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SYSTEMATIC REVIEW | Article in Press

Treatment outcomes of drug-resistant *Mycobacterium tuberculosis* disease in Cameroon: a systematic review and meta-analysis

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Abstract

Background Cameroon faces substantial challenges in managing DR-TB. However, national evidence on treatment outcomes remains unsynthesized. This systematic review and meta-analysis aimed to estimate pooled treatment outcomes, adverse drug events (ADEs), and predictors of unfavorable outcomes among patients with DR-TB in Cameroon.

Methods This systematic review and meta-analysis followed the PRISMA 2020 guidelines. PubMed, Scopus, Embase, Web of Science, Cochrane Library, and African Journals Online were searched. Studies reporting World Health Organization-defined treatment outcomes among patients with DR-TB were included. Random-effects meta-analyses using generalized linear mixed models with logit transformation were performed. Heterogeneity was assessed using the I^2 statistic, and publication bias and sensitivity analyses were conducted.

Results Fifteen studies conducted between 1998 and 2022 were included, most of which were observational cohort studies. The pooled mortality rate was 6.8% (95% CI: 4.7–9.7; 14 reports; $n = 2{,}351$ participants; $I^2 = 58.1\%$), loss to follow-up was 4.1% (95% CI: 2.8–6.1; 12 reports; $n = 2{,}244$ participants; $I^2 = 55.5\%$), and treatment failure was 4.2% (95% CI: 1.1–14.3; 13 reports; $n = 2{,}050$ participants; $I^2 = 93.3\%$). The pooled treatment success rate was 74.2% (95% CI: 60.4–84.4; 13 reports; $n = 2{,}146$ participants; $I^2 = 88.1\%$). Among patients with multidrug-resistant-TB, the pooled prevalence of adverse drug events was 70.8% (95% CI: 40.2–89.7; 3 studies; $n = 251$ participants), with ototoxicity (41.9%; 95% CI: 23.7–62.6; 3 studies; $n = 251$ participants) and gastrointestinal disorders (40.9%; 95% CI: 25.5–58.2; 2 studies; $n = 172$ participants) being the most common events. HIV co-infection was significantly associated with unfavorable treatment outcomes (pooled OR = 2.76; 95% CI: 1.95–3.93; 6 studies), and male sex was also associated with increased odds of unfavorable outcomes (OR = 1.73; 95% CI: 1.25–2.40; 5 studies).

Conclusions Approximately three-quarters of DR-TB patients in Cameroon achieved treatment success under standard regimens, falling short of the 85% target in the 2024–2026 National Strategic Plan. With mortality, treatment failure, and adverse drug events remaining major concerns, strengthening pharmacovigilance, integrating TB/HIV care, and implementing all-oral regimens are essential to improve outcomes and meet national targets.

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Keywords Drug-resistant tuberculosis · Treatment outcome · Drug-related adverse reactions · Systematic review · Meta-analysis · Cameroon

Background

Tuberculosis (TB) continues to be among the leading infectious diseases causing morbidity and mortality around the globe. Tuberculosis accounted for an estimated 10.7 million cases and 1.23 million deaths in 2024 (150,000 among people living with HIV), with only 40% of patients with drug-resistant TB accessing treatment, despite substantial progress that has saved 83 million lives since 2000 [1]. Drug-resistant tuberculosis (DR-TB) encompasses a spectrum of resistance patterns, ranging from mono-resistance to multidrug-resistant (MDR) to extensively drug-resistant forms, and poses a growing challenge to global TB control efforts [2].

Sub-Saharan Africa bears a heavy burden of tuberculosis globally. Africa makes up about 23–25% of the global TB incidence rate and more than one-third of deaths due to TB [3]. The number of cases of MDR/RR-TB (multidrug-resistant/rifampicin-resistant tuberculosis) in the WHO African Region in 2024 is estimated to be 57,000, which is about 15% of the global MDR/RR-TB burden [4]. High prevalence rates of HIV infection make outcomes for patients with drug-resistant TB even worse, since co-infection significantly increases the risk of treatment failure and death from the illness [5].

In Cameroon, an estimated 132 people per 100,000 population developed tuberculosis in 2024, corresponding to approximately 26,552 notified cases, with 14.3% co-infected with HIV. Despite a declining trend in incidence over the past decade and a treatment coverage of 69%, the COVID-19 pandemic temporarily disrupted surveillance, though notifications have shown steady recovery since 2022, reaching a historic peak of 26,552 cases in 2024. All TB patients are diagnosed and treated at the 390 diagnostic and treatment centers (CDTs) across the country under the coordination of the National TB Program [6]. Disparities exist in the distribution of DTC across the country, with the Centre (74), Littoral (53), and Far-North (62) regions concentrating the largest number of sites, while the Sud-Ouest (23), Sud (22), and Adamawa (21) regions remain the least served [6]. This may reflect geographic inequities in access to TB diagnostic and treatment services.

According to a national cross-sectional study conducted in 2018, the prevalence of RR-TB among newly bacteriologically confirmed pulmonary TB patients was found to be 1.6% (95% CI: 0.8–2.3%), slightly lower than the WHO estimated figure of 2.8%. The prevalence of RR/MDR-TB among previously treated patients has been found to range between 14 and 16% [7]. In drug resistance studies conducted in the Littoral Region, the incidence of MDR-TB was found to be 4.5%, whereas in the Northwest and Southwest regions, the prevalence of MDR-TB was 5.9% [8].

Treatment of DR-TB particularly its multidrug and rifampicin-resistant forms, involves extended second-line therapy that is considerably more toxic than routine first-line treatment. Treatment success rates for MDR/RR-TB remain significantly lower than for drug-susceptible TB globally, and mortality associated with drug-resistant disease is considerable, especially in regions where the burden of HIV is high [9].

Since the mid-2000s, Cameroon has had specialized units for treating DR-TB predominantly MDR/RR-TB cases with Jamot Hospital in Yaoundé being the main referral hospital in the country. Beginning in 2008, patients eligible for the programme were treated using a standard 12-month shorter treatment regimen involving gatifloxacin, clofazimine, prothionamide, ethambutol, and pyrazinamide for the entire period, with kanamycin and isoniazid in addition to the above drugs used for a minimum four-month intensive period [10]. In a prospective observational study carried out at two national MDR-TB treatment units, 134 out of 150 (89%) patients achieved successful treatment a feat that garnered worldwide attention [10].

The more recent information from Yaoundé shows increased adverse outcomes within routine program settings. A retrospective cohort study conducted at Jamot Hospital for 2013–2019 showed that male sex, HIV coinfection, and moderate-to-severe anemia were independent predictors of unfavorable treatment outcomes in rifampicin-resistant pulmonary tuberculosis patients [11]. A 2016–2017 database study from the Littoral Region revealed that the overall treatment success rate among DR-TB patients was 87.2%, and the risk factors for adverse outcomes included male sex, HIV status, and previous DR-TB treatment [12].

While existing systematic reviews have provided valuable insights into DR-TB treatment outcomes across Africa, country-specific estimates are essential for national program planning and resource allocation. Variations in treatment regimens, laboratory capacity, HIV prevalence, and health system performance across African countries limit the generalizability of regional estimates to Cameroon. Despite considerable primary research on DR-TB treatment in Cameroon, no systematic review has yet synthesized these data. Available studies are heterogeneous in design, duration, geographic coverage, and patient populations. A comprehensive synthesis of treatment outcomes, including treatment success, mortality, loss to follow-up, treatment failure, and adverse events, is therefore required to generate nationally representative estimates, explore sources of heterogeneity, and identify predictors of unfavorable outcomes. This evidence is essential for the National TB Program to optimize DR-TB service delivery and monitor progress toward the End TB Strategy.

Methods

Study design and registration

This systematic review and meta-analysis was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines [13]. The protocol was registered in the International Prospective Register of Systematic Reviews (PROSPERO identifier: CRD420261404490).

Eligibility criteria

Inclusion criteria: Studies were considered eligible if they: (1) were conducted in Cameroon, (2) included patients of any age with bacteriologically confirmed or clinically diagnosed drug-resistant tuberculosis (DR-TB), (3) employed an observational or interventional design (4) reported at least one WHO-defined treatment outcome (treatment success [cure and treatment completion], treatment failure, death, or loss to follow-up) or adverse drug reaction data; (5) were published in English or French and (6) involved human subjects.

Exclusion criteria: Case reports, narrative reviews, systematic reviews, meta-analyses, editorials, opinion pieces, conference abstracts, animal studies, in vitro or laboratory-only investigations, and studies where treatment outcomes, mortality, or adverse events for drug-resistant tuberculosis (DR-TB) patients could not be isolated from broader tuberculosis cohorts, were excluded. Studies with corrupted, incomplete, or unextractable outcome data were also excluded. Drug resistance surveillance studies not reporting patient-level treatment outcomes, and studies reporting outcomes only for drug-susceptible tuberculosis without disaggregation for DR-TB, were excluded. Duplicate publications of the same dataset were excluded, with the most complete and recent publication retained for analysis.

Outcomes measurement and definition

The primary outcomes included the pooled rates of treatment success (cured and treatment completion), loss to follow-up, treatment failure, mortality, and adverse drug reactions. Treatment outcomes were defined according to 2020 WHO guidelines [14]. Treatment failure was defined as a patient whose treatment regimen needed to be terminated or permanently changed to a new regimen or treatment strategy. Cured was defined as a patient

with pulmonary TB with bacteriologically confirmed TB at the beginning of treatment who completed treatment as recommended by the national policy, with evidence of bacteriologic response and no evidence of failure. Treatment completed was defined as a patient who completed treatment as recommended by the national policy but whose outcome did not meet the definition for cure or treatment failure. Mortality was defined as a patient who died before starting treatment or during the course of treatment. Lost to follow-up (LTFU) was defined as a patient who did not start treatment or whose treatment was interrupted for two consecutive months or more. Treatment success was defined as the sum of all patients cured and treatment completed. The prevalence of each outcome was calculated by dividing the number of patients experiencing the specific outcome by the total number of treated patients and presented in percentage. The secondary outcomes included factors associated with unfavorable outcomes. Unfavorable outcome included patients who were declared dead, LTFU, and treatment failure [15–17].

Search strategy

A comprehensive search was conducted in the following electronic databases: PubMed, Embase, Scopus, Web of Science, African Journals Online (AJOL), and the Cochrane Library. Grey literature was searched on Google Scholar, and reference lists of all selected studies were hand-searched. The search strategy employed controlled vocabulary terms (MeSH and Emtree) and free-text keywords using Boolean operators. For PubMed, the search strategy was as follow: ("MDR-TB"[tiab] OR "multidrug-resistant tuberculosis"[tiab] OR "multi-drug resistant tuberculosis"[tiab] OR "drug-resistant tuberculosis"[tiab]) AND ("Treatment Outcome"[MeSH] OR "Treatment Outcome"[tiab] OR "treatment success"[tiab] OR "cure rate"[tiab] OR "treatment completion"[tiab] OR "treatment failure"[tiab] OR "lost to follow-up"[tiab] OR "mortality"[tiab] OR "death"[tiab]) AND ("Cameroon"[MeSH] OR "Cameroon"[tiab] OR "Cameroun"[tiab]). The full search strategy by database is presented in Supplementary Materials (Table S1). The last search was performed on April 15, 2026.

All retrieved articles underwent deduplication and initial screening. Duplicates were excluded, and the remaining articles were screened against the inclusion criteria. Full texts of all articles were independently screened by two reviewers (FZLC and RT). Disagreements were resolved through discussion or consulting a third reviewer (MNT).

Data extraction

Data extraction was performed independently by two reviewers (FZLC and ADT) using a standardized data extraction form. Extracted information included study characteristics (first author, year of publication, year of study completion, study design, setting, region, sample size, tuberculosis disease localization, type of drug-resistant TB regimen, and outcome-related data. For each study, the total number of treated patients and the number with each treatment outcome (treatment success, death, loss to follow-up, and treatment failure) were extracted. Some studies contributed multiple reports based on distinct patient subgroups or treatment regimens, and the number of reports contributing to each outcome varied because not all reports provided data for every study outcome. Data on factors associated with unfavorable outcomes were also extracted. Disagreements between investigators were resolved through discussion or consultation with a third reviewer (MNT).

Quality assessment of included reports

The methodological quality of the included studies were assessed independently by two reviewers (FZLC and CA) using the Joanna Briggs Institute (JBI) critical appraisal tools, selected according to the design of each study. Disagreements were resolved by discussion or, when necessary, by involving a third reviewer (MNT) [18]. For cohort studies, the checklist contains eleven items assessing: the two groups were similar and recruited from the same population; exposures were measured similarly to assign people to exposed and unexposed groups; the

exposure was measured in a valid and reliable way; confounding factors were identified and strategies to deal with them stated; whether the groups/participants were free of the outcome at the start of the study (or at the moment of exposure); outcomes were measured in a valid and reliable way; whether the follow-up time was sufficient for outcomes to occur; follow-up was complete, with reasons for loss to follow-up described and explored; strategies to address incomplete follow-up were utilized; and appropriate statistical analysis was used. Each criterion was scored as 1 (yes) or 0 (no or unclear). In this study, we defined and applied the following categorization of the overall risk of bias: low = ≥70%, moderate = 50% − 69%, and high risk of bias = <50% of "Yes" scores.

Statistical analysis

Pooled prevalence estimates and associated factors were generated using a random-effects model. Heterogeneity was assessed using the I^2 statistic, with values categorized as low (<25%), moderate (25–75%), or high (>75%). The generalized linear mixed models (GLMM) with probit-logit transformation (PLOGIT) were employed to effectively handle meta-analyses of binary data and accommodate studies with 0% or 100% event rates without requiring continuity corrections [19]. Where sufficient data were available, subgroup analyses were conducted for each outcome. Statistical significance was defined as p-value < 0.05. All analyses were conducted using the 'meta' package in R Statistics version 4.6.1 [20]. Crude odds ratios were pooled, when available, to identify factors significantly associated with unfavorable outcomes. Factors reported in only one study were synthesized narratively.

Publication bias and sensitivity analysis

Publication bias was assessed graphically using funnel plots and statistically using Egger's linear regression test and Begg's rank correlation test [21, 22]. A two-tailed p-value < 0.05 was considered evidence of significant publication bias. Furthermore, a leave-one-out sensitivity analysis was performed to determine the influence of individual studies on the overall findings.

Results

Study selection and inclusion

A total of 291 records were identified through database searches (PubMed, $n = 13$; Scopus, $n = 28$; Web of Science, $n = 107$; Embase, $n = 34$; Cochrane Library, $n = 13$; African Journals Online, $n = 96$). After removing 23 duplicate records, 268 records were screened based on titles and abstracts. Of these, 230 records were excluded as they did not meet the eligibility criteria. The remaining 38 full-text reports were assessed for eligibility. Of these, 24 were excluded for various reasons. Additionally, 1,833 records were identified through other methods, comprising 176 from Google Scholar and 1,657 via reference list searching. After screening, 19 reports were sought for retrieval and assessed for eligibility, and 18 were excluded because they did not report the outcome of interest. In total, 15 studies were included in the final review (Fig. 1).

Characteristics of included studies

A total of 15 studies, conducted from 1998 to 2022, were included in this review, yielding 18 eligible reports based on distinct participant subgroups or treatment regimens. These studies were conducted across various regions of Cameroon, including the West, Littoral, Centre, North-West, South-West, and multi-regional settings. The majority were cohort studies ($n = 14$), with three cross-sectional studies and one case-control study. Most studies focused on patients with pulmonary tuberculosis (PTB; $n = 14$), with a few including both PTB and extrapulmonary TB (EPTB; $n = 3$).

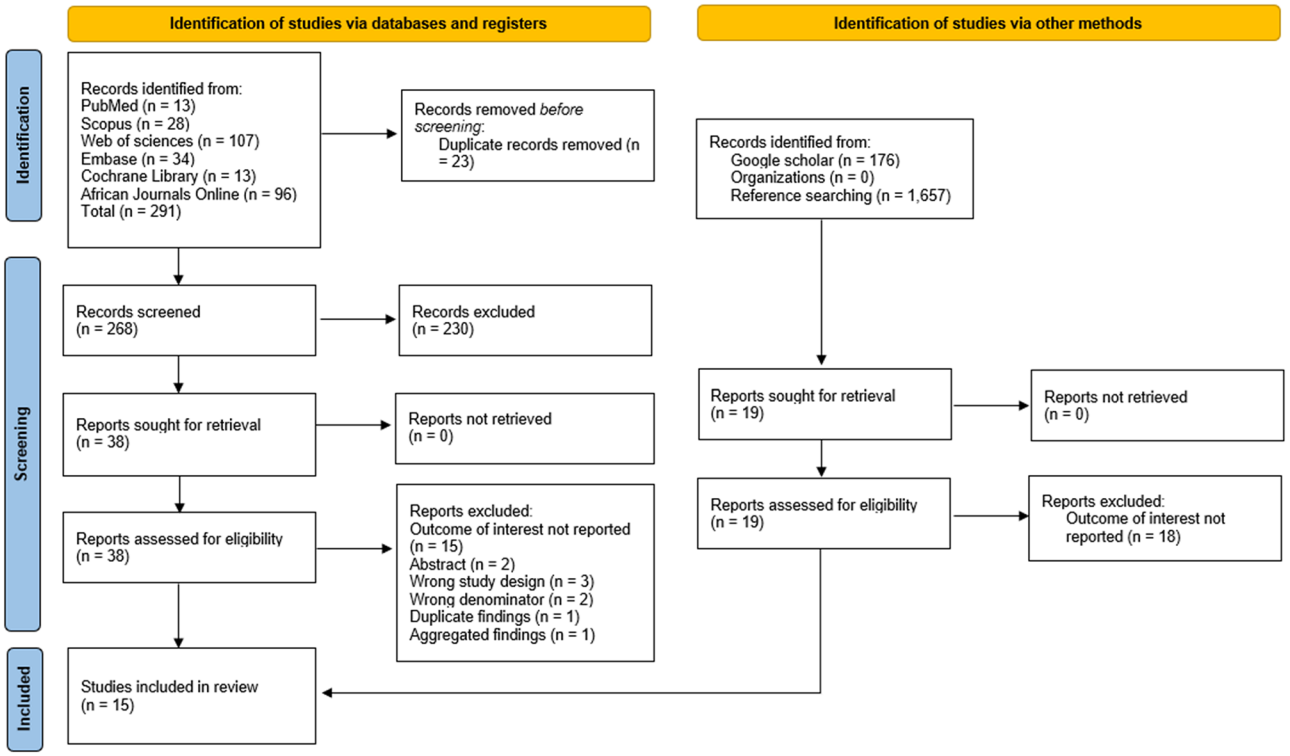

Fig. 1 PRISMA diagram flow from study identification to inclusion in the systematic review and meta-analysis [13]

The sample sizes ranged from 6 to 693 participants. Most studies ($n=13$) reported on patients receiving standard treatment regimens, while three studies evaluated modified regimens, including fluoroquinolone-resistant (FQR-Mtr) and second-line injectable-resistant (SLIr-Mtr) regimens, primarily among RR-TB or multidrug-resistant (MDR-TB) patients and patients from the general population.

Treatment outcomes were variably reported across studies. Among studies that reported treatment success ($n=13$), rates ranged from 0.0% to 100%. Death occurred in 0.0% to 14.9% of patients across studies reporting this outcome ($n=12$). Across 12 studies, the lost to follow-up rate ranged from 0.0% to 12.8%, and treatment failure ($n=13$) from 0.0% to 71.4%. Most of included studies ($n=9$) were rated as having low risk of bias (Table 1 and Table S2).

Drug-resistant tuberculosis mortality

The pooled mortality rate estimated with a random-effects model was 6.8% (95% CI: 4.7%-9.7%) among 2,351 participants from 14 study reports. The largest study ($n=693$) reported a mortality rate of 11.4% (95% CI: 9.1%-14.0%). Heterogeneity across studies was moderate ($I^2=58.1\%$; $p<0.003$) (Fig. 2). The finding was robust in the sensitivity analysis, and there was no significant sign of publication bias (Egger's [$p=0.062$] and Begg's test [$p=0.784$]) (Figs S1-2).

The type of participants was identified as a significant source ($p=0.007$) of heterogeneity among various subgroups explored for the pooled mortality rate among drug-resistant tuberculosis patients. Patients with RR-TB had the highest pooled mortality at 10.9% (95% CI: 9.2%-12.8%; 5 studies; $n=1,146$) with no heterogeneity ($I^2=0.0\%$). In contrast, patients with MDR-TB had a mortality of 5.0% (95% CI: 3.0%-8.3%; 3 studies; $n=280$), while retreated patients and those from the general population had intermediate estimates of 4.8% and 5.6%, respectively. Subgroup analyses revealed no statistically significant differences in pooled mortality estimates by study period, study design, region, tuberculosis localization, or treatment regimen (Table 2 and Figs. S3-9).

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Table 1 Synthesis of included studies characteristics

Author	Ref	Publication year	Study year[1]	Design	Region	Participant	Type of TB case	Total treated	Treatment	n (%)				Risk of bias
										Death	Success	Lost to follow-up	Failure	
Noeske,1998_1	[23]	2002	1998	Cohort	West	Patient from general population	PTB	127	Standard treatment	13 (10.2)	101 (79.5)	14/150 (9.3)	3 (2.4)	Moderate
Noeske,1998_2	[23]	2002	1998	Cohort	West	Patient from general population	PTB	23	Standard treatment	1 (3.7)	8 (34.8)		6 (26.1)	Moderate
Noeske,2009	[24]	2012	2009	Cohort	Littoral	Retreated TB patient	PTB	26	Standard treatment	0 (0.0)	12 (46.2)	3 (11.5)	11 (42.3)	Low
Kuaban,2011	[10]	2015	2011	Cohort	Multiregion	MDR-TB patient	PTB	150	Standard treatment	10 (6.7)	134 (89.3)	1 (0.7)	1 (0.7)	Low
Pefure-Yone,2012	[25]	2014	2012	Cohort	Centre	Patient from general population	PTB	7	Standard treatment	0 (0.0)	0 (0.0)	0 (0.0)	5 (71.4)	Low
Sander,2013	[26]	2016	2013	Case-control	Littoral, North-West, South-West, West	Retreated TB patient	PTB	80	Standard treatment	NR	NR	NR	32 (40.0)	Low
Schwoebel,2015	[27]	2020	2015	Cohort	Multiregion	RR-TB patient	PTB	176	Standard treatment	NR	149 (84.7)	NR	NR	Low
Kuaban,2015	[28]	2020	2015	Cohort	North-West, South-West, West, Littoral	Retreated TB patient	PTB	47	Standard treatment	7 (14.9)	32 (68.1)	6 (12.8)	0 (0.0)	Low
Merker,2015	[29]	2021	2015	Cross-sectional	North-West	RR-TB patient	PTB	195	Standard treatment	15 (7.7)	126 (64.6)	5 (2.6)	3 (1.5)	Low
Kuaban,2019	[11]	2021	2019	Cohort	Centre	RR-TB patient	PTB	242	Standard treatment	31 (12.8)	193 (79.4)	8 (3.3)	10 (4.1)	Low
Jouego,2019_1	[30]	2022	2019	Cohort	Multiregion	RR-TB patient	PTB	693	Standard treatment	79 (11.4)	587 (84.7)	26 (3.8)	1 (0.1)	Moderate
Jouego,2019_2	[30]	2022	2019	Cohort	Multiregion	RR-TB patient	PTB	6	FQR-Mtr	0 (0.0)	5 (83.3)	0 (0.0)	1 (16.7)	Moderate
Jouego,2019_3	[30]	2022	2019	Cohort	Multiregion	RR-TB patient	PTB	10	SLIr-Mtr	0 (0.0)	10 (100.0)	0 (0.0)	0 (0.0)	Moderate
Mpoh,2019	[31]	2023	2019	Cohort	Centre	MDR-TB patient	PTB and EPTB	107	Standard treatment	3 (2.8)	NR	NR	NR	Low
Ngangue,2020	[32]	2022	2020	Cross-sectional	North-West, South-West, Littoral	Patient from general population	PTB	274	Standard treatment	7 (2.6)	NR	10 (3.6)	NR	Low
Mbuh,2022	[33]	2024	2022	Cohort	Littoral	Patient from general population	PTB and EPTB	444	SLIr-Mtr	32 (7.2)	386 (86.9)	19 (4.3)	6 (1.4)	Low

Table 1 (continued)

Author	Ref	Publication year	Study year[1]	Design	Region	Participant	Type of TB case	Total treated	Treatment	n (%)				Risk of bias
										Death	Success	Lost to follow-up	Failure	
Mbuh,2017	[34]	2021	2017	Cross-sectional	Littoral	Patient from general population	PTB and EPTB	65	NR	NR	NR	NR	NR	Moderate
Poka-Mayap,2015	[35]	2020	2015	Cohort	Centre	MDR-TB patient	PTB	79	NR	NR	NR	NR	NR	Low

1: Year of study completion; Ref: Reference; TB: Mycobacterium tuberculosis; FQR-Mtr: Fluoroquinolone-resistant modified treatment regimen; SLIr-Mtr: Second-line injectable-resistant modified treatment regimen; RR-TB: Rifampicin-resistant Mycobacterium tuberculosis; MDR-TB: Multidrug-resistant Mycobacterium tuberculosis; NR; Not reported; PTB: Pulmonary Mycobacterium tuberculosis; EPTB: Extra-Pulmonary Mycobacterium tuberculosis; The sum of all outcomes in some studies does not reach 100% because some patients were transferred out during treatment

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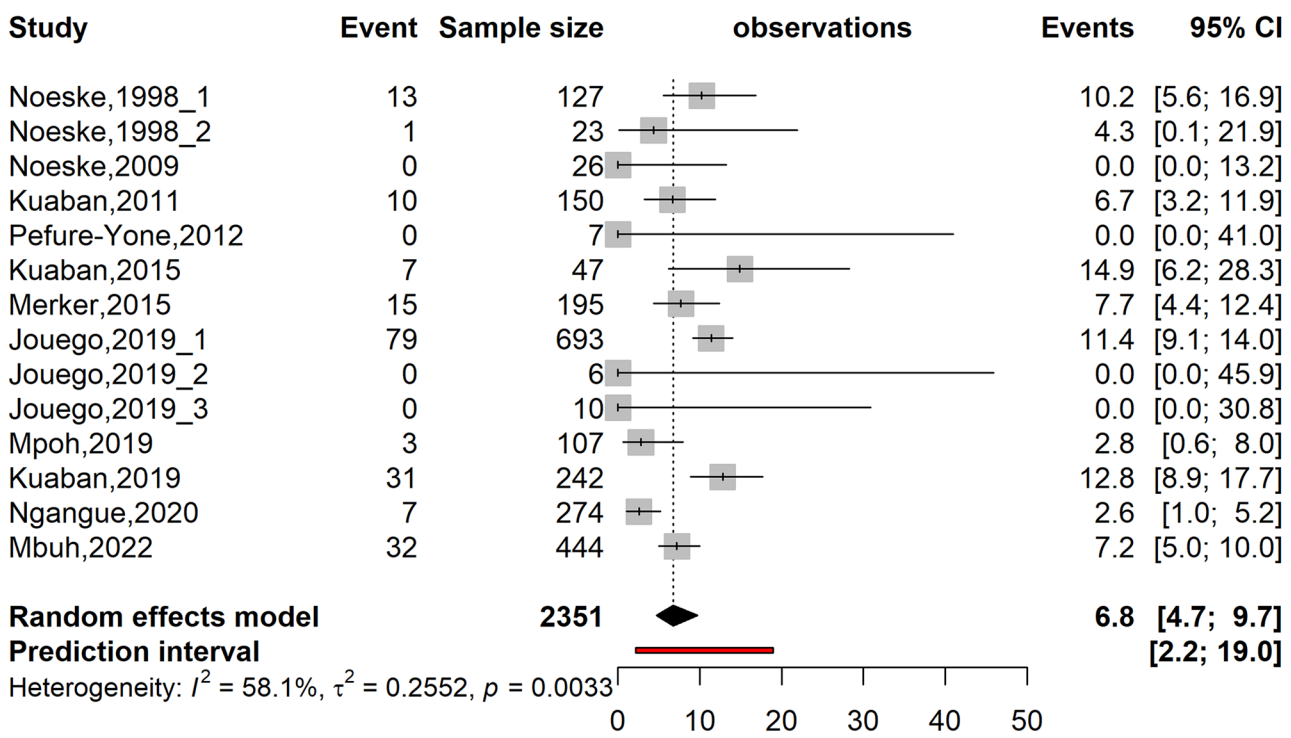

Fig. 2 Forest plot of the pooled mortality rate among anti-tuberculosis drug-resistant patients in Cameroon, 1998–2022

Drug-resistant tuberculosis treatment success

The overall pooled success rate was 74.2% (95% CI: 60.4%-84.4%; 13 reports) among 2,146 patients. However, high heterogeneity was observed across studies (I^2 = 88.1%; p < 0.001). Individual study success rates from 0.0% (95% CI: 0.0%-41.0%) to 100.0% (95% CI: 69.2%-100.0%) (Fig. 3). The sensitivity analysis revealed that the pooled estimate was robust, with no study significantly influencing the overall pooled estimate. There was no significant sign of publication bias (Egger's test p = 0.191 and Begg's test p = 0.222) (Figs. S10-11).

Subgroup analyses revealed significant effect modification for study period (p < 0.001), region (p < 0.001), disease localization (p = 0.014), and treatment regimen (p = 0.003). The success rates increased progressively over time; in the earliest period (<2005), the pooled estimate was 60.6% (95% CI: 27.5%-86.2%, 2 studies; n = 150 participants). This rose to 79.4% (95% CI: 71.8%-85.4%; 7 studies; n = 1,369) in the 2015–2019 period, and reached 86.9% (95% CI: 83.4%-89.9%; 1 study; n = 444) in the 2020+ period.

Patients with rifampicin-resistant tuberculosis achieved the highest success rate at 81.0% (95% CI: 72.9%-87.1%; n = 6 studies; n = 1,322). Patients from general population had the lowest success rate, at 51.7% (95% CI: 4.9%-95.7%; 3 studies; n = 578).

Geographically, the highest pooled estimate was observed in Multiregion studies (84.5%; 95% CI: 78.9%-88.8%; 6 studies; n = 1,082) and the lowest in the Centre region (18.0%; 95% CI: 0.1%-98.5%; 2 studies; n = 249).

Patients with mixed pulmonary and extrapulmonary tuberculosis achieved a success rate of 86.9% (95% CI: 83.4%-89.9%; 1 study; n = 444), compared to 72.6% (95% CI: 57.2%-83.9%; 12 studies; n = 1,702) among patients with pulmonary tuberculosis only. However, the mixed-group estimate should be interpreted with caution, as it is derived from a single study.

Patients receiving modified regimens comprising adapted treatment for fluoroquinolone resistance or second-line drug resistance achieved a pooled success rate of 87.2% (95% CI: 83.8% − 89.9%; 3 studies; n = 460). In

Table 2 Subgroup meta-analysis of mortality rate among drug-resistant tuberculosis patients in Cameroon, 1998–2022

Subgroup	Sample size	**Prevalence[1](%)**	**95% CI limits[1]**		Number of reports	**Heterogeneity statistic[1]**		Subgroup difference
			Lower	Upper		I^2**(%)**	***p*-value**	***p*-value**
Study period (year)[2]								0.637
<2005	150	9.3	5.6	15.1	2	0.0	0.387	
2005–2009	26	0.0	0.0	13.2	1	-	-	
2010–2014	157	6.4	3.5	11.4	2	0.0	0.999	
2015–2019	1,300	9.0	5.9	13.3	7	39.8	0.126	
2020+	718	4.6	2.2	13.1	2	84.7	0.011	
Study design								0.329
Cross-sectional	469	4.5	2.1	9.6	2	83.6	0.013	
Cohort	1,882	8.0	5.6	11.2	12	33.5	0.122	
Region								0.850
Centre	356	5.9	1.8	17.5	2	0.0	0.999	
Littoral	470	6.8	4.9	9.5	2	0.0	0.999	
North-West	195	7.7	4.4	12.4	1	-	-	
West	150	9.3	5.6	15.1	2	0.0	0.387	
Multi-region	1,180	6.5	3.4	12.2	6	73.4	0.002	
Participant								0.007
Patient from general population	852	5.6	3.0	10.3	4	68.7	0.022	
Retreated tuberculosis patient	73	4.8	0.3	48.3	2	0.0	0.999	
Rifampicin-resistant tuberculosis	1,146	10.9	9.2	12.8	5	0.0	0.552	
Multidrug-resistant tuberculosis	280	5.0	3.0	8.3	3	0.0	0.391	
Tuberculosis disease localization								0.637
Pulmonary	1,800	7.2	4.8	10.7	12	51.7	0.019	
Mixed	551	6.4	4.6	8.7	2	61.6	0.107	
Treatment regimen[3]								0.955
Standard treatment	1,891	6.9	4.5	10.3	11	64.4	0.002	
Other regimen	460	7.0	5.0	9.7	3	0.0	1.000	
Risk of bias								0.378
Moderate	1,329	8.5	5.9	11.9	7	1.3	0.415	
Low	1,022	6.4	3.8	10.7	7	74.8	<0.001	

1: Random effects model; 2: Time frame aligns with the development of successive National Strategic Plans against tuberculosis in Cameroon; CI: Confidence interval; Mixed included pulmonary and extrapulmonary tuberculosis cases; 3: Other regimen included fluoroquinolone resistant modified treatment regimen [FQr-Mtr] and second-line injectable-resistant modified treatment regimen [SLIr-Mtr]

contrast, patients receiving standard treatment regimens had a pooled success rate of 68.8% (95% CI: 52.2%-81.6%; 10 studies; $n=1,686$) (Table 3 and Figs. S12-18).

Drug-resistant tuberculosis loss to follow-up

The overall pooled LTFU rate was 4.1% (95% CI: 2.8%- 6.1%; 12 studies; $n=2,244$ participants), with moderate heterogeneity ($I^2=55.5\%$; $p=0.010$) (Fig. 4). The overall pooled estimate was robust in the sensitivity analysis and no significant sign of publication bias was detected (Egger's test $p=0.885$ and Begg's test $p=0.784$) (Figs. S19-20).

Subgroup analyses revealed significant effect modification for participant subgroup ($p=0.001$), study period ($p=0.009$) and region ($p=0.030$). No significant effect modification was observed for tuberculosis disease localization ($p=0.879$), study design ($p=0.354$), and treatment regimen ($p=0.937$).

Retreated tuberculosis patients had the highest LTFU rate at 12.3% (95% CI: 6.5%-22.0%, 2 studies; $n=73$), which was significantly higher than patients from the general population at 5.0% (95% CI: 3.2%-7.8%, 4 studies; $n=875$) and rifampicin-resistant TB patients at 3.4% (95% CI: 2.5%-4.6%, 5 studies; $n=1,146$).

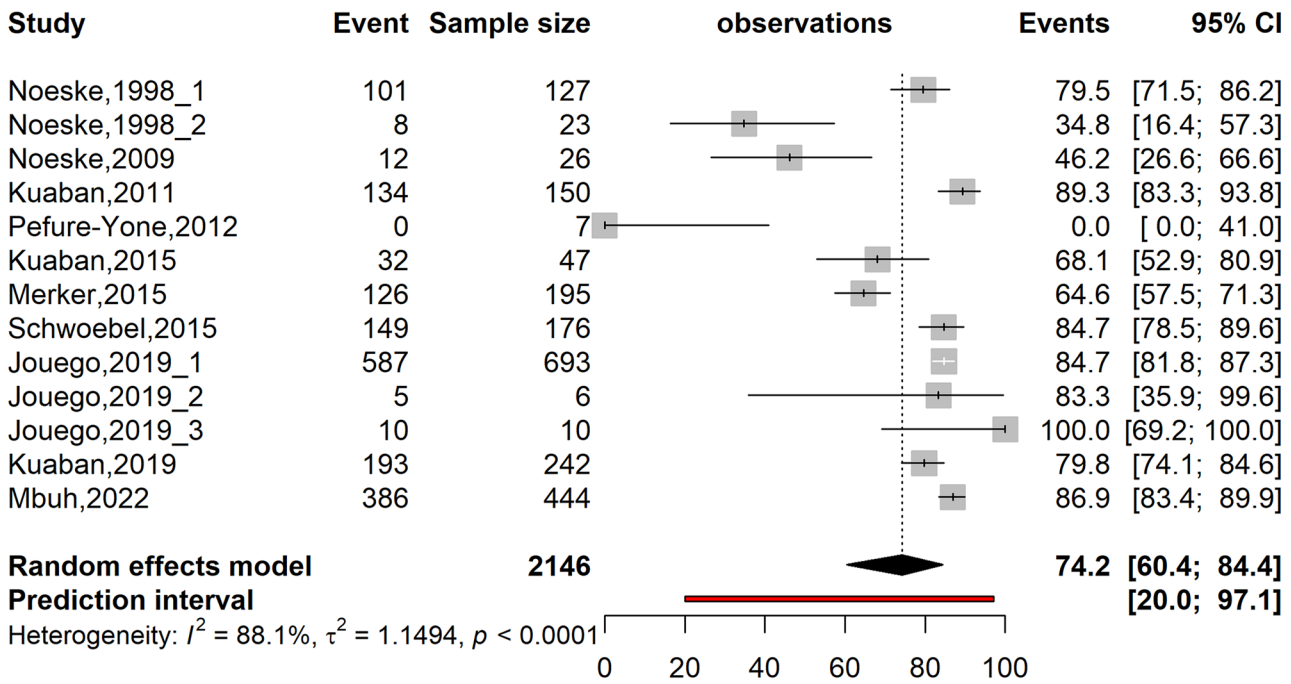

Fig. 3 Forest plot of the pooled treatment success rate among anti-tuberculosis drug-resistant patients in Cameroon, 1998–2022

A significant temporal trend toward a decline in LTFU was observed. The earliest periods reported higher rates of 9.3% (95% CI: 5.2%-15.2%, 1 study; $n=150$) for <2005 and 11.5% (95% CI: 2.4%-30.2%, 1 study; $n=26$) for 2005–2009, while studies conducted after 2015 reported consistently lower rates of 3.8% (95% CI: 2.8%-5.0%, 6 studies; $n=1{,}193$) for 2015–2019 and 4.0% (95% CI: 2.8%-5.8%, 2 studies; $n=718$) for 2020+ (Table 4 and Figs. S21-27).

Drug-resistant tuberculosis treatment failure

In this meta-analysis of 13 studies evaluating treatment failure rates among patients with drug-resistant tuberculosis in Cameroon (1998–2022), the individual study estimates varied widely, ranging from 0.0% to 71.4%. The pooled failure rate was 4.2% (95% CI: 1.1–14.3), but this summary estimate should be interpreted with caution due to substantial heterogeneity ($I^2=93.3\%$, $p<0.001$), indicating that the true effect is not consistent across settings (Fig. 5). The overall pooled failure rate was robust at sensitivity analysis, and no significant sign of publication bias was detected (Egger's test $p=0.133$ and Begg's test $p=0.903$) (Figs. S28-29).

The subgroup meta-analysis examining factors influencing treatment failure rates among patients with drug-resistant tuberculosis in Cameroon, revealed significant effect modification by study period ($p < 0.001$) and design ($p=0.001$). The temporal pattern was marked by a significant decline in failure rates from 8.0% (95% CI: 1.3–37.0; 2 studies; $n=150$) in <2005 to 1.1% (95% CI: 0.3–4.6; 6 studies; $n=1{,}193$) in 2015–2019 and 1.4% (95% CI: 0.5–2.9; 1 study, $n=444$) from 2020 onwards, coinciding with the implementation of successive National Strategic Plans against tuberculosis. Other characteristics including region of study implementation, type of participants, tuberculosis disease localization, treatment regimen, and overall risk of bias were not significant sources of heterogeneity between included reports. (Table 5 and Figs. S30-36).

Table 3 Subgroup meta-analysis of treatment success rate among drug-resistant tuberculosis patients in Cameroon, 1998–2022

Subgroup	Sample size	Prevalence[1](%)	95% CI limits[1]		Number of reports	Heterogeneity statistic[1]		Subgroup difference
			Lower	Upper		I^2(%)	*p*-value	*p*-value
Study period (year)[2]								<0.001
<2005	150	60.6	27.5	86.2	2	93.9	<0.001	
2005–2009	26	46.2	26.6	66.6	1	-	-	
2010–2014	157	19.8	0.0	99.5	2	0.0	0.999	
2015–2019	1,369	79.4	71.8	85.4	7	86.1	<0.001	
2020+	444	86.9	83.4	89.9	1	-	-	
Study design								0.660
Cross-sectional	195	64.6	57.5	71.3	1	-	-	
Cohort	1,951	75.0	59.6	85.6	12	83.2	<0.001	
Region								<0.001
Centre	249	18.0	0.1	98.5	2	0.0	0.999	
Littoral	470	71.9	38.0	91.4	2	95.8	<0.001	
North-West	195	64.6	57.5	71.3	1	-	-	
West	150	60.6	27.5	86.2	2	93.9	<0.001	
Multi-region	1,082	84.5	78.9	88.8	6	57.0	0.040	
Participant								0.051
Patient from general population	578	51.7	4.9	95.7	3	52.9	0.119	
Retreated tuberculosis patient	73	59.2	43.5	73.2	2	69.6	0.070	
Rifampicin-resistant tuberculosis	1,322	81.0	72.9	87.1	6	87.3	<0.001	
Multidrug-resistant tuberculosis	173	68.9	24.1	93.9	2	96.6	<0.001	
Tuberculosis disease localization								0.014
Pulmonary	1,702	72.6	57.2	83.9	12	87.3	<0.001	
Mixed	444	86.9	83.4	89.9	1	-	-	
Treatment regimen[3]								0.003
Standard treatment	1,686	68.8	52.2	81.6	10	89.6	<0.001	
Other regimen	460	87.2	83.8	89.9	3	0.0	0.967	
Risk of bias								0.272
Moderate	1,303	80.8	63.7	91.0	6	84.5	<0.001	
Low	843	67.5	45.5	83.8	7	87.6	<0.001	

1: Random effects model; 2: Time frame aligns with the development of successive National Strategic Plans against tuberculosis in Cameroon; CI: Confidence interval; Mixed included pulmonary and extrapulmonary tuberculosis cases; 3: Other regimen included fluoroquinolone resistant modified treatment regimen [FQr-Mtr] and second-line injectable-resistant modified treatment regimen [SLIr-Mtr]

GRADE assessment

Based on the GRADE assessment, the certainty of evidence was low for mortality and loss to follow-up, and very low for treatment success and treatment failure (Table S3).

Prevalence of adverse drug events

The pooled prevalence of ADEs among patients treated for multidrug-resistant tuberculosis in Cameroon was 70.8% (95% CI: 40.2–89.7; $I^2 = 96.1\%$; 3 studies; $n = 251$), indicating that the majority of patients experienced at least one ADE during treatment. Among specific ADE types, ototoxicity and gastro-intestinal disorders were the most frequently reported, with pooled prevalences of 41.9% (95% CI: 23.7–62.6; $I^2 = 93.2\%$; 3 studies; $n = 251$) and 40.9% (95% CI: 25.5–58.2; $I^2 = 89.5\%$; 2 studies; $n = 172$), respectively. The pooled prevalence of nephrotoxicity and neurological disorders showed moderate heterogeneity ($I^2 \leq 50\%$). Substantial heterogeneity was observed for most ADE types, particularly for the overall prevalence; ototoxicity, gastrointestinal disorders, and hepatotoxicity ($I^2 \geq 80\%$) (Fig. 6 and S37).

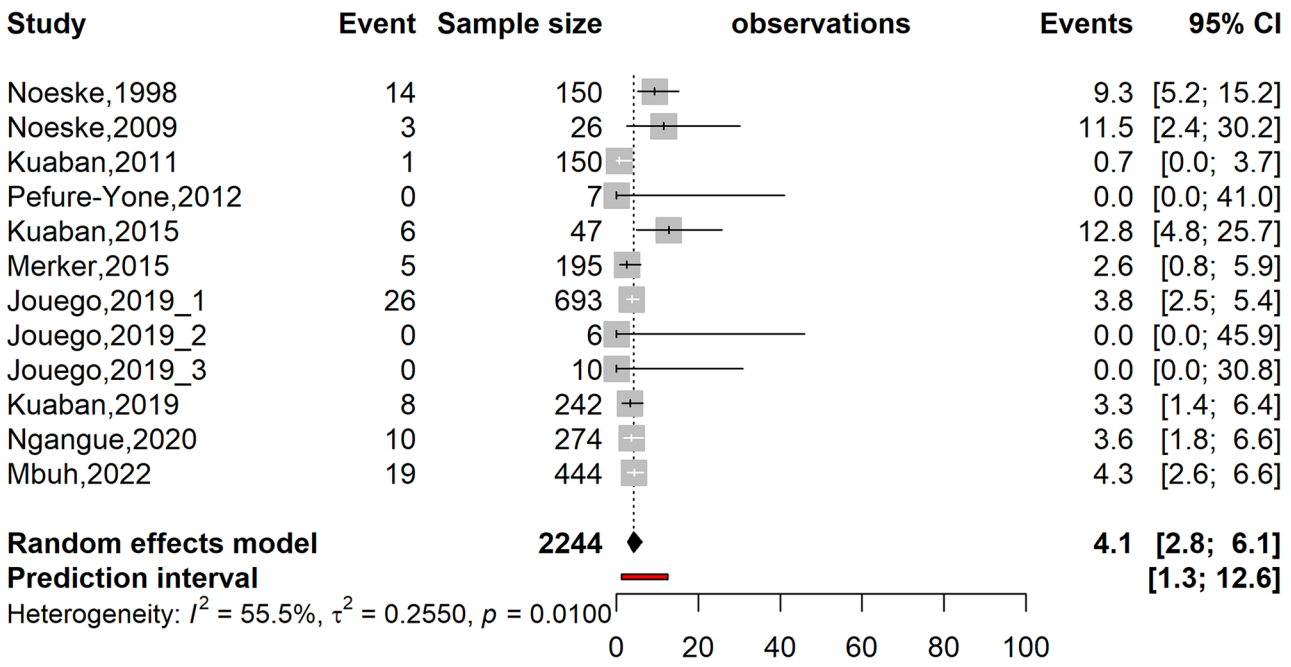

Fig. 4 Forest plot of the pooled loss to follow-up rate among anti-tuberculosis drug-resistant patients in Cameroon, 1998–2022

Factors associated with unfavorable treatment outcomes

Meta-analysis: Withing studies conducted from 2011 to 2022, HIV-positive status was identified as a significant predictor of unfavorable treatment outcomes among drug-resistant tuberculosis patients in Cameroon, with a pooled odds ratio of 2.76 (95% CI: 1.95–3.93; 6 studies). This indicated that HIV-coinfected patients had three times the odds of experiencing an unfavorable outcome compared to HIV-negative patients. The patient sex was also significantly associated with unfavorable outcome. Male sex was associated with 73% increased odds of unfavorable treatment outcomes following DR-TB management (OR: 1.73; 95% CI: 1.25–2.40; 5 studies) (Table 6 and Figs. S38-40).

Narrative review: Several additional predictors of unfavorable treatment outcomes were reported in individual studies but could not be included in the meta-analysis because they were not consistently evaluated across studies. These findings should therefore be interpreted as evidence from individual studies rather than pooled estimates. Among these, multidrug-resistant tuberculosis (MDR-TB) was associated with the highest odds of unfavorable treatment outcomes compared with non-MDR-TB (OR = 11.47, 95% CI: 3.12–42.12; $p < 0.001$) [23]. A history of previous DR-TB treatment was associated with a nearly 4-fold increased risk of poor outcomes (adjusted relative risk [aRR] = 3.9, 95% CI: 1.3–12.0, $p = 0.02$); however, this finding was based on a very small sample ($n = 9$) and should be interpreted with caution [33]. Missing baseline second-line drug susceptibility testing (DST) results were associated with a 65% higher mortality risk in RR-TB patients (adjusted sub-hazard ratio [aSHR] = 1.65, 95% CI: 1.04–2.60, $p = 0.03$). This finding was based on a very small sample ($n = 9$) and should be interpreted with caution [30]. Moderate to severe anemia (hemoglobin ≤ 10 g/dL) independently predicted unfavorable outcomes in RR-TB patients (OR: 2.87, 95% CI: 1.25–6.58, $p = 0.013$) [11]. Underweight (body mass index [BMI] <18.5 kg/m^2) significantly increased the risk of unfavorable outcome (adjusted hazard ratio [AHR]: 1.8, 95% CI: 1.4–2.5) [27]. Fluoroquinolone resistance was a strong predictor of bacteriological failure or relapse (AHR: 6.8, 95% CI: 3.5–13.2), while isoniazid resistance was also associated with an increased risk of failure/relapse (AHR: 9.4, 95% CI: 1.3–68.0) [27]. Extensive lung lesions (≥50% of lung zones affected) were independently associated with higher mortality risk (AHR: 1.6, 95% CI: 1.06–2.3) [27]. Additionally, age > 40 years was

Table 4 Subgroup meta-analysis of loss to follow-up rate among drug-resistant tuberculosis patients in Cameroon, 1998–2022

Subgroup	Sample size	Prevalence[1](%)	95% CI limits[1]		Number of studies	Heterogeneity statistic[1]		Subgroup difference
			Lower	Upper		I^2(%)	*p*-value	*p*-value
Study period (year)[2]								0.009
<2005	150	9.3	5.2	15.2	1	-	-	
2005–2009	26	11.5	2.4	30.2	1	-	-	
2010–2014	157	0.6	0.1	4.4	2	0.0	0.999	
2015–2019	1,193	3.8	2.8	5.0	6	48.3	0.085	
2020+	718	4.0	2.8	5.8	2	0.0	0.678	
Study design								0.354
Cross-sectional	469	3.2	1.9	5.2	2	0.0	0.512	
Cohort	1,775	4.5	2.7	7.3	10	58.6	0.010	
Region								0.030
Centre	249	3.2	1.6	6.3	2	0.0	0.010	
Littoral	470	4.7	3.1	7.0	2	62.3	0.103	
North-West	195	2.6	0.8	5.9	1	-	-	
West	150	9.3	5.2	15.2	1	-	-	
Multi-region	1,180	3.4	1.5	7.3	6	57.1	0.040	
Participant								0.001
Patient from general population	875	5.0	3.2	7.8	4	57.7	0.069	
Retreated tuberculosis patient	73	12.3	6.5	22.0	2	0.0	0.879	
Rifampicin-resistant tuberculosis	1,146	3.4	2.5	4.6	5	0.0	0.890	
Multidrug-resistant tuberculosis	150	0.7	0.0	3.7	1	-	-	
Tuberculosis disease localization								0.879
Pulmonary	1,800	4.1	2.5	6.5	11	59.2	0.006	
Mixed	444	4.3	2.6	6.6	1	-	-	
Treatment regimen[3]								0.937
Standard treatment	1,784	4.2	2.6	6.9	9	67.4	0.002	
Other regimen	460	4.1	2.6	6.4	3	0.0	1.000	
Risk of bias								0.228
Moderate	1,329	5.2	3.4	7.8	6	53.0	0.059	
Low	915	3.2	1.7	6.1	6	61.5	0.024	

1: Random effects model; 2: Timeframe aligns with the development of successive National Strategic Plans against tuberculosis in Cameroon; CI: Confidence interval; Mixed included pulmonary and extrapulmonary tuberculosis cases; 3: Other regimen included fluoroquinolone resistant modified treatment regimen [FQr-Mtr] and second-line injectable-resistant modified treatment regimen [SLIr-Mtr]

associated with a 62% higher risk of overall mortality among RR-TB patients (aSHR: 1.62, 95% CI: 1.01–2.60, $p=0.045$) [30].

Discussion

This systematic review and meta-analysis provide the first comprehensive synthesis of treatment outcomes among patients with DR-TB in Cameroon. In our review, the treatment success rate was 74.2%. Mortality, loss to follow-up, and treatment failure rates were 6.8%, 4.1%, and 4.2%, respectively. ADEs were common, affecting about 70.8% of patients. The most frequent complications were ototoxicity and gastrointestinal problems. HIV-positive status and male sex were significantly associated with unfavorable treatment outcomes. Although treatment success has improved over time and negative outcomes have decreased, there were still substantial differences between studies. These differences likely reflect variations in patient groups, treatments, healthcare settings, and program periods.

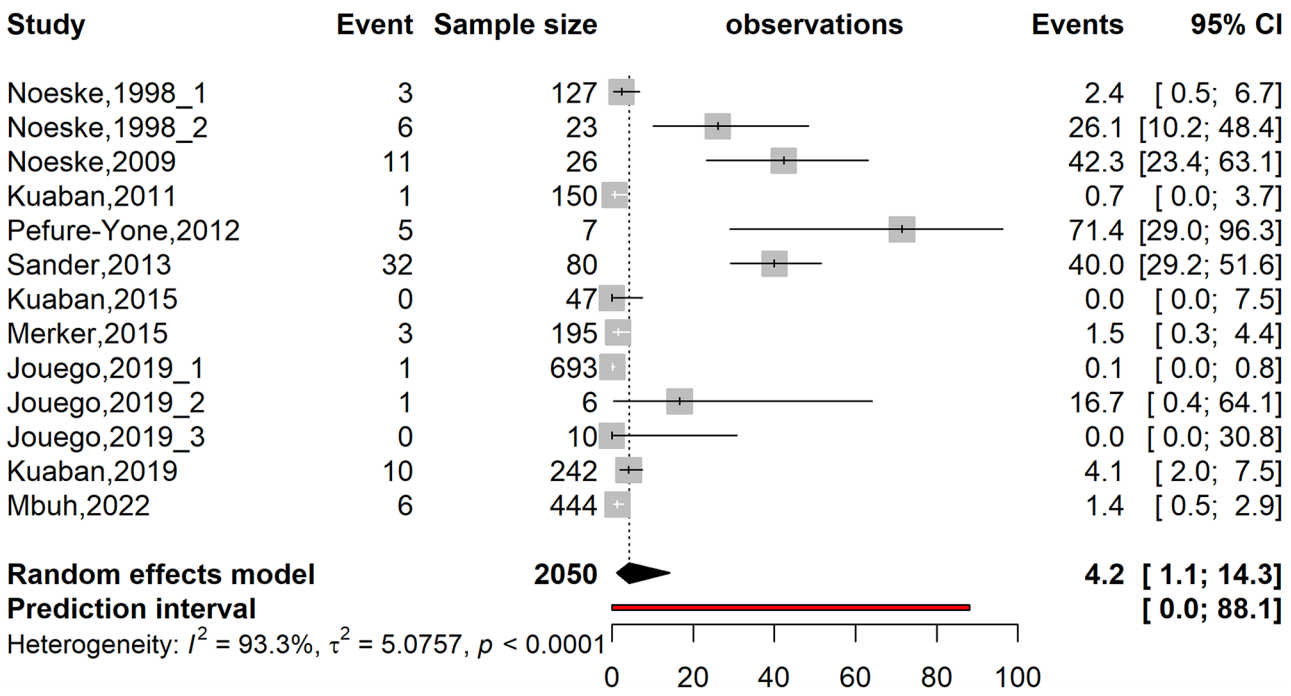

Fig. 5 Forest plot of the pooled treatment failure rate among anti-tuberculosis drug-resistant patients in Cameroon, 1998–2022

This review found that approximately 74.2% of patients with DR-TB in Cameroon achieved successful treatment outcomes, indicating that nearly three-quarters of patients completed treatment successfully. This study success rate was lower than the national target set 85% set in the 2024–2026 national strategic plan [36]. This suggests that efforts are still needed to strengthen drug-resistant TB patient management in order to improve the success rate and achieve the national target. Nevertheless, This treatment success proportion corroborated the recent global estimate of 71% among patients with MDR/RR-TB reported by the World Health Organization (WHO) [37], and is comparable to the 74.6% reported in a systematic review and meta-analysis from Central and West Africa [38]. The similarity between our findings and those reported in Central and West Africa may reflect comparable epidemiological characteristics, treatment strategies, and programmatic approaches adopted across countries in the region. Notably, treatment success improved from approximately 61% in studies conducted before 2005 to nearly 87% in studies conducted from 2020 onwards, suggesting substantial improvements in DR-TB programme performance over successive implementation periods.

Over time, improvements such as better diagnostic tools, expanded rapid molecular and drug-susceptibility testing, more decentralized care, and stronger patient monitoring have likely helped increase treatment success. These changes align with global trends, in which treatment success has gradually improved since the introduction of WHO-recommended shorter regimens and patient-centered care models [39, 40]. Although patients receiving modified regimens achieved higher treatment success than those receiving standard regimens, this finding should be interpreted with caution, as it is based on a small number of observational studies. Additionally, treatment periods differed substantially across studies. Confounding by timeframe is likely, as improvements in diagnostics, treatment monitoring, and health systems over the study period may have contributed to better outcomes independently of the regimen type. Furthermore, newer WHO recommendations for MDR-TB treatment usually coincide with broader health system strengthening, which may have influenced patient outcomes.

In our review, we observed a pooled mortality proportion of 6.8%, which indicates that death remains an important unfavorable outcome among patients with DR-TB in Cameroon. This pooled mortality is lower than estimates reported in systematic reviews from Central and West Africa and among HIV co-infected MDR-TB patients in sub-Saharan Africa [38, 41, 42]. However, these comparisons should be interpreted with caution due

Table 5 Subgroup meta-analysis of failure rate among drug-resistant tuberculosis patients in Cameroon, 1998–2022

Subgroup	Sample size	Prevalence[1](%)	95% CI limits[1]		Number of studies	Heterogeneity statistic[1]		Subgroup difference
			Lower	Upper		I^2(%)	*p*-value	*p*-value
Study period (year)[2]								<0.001
<2005	150	8.0	1.3	37.0	2	92.1	<0.001	
2005–2009	26	41.3	23.4	63.1	1	-	-	
2010–2014	237	18.1	1.1	81.4	3	91.4	<0.001	
2015–2019	1,193	1.1	0.3	4.6	6	66.0	0.012	
2020+	444	1.4	0.5	2.9	1	-	-	
Study design								0.001
Cross-sectional	195	1.5	0.3	4.4	1	-	-	
Case-control	80	40.0	29.2	51.6	1	-	-	
Cohort	1,775	3.5	0.8	14.2	11	90.7	<0.001	
Region								0.064
Centre	249	22.7	1.5	84.5	2	95.1	<0.001	
Littoral	470	8.8	0.6	61.3	2	97.9	<0.001	
North-West	275	9.2	0.7	60.1	2	97.2	<0.001	
West	150	8.0	1.3	37.0	2	92.1	<0.001	
Multi-region	906	0.4	0.1	2.6	5	64.8	0.023	
Participant								0.451
Patient from general population	578	7.6	0.6	54.8	3	93.7	<0.001	
Retreated tuberculosis patient	153	12.4	0.7	74.2	3	0.0	0.979	
Rifampicin-resistant tuberculosis	1,146	1.4	0.3	5.9	5	72.8	0.005	
Multidrug-resistant tuberculosis	173	4.5	0.2	46.8	2	92.2	<0.001	
Tuberculosis disease localization								0.133
Pulmonary	1,606	4.6	1.1	17.1	12	92.1	<0.001	
Mixed	444	1.4	0.5	2.9	1	-	-	
Treatment regimen[3]								0.178
Standard treatment	1,590	4.9	1.0	20.4	10	93.6	<0.001	
Other regimen	460	1.5	0.7	3.2	3	61.9	0.072	
Risk of bias								0.325
Moderate	1,303	2.2	0.4	10.4	6	88.0	<0.001	
Low	747	7.2	1.2	33.9	7	93.9	<0.001	

1: Random effects model; 2: Timeframe aligns with the development of successive National Strategic Plans against tuberculosis in Cameroon; CI: Confidence interval; Mixed included pulmonary and extrapulmonary tuberculosis cases; 3: Other regimen included fluoroquinolone-resistant modified treatment regimen [FQr-Mtr] and second-line injectable-resistant modified treatment regimen [SLIr-Mtr]

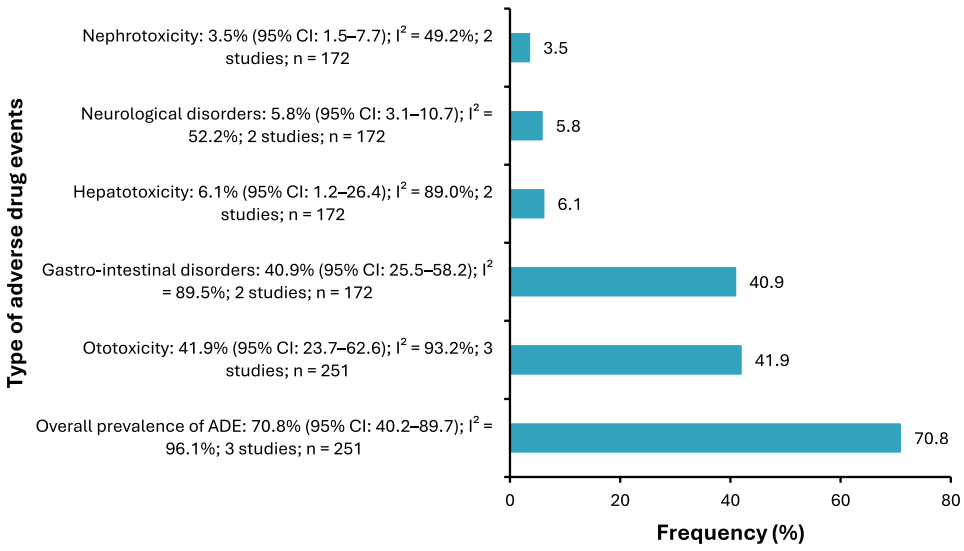

Fig. 6 Pooled prevalence of adverse drug events (ADE) types among patients treated for multidrug-resistant tuberculosis disease in Cameroon, 2015–2019

Table 6 Predictors of unfavorable outcome among patients treated for drug-resistant tuberculosis in Cameroon, 2011–2022

Predictor	Modality	OR[1]	95% Confidence interval		Reports included	Heterogeneity	
			Lower	Upper		I^2(%)	*p*-value
Sex	Male vs. Female	1.73	1.25	2.40	5	41.0	0.148
HIV status	Positive vs. Negative	2.76	1.95	3.93	6	46.8	0.094
Previous TB treatment	Yes vs. No	0.87	0.59	1.29	2	0.0	0.536

[1] Random effect model; TB: Mycobacterium tuberculosis disease; HIV: Human immunodeficiency virus;

to differences in study populations, treatment regimens, and healthcare settings. The relatively low mortality observed in Cameroon may reflect improvements in early diagnosis, wider access to drug-susceptibility testing, expansion of specialized DR-TB treatment centers, and strengthened programmatic management under the National Tuberculosis Program. In addition, the progressive integration of TB and HIV services and improved access to antiretroviral therapy may have contributed to better survival among co-infected patients [43]. Nevertheless, mortality remains an important challenge, particularly among patients with HIV co-infection and severe anemia, both of which have been consistently associated with unfavorable treatment outcomes in Cameroon and other settings [28, 41, 42]. These findings underscore the importance of strengthening early case detection, integrating TB screening in HIV management, and ensuring prompt initiation of effective treatment to further reduce mortality among patients with DR-TB in Cameroon.

The pooled LTFU proportion of 4.1% in our review indicates relatively good retention among patients receiving DR-TB treatment in Cameroon. Moreover, LTFU declined over time, from 9.3% before 2005 to approximately 4% in studies conducted after 2015. This trend likely reflects improvements in patient follow-up and the progressive strengthening of DR-TB services under the National Tuberculosis Program. However, retreated tuberculosis patients had a substantially higher LTFU than other patient groups, suggesting that previous treatment history remains an important barrier to treatment completion. Similar observations have been reported in previous studies, where treatment fatigue, prolonged treatment duration, socioeconomic challenges, and previous negative treatment experiences contributed to poor adherence among previously treated patients [42, 44]. These findings highlight the importance of providing targeted adherence support for patients with a history of previous tuberculosis treatment.

Similarly, the pooled treatment failure proportion of 4.2% was relatively low and declined markedly over successive study periods. The reduction in treatment failure probably reflects improvements in diagnosis, treatment monitoring, and the implementation of more effective treatment regimens. However, treatment failure remained an important unfavorable outcome, particularly in earlier study periods, highlighting the need for continued efforts to optimize DR-TB management. These findings underscore the importance of expanding drug susceptibility testing and ensuring timely initiation of appropriate treatment to further reduce treatment failure among patients with DR-TB in Cameroon, in line with current WHO recommendations [45].

The pooled prevalence of ADEs of 70.8% in this review indicates that treatment-related toxicity remains a challenge in the management of DR-TB in Cameroon. However, these pooled estimates are based on a limited number of studies, all conducted during the 2015–2019 period, and should therefore be interpreted with caution. Ototoxicity and gastrointestinal disorders were the most frequently reported adverse events, consistent with previous reports from Cameroon and the known toxicity profile of second-line anti-tuberculosis drugs [34, 35]. These adverse events may compromise treatment adherence and contribute to unfavorable treatment outcomes. The high burden of ADEs observed in this review further supports the WHO recommendation to transition from injectable-containing regimens to safer all-oral regimens whenever appropriate [2].

HIV-positive patients had nearly threefold higher odds of unfavorable treatment outcomes, while male patients had 73% higher odds of unfavorable outcomes than females. These findings are consistent with previous systematic reviews and meta-analyses, which have shown that HIV co-infection and male sex are associated with poorer DR-TB treatment outcomes [41, 46]. HIV may adversely affect treatment outcomes through immunosuppression, increased susceptibility to opportunistic infections, and an elevated risk of adverse drug events due to drug-drug

interactions between anti-TB drugs and antiretroviral therapy [43]. In contrast, poorer outcomes among men have been attributed to delayed healthcare seeking, lower treatment adherence, and a higher prevalence of behavioral risk factors, including smoking and alcohol use [41, 46]. These findings highlight the importance of strengthening integrated TB/HIV services and ensuring rigorous treatment follow-up for TB/HIV-coinfected patients to improve treatment outcomes among those with DR-TB.

The findings of this review have important implications for DR-TB management in Cameroon. Although treatment outcomes have improved over time, sustaining this progress will require ongoing investment in rapid drug susceptibility testing, integrated TB/HIV services, patient-centered adherence support, and pharmacovigilance. Strengthening these components of the National Tuberculosis Program and scaling up WHO-recommended treatment strategies could further improve outcomes and accelerate progress toward the End TB Strategy goals [39].

Limitations

Several limitations should be acknowledged in this review. First, the predominance of observational studies restricts the ability to draw causal inferences. Second, considerable heterogeneity was identified across some of the pooled estimates indicating that the pooled estimates should be interpreted with caution and considered as average measures of the true effect. Third, analyses concerning adverse drug events and predictors of unfavorable outcomes, relied on a small number of studies this limited the ability to estimate the national incidence. Adverse event definitions may have varied considerably across studies. Reporting practices also differed which likely contributed to under-reporting of adverse events, particularly those with gradual onset such as ototoxicity and peripheral neuropathy. Limitations also include varying follow-up durations, potential survivor bias, and the inability to assess individual patient-level predictors from aggregate study-level data. Additionally, the included studies did not represent all regions of Cameroon, as most of the evidence came from only a few regions. As a result, the pooled estimates may not comprehensively reflect the national epidemiology and treatment outcomes of DR-TB. Despite these limitations, this review presents the first comprehensive synthesis of DR-TB treatment outcomes in Cameroon and provides valuable evidence to guide policy, clinical practice, and future research.

Conclusions

This systematic review and meta-analysis is the first to synthesize data on treatment outcomes among patients with DR-TB in Cameroon. Treatment success has increased over time but remained below the national target of 85% for drug-resistant TB treatment success, as set in the 2024–2026 National Strategic Plan for the Fight against Tuberculosis. The rates of death, loss to follow-up, and treatment failure have stayed relatively low. Adverse drug events were common, and people living with HIV had worse treatment outcomes. These results show progress in managing DR-TB in Cameroon but also highlight the need for ongoing efforts to improve outcomes. Improving rapid drug susceptibility testing, integrating TB and HIV services, focusing on patient-centered care, and monitoring drug safety will be important for better DR-TB management and for reaching the WHO End TB Strategy goals.

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ADT, CA, RT, RKNO, CJKM, and MNT critically reviewed and revised successive drafts of the manuscript. FZLC, ADT, CA, RT, RKNO, CJKM, and MNT read and approved the final version of the manuscript.

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Declarations

Ethical approval and consent to participate Not applicable.

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References

1. WHO. Tuberculosis (TB). WHO, Geneva. 2026. https://www.who.int/news-room/fact-sheets/detail/tuberculosis. Accessed 25 Aug 2026.
2. WHO. WHO consolidated guidelines on tuberculosis. Module, 4: treatment - drug-resistant tuberculosis treatment, 2022 update. WHO, Geneva. 2022. https://www.who.int/publications/i/item/9789240063129. Accessed 7 July 2026.
3. Ledesma JR, Ma J, Zhang M, Basting AVL, Chu HT, Vongpradith A, et al. Global, regional, and national age-specific progress towards the 2020 milestones of the WHO end TB strategy: a systematic analysis for the global burden of disease study 2021. The Lancet Infect Dis. 2024;24(7):698–725. https://doi.org/10.1016/S1473-3099(24)00007-0.
4. WHO. Tuberculosis (TB). WHO | Regional Office for Africa, Brazzaville. 2026. https://www.afro.who.int/health-topics/tuberculosis-tb. Accessed 7 July 2026.
5. Nyasulu PS, Doumbia CO, Ngah V, Togo ACG, Diarra B, Chongwe G. Multidrug-resistant tuberculosis: latest opinions on epidemiology, rapid diagnosis and management. Curr Opin Pulm Med. 2024;30(3):217–28. https://doi.org/10.1097/MCP.0000000000001070.
6. National programme for the fight against tuberculosis. National strategic plan to fight against tuberculosis 2027-2030. MINSANTE, Yaoundé. 2026. https://cdnss-minsante.cm/cdnss-download. Accessed 13 Sept 2026.
7. Noeske J, Yakam AN, Foe JLA, Nguafack D, Kuaban C. Rifampicin resistance in new bacteriologically confirmed pulmonary tuberculosis patients in Cameroon: a cross-sectional survey. BMC Res Notes. 2018;11(1):580. https://doi.org/10.1186/s13104-018-3675-0.
8. Meriki HD, Tufon KA, Atanga PN, Ane-Anyangwe IN, Anong DN, Cho-Ngwa F, et al. Drug resistance profiles of *mycobacterium tuberculosis* complex and factors associated with drug resistance in the northwest and Southwest regions of Cameroon. PLoS One. 2013;8(10):e77410. https://doi.org/10.1371/journal.pone.0077410.
9. Falzon D, Gandhi N, Migliori GB, Sotgiu G, Cox H, Holtz TH, et al. Resistance to fluoroquinolones and second-line injectable drugs: impact on multidrug-resistant TB outcomes. Eur Respir J. 2013;42(1):156–68. https://doi.org/10.1183/09031936.00134712.
10. Kuaban C, Noeske J, Rieder HL, Aït-Khaled N, Abena Foe JL, Trébucq A. High effectiveness of a 12-month regimen for MDR-TB patients in Cameroon. Int J Tuberc Lung Dis. 2015;19(5):517–24. https://doi.org/10.5588/ijtld.14.0535.
11. Kuaban A, Balkissou AD, Essadi Ekongolo MC, Nsounfon AW, Pefura-Yone EW, Kuaban C. Incidence and factors associated with unfavourable treatment outcome among patients with rifampicin-resistant pulmonary tuberculosis in Yaounde, Cameroon. Pan Afr Med J. 2021;38:38. https://doi.org/10.11604/pamj.2021.38.229.28317.

12. Mbuh TP, Wandji A, Keugni L, Mboh S, Ane-Anyangwe I, Mbacham WF, et al. Predictors of drug-resistant tuberculosis among high-risk population diagnosed under national program conditions in the Littoral Region, Cameroon. Biomed Res Int. 2021;2021(1):8817442. https://doi.org/10.1155/2021/8817442.
13. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;372:n71. https://doi.org/10.1136/bmj.n71.
14. WHO. Outcome definitions. WHO TB Knowledge Sharing Platform. 2026. https://tbksp.who.int/en/node/3027. Accessed 28 June 2026.
15. Kaapu KG, Rukasha I. Trends and treatment outcomes of drug resistant tuberculosis in Limpopo Province, South Africa (2011–2019): a retrospective study. PLoS One. 2025;20(11):e0335600. https://doi.org/10.1371/journal.pone.0335600.
16. Poka-Mayap V, Dombu-Guiafaing RC, Balkissou AD, Endale Mangamba L-M, Kuaban A, Nsounfon AW, et al. Trends and determinants of unfavourable outcomes in paediatric tuberculosis: insights from a 20-year cohort in Cameroon. BMJ Open Resp Res. 2025;12(1):12. https://doi.org/10.1136/bmjresp-2025-003292.
17. Vadakunnel MJ, Nehru VJ, Brammacharry U, Ramachandra V, Palavesam S, Muthukumar A, et al. Factors associated with unfavourable treatment outcomes among patients with multidrug-resistant tuberculosis receiving outpatients care. Sci Rep. 2025;15(1):28335. https://doi.org/10.1038/s41598-025-13227-5.
18. McArthur A, Cooper A, Edwards D, Klugarova J, Yan H, Barber BV, et al. Textual evidence systematic reviews series paper 3: critical appraisal of evidence from narrative, opinion, and policy. JBI Evidence Synth. 2025;23(5):833–39. https://doi.org/10.11124/JBIES-24-00293.
19. Stijnen T, Hamza TH, Ozdemir P. Random effects meta-analysis of event outcome in the framework of the generalized linear mixed model with applications in sparse data. Stat Med. 2010;29(29):3046–67. https://doi.org/10.1002/sim.4040.
20. R Core Team. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. 2024. https://www.R-project.org/. Accessed 30 May 2024.
21. Egger M, Davey Smith G, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. BMJ (Clin Res Ed). 1997;315(7109):629–34. https://doi.org/10.1136/bmj.315.7109.629.
22. Begg CB, Mazumdar M. Operating characteristics of a rank correlation test for publication bias. Biometrics. 1994;50(4):1088. https://doi.org/10.2307/2533446.
23. Noeske J, Nguenko PN. Impact of resistance to anti-tuberculosis drugs on treatment outcome using world health organization standard regimens. Trans R Soc Trop Med Hyg. 2002;96(4):429–33. https://doi.org/10.1016/S0035-9203(02)90383-4.
24. Noeske J, Voelz N, Fon E, Abena Foe J-L. Early results of systematic drug susceptibility testing in pulmonary tuberculosis retreatment cases in Cameroon. BMC Res Notes. 2012;5(1):160. https://doi.org/10.1186/1756-0500-5-160.
25. Pefura-Yone EW, Kengne AP, Kuaban C. Non-conversion of sputum culture among patients with smear positive pulmonary tuberculosis in Cameroon: a prospective cohort study. BMC Infect Dis. 2014;14(1):138. https://doi.org/10.1186/1471-2334-14-138.
26. Sander MS, Vuchas CY, Numfor HN, Nsimen AN, Abena J-L, Noeske J, et al. Sputum bacterial load predicts multidrug-resistant tuberculosis in retreatment patients: a case-control study. Int J Tuberc Lung Dis. 2016;20(6):793–99. https://doi.org/10.5588/ijtld.15.0259.
27. Schwœbel V, Trébucq A, Kashongwe Z, Bakayoko AS, Kuaban C, Noeske J, et al. Outcomes of a nine-month regimen for rifampicin-resistant tuberculosis up to 24 months after treatment completion in nine African countries. eClinicalmedicine. 2020;20:20. https://doi.org/10.1016/j.eclinm.2020.100268.
28. Kuaban C, Toukam LDI, Sander M. Treatment outcomes and factors associated with unfavourable outcome among previously treated tuberculosis patients with isoniazid resistance in four regions of Cameroon. Pan Afr Med J. 2020;37:1–12. https://doi.org/10.11604/pamj.2020.37.45.25684.
29. Merker M, Egbe NF, Ngangue YR, Vuchas C, Kohl TA, Dreyer V, et al. Transmission patterns of rifampicin resistant *mycobacterium tuberculosis* complex strains in Cameroon: a genomic epidemiological study. BMC Infect Dis. 2021;21(1):891. https://doi.org/10.1186/s12879-021-06593-8.
30. Jouego CG, Gils T, Piubello A, Mbassa V, Kuate A, Ngono A, et al. Programmatic management of rifampicin-resistant tuberculosis with standard regimen in Cameroon: a retrospective cohort study. Int J Infect Dis. 2022;124:81–88. https://doi.org/10.1016/j.ijid.2022.09.012.
31. Mpoh M, Deli V, Daniel T, Salvo F. Safety of antituberculosis agents used for multidrug-resistant tuberculosis among patients attending the jamot hospital of Yaounde, Cameroon. Int J Mycobacteriol. 2023;12(2):168. https://doi.org/10.4103/ijmy.ijmy_88_23.
32. Ngangue YR, Mbuli C, Neh A, Nshom E, Koudjou A, Palmer D, et al. Diagnostic accuracy of the Truenat MTB plus assay and comparison with the Xpert MTB/RIF assay to detect tuberculosis among hospital outpatients in Cameroon. J Clin Microbiol. 2022;60(8):e00155–22. https://doi.org/10.1128/jcm.00155-22.
33. Mbuh TP, Mendjime P, Goupeyou-Wandji I-A, Donkeng-Donfack VF, Kahou J, Endale Mangamba L-M, et al. Trends of drug-resistant tuberculosis and risk factors to poor treatment-outcome: a database analysis in littoral region-cameroon, 2013–2022. BMC Public Health. 2024;24(1):3195. https://doi.org/10.1186/s12889-024-20585-8.

34. Mbuh TP, Meriki HD, Thumamo Pokam BD, Adeline W, Enoka F, Ghislain T, et al. Incidence of adverse drug events among patients on second Line Anti-tuberculosis regimen in the littoral region of Cameroon. Int J Mycobacteriol. 2021;10(4):463–68. https://doi.org/10.4103/ijmy.ijmy_160_21.
35. Poka-Mayap V, Balkissou Adamou D, Pefura-Yone EW, Kuaban C. Ototoxicité liée à la kanamycine au cours du traitement de la tuberculose multirésistante. Revue des Mal Respiratoires. 2020;37(5):369–75. https://doi.org/10.1016/j.rmr.2019.12.005.
36. PNLT/MINSANTE. 2024–2026 strategic Plan against tuberculosis in Cameroon. Scribd. Inc, San Franciso. 2022. https://fr.scribd.com/document/834403466/CMR-PSN-TB-2020-2024-Extension-2026-2,. Accessed 23 Sept 2026.
37. WHO. Global tuberculosis report 2025. WHO, Geneva. 2025. https://www.who.int/teams/global-programme-on-tuberculosis-and-lung-health/tb-reports/global-tuberculosis-report-2025. Accessed 13 Sept 2026.
38. Toft AL, Dahl VN, Sifna A, Ige OM, Schwoebel V, Souleymane MB, et al. Treatment outcomes for multidrug- and rifampicin-resistant tuberculosis in central and West Africa: a systematic review and meta-analysis. Int J Infect Dis. 2022;124(Suppl 1):S107–16. https://doi.org/10.1016/j.ijid.2022.08.015.
39. WHO. Global tuberculosis report 2024. WHO, Geneva. 2026. https://www.who.int/teams/global-programme-on-tuberculosis-and-lung-health/tb-reports/global-tuberculosis-report-2024. Accessed 7 July 2026.
40. Tiberi S, Utjesanovic N, Galvin J, Centis R, D'ambrosio L, van den Boom M, et al. Drug resistant TB – latest developments in epidemiology, diagnostics and management. Int J Infect Dis. 2022;124(Suppl 1):S20–5. https://doi.org/10.1016/j.ijid.2022.03.026.
41. Chem ED, Van Hout MC, Hope V. Treatment outcomes and antiretroviral uptake in multidrug-resistant tuberculosis and HIV co-infected patients in sub Saharan Africa: a systematic review and meta-analysis. BMC Infect Dis. 2019;19(1):723. https://doi.org/10.1186/s12879-019-4317-4.
42. Teferi MY, El-Khatib Z, Boltena MT, Andualem AT, Asamoah BO, Biru M, et al. Tuberculosis treatment outcome and predictors in Africa: a systematic review and meta-analysis. Int J Environ Res Public Health. 2021;18(20):10678. https://doi.org/10.3390/ijerph182010678.
43. Cioboata R, Balteanu MA, Osman A, Vlasceanu SG, Zlatian OM, Mitroi DM, et al. Coinfections in tuberculosis in low- and middle-income countries: epidemiology, clinical implications, diagnostic challenges, and management strategies-A narrative review. J Clin Med. 2025;14(7):14. https://doi.org/10.3390/jcm14072154.
44. Walker EF, Flook M, Rodger AJ, Fielding KL, Stagg HR. Quantifying non-adherence to anti-tuberculosis treatment due to early discontinuation: a systematic literature review of timings to loss to follow-up. BMJ Open Resp Res. 2024;11(1):11. https://doi.org/10.1136/bmjresp-2023-001894.
45. Lee H, Kim J, Kim J, Park Y-J. [Review of the global burden of tuberculosis in 2023: insights from the WHO global tuberculosis report 2024]. Jugan Geongang Gwa Jilbyeong. 2025;18(11 Suppl):55–69. https://doi.org/10.56786/PHWR.2025.18.11suppl.5.
46. Chidambaram V, Tun NL, Majella MG, Ruelas Castillo J, Ayeh SK, Kumar A, et al. Male sex is associated with worse microbiological and clinical outcomes following tuberculosis treatment: a retrospective cohort study, a systematic review of the literature, and meta-analysis. Clin Infect Dis. 2021;73(9):1580–88. https://doi.org/10.1093/cid/ciab527.

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