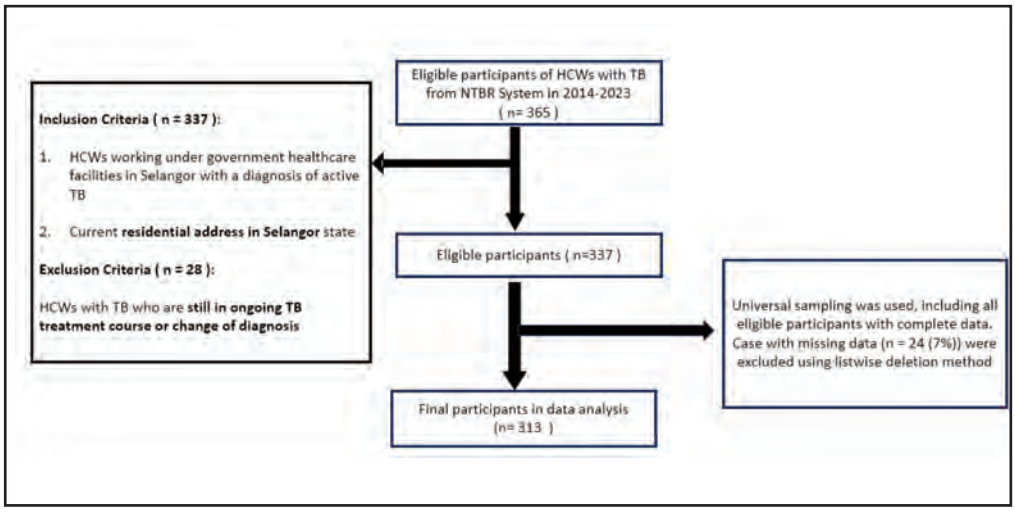

Fig. 1: Flow chart of data extraction and sample size selection

The "unsuccessful TB treatment" is encapsulated within a range of undesirable outcomes, such as died, treatment failed, loss to follow-up, transferred out or not evaluated. According to the same guideline, died defines as "a TB patient who dies for any reason before starting or during the course of treatment". 'Treatment failed' define as" a TB patient whose sputum smear or culture is positive at month 5 or later during treatment" while 'loss to follow up' define as "a TB patient who does not start treatment or whose treatment is interrupted for two consecutive months or more". Cases were also deemed unsuccessful if they were "transferred out" to another unit with an unknown outcome, "not evaluated" means no assigned outcome, including transfers to other countries or cases with unknown outcomes, and "change of diagnosis" where the initial TB diagnosis was later found to be incorrect. Although loss to follow-up and transferred-out cases were included in the predefined outcome definition, no such cases were identified among HCWs in the final analytical dataset. Our independent variables were systematically grouped for comprehensive analysis (Tables I and II). Certain aspects, like social support, cultural beliefs, stigma and treatment acceptance, were not included in the study due to limitations in data availability within the registry.

In a collaborative effort, data management protocols were rigorously followed to ensure the integrity and security of the information obtained. The data collection process was supervised by relevant personnel and were de-identified before being copied to an external hard disk. The data were later stored online with backup storage, and all digital data in Google Drive and Excel were password protected. During data cleaning, all variables were screened for duplication and assessed for completeness. A total of 337 eligible healthcare workers were identified in the NTBR, of whom 24 (7.1%) had incomplete data and were excluded using listwise deletion before statistical analysis. Given the relatively small proportion of missing data, complete-case analysis using listwise deletion was considered appropriate. The data extraction and sample selection process are presented in Figure 1.

Statistical Analysis

Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) version 29. A value of $p<0.05$ was considered statistically significant with $\alpha = 0.05$ in the final statistical analysis. Results were analysed based on descriptive statistics, including frequencies and percentages, to determine the proportion of TB treatment success. The Simple Logistic Regression (SLogR) was used to determine crude outcome by taking into consideration of significant level, p-value < 0.25. Simple logistic regression with p-value <0.25 was used to screen variables to reduce overfitting of the model, and only the variables that passed the screening were added to the multiple logistic regression model. The model diagnostics such as multicollinearity, interaction terms, goodness of fit, and influential observations were carried out to assess model stability. The events-per-variable (EPV) ratio was not formally assessed during model development. Nevertheless, model stability was evaluated using multiple diagnostic procedures, including assessment of multicollinearity, interaction terms, Hosmer–Lemeshow goodness-of-fit, ROC analysis, and Cook's distance, all of which demonstrated acceptable model performance.

These findings were later proceeded to Multiple Logistic Regression (MLogR) to determine the association by controlling for potential confounders (p-value <0.05). Model fitness was checked using the Hosmer-Lemeshow goodness-of-fit. Receiver Operating Characteristic (ROC) curve were calculated to evaluate the discriminatory power and predictive capability of the model to achieve the observed outcome. The Cox & Snell is used to show how well the model explains differences of the outcomes. Another model diagnostic test is by checking the multicollinearity among independent variables by using the Variance Inflation Factor (VIF). We also checked for potential interaction among variables; and no statistically significant interactions were found, suggesting that the variables acted independently in the model. Influential outliers, which could disproportionately affect the regression results, were identified and assessed using Cook's influential statistics.

Table I: Result descriptive analysis proportion and characteristic of TB treatment success among HCWs in Selangor from 2014 to 2023 (N = 313)

Variables			N (%)
Sociodemographic Factors			
Age (in years)		< 34 years old	204 (65.2%)
		≥ 34 years old	109 (34.8%)
Gender		Male	79 (25.5%)
		Female	234 (74.8%)
Nationality		Malaysian	313 (100.0%)
Ethnicity		Malay	251 (80.2%)
		Chinese	18 (5.8%)
		Indian	32 (10.2%)
		Others	12 (3.8%)
Education Level		Secondary	118 (37.7%)
		Tertiary	195 (62.3%)
Monthly Personal Income		< RM 3365	159 (50.8%)
		> RM 3365	154 (49.2%)
Socio-cultural Factors			
High Risk Behaviour	Smoking	Yes	33 (10.5%)
		No	280 (89.5%)
	Alcohol	Yes	4 (1.3%)
		No	309 (98.7%)
	History of Drug Use	Yes	0 (0.0%)
		No	313 (100.0%)
Occupation Factor			
Job Role		Doctor	78 (24.9%)
		Paramedics	113 (36.1%)
		Supporting Staff	122 (39.0%)
Type of Facilities		Hospital	255 (81.5%)
		Primary Health Clinic	58 (18.5%)
Department of Work		General Medicine Department	83 (26.5%)
		Emergency Department	31 (9.9%)
		Outpatient	64 (20.4%)
		Others	135 (43.1%)
Duration of Service		< 36 months	166 (53.0%)
		> 36 months	147 (47.0%)
Clinical Factor			
Co-morbidity	Diabetes Mellitus	Yes	16 (5.1%)
		No	297 (94.9%)
	Hypertension	Yes	19 (6.1%)
		No	294 (93.9%)
	Chronic Lung Disease	Yes	0 (0.0%)
		No	313 (100.0%)
	HIV Status	Positive	3 (1.0%)
		Negative	310 (99.0%)
Types of TB		Pulmonary TB	230 (73.5%)
		Extrapulmonary TB	83 (26.5%)
History of TB		Yes	10 (3.2%)
		No	303 (96.8%)
	Sputum Pre-Treatment	Positive	169 (54.0%)
		Negative	144 (46.0%)
Chest X-ray Pre-Treatment		No Lesion	74 (23.6%)
		Minimal	167 (53.4%)
		Moderate Advanced	63 (20.1%)
		Far Advanced	9 (2.9%)
BCG Vaccination		Yes	310 (99.0%)
		No	3 (1.0%)

Ethical Approval

The study received full ethical approval from the Research Ethics Committee of Universiti Teknologi MARA (UiTM) through its Faculty Ethics Review Committee (FERC). All necessary approvals were secured from the National Medical Research Register (NMRR) and the Medical Research and Ethics Committee (MREC) of the Ministry of Health Malaysia, formally identified by the NMRR ID-25-00516-NRM (IID). JKNS has granted permission to utilise their data from the NTBR System for the purposes of this study.

RESULTS

Both analytical methods were employed to understand the descriptive characteristics and proportion of this cohort and the key determinants influencing treatment success among HCWs (Table I). A total of 140 cases (51.5%) were classified as "cured", while the remaining 48.5% achieved "treatment completed" status. Unfortunately, 41 cases (13.1%) of the studied group were categorised as "unsuccess TB treatment" outcomes, where six cases were reported as death in the system, while the remainder were classified as treatment

Table II: Analyses of factors associated with TB treatment success among HCWs in Selangor from 2014 to 2023 (N = 313)

Variables		COR	p-value	AOR	p-value
Sociodemographic Factors					
Age	< 34 years old	3.947 (1.988, 7.837)	0.152*	5.071 (2.009, 12.801)	0.001**
(in years)	≥ 34 years old	1	Ref	1	Ref
Gender	Male	1.499 (0.710, 2.959)	0.308		
	Female	1	ref		
Ethnicity	Malay	1	ref		
	Chinese	0.363 (0.047, 2.815)	0.332		
	Indian	1.143 (0.413, 3.166)	0.797		
	Others	0.000	0.999		
Education Level	Secondary	1	Ref		
	Tertiary	1.509 (0.779, 2.925)	0.223*		
Monthly Personal	< RM 3365	1	Ref		
Income	> RM 3365	1.228 (0.636, 2.372)	0.541		
Socio-cultural Factors					
High Risk Behaviour					
Smoking	Yes	1	Ref		
	No	3.492 (1.521, 8.027)	0.003*		
Alcohol Consumption	Yes	1	Ref		
	No	2.242 (0.277, 22.079)	0.489		
Occupation Factor					
Job Role	Doctor	0.064 (0.008, 0.491)	0.008*	0.024 (0.003, 0.218)	0.001**
	Paramedics	1	Ref	1	Ref
	Supporting Staff	1.010 (0.507, 2.010)	0.978	0.366 (0.143, 0.936)	0.036**
Type of Facilities	Hospital	2.291 (0.783, 6.705)	0.130*		
	Primary Health Clinic	1	Ref		
Department of Work	General Medicine Department	1	Ref		
	Emergency Department	1.005 (0.249, 4.057)	0.995		
	Outpatient	1.339 (0.474, 3.787)	0.582		
	Others	1.825 (0.772, 4.314)	0.170*		
Duration of Service	< 36 months	1	Ref		
	> 36 months	2.163 (1.097, 4.265)	0.026*		
Clinical Factor					
Co-morbidity					
Diabetes Mellitus	Yes	6.016 (2.104, 17.198)	0.001*		
	No	1	Ref		
Hypertension	Yes	1	Ref		
	No	5.752 (2.159, 15.327)	0.001*		
HIV Status	Positive	1	Ref		
	Negative	3.375 (0.299, 38.081)	0.325		
Types of TB	Pulmonary TB	1.329 (0.605, 2.917)	0.478		
	Extrapulmonary TB	1	Ref		
History of TB	Yes	1	Ref		
	No	1.692 (0.347, 8.262)	0.515		
Sputum Pre-Treatment	Positive	2.001 (0.994, 4.028)	0.052*		
	Negative	1	Ref		
Chest X-ray	No Lesion	< 0.001 (0.00)	0.997	0.000	0.997
Pre-Treatment	Minimal	1	Ref	1	Ref
	Moderate Advanced	9.077 (4.193, 19.649)	<0.001*	14.686 (5.873, 36.724)	<0.001**
	Far Advanced	6.458 (1.434, 29.095)	0.015*	10.783 (1.909, 60.904)	0.007**
BCG Vaccination	Yes	< 0.001 (0.00)	0.999		
	No	1	Ref		

Note:
N, total number of units in the sample; p value based on chi-squared test or Fishers exact test for categorical variables; *Significant factor in simple logistic regression analysis (p-value <0.25). **Significant determinant included in the final model (p-value <0.05).
BCG: Bacillus Calmette- Guérin, CI: confidence interval, HIV: human immunodeficiency virus, COR: crude odds ratio, AOR: adjusted odds ratio.
***ROC was 88.3%; Hosmer-Lemeshow goodness-of-fit = 0.858, Cox & Snell = 0.264.
****No multicollinearity, Cook's influential statistic shows no influential outliers.

failures. There were no "loss to follow-up" or "transferred out" cases among these HCWs.

By looking under the sociodemographic factors, the majority of HCWs diagnosed with TB were below 34 years old (65.2%) and predominantly female (74.8%). The educational attainment within the studied cohort was considered high, as most HCWs had achieved a tertiary education level (62.3%). Most participants claimed they did not smoke (89.5%) or consume alcohol (98.7%). Significantly, no participants reported a history of drug use (0.0%). Most affected job roles were among supporting staff (39.0%) which comprises lab personnel, cleaners, administrative, assistant environmental health officer (PPKP), public health assistant (PKA) and health care assistant (PPK); followed by paramedics (36.1%) and doctors (24.9%). The majority of HCWs reported working in a hospital setting (81.5%) compared to 18.5% working at primary health care facilities. A slightly majority (53.0%) of the HCWs reported less than 36 months of working experience in the healthcare sector.

Only a small percentage reported being diagnosed with chronic illness; diabetes mellitus (5.1%), hypertension (6.1%) and HIV (1.0%). A history of previous or recurrent TB was found to be uncommon (only 3.2%), and 99.0% claimed to have received BCG vaccination. Sputum results upon TB diagnosis were found almost evenly split between positive (54.0%) and negative (46.0%).

By using the SLogR method, several factors show statistically significance which indicates a potential association before adjustment. After analysing using the MLogR model, only three variables were found to be statistically significant (Table II). HCWs age less than 34 years old had significantly higher odds of TB treatment success (AOR=5.071, (95% CI: 2.009–12.801) compared to the higher age group. Doctors (AOR=0.024, 95% CI: 0.003–0.218) and supporting staff (AOR=0.366, 95% CI: 0.143–0.936) show significantly lower odds compared to paramedics. As for the CXR, those presented with moderate (AOR=14.686, 95% CI: 5.873–36.724) and far advanced (AOR=10.783, 95% CI: 1.909–60.904) CXR changes upon diagnosis had significantly higher odds of TB treatment success compared to those with minimal changes group.

DISCUSSION

With the findings of 86.9% treatment success rate, Selangor is brought closer to the WHO "End-TB Strategy" target of 90% by 2025. This figure is slightly higher compared to other studies by Uchimura et al. involving HCWs in Japan and from Cardos et al. from Brazil, which both reported at 80.0% success rate.[17,22] Another study by Pleszewski et al. reported 84.0% of TB treatment success rate.[18]

From Table I, most HCWs diagnosed with TB were predominantly female (74.8%). A paper by Lee et al. shows risk factors of TB among HCWs, including nursing professionals, due to its job requiring direct and extended contact with patients.[18-19] Since this profession is usually female dominated, might indirectly lead to a higher number of exposures compared to males. Regarding education level, one might assume that individuals with higher education have a lower risk of infection due to their better knowledge. However, in real healthcare settings, particularly concerning TB cases, the situation is often the opposite. Professions with a tertiary education level, such as doctors, nurses and medical assistants, generally have the most direct and prolonged contact with patients compared to supporting staff, thereby posing a higher risk of occupational TB exposure. This is supported by a paper by Tudor et al. which shows HCWs who spent more time working with patients had twice the odds of developing TB.[20]

In Table II, several significant determinants show a p-value <0.05 which indicates a significant association with the outcome. HCWs aged less than 34 years old show 5 times odds (AOR=5.071, 95% CI: 2.009–12.801) of having better treatment outcomes compared to older ages. This aligns with some literature indicating older age has lower TB treatment success rate.[13,21-22] Doctors (AOR = 0.024, 95% CI: 0.003 - 0.218) and supporting staff (AOR = 0.366, 95% CI: 0.143 - 0.936) both show a significantly lower odds of treatment success compared to paramedics. The findings for doctors might be surprising, as they were expected to have better treatment outcome due to their knowledge and access to healthcare. This may be explained by long working hours and chronic stress, as high stress levels are known to reduce treatment adherence, leading to low success rate.[23-24] Other possibilities include treatment interruptions caused by busy schedules or the tendency to self-treat or self-adjust treatment,[25] believing they know better compared to treating physicians. A paper by Nezenega et al. mentioned perceived stigma and discrimination towards the disease itself may lead to delay in diagnosis and compromise treatment adherence, reducing treatment success rate.[26-27] As for the supporting staff, the lower odds may be due to low health literacy as they don't perceive themselves as frontliners and underestimate risk of contracting TB as mentioned by Engelbrecht et al.[28] Similarly to doctors, they may also experience stigma or fear of being terminated, leading them to hide their illness or avoid regular follow-up, which will affect their outcomes. Unfortunately, all these factors were not studied in this research due to insufficient data availability.

In addition, those who had moderate (AOR=14.686, 95% CI: 5.873–36.724) and far advanced (AOR=10.783, 95% CI: 1.909–60.904) CXR findings at diagnosis had significantly higher odds of treatment success than those who had minimal CXR changes. This finding should be interpreted cautiously, as it is not consistent with the conventional expectation that more severe disease is associated with poorer treatment outcomes. Relatively small sample size of HCWs in far advanced disease (n=9) may have contributed to the wide confidence intervals observed and estimate instability. Furthermore, this association may have been influenced by other unmeasured factors, or by differences in clinical management, in residual confounding, or in disease classification. The reasons for this could not be fully explored as the NTBR does not collect detailed data on treatment adherence, intensity of treatment follow-up or changes in disease severity during treatment. Therefore, this finding should not be interpreted as evidence of a true clinical association between more severe radiographic disease and

better treatment outcomes. Rather, it may reflect estimate instability resulting from the small number of far advanced cases, residual confounding, or other unmeasured factors. Further studies with larger sample sizes are required to confirm this association.

Several variables that were commonly discussed and highlighted in other TB-related literature, however, were found to be statistically insignificant in our study. This includes HIV co-infections, DM, smoking habits and BCG vaccination status.[31-33] These insignificant findings might be due to the relatively small number of cases among the study population, which limited the statistical power to detect associations. Additionally, the unique characteristics of our study population and the potential role of confounding may have influenced these results.

One of the strengths is the utilisation of a comprehensive and reliable 10-year period of data obtained from the NTBR system from 2014 to 2023. This large, real-world dataset enables extensive analysis and provides strong statistical power to study the determinants of TB treatment outcome. The use of universal sampling indicates less data bias and leads to good representativeness of the actual situation in Selangor. Furthermore, the findings from this study may establish a new baseline, offering supplementary insights for the MOH and the Selangor State Health Department, particularly due to the scarcity of published research concerning the healthcare worker population in Malaysia. This study addresses the current gap and may be further investigated in future study.

LIMITATIONS

Although this study demonstrates several strengths, it is not without limitations. By using cross-sectional study design, we can only identify association, but unable to establish cause-effect relationship or measure incidence. Therefore, future researchers should consider conducting a longitudinal study to explore the causal relationship between occupational factors and socio-cultural factors towards TB treatment outcome over time. Full reliance on the NTBR data registry means we missed certain potentially associated factors that are not routinely captured in the systems such as psychosocial factors, adherence behaviours, stigma even cultures. Although only 24 records (7.1%) were excluded because of missing data, the use of listwise deletion may have introduced selection bias if the missingness was not completely random. In the future, the relevant unit should emphasize on improvement of data quality in the system to ensure the accuracy and completeness of recorded variables to minimise missing data. However, another drawback is the small number of patients in some groups, including those with HIV infection (n=3), diabetes mellitus (n=16), and those with far advanced CXR findings (n=9). These low numbers may have caused imprecise estimates, broad confidence intervals and decreased statistical power to detect significant associations. Another limitation of the system is that it is self-reported, which may result in recall error or under-reporting. The use of the Selangor NTBR database also introduces a potential source of selection bias. Healthcare workers who work in Selangor but live outside the state may not have been captured if their case was registered in another state's registry, as registration in the NTBR is mostly based on place of residence. The same applies to HCWs who reside in Selangor but work outside of the state and to whom investigations in the workplace may have been incomplete and not adequately documented. Therefore, the results may not reflect the entire HCWs population in Selangor especially for those who cross state lines to work. Future studies utilising the national NTBR database would provide a more comprehensive assessment of TB treatment outcomes among HCWs regardless of their state of residence.

Despite ongoing programs to improve TB treatment outcome among HCWs, one cannot deny the potential negative impact of mental health status on the TB treatment adherence. In the future, the MOH may consider prioritising and ensuring sufficient resource allocation, especially mental health support, as one of the elements in improving treatment outcomes. Since, from the study, doctors and supporting staff has lower odds-on treatment outcome, the management may consider role-specific intervention to improve the results in future.

CONCLUSION

High TB treatment success rate was found among HCWs in Selangor (86.9%) nearing to WHO's "End-TB Strategy" target. Younger age and advanced CXR upon diagnosis were found positively associated with better outcomes, while doctors and supporting staff show a contrary effect. Common risk factors such as HIV, smoking, diabetes and BCG were found to be non-significant in this study. Future research should consider conducting longitudinal studies to establish causal relationships by including additional socio-cultural and occupational factors. Several recommendations have also been suggested, such as strengthening mental health support for HCWs; implementing job-based targeted interventions; and improving data quality and completeness in the NTBR system, including capturing data on psychosocial, cultural influences and adherence-related factors. Hopefully by integrating these recommendations, Malaysia will be able to enhance its TB control and management efforts, as well as promoting a healthier and more effective healthcare workforce.

CONFLICT OF INTEREST

There are no conflicts of interest.

ACKNOWLEDGMENT

We are gratefully acknowledging the TB/Leprosy Unit in Public Health Division under Selangor State Health Department, Ministry of Health, Malaysia, for the use of NTBR System database.

FUNDING

This study did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

REFERENCES

1. Chen Z, Wang T, Du J, Sun L, Wang G, Ni R, et al. Decoding the WHO global tuberculosis report 2024: a critical analysis of global and Chinese key data. Zoonoses. 2025; 5(1): 1.
2. Fritschi N, Curtis N, Ritz N. Bacille Calmette Guérin (BCG) and new TB vaccines: specific, cross-mycobacterial and off-target effects. Paediatr Respir Rev. 2020; 36: 57-64.
3. Gebreweld FH, Kifle MM, Gebremicheal FE, Simel LL, Gezae MM, Ghebreyesus SS, et al. Factors influencing adherence to tuberculosis treatment in Asmara, Eritrea: a qualitative study. J Health Popul Nutr. 2018; 37(1): 1.
4. Inchai J, Liwsrisakun C, Bumroongkit C, Euathrongchit J, Tajarernmuang P, Pothirat C. Tuberculosis among healthcare workers at Chiang Mai University Hospital, Thailand: clinical and microbiological characteristics and treatment outcomes. Int J Infect Dis. 2018; 71(3): 214-9.
5. Junaidi H, Adi AC, Arfan I, Ningrum PT. Non-success in pulmonary tuberculosis treatment: a narrative review of key contributing factors. Afr J Reprod Health. 2024; 28(10): 421-9.
6. Kamarul Zaman MF, Nik Husain NR, Sidek MY, Abu Bakar Z. Determinants of unfavourable treatment outcomes of drug-resistant tuberculosis cases in Malaysia: a case-control study. BMJ Open 2025; 15(2): e093391.
7. Müller AM, Osório CS, Silva DR, Sbruzzi G, De Tarso Roth Dalcin P. Interventions to improve adherence to tuberculosis treatment: systematic review and meta-analysis. Int J Tuberc Lung Dis 2018; 22(7): 731-40.
8. Muzaini K, Yasin SM, Ismail N, Abdul Rani MF, Ismail AI, Razali A, et al. Determinants of tuberculosis treatment success among the working population in Malaysia. Singapore Med J 2026; 67(Suppl 1): S102-7.
9. Nidoi J, Muttamba W, Walusimbi S, Imoko JF, Lochoro P, Ictho J, et al. Impact of socio-economic factors on tuberculosis treatment outcomes in north-eastern Uganda: a mixed methods study. BMC Public Health 2021; 21(1): 2167.
10. Pan SC, Chen YC, Wang JY, Sheng WH, Lin HH, Fang CT, et al. Tuberculosis in healthcare workers: a matched cohort study in Taiwan. PLoS One 2015; 10(12): e0145047.
11. Peddireddy V. Quality of life, psychological interventions and treatment outcome in tuberculosis patients: the Indian scenario. Front Psychol 2016; 7: 1664.
12. Pinho STR, Rodrigues P, Andrade RFS, Serra H, Lopes JS, Gomes MGM. Impact of tuberculosis treatment length and adherence under different transmission intensities. Theor Popul Biol 2015; 104: 68-77.
13. Putra KWR, Toonsiri C. Factors related to the successful treatment of tuberculosis: a literature review. Belitung Nurs J 2019; 5(4): 136-46.
14. Skodric-Trifunovic V, Markovic-Denic L, Nagorni-Obradovic L, Vlajinac H, Woeltje KF. The risk of occupational tuberculosis in Serbian health care workers. Int J Tuberc Lung Dis 2009; 13(5): 640-4.
15. Thomas BE, Thiruvengadam K, Rani S, Kadam D, Ovung S, Sivakumar S, et al. Smoking, alcohol use disorder and tuberculosis treatment outcomes: a dual comorbidity burden that cannot be ignored. PLoS One 2019; 14(7): e0220507.
16. Uden L, Barber E, Ford N, Cooke GS. Risk of tuberculosis infection and disease for health care workers: an updated meta-analysis. Open Forum Infect Dis 2017; 4(3): ofx137.
17. Uchimura K, Ngamvithayapong-Yanai J, Kawatsu L, Ohkado A, Yoshiyama T, Shimouchi A, et al. Characteristics and treatment outcomes of tuberculosis cases by risk groups, Japan, 2007–2010. West Pac Surveill Response J 2013; 4(1): 11-8.
18. Pleszewski B, FitzGerald JM. Tuberculosis among health care workers in British Columbia. Int J Tuberc Lung Dis. 1998; 2(11): 898-903.
19. Lee S, Lee W, Kang SK. Tuberculosis infection status and risk factors among health workers: an updated systematic review. Ann Occup Environ Med 2021; 33: e17.
20. Tudor C, Van der Walt ML, Margot B, Dorman SE, Pan WK, Yenokyan G, et al. Occupational risk factors for tuberculosis among healthcare workers in KwaZulu-Natal, South Africa. Clin Infect Dis 2016; 62(Suppl 3): S255-61.
21. Chilyabanyama R, Kamanga N, Mwandia JN. Factors associated with tuberculosis treatment outcomes among TB patients aged 15 years and older at Chawama Level One Hospital in Lusaka, Zambia. Glob Public Health 2024; 19(1): 2307979.
22. Cardoso MA, do Brasil P, Schmaltz CAS, Sant'Anna FM, Rolla VC. Tuberculosis treatment outcomes and factors associated with each of them in a cohort followed up between 2010 and 2014. Biomed Res Int 2017; 2017: 3974651.
23. Tok PSK, Liew SM, Wong LP, Razali A, Loganathan T, Chinna K, et al. Determinants of unsuccessful treatment outcomes and mortality among tuberculosis patients in Malaysia: a registry-based cohort study. PLoS One 2020; 15(4): e0231986.
24. Agbeko CK, Mallah MA, He B, Liu Q, Song H, Wang J. Mental health status and its impact on tuberculosis treatment and its outcomes: a scoping literature review. Front Public Health 2022; 10: 855515.
25. Tola HH, Garmaroudi G, Shojaeizadeh D, Tol A, Yekaninejad MS, Ejeta LT, et al. The effect of psychosocial factors and patients' perception of tuberculosis treatment non-adherence in Addis Ababa, Ethiopia. Ethiop J Health Sci 2017; 27(5): 447-58.
26. Domeyer-Klenske A, Rosenbaum M. When doctor becomes patient: challenges and strategies in caring for physician-patients. Fam Med 2012; 44(7): 471-7.
27. Nezenega ZS, Perimal-Lewis L, Maeder AJ. Factors influencing patient adherence to tuberculosis treatment in Ethiopia: a literature review. Int J Environ Res Public Health 2020; 17(15): 5626.
28. Engelbrecht M, Rau A, Kigozi G, Janse van Rensburg A, Wouters E, Sommerland N, et al. Waiting to inhale: factors associated with healthcare workers' fears of occupationally-acquired tuberculosis (TB). BMC Infect Dis 2019; 19(1): 475.
29. Umayorubhagom A, Baliga SS. Factors affecting tuberculosis treatment outcome among newly diagnosed tuberculosis patients – a longitudinal study. Indian J Tuberc. 2024; 71(3): 337-43.
30. Ministry of Health Malaysia. Management of tuberculosis (4th ed). Putrajaya: Ministry of Health Malaysia; 2021. [cited 2025 May] Available from: https://www.moh.gov.my/moh/resources/Penerbitan/CPG/Respiratory/CPG-_Management_of_Tuberculosis_(4th_Edition).pdf. Accessed 2 October 2025.
31. Selimin DS, Ismail A, Ahmad N, Ismail R, Mohd Azman NF, Azman A. Tuberculosis treatment outcome in patients with TB-HIV coinfection in Kuala Lumpur, Malaysia. J Trop Med 2021; 2021: 9923378.
32. Alayu Alemu M, Yesuf A, Girma F, Adugna F, Melak K, Biru M, et al. Impact of HIV-AIDS on tuberculosis treatment outcome in Southern Ethiopia – a retrospective cohort study. J Clin Tuberc Other Mycobact Dis 2021; 25: 100279.
33. Ahmad SR, Yaacob NA, Jaeb MZ, Hussin Z, Wan Mohammad WMZ. Effect of diabetes mellitus on tuberculosis treatment outcomes among tuberculosis patients in Kelantan, Malaysia. Iran J Public Health 2020; 49(8): 1485-93.