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Molecular Resistance of the Mycobacterium Tuberculosis Complex to First-Line Anti-Tuberculosis Drugs (Isoniazid and Rifampicin) Associated with HIV and Hepatitis B Co-Infections in Burkina Faso

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Abstract

Context: Multidrug-resistant tuberculosis (MDR-TB) represents a threat to tuberculosis control in Burkina Faso and in countries with a high prevalence of HIV and hepatitis B. **Objective:** This study aimed to determine the prevalence of rifampicin (RIF) and isoniazid (INH) resistance by PCR and to assess the influence of HIV/HBV co-infections as well as treatment adherence on these resistances. **Methods:** This was a cross-sectional study involving 4358 patients suspected of having tuberculosis in 2023 and 2024. The diagnosis of TB and the detection of RIF resistance were performed using Xpert MTB/RIF Ultra. INH resistance was detected using Xpert MTB/XDR. HIV and HBV statuses (HBsAg) were determined by rapid serological tests. Treatment adherence and outcomes were analyzed. **Results:** Among the patients, 903 (20.7%) were positive for *M. tuberculosis*. The prevalences of co-infections among TB+ patients were 5.20% for HIV, 0.78% for HBV, and 0.33% for triple co-infection. The prevalence of resistance was 1.44% (13/903) for RIF and 0.44%

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(4/903) for INH, with 4 cases of MDR-TB (0.44%). High adherence (93% - 100%) was observed among co-infected patients. Non-co-infected patients accounted for all treatment failures (n = 85) and treatment restarts (n = 12), despite a reported adherence rate of 84.4%. **Conclusion:** Resistance to RIF and INH remains rare in Burkina Faso and is primarily of primary origin. HIV/HBV co-infections did not increase the risk of MDR-TB but justify integrated management. The paradox of unfavorable outcomes among "TB-only" patients despite good adherence was observed.

Keywords

Multidrug-Resistant Tuberculosis, HIV/HBV Coinfection, Burkina Faso

1. Introduction

Tuberculosis (TB), caused by the *Mycobacterium tuberculosis* complex, remains a major global scourge: approximately 10.7 million people developed TB in 2024, and 1.23 million died from it. This makes TB the leading cause of death from a single infectious agent [1]. Tuberculosis also remains the leading cause of death among people living with HIV, with over 150,000 associated deaths in 2024 [1]. Despite a slight decrease in mortality rates over the past decade, multidrug-resistant TB remains a major public health problem, with hundreds of thousands of newly estimated resistant cases each year [1]. Furthermore, multidrug-resistant tuberculosis (MDR-TB), defined as resistance to at least rifampicin and isoniazid, represents a significant therapeutic challenge. In 2023, approximately 410,000 new cases of rifampicin-resistant tuberculosis (RR-TB) were estimated worldwide, with higher resistance rates among previously treated patients [2].

Resistance to M. tuberculosis is promoted by poor treatment adherence, co-infections with the Human Immunodeficiency (HIV) and the hepatitis B virus (HBV). A recent systematic review identified major social determinants affecting adherence to antituberculosis treatment among TB/HIV patients, which may contribute to adverse treatment outcomes and the development of resistance [3].

Moreover, Burkina Faso, a country with a high burden of TB/HIV co-infection, also reports a high endemicity of hepatitis B with an HBsAg prevalence of approximately 9% in the general population, underscoring the importance of monitoring HIV/TB/HBV co-infection in resistance dynamics [4].

The coexistence of HBV infection with hepatotoxic anti-tuberculosis treatment exposes patients to a high risk of liver complications, which can compromise adherence and promote the emergence of resistance.

Few local data exist on the molecular profile of resistance and the actual impact of HIV/HBV co-infections in Burkina Faso.

This study aims to determine the prevalence of rifampicin and isoniazid resistance in tuberculosis patients, while assessing the impact of HIV and HBV co-infections as well as treatment adherence on the emergence of multidrug-resistant

TB.

2. Materials and Methods

2.1. Site, Study Population, and Sample Collection

Paul VI Hospital in Ouagadougou and the Burkina Faso National Tuberculosis Program served as frameworks for sample collection and analysis, while the Pietro Annigoni Biomolecular Research Center (CERBA) was responsible for data analysis. This was a descriptive cross-sectional study conducted over 24 months (January 2023 to December 2024) including 4358 patients. Patients enrolled in this study were those who came to the laboratory either for tuberculosis screening or for monitoring during or after first-line treatment, as well as patients with treatment failure who were receiving rifampicin and isoniazid. Subsequently enrolled were new tuberculosis cases whose real-time PCR was positive for the *M. tuberculosis* complex and who had never been treated with anti-tuberculosis drugs or had been treated for at least one month. Patients with positive AFB microscopy and positive PCR were also included.

All records corresponding to specimens analyzed in the laboratory between January 2023 and December 2024 were included. Recruitment was therefore consecutive, with no prior selection of records during the study period. The comprehensive results dataset was compiled and organized in Excel, then reviewed to identify and eliminate duplicates, ensuring that only one record per patient was retained for analysis. Patients treated at the selected facilities were primarily referred to the laboratory for diagnostic screening for tuberculosis or as part of follow-up for tuberculosis that had already been diagnosed or was undergoing treatment. Screening involved patients suspected of having tuberculosis from whom a respiratory specimen—particularly sputum—was collected for diagnostic purposes. Follow-up involved patients already diagnosed with or being treated for tuberculosis who underwent microbiological monitoring during or after their treatment. Based on their treatment history, patients were classified as new patients or previously treated patients. A new patient was defined as one who had never received antituberculosis treatment or had received it for less than one month. A previously treated patient was defined as one who had received antituberculosis treatment for at least one month.

This category included relapses, treatment failures, patients who resumed treatment, and other previously treated patients. A relapse was defined as a previously treated patient who had been declared cured or had completed treatment but was subsequently diagnosed with a new episode of active tuberculosis. Treatment failure was defined as the persistence of a positive smear test after five months or more of treatment, specifically at the fifth or eighth month according to the follow-up protocol. Resumption of treatment referred to patients who had interrupted their treatment and were classified as lost to follow-up, but were later located and returned to treatment. Finally, the other previously treated patients were those for whom the outcome of the last course of treatment was unknown or

undocumented. For the analysis of rifampicin resistance, patients with an interpretable result from the Xpert MTB/RIF Ultra test were included; the study of isoniazid resistance included TB-RR patients who had undergone an additional Xpert test.

2.2. Identification of the *Mycobacterium tuberculosis* Complex and Determination of the Genetic Resistance Profile to Rifampicin and Isoniazid

Identification of the *Mycobacterium tuberculosis* complex and rifampicin resistance was performed by real-time PCR from patient sputum using the Xpert MTB/RIF/ULTRA kit on GeneXpert® systems from Cepheid (GeneXpert® from Cepheid 2020). Detection of mutations responsible for isoniazid resistance was performed by real-time PCR using the Xpert MTB/XDR kit (GeneXpert® from Cepheid 2020), which detects mutations associated with isoniazid (INH) resistance in the katG and fabG1 genes, the oxyR-ahpC intergenic region, and the inhA promoter; resistance to ethionamide (ETH) associated only with inhA promoter mutations; mutations associated with fluoroquinolone (FLQ) resistance in the quinolone resistance-determining regions (QRDR) gyrA and gyrB; and mutations associated with second-line injectable drugs (SLID) in the rrs gene and the eis promoter region.

2.3. Serological Status

Simultaneously, HIV serology using two tests (Determine® HIV; OnSite HIV 1/2 Ab) and hepatitis B serology (OnSite HBsAg Combo R kit) were performed to investigate the involvement of HIV and hepatitis B in rifampicin and isoniazid resistance.

2.4. Statistical Analyses

The collected data were entered and cleaned in Excel 2016 before being transferred to the R software (version 4.2.1) for statistical analysis. Qualitative variables were expressed as counts and percentages. Proportions between groups were compared using Pearson's chi-square test, with a significance level set at 5% ($p < 0.05$). Confidence intervals were calculated at the 95% level. To identify factors associated with resistance and adherence, univariate and then multivariate logistic regression models were constructed, with calculation of odds ratios (OR) and their 95% confidence intervals. Translated with DeepL.com (free version)were used to determine the levels of association between study variables.

2.5. Ethical Considerations

The study protocol received approval from the Health Research Ethics Committee of Burkina Faso under deliberation number N˚2024-09-273. Free and informed consent was obtained from each patient. Patients with TB were treated in accordance with the recommendations of the National Tuberculosis Control Program

(PNT).

3. Results

3.1. General Characteristics of the Study Population

3.1.1. Sociodemographic Characteristics of Patients

A total of 4358 patients were enrolled in this study, including 2864 screening cases and 1494 monitoring cases. The population was predominantly male, with a sex ratio of 2 men for every 1 woman, both in the general population (66.82%) and among tuberculosis cases (78.16%). The mean age of the general population was 40.80 ± 17.73 years, with 40.86 ± 19.25 for women and 40.77 ± 16.93 for men. The 20 - 40 year age group was the most represented (46.3%), followed by the 40 - 60 year age group (28.0%). Youth (0 - 20 years) represented only 10.6% of the population, while elderly (60+ years) represented approximately 15%. For all age groups, the difference in distribution between men and women is highly significant within each age group ($p < 0.001$). (Table 1)

Table 1. Caractéristiques sociodémographiques de la population d'étude.

Parameters Age classes (years)	**Effectif** **n (%)**	**Mean age (years)**	**Females** **n (% total)**	**Males** **n (% total)**	**P-Value**
0 < X ≤ 20	460 (10.6%)	14.74 ± 4.82	185 (4.25%)	275 (6.31%)	
20 < X ≤ 40	2018 (46.3%)	31.41 ± 5.98	653 (14.98%)	1.365 (31.32%)	
40 < X ≤ 60	1220 (28.0%)	49.58 ± 5.89	340 (7.80%)	880 (20.19%)	**< 0.001**
60 < X	660 (15.1%)	71.46 ± 7.76	268 (6.15%)	392 (8.99%)	
Total	4358 (100.0%)	40.80 ± 17.73	1446 (33.18%)	2912 (66.82%)	
Genre					
Female	1446 (33.18%)	40.86 ± 19.25			0.847
Male	2912 (66.82%)	40.77 ± 16.93			0.847

3.1.2. Distribution of Patients According to Reason for Visit

Of a total of 4358 samples, screening represented the majority of analyses (65.72%) in the general population and in both sexes. Among men, screening accounted for 60.27% versus 39.73% for monitoring. Among women, the proportion of screening was 76.69% versus 23.31% for monitoring. From a general perspective, screening was significantly more frequent than monitoring in all age groups. Screening was particularly high among those under 20 years (82.61%), followed by those over 60 years (79.39%), then those aged 40 - 60 years (65.08%), and finally those aged 20 - 40 years (57.78%), likely corresponding to therapeutic monitoring of already confirmed cases in these active age groups (Table 2).

3.2. Prevalence of Tuberculosis and Molecular Resistance

Among the 4358 patients tested, 903 were confirmed positive for *M. tuberculosis* by PCR, corresponding to an overall prevalence of 20.7%. No significant difference was observed between the screening and monitoring groups (21.1% vs

19.9%; p = 0.430) (Table 3).

Table 2. Distribution of screening and monitoring patients according to age and sex.

Samples	Gender		Total	Age classes (years)			
	F	M		1	2	3	4
Monitoring	337 23.31%	1157 39.73%	1494 34.28%	80 17.39%	852 42.22%	426 34.92%	136 20.61%
Screenin	1109 76.69%	1755 60.27%	2864 65.72%	380 82.61%	1166 57.78%	794 65.08%	524 79.39%
Total	1446 100.0%	2912 100.0%	4358 100.0%	460 100.0%	2018 100.0%	1220 100.0%0	660 100.0%

Legend: F: Female; M: Male; 1: 0 < X ≤ 20 ans; 2: 20 < X ≤ 40; 3: 40 < X ≤ 60; 4: 60 < X.

The prevalence of resistance to first-line anti-tuberculosis drugs among confirmed tuberculosis cases was overall low. Rifampicin resistance, associated with *rpoB* gene mutations, was detected in 1.44% (13/903) of patients. These mutations, particularly in the RRDR region, constitute the main mechanism of rifampicin resistance and are widely used as markers of multidrug-resistant TB. Although not statistically significant (p = 0.125), this resistance was more than twice as frequent in monitoring patients (2.35%) than in screening patients (0.99%).

A total of 63 samples were analyzed using the Xpert MTB/XDR test. These samples included cases of tuberculosis with detected rifampin resistance (TB-RR) as well as samples with an indeterminate result for rifampin resistance on the Xpert MTB/RIF Ultra test. All 63 Xpert MTB/XDR tests performed yielded a valid and interpretable result. The indeterminate results obtained with the Xpert MTB/RIF Ultra were retested, either using a new sample or by repeating the Xpert MTB/RIF Ultra and/or Xpert MTB/XDR test, until an interpretable result was obtained. Invalid results were retested using a new sample. Thus, no invalid or indeterminate Xpert MTB/XDR data were included in the final analysis.

Resistance to INH was assessed by Xpert MTB/XDR in 63 patients (TB-RR cases and indeterminate cases on the Xpert MTB/RIF Ultra). All tests yielded a valid result after retesting. The INH resistance rate among the 63 valid tests is 6.35% (4/63). According to the national algorithm and by extrapolation, the INH resistance rate relative to all PCR-confirmed TB cases is 0.44% (4/903).

Isoniazid resistance, associated with mutations in the katG, fabG1 genes, the oxyR-ahpC intergenic region, or the inhA promoter, was even rarer, with a prevalence of 0.44% (4/903). The katG gene, involved in isoniazid activation, remains the main site of mutations conferring high-level resistance, while inhA promoter mutations are responsible for low-level resistance. A similar trend toward higher frequency in the monitoring group was observed, without reaching statistical significance (p = 0.118) (Table 3).

Analysis of resistance profiles revealed that all INH-resistant cases were also

resistant to RIF, thus defining 4 cases of multidrug-resistant tuberculosis (MDR-TB), representing a prevalence of 0.44% among TB+ cases. No cases of isolated INH resistance were identified. The vast majority of strains (98.5%) were susceptible to both first-line drugs (Table 3). When reporting the resistance burden to the entire tested population (N = 4358), the prevalence of RIF resistance was 0.30% and that of INH resistance was 0.09%.

Table 3. Prevalence of tuberculosis and first-line drug resistance profile.

Variable	Total	Screening	Monitoring	p-value
PCR TB Positive, n (%)	903 (20.7)	605 (21.1)	298 (19.9)	0.430
RIF Resistance, n (%)	13 (1.44)	6 (0.99)	7 (2.35)	0.125
INH Resistance, n (%)	4 (0.44)	1 (0.17)	3 (1.01)	0.118
Resistance profile (n = 903)				
Susceptible (RIF-S/INH-S)	890 (98.5)	599 (66.3)	291 (32.2)	0.27
RIF-R only	9 (1.0)	6 (0.67)	3 (0.33)	1
MDR-TB (RIF-R/INH-R)	4 (0.44)	1 (0.11)	3 (0.33)	0.18
INH-R only	0 (0.0)	0	0	NA

RIF: Rifampicine; INH: Isoniazide; TB-MDR: Tuberculose Multirésistante; RIF-R/INH-R: Résistant.

3.3. Prevalence and Profile of Co-Infections among Confirmed Tuberculosis Cases

In our study, among the 903 confirmed cases of tuberculosis, 47 (5.20%) tested positive for HIV. Among these TB+/HIV+ patients, 21 (44.7%) were women and 26 (55.3%) were men. The majority of patients coinfected with HIV were in the 20 - 40 age group (24/47; 51.1%) and the 40 - 60 age group (15/47; 31.9%), accounting for 83.0% of cases aged 20 - 60.

Table 4 presents the distribution of TB+/HIV+ and TB+/HBsAg+ and TB+/HIV+/HBsAg+ patients by age and sex. Regarding TB/HIV coinfection, a moderate predominance of males was observed, with 55.3% men compared to 44.7% women. This difference was not statistically significant. Regarding TB/HBV coinfection, 7 patients tested positive for HBsAg, representing a prevalence of 0.78% among confirmed tuberculosis cases. They were predominantly men (6/7; 85.7%) and were mainly in the 20 - 40 age group (5/7; 71.4%).

Among all patients tested, the prevalence of HIV was 1.08%. It was higher among patients with confirmed active tuberculosis, reaching 5.20% (47/903), with a statistically significant difference ($p < 0.001$). This difference reflects a higher prevalence of HIV among patients with confirmed tuberculosis.

The overall prevalence of HBsAg among all tested patients was 0.16%, compared with 0.78% (7/903) among patients with confirmed tuberculosis. This difference was also statistically significant ($p < 0.001$), indicating a higher rate of HBsAg positivity among TB-positive patients.

Three patients (0.33%) were simultaneously HIV-positive and HBsAg-positive,

corresponding to a triple TB/HIV/HBV coinfection. The TB+/HIV+ (n = 47) and TB+/HBsAg+ (n = 7) groups include these three patients. For comparative analyses, the co-infection categories were defined as mutually exclusive: TB alone (n = 852), TB/HIV alone (n = 44), TB/HBsAg alone (n = 4), and TB/HIV/HBsAg (n = 3). Comparisons by age and sex showed no statistically significant differences between the study groups (generalized Fisher's exact test; p = 0.509 for age and p = 0.364 for sex). These results indicate that the variations observed in the distribution of sociodemographic characteristics should be considered descriptive trends and do not allow for the establishment of a statistically significant difference between co-infection profiles.

Of the 903 patients with tuberculosis confirmed by Xpert MTB/RIF Ultra, all underwent screening for HIV and hepatitis B surface antigen (HBsAg) before starting antituberculosis treatment or during follow-up visits while on treatment, depending on the patient's clinical situation. No missing serological results were recorded. For comparative analyses, the coinfection categories were defined as mutually exclusive: TB alone (n = 852), TB/HIV alone (n = 44), TB/HBsAg alone (n = 4), and TB/HIV/HBsAg (n = 3). The total number of positive cases was 47 for HIV and 7 for HBsAg, with both figures including the three patients with triple co-infection.

Table 4. Répartition des co-infections parmi les patients TB+ selon l'âge et le sexe.

Caractéristique	TB+/VIH+ (n = 47)	TB+/AgHBs+ (n = 7)	TB+/VIH+/AgHBs+ (n = 3)	p-value
Tranche d'âge, n (%)				**0.498**
0 < X ≤ 20	1 (2.1)	1 (14.3)	0 (0.0)	
20 < X ≤ 40	24 (51.1)	5 (71.4)	2 (66.7)	
40 < X ≤ 60	15 (31.9)	1 (14.3)	1 (33.3)	
60 < X	7 (14.9)	0 (0.0)	0 (0.0)	
Genre, n (%)				**0.301**
Femmes	21 (44.7)	1 (14.3)	1 (33.3)	
Hommes	26 (55.3)	6 (85.7)	2 (66.7)	

In our study of 903 confirmed tuberculosis cases, 21 (44.7%) men and 26 (55.3%) women had HIV, representing an overall prevalence of 5.20% among TB patients. Table 5 presents the distribution of TB/HIV (TB+/HIV+) and TB/HBV (TB+/HBsAg+) co-infections according to age group and sex. TB-HIV co-infection primarily affected young and middle-aged adults (20 - 60 years, 83% of cases), with a balanced distribution between sexes. This active population is most exposed to transmission risks, especially in areas with high socio-economic dynamics. The distribution by sex is relatively balanced (55.3% men and 44.7% women), reflecting comparable exposure between genders. A notable difference in HIV prevalence was observed between the "Screening" group (1.57%) and the

"Monitoring" group (0.13%) among TB+ patients.

In contrast, TB/HBV co-infection shows a strong male predominance (85.7%) and mainly concerns young adults aged 20 to 40 years (71.4% of cases). A prevalence of TB/HBV co-infection of 0.78% was observed among TB+ patients.

The differences observed between TB+/HIV+ and TB+/HBsAg+ according to age and sex are not statistically significant ($p = 0.205$ and $p = 0.265$, respectively), indicating that, although descriptive trends are observed, there are no marked demographic distinctions between these groups.

The prevalence of HIV among all patients tested was 1.08%. However, this prevalence was significantly higher (5.20%) among patients with confirmed active tuberculosis ($p < 0.001$), confirming a close link between tuberculosis and HIV infection.

The prevalence of HBsAg (HBV) was overall low (0.16%) but also significantly higher among TB+ patients (0.78%, $p < 0.001$).

Three cases of triple co-infection (TB/HIV/HBV) were identified, indicating a complex epidemiological interaction.

Statistical analyses show that neither age ($p = 0.205$) nor sex ($p = 0.265$) show a significant difference between the TB+/HIV+ and TB+/HBsAg+ groups. The observed variations appear to reflect descriptive trends but do not allow concluding a true epidemiological distinction between the two types of co-infection.

Table 5. Distribution of co-infections among TB+ patients according to age and sex.

Characteristic	TB+/VIH+ (n = 47)	TB+/AgHBs+ (n = 7)
Age group, n (%)	P = 0.205	
0 < X ≤ 20	1 (2.1%)	1 (14.3%)
20 < X ≤ 40	24 (51.1%)	5 (71.4%)
40 < X ≤ 60	15 (31.9%)	1 (14.3%)
60 < X	7 (14.9%)	0 (0.0%)
Gender, n (%)	P = 0.265	
Women	21 (44.7%)	1 (14.3%)
Men	26 (55.3%)	6 (85.7%)

3.4. Adherence and Treatment Outcomes According to Viral Status

The vast majority (92.3%, n = 12/13) of RIF-resistant strains were detected in patients declared as adherent. Only one (1) case of resistance was observed in a patient with treatment failure (7.7%).

INH resistance showed a profile of 4 detected cases (0.44%) exclusively in adherent patients. A total absence of resistance was observed in failure or relapse groups.

The proportion of patients (9.4%, n = 84) in treatment failure despite PCR-

confirmed susceptibility to RIF is particularly high (9.4%, n = 84).

No cases of treatment failure or restart were observed among patients co-infected with HIV (n = 44), HBV (n = 4), or both (n = 3).

The proportion of unfavorable outcomes (only relapses in the HIV group) was significantly lower among TB+/HIV+ patients than in the TB-only group (p = 0.001).

Conversely, the group of patients without documented viral co-infection ("TB alone") accounted for all failures (n = 85) and treatment restarts (n = 12), representing nearly 12% of this cohort. This occurred despite the discrepancy between high reported adherence (84.4%) and clinical outcome (Table 6).

For rifampicin (RIF) and isoniazid (INH) resistance, the p-values (both = 1.0) indicate the absence of a statistically significant difference.

Table 6. Adherence and treatment outcomes according to viral status.

Group	Adherent n (%)	Relapse n (%)	Failure n (%)	Restart n (%)	Susceptible RIF	Resistant RIF	Susceptible INH	Resistant INH	p-value Adherent	p-value Relapse	p-value Failure	p-value Restart	Total
TB Alone (n = 852)	719 (84.4)	36 (4.2)	85 (10.0)	12 (1.4)	839	13	848	4	Réf.	Réf.	Réf.	Réf.	852
TB+/VIH+ (n = 44)	41 (93.2)	3 (6.8)	0 (0.0)	0 (0.0)	44	0	44	0	**0.110**	**0.409**	NC	NC	44
TB+/AgHBs+ (n = 4)	4 (100)	0 (0.0)	0 (0.0)	0 (0.0)	4	0	4	0	**0.390**	NC	NC	NC	4
TB+/VIH+/AgHBs+ (n = 3)	3 (100)	0 (0.0)	0 (0.0)	0 (0.0)	3	0	3	0	**0.457**	NC	NC	NC	3
Total (n = 903)	767 (85.0)	39 (4.3)	85 (9.4)	12 (1.3)	890	13	899	4	—	—	—	—	903

4. Discussion

The emergence and spread of multi-drug resistant tuberculosis (MDR-TB), defined as resistance to at least isoniazid (INH) and rifampicin (RIF), constitutes a major threat to global health security, particularly in sub-Saharan Africa where the syndemic convergence with human immunodeficiency virus (HIV) and hepatitis B virus (HBV) remains highly prevalent [1]. This study provides critical molecular insights into the mutational landscape of Mycobacterium tuberculosis complex (MTBC) resistance to first-line drugs and investigates its clinical association with HIV and HBV co-infections in Burkina Faso.

4.1. Sociodemographic Characteristics and Screening Strategy

Our study included 4358 patients suspected of having tuberculosis. The mean age of the general population was 40.80 ± 17.73 years with a observed male predominance (66.8%, sex ratio M/F ≈ 2). The 20 - 40 year age group was the most represented (46.3%), followed by the 40 - 60 year age group (28%). Young people aged 0 to 20 years represented only 10.6% of the population, compared to approximately 15% for the elderly (60+ years).

Disparity in Cases Between Men and Women and Epidemiological Implications

A marked predominance of men was observed in our study, with 66.8% of men

and a sex ratio of 2 men to 1 woman. This disparity in cases between men and women has epidemiological implications and a societal impact. Indeed, adult men constitute the primary reservoir for tuberculosis transmission in the community, contributing disproportionately to the chain of transmission, particularly in crowded settings (public transportation, workplaces, markets). Since men are also more mobile and more exposed to risk factors such as smoking, alcohol consumption, and occupational exposure, they contribute to maintaining a high level of transmission in the general population.

From a societal perspective, men are 2 to 3 times more likely to be infected with tuberculosis than women in most studies conducted in sub-Saharan Africa [5], [6]. This disproportionate burden has profound consequences, not only for men's individual health but also for their families and society as a whole. Indeed, since men are often the primary breadwinners in households, their prolonged disability due to tuberculosis can lead to a significant loss of economic productivity and compromise the food security of their families.

From an epidemiological perspective, men generally seek medical care later than women, which delays diagnosis, increases the risk of transmission, and worsens the prognosis. Thus, the burden of tuberculosis represents a public health and socioeconomic development challenge.

Explanation for the High Prevalence among Men

The high prevalence of tuberculosis among men observed in our study could be explained, in part, biologically by sex-related immunological differences that may influence susceptibility to infection and progression to disease, although these mechanisms remain poorly understood. Sex hormones, particularly estrogen, may play a protective role in women by modulating the anti-mycobacterial immune response. Furthermore, from a behavioral and environmental perspective, men are more exposed to the classic risk factors for tuberculosis: smoking, alcohol consumption, malnutrition, and occupational exposure in high-risk sectors (mining, construction sites, manufacturing, and transportation). These factors, which are often more common among men, increase susceptibility to infection and reduce resistance to progression to active tuberculosis [7]. Furthermore, healthcare-seeking behaviors differ significantly between the sexes.

Men generally seek medical care later than women, which facilitates transmission and worsens the prognosis. This trend is reinforced by social norms that associate masculinity with strength and resilience, thereby discouraging men from acknowledging their symptoms and seeking medical care. Studies conducted in West Africa have shown that men perceive tuberculosis as a stigmatizing disease, which further delays their access to care [8].

Finally, men are often more mobile than women for work-related reasons, which increases their exposure to high-risk environments in urban areas, construction sites, mines, and densely populated areas, thereby contributing to sustained tuberculosis transmission in the community.

Our results are similar to those of Bagaya *et al.*, Burkina Faso 2025, who found

in a retrospective study conducted in Burkina Faso from 2021 to 2023 that the median age of patients was 31 years. The 25 - 34 years age group represented 27.8% of cases. The sex ratio was 3.8 in favor of men [9]. This trend was also observed by Boncoungou *et al.*, in 2023 in Burkina Faso, who found a mean patient age of 46.3 years ± 9.46 with a male predominance of 85.7% [10]. Together, individuals aged 20 to 60 years constitute nearly three-quarters (74.3%) of the entire study cohort. This concentration in early to middle adulthood reflects the classic text-book profile of TB epidemics in high-transmission settings.

During adolescence and early adulthood, the physiological and immunological risk of progressing from latent tuberculosis infection (LTBI) to active clinical disease increases dramatically.

This age cohort experiences the highest rates of daily social mixing, public transport usage, and congregate indoor exposures, which drives the force of infection Our results are consistent with those from Mali where, in one study, the majority of pulmonary tuberculosis patients had a mean age of 38.25 ± 13.80 years. Males showed a clear predominance with a ratio (M/F) of 3, *i.e.*, 75% [11]. The same is true in Senegal, where Sow *et al.* also found that the most affected age group was 25 - 34 years (29.66%) with an M/F sex ratio of 2.33 in favor of men [12]. Our results are close to those from Niger in 2024, which found a male predominance (77%) with a sex ratio of 3.3 and a mean patient age of 33.5 ± 17.08 years, the majority (70.16%) being found in the 16 to 47 year age group [13].

The distribution of samples, predominantly oriented toward initial screening (65.7%), reflects the strategic prioritization of active identification of new cases, in accordance with WHO guidelines [14]. Nevertheless, the non-negligible proportion of monitoring patients (34.3%) is an important indicator. It signals a significant flow of patients requiring therapeutic monitoring due to failure, relapse, or treatment restart. Our data are consistent with those of Bagaya *et al.* 2025, which show a predominance of screening among the tests performed. Of a total of 1581 registered tuberculosis cases, 92.6% were new cases [9].

4.2. Prevalence of Tuberculosis and Resistance Profile

The prevalence of PCR-confirmed tuberculosis among suspected patients in our study was 20.7%. Resistance to rifampicin (RIF) was 1.44% and to isoniazid (INH) was 0.44% among confirmed cases. In Burkina Faso, reports from the National Tuberculosis Control Program indicate a prevalence of rifampicin resistance generally below 2%. The number of patients diagnosed with TB using Xpert as the initial test was 4042 in 2023. Among them, 85 cases (2.10%) of MTB Rifampicin-Resistant were detected compared to 3728 cases (92.23%) non-resistant. Among these Rifampicin-Resistant TB (RR-TB) patients, 53 cases (including 25 new cases and 28 previously treated) underwent Xpert MTB XDR testing. Among the 25 new RR-TB patients tested, 15 had MDR-TB, 7 had MDR-TB/Eto, 1 had Pre-XDR, and 2 had RR-TB/Hs. Among the 28 previously treated patients, XDR testing showed that 17 had MDR-TB, 4 had MDR-TB/Eto, 1 had Pre-XDR, and 6 had RR-TB/Hs

[15]. The overall PCR-confirmed tuberculosis prevalence of 20.7% among suspected patients reflects a high diagnostic yield in clinical settings, consistent with pulmonary TB surveillance across sub-Saharan Africa. Among confirmed cases, the low rates of primary resistance to rifampicin (1.44%) and isoniazid (0.44%) align with national historical data from Burkina Faso's National Tuberculosis Control Program, where rifampicin resistance (RR) consistently remains under the 2% threshold in primary screening [16]. This relatively low baseline resistance rate demonstrates effective first-line case management and controlled transmission dynamics in the general population compared to high-burden MDR-TB regions in Eastern Europe or Southern Africa.

Our results are lower than those reported in Burkina Faso by Gomgnibou *et al.* in 2025, who found a prevalence of 33.7% among 500 suspected patients with a multidrug-resistant tuberculosis (MDR-TB) prevalence based on Xpert MTB/RIF results of 24.26% (41/169) [17]. Our results are higher than those of Boncoungou *et al.*, who found in 2023 in Ouagadougou that 14 cases of Pre-XDR and XDR tuberculosis were screened, representing a prevalence of 4.54% in a cohort of 308 patients [10].

Our results differ from those of Senegal, where K Djibril Saw *et al.* in 2022 reported a prevalence of 67.42% among suspected tuberculosis cases with an MDR-TB rate of 11% [12].

The slight difference observed between our study (1.44%) and the national data (2.10%) can be explained by several factors. First, our study population likely differs from the national population in terms of clinical characteristics and the distribution between new cases and previously treated patients. Resistance to rifampicin is known to be significantly more common among patients with a history of anti-tuberculosis treatment. Second, the observed variations may reflect differences in the study period, geographic coverage, or sample size.

Our results nevertheless confirm that primary rifampicin resistance remains relatively rare in Burkina Faso, which likely reflects the effectiveness of national strategies for the management and surveillance of drug-resistant tuberculosis. However, even though the prevalence remains low, each case of drug-resistant tuberculosis represents a major public health challenge due to the complexity of treatment, the high cost of care, and the risk of transmission of resistant strains.

The 2023 National Tuberculosis Program (PNT) data also illustrate the value of using the Xpert MTB/XDR test after rifampin resistance is detected. Among the 53 patients with rifampicin-resistant tuberculosis (TB-RR) who underwent this test, a significant proportion had multidrug-resistant tuberculosis (TB-MR) or additional resistance to ethionamide, underscoring that rifampicin resistance is often an excellent marker of multidrug resistance. This finding fully supports the current WHO recommendations to routinely perform a second-line susceptibility test in all patients identified as rifampicin-resistant.

Furthermore, the very low prevalence of isoniazid resistance (0.44%) observed in our study suggests that isolated resistance to this drug remains limited in our

setting. However, this estimate should be interpreted with caution, since screening for isoniazid resistance requires specific molecular tests such as Xpert MTB/XDR or line probe assays (LPA), which are not yet routinely available in all diagnostic centers.

These data confirm that resistance to first-line anti-tuberculosis drugs remains relatively low in West Africa, while highlighting the need for strengthened therapeutic monitoring and molecular resistance surveillance. These figures are significantly lower than the average WHO estimates for the African Region, which were 2.5% for RIF resistance and 11% for INH resistance among new TB cases in 2022 [18].

4.3. Prevalence and Profile of Viral Co-Infections

In our cohort, among 903 confirmed tuberculosis cases, 21 (44.7%) were men and 26 (55.3%) were women, representing an overall prevalence of 5.20% among TB patients. Our study showed a predominance of TB/HIV co-infection in the 20 - 40-year age group (51.1%), reflecting the vulnerability of the active and sexually active population. The finding of an overall TB/HIV co-infection prevalence of 5.20% (n = 47) among 903 PCR-confirmed tuberculosis cases, along with the specific age and sex breakdowns, provides valuable insights into the ongoing dynamics of the TB/HIV syndemic in Burkina Faso and similar West African contexts.

The observed prevalence of tuberculosis-HIV coinfection (5.20%), although it may seem relatively low, is clinically significant. It corresponds to a high-risk clinical subgroup. HIV-induced immunosuppression alters the clinical presentation of pulmonary tuberculosis, frequently resulting in low-bacillary sputum, atypical radiological findings, and higher rates of extrapulmonary dissemination, which complicates routine diagnosis and increases early mortality in the absence of prompt treatment.

Beyond the overall prevalence of coinfection, its distribution by sex also warrants special attention. A striking finding in this cohort is the shift in sex distribution between tuberculosis monoinfection and tuberculosis/HIV coinfection. The higher prevalence of tuberculosis/HIV co-infection among women is well documented throughout sub-Saharan Africa and is explained by underlying epidemiological and health-system factors (biological and structural vulnerability to HIV; differences in healthcare-seeking behaviors and access to testing).

The distribution by age is another important aspect of the analysis. The concentration in the 20 - 40 age group (51.1%) highlights the overlap of two periods of peak risk: the age at which sexual activity is most intense (a key determinant of HIV infection) and the age at which social contacts are most frequent and physiological susceptibility to active tuberculosis is highest.

From a clinical and programmatic perspective, these findings highlight the importance of integrated management of both infections. These results reinforce the key priorities for integrated disease management within district health networks. Systematic and routine HIV screening must be maintained for all patients with

confirmed tuberculosis. Antiretroviral therapy (ART) and preventive tuberculosis treatment (PTT) should be initiated early to reduce mortality among the co-infected population. Antiretroviral therapy (ART) should be initiated within 2 to 8 weeks of starting antituberculosis treatment (depending on CD4 count and CNS involvement). Furthermore, it is essential to expand preventive tuberculosis treatment to all eligible people living with HIV in order to prevent disease reactivation among those aged 20 - 40. Gender-specific interventions should be implemented if maternal health facilities focused on women can effectively screen for co-infections in women. Targeted community awareness strategies are needed to reach men aged 20 to 40 who may have undiagnosed HIV-associated tuberculosis.

Our results are lower than those reported by S. Maiga *et al.* (2021) in Burkina Faso, who found a TB/HIV prevalence of 9.8% [19].

They are also higher than those of H. Issa *et al.* in Niger in 2024, who found 6 (2.41%) HIV-positive patients out of a total of 248 patients [13]. Conversely, when considering the group of people living with HIV (PLHIV), out of a total of 258 HIV-infected patients, 103 tuberculosis cases were detected, with an estimated co-infection prevalence of 39.9% [20].

These results support the idea that tuberculosis remains one of the main opportunistic infections during HIV in the sub-region. The stabilization of the rates observed in your study could reflect an improvement in screening strategies and antiretroviral coverage in Burkina Faso.

In our study, a prevalence of TB/HBV co-infection of 0.78% was observed among TB+ patients. Our results are lower than those of Sanou *et al.* in Burkina Faso, who in a cross-sectional analytical study conducted in health facilities participating in TB management in the Hauts-Bassins region of Burkina Faso between October 2023 and June 2024 obtained, out of a total of 259 TB patients, an overall HBsAg prevalence of 10.03% [21].

Our results are lower than those of Agabi *et al.* in Nigeria in 2023, who among seventy-one (71) tuberculosis patients in their research found that 4 (5.6%) patients were infected with hepatitis B viruses. HBV seroprevalence was 3 (13.1%) and 1 (11.1%) among two age groups: 26 - 30 and 36 - 40 years, respectively [22].

TB/HBV co-infection, although less frequent, deserves special attention due to possible liver complications during anti-TB treatment, particularly with hepatotoxic drugs (isoniazid, pyrazinamide).

4.4. Coinfection, Adherence and Resistance Profile

In the present study, reported treatment adherence was high (85.0%) and 9.4% of patients experienced treatment failure, mainly in the TB-only group. The majority of rifampicin (RIF) and isoniazid (INH) resistant strains were detected in patients declared as adherent (92.3% for RIF, and 100% of INH cases).

Our results are comparable to those reported by Bagaya *et al.* in Burkina Faso in 2025, which showed that despite improved tuberculosis management, the overall treatment success rate was 78.3% (1238/1581). The failure rate was 3.92% (62

patients/1581), the default rate was 8.67% (137 patients/1581), and the death rate reached 9.11% (144 patients/1581) [9].

Our results are comparable to those of Germain *et al.* in Kisangani in 2024, who found among 1365 analyzed tuberculosis cases a treatment success rate of 95.8% versus a treatment failure rate of 4.2% [23].

A) Patients with tuberculosis alone (TB alone)

According to the National Tuberculosis Control Program (PNLT), therapeutic adherence rates among TB patients without co-infection vary between 85% and 90% depending on the region (PNLT, 2020). These results are comparable to the adherence rate of 84.4% observed in our study. These results confirm national findings. Indeed, according to the National Population Health Observatory of Burkina Faso (ONSP), between 2015 and 2021 the treatment success rate for anti-tuberculosis treatment increased from 72% to 80.9%. This remains below the expected WHO target of 90% [24].

Our results differ from those of Diarra *et al.* in Mali in 2024, who in a study of 172 patients saw the follow-up rate reach 98.8% for follow-up 0% and 75% for follow-up 6, with a cure rate of 76.7% and a death rate of 14% versus 1.2% treatment failure [25].

B) Patients with tuberculosis and HIV (TB/HIV)

For TB/HIV co-infections, Zoungrana *et al.* 2025 in Burkina Faso reported high therapeutic adherence among TB/HIV patients in a study on the knowledge and perceptions of people living with HIV regarding adherence support mechanisms in treatment centers in the Plateau-Central region of Burkina Faso, November 2024. Indeed, out of a total of 347 people living with HIV (PLHIV), 80% of participants adhered to treatment. Almost all PLHIV (99.7%) were aware of adherence support devices [26]. This adherence could be attributed to the integration of TB care into HIV programs.

C) Patients with tuberculosis and HBV (TB/HBV)

For TB/HBV co-infections, Sanou *et al.* in Burkina Faso report a prevalence of TB/HBV co-infection of 10.0% among tuberculosis patients in the Hauts-Bassins region [21]. This value is significantly higher than that observed in our study (0.78%). This difference could be explained by systematic HBV screening in Sanou's study, a more exposed population, or regional variations in HBV endemicity in Burkina Faso. It highlights the risk of underestimation when HBV screening is not systematic.

Our results are lower than those of Ayanyinka *et al.* in Nigeria, who reported an overall hepatitis B (HBsAg) prevalence of 11.6% (25/216), with a higher prevalence among 30 - 44 years old (4.6%) in a study on the prevalence of hepatitis B virus infection among people with active tuberculosis attending selected directly observed treatment (DOT) clinics in Oyo State, Nigeria in 2025 [27].

Overall, the prevalence of TB/HBV co-infection observed in our study (0.78%) is lower than those reported in Burkina Faso and other West African countries. The differences observed between studies could be explained by the heterogeneity

of screening strategies, regional variability of HBV endemicity, and the characteristics of the studied populations. These results argue in favor of systematic HBV screening among tuberculosis patients, in order to improve management and prevent liver complications related to anti-tuberculosis treatments.

Regarding treatment adherence, we can state that self-reported treatment adherence was high (85.0%), with a treatment failure rate of 9.4%, observed primarily among patients with tuberculosis alone. The majority of rifampicin-resistant cases (92.3%) and all isoniazid-resistant cases were identified among patients who reported adhering to treatment, indicating that the observed resistance is more closely linked to the transmission of already resistant strains (primary resistance) than to poor adherence. This finding is consistent with national data showing a low prevalence of multidrug-resistant tuberculosis in Burkina Faso and rising treatment success rates.

Among patients with TB/HIV coinfection, the absence of treatment failure in our series could be explained by enhanced follow-up and the integration of HIV and tuberculosis care, which promote better treatment adherence. Similarly, the very low prevalence of TB/HBV coinfection (0.78%) is lower than the data reported in several African studies, likely due to differences in screening strategies, characteristics of the study populations, and regional variations in HBV endemicity.

Overall, these results underscore that the quality of treatment monitoring, early diagnosis of co-infections, and systematic HBV screening are essential for improving tuberculosis treatment outcomes and limiting complications, particularly hepatotoxicity and the emergence of drug resistance. They also confirm the value of integrated care for patients with tuberculosis, especially when they have a viral co-infection.

5. General Conclusion

This study provides a pivotal update of compelling evidence on the molecular epidemiology of Mycobacterium tuberculosis complex (MTBC) and first-line drug resistance profiles within the health delivery context of Burkina Faso. It confirms a stable TB prevalence (20.7%) among suspects, but reassures with the low prevalence of rifampicin (1.44%) and isoniazid (0.44%) resistance, as well as MDR-TB (0.44%). The use of Xpert molecular tests proves relevant in this context of low resistance.

The co-infection profile highlights the persistent burden of HIV (5.20% among TB+ patients) and underscores the importance of systematic HBV screening (0.78% among TB+ patients) to prevent hepatotoxicity.

The most significant finding is the paradox of treatment outcomes. The complete absence of failure among co-infected patients, contrasting with a nearly 12% rate of unfavorable outcomes (failures + restarts) among "TB-only" patients, demonstrates the effectiveness of the integrated and reinforced management model applied to chronic diseases such as HIV. This success should serve as a benchmark.

This study highlights a high prevalence of tuberculosis among suspected patients in Burkina Faso, while confirming low circulation of rifampicin and isoniazid-resistant strains. The low proportion of multidrug-resistant tuberculosis observed suggests an overall effectiveness of current diagnostic and management strategies, supported by the use of rapid molecular tests.

HIV and HBV co-infections, although present, were not associated with an increased risk of molecular resistance or unfavorable treatment outcomes. On the contrary, co-infected patients exhibited high adherence and better clinical outcomes, likely related to reinforced and integrated medical follow-up.

The major finding of this study lies in the concentration of treatment failures and restarts among tuberculosis patients without viral co-infection, despite satisfactory reported adherence. This paradox suggests that factors other than treatment adherence, such as diagnostic delay, initial bacillary load, undocumented comorbidities, or quality of follow-up, play a determining role in clinical outcomes.

These results underscore the need to strengthen therapeutic monitoring for all tuberculosis patients, expand systematic screening for viral co-infections, and improve care integration in order to consolidate gains in the fight against tuberculosis in Burkina Faso.

Data Availability

The data generated and/or analyzed during this study are available from the corresponding author upon reasonable request.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] WHO (2025) Global Tuberculosis Report 2025. WHO.

[2] WHO (2024) Global Tuberculosis Report 2024. 1st Edition, World Health Organization.

[3] Lawal, A., Hussein, A., Tiberi, S. and Kunst, H. (2025) Barriers to and Enablers of Adherence to the Treatment of Active Drug-Sensitive Tuberculosis in People Living with HIV: A Mixed Method Systematic Review. *BMC Public Health*, **26**, Article No. 39. https://doi.org/10.1186/s12889-025-25631-7

[4] Meda, N., Tuaillon, E., Kania, D., Tiendrebeogo, A., Pisoni, A., Zida, S., *et al.* (2018) Hepatitis B and C Virus Seroprevalence, Burkina Faso: A Cross-Sectional Study. *Bulletin of the World Health Organization*, **96**, 750-759.

https://doi.org/10.2471/blt.18.208603

[5] Baya, B., Diarra, B., Diabate, S., Kone, B., Goita, D., Sarro, Y.D.S., *et al.* (2020) Association of *Mycobacterium africanum* Infection with Slower Disease Progression Compared with Mycobacterium Tuberculosis in Malian Patients with Tuberculosis. *The American Journal of Tropical Medicine and Hygiene*, **102**, 36-41. https://doi.org/10.4269/ajtmh.19-0264

[6] Sow, K.D., Yanogo, P., Ndiaye, M., *et al.* (2018) Profil épidémiologique de la Tuberculose, Sénégal, 2009-2018. *The Journal of Interventional Epidemiology and Public Health*, **4**, Article 12. https://www.afenet-journal.net/content/series/4/3/12/full

[7] Lönnroth, K., Jaramillo, E., Williams, B.G., Dye, C. and Raviglione, M. (2009) Drivers of Tuberculosis Epidemics: The Role of Risk Factors and Social Determinants. *Social Science & Medicine*, **68**, 2240-2246. https://doi.org/10.1016/j.socscimed.2009.03.041

[8] WHO (2002) Gender in Tuberculosis Research: International Perspectives. WHO.

[9] Bagaya, S.M., Bebane, I., Boro, D., *et al.* (2025) Profil épidémiologique de la tuberculose dans un contexte sécuritaire difficile (2021-2023): Région du Centre-Est, Burkina Faso. *Pan African Medical Journal*, **52**, Article 119.

[10] Boncoungou, K., Halidou Moussa, S., Maiga, S., *et al.* (2023) Outcome of Patients Affected by Pulmonary Tuberculosis with Pre-Ultraresistant and Ultraresistant Bacilli in Burkina Faso. *Journal of Functional Ventilation and Pulmonology*, **44**, 1-56.

[11] Marietou, T., Coulibaly, S., Konaté, M. and Traoré, T. (2023) Profil épidémiologique des patients ayant abandonnés leurs traitements antituberculeux dans le district sanitaire de la commune VI de Bamako de 2018-2020. *Mali Santé Publique*, **12**, 70-78. https://doi.org/10.53318/msp.v12i01.2426

[12] Djibril Sow, K., Ndiaye, M., Kane, M., Sawadogo, B., Laurent, M., Diallo, F., *et al.* (2022) Profil épidémiologique de la tuberculose, Sénégal, 2009-2018. *Revue d'Épidémiologie et de Santé Publique*, **70**, S161-S162. https://doi.org/10.1016/j.respe.2022.06.093

[13] Hamidou, I., Aim, G., Garba, A.A., *et al.* (2024) Profil épidémiologique et évolutif de la tuberculose à l'Hôpital National de Zinder (HNZ) au Niger. *Health Sciences and Diseases*, **25**, 116-120.

[14] WHO (2020) WHO Operational Handbook on Tuberculosis. Module 4: Treatment—Drug-Resistant Tuberculosis Treatment. World Health Organization.

[15] PNT Burkina Faso (2023) Rapport annuel de lutte contre la tuberculose. Ministère de la Santé.

[16] Diandé, S., Badoum, G., Combary, A., Zombra, I., Saouadogo, T., Sawadogo, L.T., *et al.* (2019) Multidrug-Resistant Tuberculosis in Burkina Faso from 2006 to 2017: Results of National Surveys. *European Journal of Microbiology and Immunology*, **9**, 23-28. https://doi.org/10.1556/1886.2018.00029

[17] Gomgnimbou, M.K., Kambiré, D., Paré, S.J.E., Belem, L.R.W., Sawadogo, L.T., Sanou, A.Q., *et al.* (2025) Molecular Detection of Multidrug-Resistant Tuberculosis Reveals High Prevalence among Previously Treated Tuberculosis Patients in Burkina Faso. *American Journal of Molecular Biology*, **15**, 135-149. https://doi.org/10.4236/ajmb.2025.152011

[18] World Health Organization (2023) Global Tuberculosis Report 2023. 1st Edition, World Health Organization.

[19] Maïga, S., Ouédraogo, K.O., Nacanabo, R.N., *et al.* (2021) Profil épidémio-clinique et issue thérapeutique de la tuberculose dans la ville de Ouahigouya—Burkina Faso.

Journal de la Fonction Ventilatoire et de Pneumonogie-Sommeil, **12**, 12.

[20] Ouedraogo, G.A., Maïga, S., Sawadogo, A., Ouedraogo, A., Gnamou, A., Zonon, H., *et al.* (2025) Prevalence and Associated Factors of Tuberculosis-HIV Co-Infection among Patients Hospitalized at CHU Yalgado Ouédraogo (2019-2024). *Asian Journal of Research in Infectious Diseases*, **16**, 45-53. https://doi.org/10.9734/ajrid/2025/v16i9490

[21] Sanou, A.M., Dera, A., Diendere, J., Ouattara, N.M.G., Kyelem, E., Traore, A.S., *et al.* (2025) Hepatitis B and C Infection in Tuberculosis Patients in the Hauts Bassins Region of Burkina Faso, West Africa. *Journal of Clinical Virology Plus*, **5**, Article 100211. https://doi.org/10.1016/j.jcvp.2025.100211

[22] Agabi, Y.A., Onyedikachukwu, A.J., Udeogu, K.E., Chukwu, C., Nkup, J.Y., Okojokwu, O.J., *et al.* (2023) Coinfections with Hepatitis B Virus and Hepatitis C Virus among Tuberculosis Patients in Jos, Nigeria. *Sri Ramachandra Journal of Health Sciences*, **3**, 14-18. https://doi.org/10.25259/srjhs_6_2023

[23] Mambandu Germain, L., Tagoto Alliance, T., BisutaSerge, F. and Likwela Joris, L. (2024) Succès thérapeutique et facteurs associés chez les patients tuberculeux à Kisangani de 2020 à 2023. *International Journal Dental and Medical Sciences Research*, **6**, 7-19.

[24] ONSP-SANTE-BF (2023) Profil du Burkina Faso sur la Tuberculose. https://www.cns.bf/media/statistiques/ms/DGESS-MS/Autres%20documents%20statistiques/Profil%20du%20Burkina%20sur%20la%20tuberculose.pdf

[25] Diarra, K. (2023) Evaluation du suivi du traitement de la tuberculose dans le district sanitaire de Koro de 2019-2021. *Mali Santé Publique*, **13**, 12-16. https://doi.org/10.53318/msp.v13i1.2638

[26] Zoungrana-Yameogo, W.N., Yabre, D.H.L., Bakiono, F., *et al.* (2025) Connaissances et perceptions des personnes vivant avec le VIH sur les dispositifs d'aide à l'observance dans les centres de traitement de la région du Plateau-Central du Burkina Faso, novembre 2024. *Médecine Tropicale et Santé Internationale*, **5**, mtsi.v5i2.2025.643.

[27] Ayanyinka, A.D., Oyelayo, I.C., Abiona, H.O., Ojeniyi, F.D., Opaleye, O.O., Ojurongbe, O., *et al.* (2025) Prevalence of Hepatitis B Virus Infection among Individuals with Active Tuberculosis Attending Selected Directly Observed Therapy (DOT) Clinics in Oyo State, Nigeria. *BMC Infectious Diseases*, **25**, Article No. 1753. https://doi.org/10.1186/s12879-025-12171-z