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# Drug-resistant tuberculosis treatment success predictors in Namibia

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**Background:** Drug-resistant tuberculosis (DR-TB) is a considerable barrier to ending TB globally by 2035. In most high TB-burden countries in the sub-Saharan region, drivers of DR-TB treatment success are unknown.

**Objectives:** To determine predictors and patterns of treatment success rates (TSRs) in DR-TB in Namibia to inform strategies of national TB programmes.

**Methods:** A nationwide retrospective observational cohort study of a 6 year DR-TB database, 2014–19, was carried out. Independent predictors of successful treatment outcome in DR-TB were determined by multivariate logistic regression.

**Results:** Of the 1494 DR-TB patients included, 56.3% ($n=841$) were male, the mean (±SD) age was 35.6 ± 14.2 years, and 8.3% had TB/HIV coinfection. The overall TSR was 66.5% ($n=994$) and it increased marginally between implementation of the second and third medium-term plans for TB and leprosy (MTP-II and MTP-III). Being female was associated with lower odds of treatment success [adjusted OR (aOR) = 0.6; 95% CI: 0.34–0.89; $P=0.015$), as was a young age (under 5 years) (aOR = 0.1; 95% CI: 0.0007–0.421; $P=0.005$) and ages of 5–14 years (aOR = 0.0; 95% CI: 0.002–0.269; $P=0.002$). Namibian nationality also showed a reduced likelihood of treatment success (aOR = 0.3; 95% CI: 0.089–0.961; $P=0.043$). Among clinical predictors, bilateral pulmonary forms were inversely associated with treatment success (aOR = 0.2; 95% CI: 0.057–0.498; $P=0.001$). Conversely, baseline monoresistance was linked to an increased likelihood of treatment success (aOR = 7.6; 95% CI: 1.427–40.631; $P=0.018$).

**Conclusions:** Whilst DR-TB TSRs improved, they are below the global target and vary by clinical and patient demographics. Targeted interventions for high-risk patients, including female patients, those aged under 15 years, locals and those with bilateral pulmonary disease using community-based approaches to boost adherence, alongside leveraging the skills of clinical pharmacists, should now be explored.

## Introduction

Drug-resistant TB (DR-TB), a global emergency associated with poor treatment outcomes, threatens efforts gained towards ending TB by 2035.[1] In 2021, the WHO estimated the global burden of DR-TB at 45 cases per 100 000 (95% CI: 399 000–501 000); 33.4% of these were MDR TB (MDR-TB) and 17% (77 000) were in sub-Saharan Africa.[1] There are increasing reports of XDR (XDR-TB) in this region, where 1079 laboratory-confirmed pre-XDR-TB or XDR-TB cases were recorded in 2021.[1] Depending on the susceptibility to the antimicrobials, DR-TB may be classified into monoresistant [either isoniazid- or rifampicin-resistant (RR)-TB), MDR-TB (resistance to both isoniazid and rifampicin), pre-XDR-TB, which is MDR-TB with fluoroquinolone resistance, and XDR-TB, which is resistant to rifampicin, plus any fluoroquinolone, and either bedaquiline or linezolid.[2] The interplay between HIV and TB makes the comorbidity more challenging to manage, especially in sub-Saharan countries like Namibia.

HIV coinfection accelerates the DR-TB disease progression and complicates its treatment, leading to poorer treatment

outcomes and adverse events.[3] Moreover, it was also observed that there was a statistically significant association between HIV-positive individuals and DR-TB strains, as the odds of developing the disease were 1.42 times more among the HIV- positive individuals, compared with the HIV-negative ones.[4]

In Namibia, despite the declining incidence of MDR-TB, the country is still classified among the high TB-burden countries globally.[5,6] The suboptimal treatment success rates (TSRs) for MDR-TB, estimated at 56% globally and at 69% for Africa, are a major public health concern and hinder achievement of the WHO's strategic goals.[7–9] A marginal improvement of 1% in TSR among patients with MDR-TB, as well as those with RR-TB, was reported in 2020.[9] The WHO recommends countries to have an MDR-TB TSR of 95%.[1] In 2014, Namibia reported 74% TSR among MDR-TB cases, reflecting high rates of loss to follow-up and unevaluated treatment outcomes, as well as treatment failure.[10,11]

The suboptimal TSR for DR-TB was mainly attributed to the complexity of the disease and drug regimens, which often had low efficacy and safety profiles, and were prescribed for longer than 9–18 months.[12] The updated treatment guideline recommends a reduced duration of only 6–9 months, which is much preferred over the previous one.[13] Current evidence suggests that the determinants of DR-TB treatment outcomes are diverse and need to be contextualized to the setting.[5] Studies attribute poor treatment outcomes in DR-TB to patient and treatment-related factors including male sex, poor adherence, being underweight and adverse effects, as well as disease-related sequelae.[14] There are conflicting reports among studies undertaken in Malaysia, Ethiopia and Pakistan on the effect of a patient's sociodemographic factors including sex, age and alcohol use on TSR in DR-TB.[15–18] Published studies have also shown that pre-treatment positive smear, HIV coinfection and diabetes mellitus predict poor DR-TB treatment outcomes.[15,18,19] However, others report no such associations.[20] A study in Namibia among drug-susceptible TB patients also found sputum non-conversion at Month 2 to be an important risk factor for unsuccessful treatment outcomes in drug-susceptible TB.[5]

Despite these studies, there continues to be a paucity of data in high TB-burden countries in sub-Saharan Africa regarding the influence of sociodemographic, programmatic and clinical factors on TSR.[16] This needs to be urgently explored given the rising burden of DR-TB with weak health systems in the region and high poverty rates.[21–23] Consequently, the study aimed to determine the predictors and patterns of TSR among DR-TB patients in Namibia to help strengthen national TB strategies to optimize treatment outcomes and end TB. The findings should also be of interest to other similar studies, with the future goal of ending TB.

## Methods

### Design and population

A nationwide retrospective observational cohort study was conducted to analyse a 6 year database (2014–19) of DR-TB patients to determine potential predictors and patterns of treatment success over this period. Patients were divided into two groups based on their treatment outcomes: those with a successful outcome as defined by WHO, i.e. cured bacteriologically or having completed treatment; and those with unsuccessful outcomes, including those who were lost to follow-up, died, defaulted treatment, or transferred out of the facility.

### Procedure

Data on patient sociodemographic, clinical and treatment characteristics, as well as treatment outcomes, were extracted from the DR-TB database, the Electronic TB Register (ETR.net), spanning from 2014 to 2019, using a pre-validated data abstraction tool (Appendix A, available as Supplementary data at *JAC-AMR* Online). Patients were notified over the 6-year period, from January 2014 to December 2019. The tool was adapted from the National Guidelines for the Management of DR-TB, as per the WHO recommendations.[11] DR-TB patients with a treatment outcome were purposively included in the analysis. Data abstracted included patient sociodemographic characteristics, TB programme-related characteristics including directly observed treatment short-course strategy (DOTS) supporter or facility, TB/HIV coinfection, comorbidities, ART and DR-TB treatment. Multiple imputations were completed to address missing data prior to analysis. These results were excluded from the main study results.

### DR-TB programme in Namibia

The national TB and leprosy programme (NTLP) in Namibia was established in 1991 and has been under the Special Programmes Directorate since 2004.[11] The programme is implemented through a decentralized system from national to regional, district and community levels. Namibia subsequently implemented the DOTS strategy in the year 1995, as recommended by the WHO to control TB.[24] Directly observing DR-TB patients taking their medications is seen as enhancing treatment adherence and leading to better treatment outcomes.[25] The national level coordinates, implements, monitors and evaluates all activities, while health services for the care and prevention of TB and leprosy are undertaken at the referral hospital, 14 regional health directorates, 3 intermediate hospitals, 35 district hospitals, 44 health centres, 267 clinics and 1150 outreach points, along with private sector and non-governmental organization (NGO) assistance also being involved with the care of patients with TB.

### Data analysis

After collection, the data were exported to a Microsoft Excel 2016 spreadsheet for cleaning and then imported to SPSS version 25 for quantitative analysis. Predictors were initially determined by calculating crude ORs (cORs) using bivariate analysis to assess the statistical significance of the relationship between TB treatment outcomes and a range of factors. These included sociodemographic characteristics, clinical and programme-related factors, alcohol abuse and time to treatment initiation. Factors that returned a $P$ value of $\leq 0.25$ were further analysed using multivariate logistic regression to identify the independent predictors of DR-TB treatment outcomes by adjusted ORs (aORs) and to control confounders of treatment outcomes. For all significance tests, the alpha level was set at $P < 0.05$. The reference category in the model was a successful TB treatment outcome.

### Ethics

Ethical approval and permission to carry out the study were obtained from the University of Namibia Human Research Ethics Committee (Reference number: H-G CAMPUS/565/2020) and the Ministry of Health and Social Services Research Unit (Ref: 17/3/3VNN).

## Results

### Characteristics of study subjects

Table 1 summarizes the demographic characteristics. A total of 1494 patients with DR-TB were included in the analysis, of which more than half were male ($n = 841$; 56.3%) and at least 82% of patients were Namibian. The mean (±SD) age was 35.6 ±

**Table 1.** Characteristics and crude predictors of DR-TB treatment outcomes ($n = 1494$)

| | | DR-TB treatment outcome | | | |
|---|---|---|---|---|---|
| Characteristic | Frequency (%) | Unsuccessful (controls) (%) | Successful (cases) (%) | cOR (95% CI) | *P* value |
| DR-TB patients | 1494 | 500 (33.5) | 994 (66.5) | | |
| Age group (years) | | | | | |
| <5 | 41(2.7) | 7 (17.1) | 34 (82.9) | 1 | <0.001[a] |
| 5–14 | 36 (2.4) | 3 (8.3) | 33 (91.7) | 5.6 (2.1–4.8) | <0.001[a] |
| 15–24 | 206 (13.8) | 61 (29.6) | 145 (70.4) | 12.7 (3.5–46.7) | <0.001[a] |
| 25–34 | 467 (31.3) | 161 (34.5) | 306 (65.5) | 2.7 (1.5–5.0) | 0.001[a] |
| 35–44 | 403 (27.0) | 127 (31.5) | 276 (68.5) | 2.2 (1.3–3.8) | 0.006[a] |
| 45–54 | 201 (13.5) | 78 (38.8) | 123 (61.2) | 2.5 (1.4–4.4) | 0.001[a] |
| 55–64 | 84 (5.6) | 33 (39.3) | 51 (60.7) | 1.8 (1.0–3.3) | 0.049[a] |
| Sex | | | | | |
| Female | 653 (43.7) | 194 (29.7) | 459 (70.3) | 1.4 (1.1–1.7) | 0.007[a] |
| Male | 841 (56.3) | 306 (36.4) | 535 (63.6) | 1 | |
| Nationality | | | | | |
| Namibian | 1230 (82.3) | 395 (32.1) | 835 (67.9) | 2.2 (1.2–3.8) | 0.008[a] |
| Non-Namibian | 184 (12.3) | 83 (45.1) | 101 (54.9) | 1.7 (1.3–2.4) | 0.001[a] |
| Not indicated | 80 (5.4) | 22 (27.5) | 58 (72.5) | 1 | |
| Alcohol abuse | | | | | |
| No | 1337 (89.5) | 394 (29.5) | 943 (70.5) | 2.3 (1.1–4.8) | 0.023[a] |
| Yes | 29 (10.5) | 15 (51.7) | 14 (48.3) | 1 | |
| Region of residence | | | | | |
| Erongo | 102 (6.8) | 27 (26.5) | 75 (73.5) | 0.57 (0.2–2.1) | 0.385 |
| Hardap | 43 (2.9) | 17 (39.5) | 26 (60.5) | 0.9 (0.2–3.7) | 0.913 |
| Karas | 33 (2.2) | 9 (27.3) | 24 (72.7) | 0.5 (0.1–2.2) | 0.510 |
| Kavango | 157 (10.5) | 47 (29.9) | 110 (70.1) | 0.9 (0.2–4.0) | 0.889 |
| Khomas | 149 (10.0) | 56 (37.6) | 93 (62.4) | 0.8 (0.2–3.0) | 0.780 |
| Kunene | 16 (1.1) | 7 (43.8) | 9 (56.3) | 0.6 (1.1–2.1) | 0.554 |
| Ohangwena | 63 (4.2) | 25 (39.7) | 38 (60.3) | 0.4 (0.1–2.2) | 0.429 |
| Omaheke | 15 (1.0) | 1 (6.7) | 14 (93.3) | 0.5 (0.1–2.1) | 0.507 |
| Omusati | 57 (3.8) | 18 (31.6) | 39 (68.4) | 4.7 (0.4–52.1) | 4.667 |
| Oshana | 118 (7.9) | 35 (29.7) | 83 (70.3) | 0.7 (0.2–3.0) | 0.722 |
| Oshikoto | 53 (3.5) | 9 (17.0) | 44 (83.0) | 0.8 (0.2–3.1) | 0.790 |
| Other | 2 (0.13) | 0 (0) | 2 (100) | 1.6 (0.4–7.2) | 1.630 |
| Otjozondjupa | 102 (6.8) | 32 (31.4) | 70 (68.6) | 0.53 (0.17–7.4) | 0.537 |
| Zambezi | 12 (0.80) | 3 (25.0) | 9 (75.0) | 0.7 (0.2–2.9) | |
| Not indicated | 572 (38.2) | 214 (37.4) | 358 (62.6) | 1 | 0.729 |
| TB MTP period | | | | | |
| Pre-MTP | 2 (0.1) | 2 (100) | — | 0.12 (0.1–0.357) | 0.999 |
| MTP II (2010–15) | 1182 (79.2) | 396 (33.5) | 786 (66.5) | 0.8 (0.4–1.5) | 0.980 |
| MTP III (2016–20) | 310 (20.7) | 102 (32.9) | 208 (67.1) | 0.32 (0.16–0.637) | 0.999 |
| Type of TB drug resistance | | | | | |
| Not indicated | 18 (1.2) | 5 (27.8) | 13 (72.2) | | |
| Extensive | 27 (1.8) | 16 (59.3) | 11 (40.7) | 2.0 (0.693–5.640) | 0.202 |
| Mono | 87 (5.8) | 28 (32.2) | 59 (67.8) | 0.5 (0.237–1.152) | 0.108 |
| Multi | 846 (56.6) | 243 (28.7) | 603 (71.3) | 1.6 (0.985–2.607 | 0.057 |
| Poly | 60 (4.0) | 11 (18.3) | 49 (81.7) | 1.9 (1.488–2.394) | <0.001[a] |
| Rifampicin | 456 (30.5) | 197 (43.2) | 259 (56.8) | 3.4 (1.717–6.686) | <0.001[a] |
| Pulmonary forms | | | | | |
| Not indicated | 161 (10.8) | 107 (66.5) | 54 (33.5) | 0.2 (0.154–4.132) | <0.001[a] |
| Bilateral disease | 4 (0.3) | 0 | 4 (100) | 0 (0) | 0.999 |
| Unilateral (>1 lobe) | 299 (20.0) | 81 (27.1) | 218 (72.9) | 0.702 (0.541–14.50) | 0.286 |
| Unilateral lower lobe | 1030 (68.9) | 312 (30.3) | 718 (69.7) | 1.17 (0.877–1.559) | <0.001[a] |

*Continued*

**Table 1.** *Continued*

| Characteristic | Frequency (%) | DR-TB treatment outcome | | cOR (95% CI) | *P* value |
|---|---|---|---|---|---|
| | | Unsuccessful (controls) (%) | Successful (cases) (%) | | |
| Extrapulmonary forms | | | | | |
| Not indicated | 78 (5.2) | 36 (46.2) | 42 (53.8) | | |
| Abdominal TB | 3 (0.2) | 1 (33.3) | 2 (66.7) | 0.57(0.36–0.99) | 0.015[a] |
| Brain tissue | 28 (1.9) | 11 (39.3) | 17 (60.7) | 0.97(0.088–1.07) | 0.979 |
| Genital/urinary tract TB | 1385 (92.7) | 452 (32.6) | 933 (67.4) | 0.75(0.35–1.61) | 0.459 |

[a]$P < 0.05$.

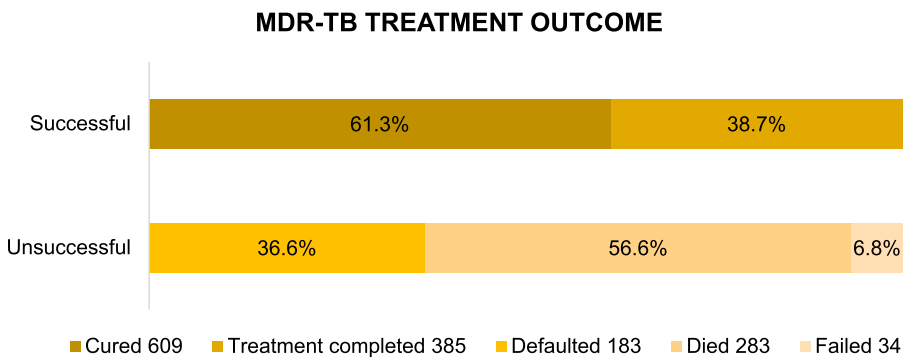


**Figure 1.** DR-TB treatment outcome.

14.2 years and more than half of the patients were aged between 25 and 45 years ($n=870$). Over one third (35.2%; $n=526$) of patients resided in 4 of the 12 regions of Namibia, i.e. Erongo, Khomas, Kavango and Oshana regions. Several patients had comorbid conditions including HIV ($n=124$; 8.3%), diabetes ($n=11$; 0.7%), renal failure ($n=4$; 0.3%), high blood pressure ($n=11$; 0.7%) and respiratory illness ($n=1$; 0.1%). The overall treatment success rate was 66.5% ($n=994/1494$), of which more than two-thirds of patients ($n=609/994$) were cured, and the rest completed treatment ($n=385/994$). Among those with unsuccessful treatment outcomes ($n=500/1494$; 33.5%), more than half died (56.6%; $n=283/500$), one-third defaulted treatment ($n=183/500$; 36.6%) and 6.8% had treatment failure (Figure 1). Unsuccessful treatment outcomes were more frequently observed in the age group of 55–64 years (39.3%; $n=33/84$). The Kunene region had the highest proportion of unsuccessful outcomes notified (43.8%; $n=7/16$).

### *Crude predictors of DR-TB treatment outcomes in Namibia (n = 1494)*

Table 1 summarizes the crude predictors of DR-TB treatment outcomes. The following variables were found to be associated with successful treatment outcomes: age, sex, nationality, alcohol abuse, drug resistance type, unilateral lower lobe disease and abdominal extrapulmonary TB type. All age groups were significantly associated with successful treatment outcomes except those under 14 years and those older than 64 years. Significantly associated age groups included: 15–24 years (cOR = 12.7; 95% CI: 3.5–46.7; $P<0.001$); 25–34 years (cOR = 2.7; 95% CI: 1.5–5.0; $P=0.001$), 35–44 years (cOR = 2.2; 95% CI: 1.3–3.8; $P=0.006$), 45–54 years (cOR = 2.5; 95% CI: 1.4–4.4; $P=0.001$) and 55–64 years (cOR = 1.8; 95% CI: 1.0–3.3; $P=0.049$). Female patients were 1.4 times more likely to have successful outcomes than male patients (cOR = 1.4; 1.1–1.7; $P=0.007$). Namibian nationals were 2.2 times more likely to be successfully treated (cOR = 2.2; 95% CI: 1.2–3.8; $P=0.008$). Patients who did not abuse alcohol were 2.3 times more likely to have completed treatment successfully (cOR = 2.3; 95% CI: 1.1–4.8; $P=0.023$). Polyresistance (cOR = 1.9; 95% CI: 1.488–2.394; $P<0.000$), rifampicin resistance (cOR = 3.4; 95% CI: 1.717–6.686; $P<0.000$) and unilateral lower lobe disease (cOR = 1.17; 95% CI: 0.877–1.559; $P<0.000$) were also significantly associated with treatment success. Patients with abdominal TB disease were 57% less likely to have successful DR-TB treatment (cOR = 0.57; 95% CI: 0.36–0.99; $P=0.015$). None of the other factors were found to be statistically significant for treatment outcomes (see complete tables in Appendix A).

### *Predictors of TB treatment success in DR-TB*

Table 2 summarizes the results of the multivariate logistic regression for predictors of DR-TB treatment outcomes. The study found that the independent sociodemographic predictors of reduced odds of treatment success were being female (aOR = 0.6; 95% CI: 0.34–0.89; $P=0.015$), <5 years old (aOR = 0.1; 95% CI: 0.0007–0.421; $P=0.005$), aged 5–14 years (aOR = 0.0; 95% CI: 0.002–0.269; $P=0.002$) and of Namibian nationality (aOR = 0.3;

95% CI: 0.0890.961; $P=0.043$). A clinical predictor of treatment success was bilateral pulmonary forms (aOR=0.2; 95% CI: 0.057–0.498; $P=0.001$), while baseline monoresistance was associated with reduced odds of treatment success (aOR=7.6; 95% CI: 1.427–40.631; $P=0.018$). Overall, female sex, young age, Namibian nationality and bilateral lung involvement are linked to a decreased likelihood of achieving treatment success, while monoresistance shows an increased likelihood.

**Table 2.** Multivariate logistic regression for predictors of DR-TB successful treatment outcomes in Namibia

| Covariates | aOR (95% CI) | *P* value |
|---|---|---|
| Sex | | |
| Female | 0.6 (0.338–0.892) | 0.015[a] |
| Male | | |
| Age groups (years) | | |
| <5 | 0.1 (0.007–0.421) | 0.005[a] |
| 5–14 | 0.0 (0.002–0.269) | 0.002[a] |
| 15–24 | 0.3 (0.068–1.055) | 0.060 |
| 25–34 | 0.5 (0.140–1.802) | 0.290 |
| 35–44 | 0.3 (0.091–1.213) | 0.095 |
| 45–54 | 0.4 (0.103–1.617) | 0.202 |
| 55–64 | 0.3 (0.055–1.349) | 0.111 |
| Nationality | | |
| Namibian | 0.3 (0.089–0.961) | 0.043[a] |
| Non-Namibian | 0.6 (0.287–1.078) | 0.082 |
| Resistance type | | |
| Extensive | 1.0 (0.123–8.579) | 0.980 |
| Mono | 7.6 (1.427–40.631) | 0.018[a] |
| Multi | 1.0 (0.366–2.562) | 0.948 |
| Poly | 0.6 (0.358–1.063) | 0.082 |
| Rifampicin | 0.4 (0.099–1.449) | 0.156 |
| Pulmonary forms | | |
| Bilateral disease | 0.2 (0.057–0.498) | 0.001[a] |
| Unilateral lower lobe | 0.9 (0.476–1.572) | 0.635 |

[a]$P<0.05$.

### *Patterns of TSR for DR-TB population*

Of the total number of records retrieved, 66.5% ($n=994/1494$) had a successful treatment outcome, 25.8% ($n=385$) completed treatment and 40.8% ($n=609$) were cured (Figure 2). Treatment success was observed more frequently among younger patients in the age groups 5–14 years (91.7%; $n=33/36$) and under 5 years (90.2%; $n=37/41$), as well as among female patients (70.3%, $n=459/653$). In addition, the Omaheke region had the highest proportion of patients with successful outcomes (93.3%), followed by the Oshikoto (83%) and Zambezi (75%) regions. TSRs increased marginally from 66.5% during the second medium-term plan for tuberculosis and leprosy implemented from 2010 to 2015 (TBL MTP-II) to 67.1% during the third medium-term plan (MTP-III) implemented from 2016 to 2020 (Figure 2). Medium-term plans are strategic TB treatment proposals that set out to carry out TB treatment over 3–5 years, focusing on implementing TB treatment protocols, allocating sufficient resources, building capacity and monitoring and evaluating programme efficacy.[14]

## Discussion

The study aimed to determine the patterns and predictors of TSR in DR-TB patients in Namibia. The TSR for DR-TB observed in Namibia is low compared with the WHO global target (66.5% versus 90%), as well as the global and African averages of 78.9% and 80.1%, respectively, which is a concern.[26] Most patients were male, young or middle-aged (21–49 years), and predominantly resided in central business and border districts of Namibia. Similarly, studies in sub-Saharan Africa report a high DR-TB prevalence among middle-aged men, attributed to their high risk of

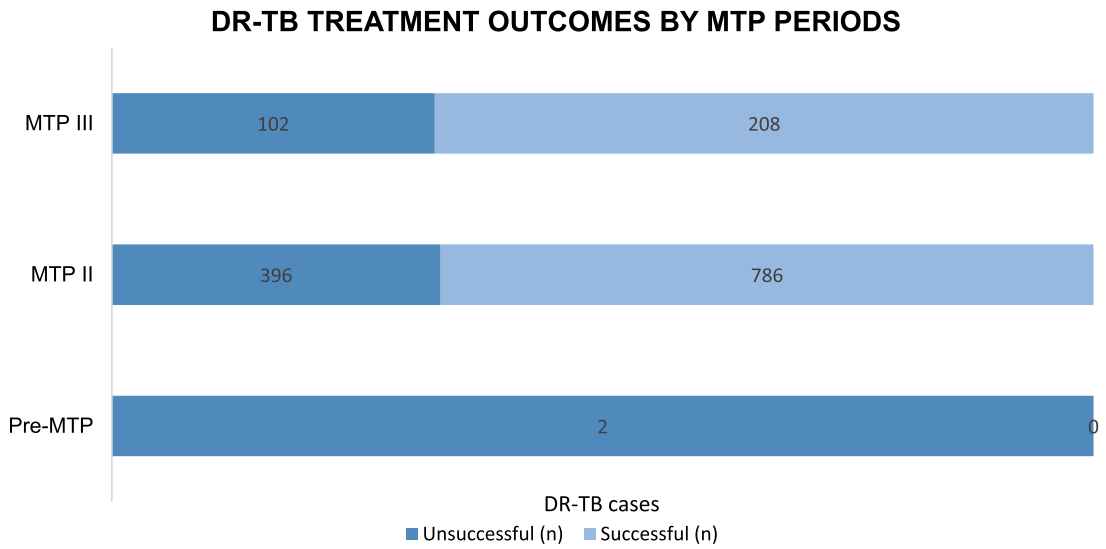


**Figure 2.** Distribution of DR-TB treatment outcomes by MTP period ($n=1494$).

exposure to TB through alcoholism, HIV and urban and cross-border migration.[15,27–31]

Comparing gender differences, the results indicate that more men than women had DR-TB, although being female was a negative predictor of successful treatment outcomes in this study. This finding is similar to a Ugandan study, where being a man was a significant predictor.[31] However, the finding is different to the findings in studies from Kenya and Pakistan, where female sex was a predictor of DR-TB treatment success.[17,32] This disparity may be attributed to cultural differences between genders as women can be more challenged to get high-quality medical care due to financial dependency, cultural inequity, participation in work with high DR-TB exposure, and lower levels of education.[33,34]

Despite the availability of highly effective regimens, the estimated TB global mortality among children is 239 000, annually.[35] Our study found that being a paediatric patient (age 5–14 years) was associated with significantly reduced odds of treatment success, as indicated by the aOR (aOR = 0.0; 95% CI: 0.002–0.269; $P = 0.002$). This finding contrasts with other studies in Africa, which generally indicate that older patients have poorer outcomes.[36,37] One possible explanation for this disparity could be the high rates of malnutrition among Namibian children, as nearly one-third of children under 5 years of age are malnourished, and malnutrition has been consistently linked to poorer TB treatment outcomes.[35,38]

Furthermore, our analysis revealed that Namibian nationality was also a negative predictor of treatment success (aOR = 0.3; 95% CI: 0.089–0.961; $P = 0.043$). This could be explained by the fact that Namibia is still grappling with key issues including stigma, poverty and access to healthcare.[25] High levels of poverty appear to hinder treatment adherence due to inadequate nutrition, which is a concern in Namibia. Stigma and poor TB awareness were also identified as barriers to favourable treatment outcomes as they adversely impact on timely treatment initiation, as well as increasing transmission within communities. Alongside this, Namibia is a vast country with sparsely located health facilities that limit access to healthcare and DOTS services. All of these factors, compounded by the complexities of the disease, contribute to poor DR-TB treatment outcomes.[6] It is reported that patients who defaulted were among previously treated patients, which may lead to this.[39]

Monoresistant TB was found to have a higher rate of treatment success compared with polyresistant and XDR-TB forms. Whilst the specific monoresistant drug in this study is unknown, reports from several studies indicate that risk factors of rifampicin and isoniazid monoresistance, illicit drugs, HIV/TB coinfection, prior TB treatment, being male and alcohol and cigarette smoking contribute to this.[40–42] This presents an opportunity for further Namibian researchers to study risk factors associated with monoresistant TB. Coupled with this, there is an urgent need in Namibia to prevent the further emergence and prevalence of resistant strains, as well as to pay special attention to patients exhibiting resistance to fluoroquinolones, kanamycin, ethionamide, ethambutol and rifampicin at baseline in Namibia. We will also be following this up in future research projects.

Having TB with bilateral lung involvement was also a negative predictor of successful DR-TB treatment outcomes in this study (aOR = 0.2; 95% CI: 0.057–0.498; $P = 0.001$). This finding is consistent with studies that link extensive lung involvement to MDR-TB treatment failure in Estonia, Latvia, the Philippines, Russia and Peru.[18] This is because the chance of effective therapy is reduced among those patients who have extensive bilateral cavity lesions, leading to failure of therapy and extended culture conversion.[33]

The results of the current study further highlight the need for special attention to prevent DR-TB, as well as to manage DR-TB using existing and innovative measures in Namibia. They propose that the following patients need special attention for better treatment outcomes: multi-drug resistance to TB drugs at baseline; and bilateral lung involvement. Further studies though need to be conducted to find out how patient-centred and community-based approaches to DR-TB promote adherence and better treatment outcomes. Additionally, exploring the function of clinical pharmacy services in DR-TB management could shed light on improving treatment outcomes.[43] This is because the number of effective drugs for DR-TB is limited. Consequently, patients having risk factors associated with an increased likelihood of death or treatment failure should receive individualized targeted attention. Alongside this, future studies are needed in Namibia to determine the impact of such interventions on time-to-culture conversion and treatment outcomes.

Our study faced limitations, particularly concerning missing data. We excluded 21 records (1.38% of the total), which may have impacted on the results. Nevertheless, we believe this study provides a valuable nationwide dataset from a high TB-burden country over a significant time frame (2014–19).

### *Conclusions and recommendations*

The DR-TB treatment success rate in Namibia currently falls below the WHO global target of 90%. Additionally, success varies considerably among individual patients, as well as across regions. Multiple factors that influence DR-TB TSRs must be comprehensively understood to improve future patient care. Targeted interventions should be developed for patients at high risk of treatment failure, alongside the initiation of treatment enhancement programmes in Namibia. Addressing socioeconomic barriers and enhancing healthcare access will also be crucial in Namibia for improving DR-TB treatment outcomes. These suggestions will continue to be monitored to help meet future WHO targets.

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## Transparency declarations

None to declare.

### *Author contributions*

All authors (V.M., M.A., B.G., D.K.) contributed to the conceptualization and appraised the article through the various stages of development. V.N. and D.K. performed the data analysis. All authors reviewed successive drafts and approved the final version.

## Supplementary data

Appendix A is available as Supplementary data at *JAC-AMR* Online.

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