

# The Epidemiology of Tuberculosis in Western Sudan during the Sudan War 2023-2024

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## Abstract

**Background:** Tuberculosis is endemic in Sudan and has witnessed a major surge amid the country's continuous conflict. The goal of this study is to analyze the epidemiological aspects of tuberculosis in Western Sudan from 2023 to 2024, during the Sudan War. **Methodology:** This is a retrospective descriptive study that was carried out at El-Obeid Teaching Hospital in North Kordofan State, Sudan, during August and September 2024. All information on tuberculosis patients diagnosed between 15 April 2023, and 15 April 2024, was obtained from the hospital. **Results:** The results showed that 71% of the 751

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tuberculosis patients had pulmonary tuberculosis, while 29% had extrapulmonary tuberculosis. Among the 533 patients with pulmonary tuberculosis, 74.3% were male and 62% were female. Among the 218 patients with extrapulmonary tuberculosis, 19% were males and 37.9% were females. The predominant age group for pulmonary tuberculosis was 19 - 25 years, followed by  $\geq 46$  and 26 - 35 years, with incidence rates of 25.3%, 25%, and 24.6%, respectively. Extrapulmonary tuberculosis was most prevalent in those aged  $\geq 46$  years, followed by those aged  $\leq 18$  years and 26 - 35 years, representing 38%, 18.3%, and 16%, respectively. **Conclusion:** Tuberculosis is prevalent in western Sudan and has seen a significant rise during the region's conflict. Tuberculosis predominantly impacts individuals in their younger years. The heightened operations of conventional gold mining, coupled with the escalating urban air pollution, have markedly influenced the elevated epidemiological rates of the disease in Sudan. A significant number of individuals receive diagnoses and treatment at a delayed stage, potentially facilitating the propagation of infection.

## Keywords

Tuberculosis, Pulmonary TB, Extra Pulmonary TB, Sudan, Mycobacterium Tuberculosis

## 1. Introduction

Tuberculosis (TB) constitutes a significant global health challenge and ranks among the foremost causes of mortality worldwide, resulting in around 1.5 million fatalities. With multidrug-resistant tuberculosis (MDR-TB) becoming a significant hazard, healthcare authorities require dependable epidemiological evidence as an essential reference to properly tackle this issue [1].

Approximately one-quarter of the global population is infected with Mycobacterium tuberculosis, with 5% - 10% of those infected developing tuberculosis during their lifetime [2]. Preventing tuberculosis is a critically neglected yet vital aspect of mitigating the tuberculosis epidemic [3]. Furthermore, contemporary information demonstrates that tuberculosis symptoms exist on a continuum from infection to disease rather than in a binary framework as previously understood. Clarifying the factors influencing the transition between these stages is essential for reducing the tuberculosis burden and achieving the WHO's END-TB Strategy objectives. Vaccination, infection diagnosis, and the administration of preventative medication are essential components of tuberculosis prevention [4].

According to estimates, tuberculosis contributed to 1% of all inpatient deaths in Sudan in 2017. The combined prevalence of tuberculosis in Sudan was 30.72% [5]. The resistance profile of previously treated individuals was much higher than that of newly diagnosed TB patients. The considerable prevalence estimate of anti-TB medication resistance necessitates the enhancement of TB control and treatment

techniques in Sudan [6].

Armed conflicts without appropriate interventions correlated with poorer tuberculosis treatment outcomes, characterized by reduced treatment success rates and increased instances of loss to follow-up, mortality, and treatment failure [7].

In the context of the 2023 conflict in Sudan, many individuals are vulnerable to tuberculosis due to a lack of basic necessities, resulting in malnutrition, increased disease prevalence, and diminished immunity. Furthermore, many patients discontinued their treatment, becoming vectors of infection. This study aims to assess the epidemiological characteristics of tuberculosis in Western Sudan during the Sudan War from 2023 to 2024.

## 2. Materials and Methods

This is a retrospective descriptive study carried out at El-Obeid Teaching Hospital in North Kordofan State, Sudan, from August 2024 to September 2024. We obtained all data pertaining to patients diagnosed with tuberculosis between 15 April 2023 and 15 April 2024 from the hospital. The sample size encompasses the complete population of TB patients over the specified timeframe (one year amid the Sudan War, 2023-2024). Over the period, approximately 1186 patients exhibited symptoms of tuberculosis (TB), with 751 of them receiving a positive diagnosis. In addition to clinical information, the patient files include demographic data such as age, sex, education level, occupation, marital status, and domicile.

The diagnosis of tuberculosis is based on medical history, Physical examination, tuberculosis blood tests or skin tests, chest radiograph, and bacteriologic examination (including sputum smear microscopy, nucleic acid amplification testing, culture, and drug susceptibility testing).

## 3. Statistical Analysis

We organized all collected data into data sheets and then input them into the Statistical Package for Social Sciences (SPSS) version 24, located in Chicago, USA. We examined the data to derive frequencies, percentages, and cross-tabulations.

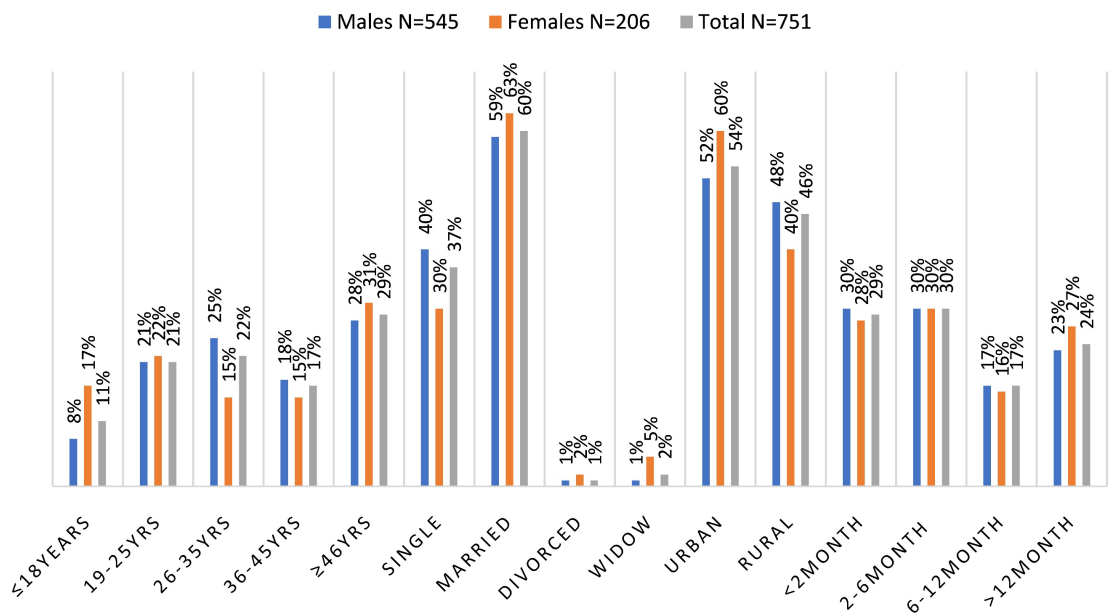
## 4. Results

This study included 751 tuberculosis patients aged one year to 90 years, with a mean age and standard deviation of  $37.7 \pm 18.6$ . Approximately 82/751 (10.9%) patients were under 18 years old, whereas 216/751 (28.8%) were over 46 years old. Out of the 751 patients, 545/751 (72.6%) were males and 206/751 (27.4%) were females, resulting in a male-female ratio of 2.65:1.00. The majority of patients were married (450/751, 59.9%), followed by singles (278/751, 37%), as shown in **Table 1** and **Figure 1**.

Most patients received treatment within 2-6 months of symptom onset, with 227/751 (30%), 219/751 (29%), and 180/751 (24%), as shown in **Table 1** and **Figure 1**.

**Table 1.** Distribution of the study population by sex and marital status & duration of symptoms before starting the treatment.

Variable	Males n = 545	Females n = 206	Total n = 751
<b>Age</b>			
≤18 years	46	36	82
19 - 25	115	45	160
26 - 35	136	30	166
36 - 45	96	31	127
≥46	152	64	216
<b>Marital status</b>			
Single	217	61	278
Married	320	130	450
Divorced	3	4	7
Widow	5	11	16
<b>Residence</b>			
Urban	286	123	409
Rural	259	83	342
<b>Duration of symptoms/month</b>			
<2 month	161	58	219
2 - 6	166	61	227
6 - 12	93	32	125
>12	125	55	180

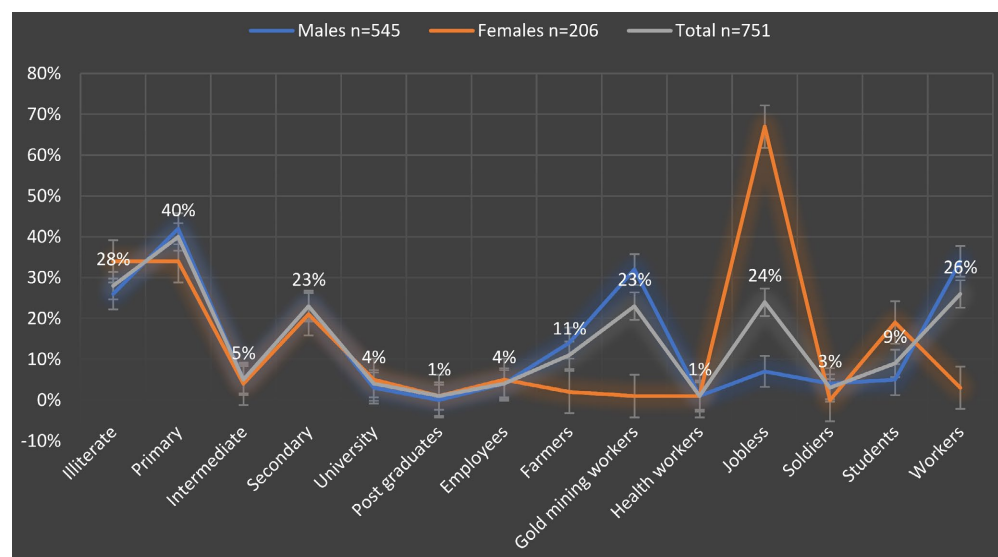


**Figure 1.** Describes the study population by sex, marital status, and the duration of symptoms before starting the treatment.

**Table 2** and **Figure 2** describe the study population's distribution by degree of education and occupation. The bulk of the patients had a primary level of education, followed by illiterates and secondary, with 301/751 (40%), 214/751 (28%), and 171/751 (22.8%), respectively. In terms of occupation, the majority of patients were conventional workers, followed by jobless and gold mining workers, who accounted for 195/751 (26%), 177/751 (23.6%), and 175/751 (23%), respectively.

**Table 2.** Distribution of the study population by level of education and occupation.

Variable	Males n = 545	Females n = 206	Total n = 751
<b>Education</b>			
Illiterate	143	71	214
Primary	230	71	301
Intermediate	28	9	37
Secondary	127	44	171
University	17	10	27
Post graduates	0	1	1
<b>Occupation</b>			
Employees	20	10	30
Farmers	74	5	79
Gold mining workers	172	3	175
Health workers	3	2	5
Jobless	38	139	177
Soldiers	24	0	24
Students	26	40	66
Workers	188	7	195

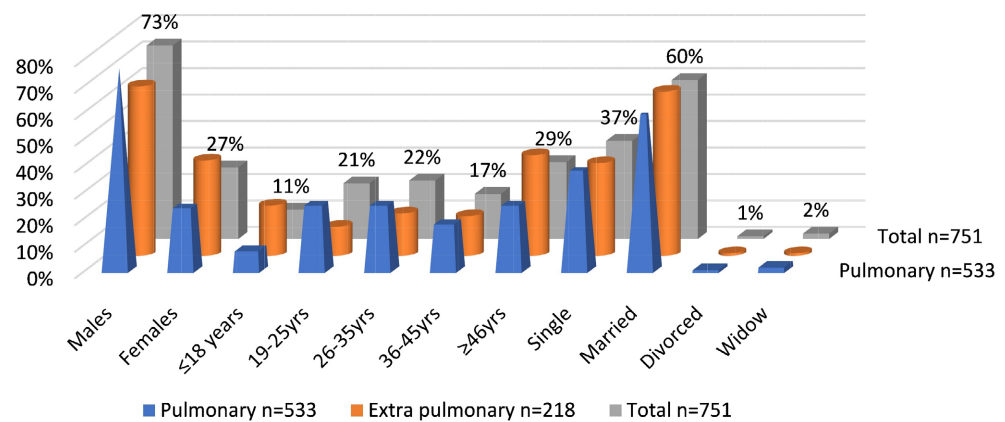


**Figure 2.** Provides a description of the patients based on their demographic characteristics.

**Table 3** and **Figure 3** summarize the study population’s distribution by type of tuberculosis and sex, age, and marital status. Out of 751 TB patients, 533/751 (71%) had pulmonary TB, whereas the remainder (218/751) (29%) had extrapulmonary TB. Of the 533 pulmonary tuberculosis patients, 405/545 (74.3%) were men and 128/206 (62%) were women. Of the 218 individuals with extrapulmonary tuberculosis, 104/545 (19%) were men and 78/206 (37.9%) were women.

**Table 3.** Distribution of the study population by type of TB and sex, age, and marital status.

Variable	Pulmonary n = 533	Extra pulmonary n = 218	Total n = 751
<b>Sex</b>			
Males	405	140	545
Females	128	78	206
<b>Age</b>			
≤18 years	40	42	82
19 - 25	135	25	160
26 - 35	131	35	166
36 - 45	94	33	127
≥46	133	83	216
<b>Marital status</b>			
Single	202	76	278
Married	314	136	450
Divorced	4	3	7
Widow	13	3	16



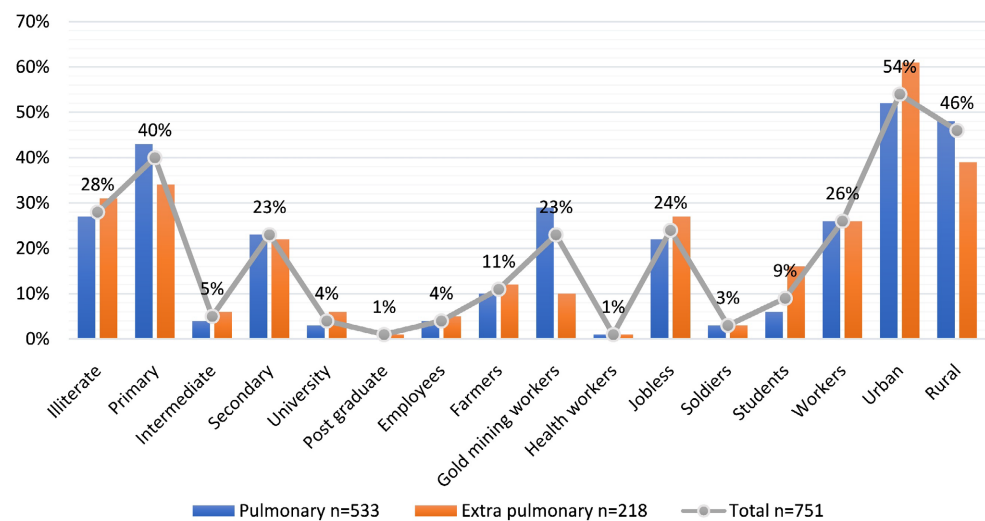
**Figure 3.** Description of the patients by TB type and demographic characteristics.

The most common age group for pulmonary tuberculosis was 19 - 25 years, followed by ≥46 and 26 - 35 years, with 135/533 (25.3%), 133/533 (25%), and 131/533 (24.6%) cases, respectively. Extrapulmonary tuberculosis was more prevalent in individuals aged ≥46 years, followed by those aged ≤ 18 years and 26 - 35 years, with 83/218 (38%), 40/218 (18.3%), and 35/218 (16%) cases, respectively.

The majority of patients with both TB types were married, followed by singles, as shown in **Table 3** and **Figure 3**.

**Table 4.** Distribution of the study population by type of TB and education, occupation, residence.

Variable	Pulmonary n = 533	Extra pulmonary n = 218	Total n = 751
<b>Education</b>			
Illiterate	146	68	214
Primary	227	74	301
Intermediate	23	14	37
Secondary	123	48	171
University	14	13	27
Postgraduate	0	1	1
<b>Occupation</b>			
Employees	19	11	30
Farmers	52	27	79
Gold mining workers	153	22	175
Health workers	3	2	5
Jobless	118	59	177
Soldiers	17	7	24
Students	32	34	66
Workers	139	56	195
<b>Residence</b>			
Urban	277	132	409
Rural	256	86	342



**Figure 4.** Provides a description of patients by TB type and demographical characteristics.

**Table 4** and **Figure 4** summarize the study population's distribution by type of tuberculosis, education, occupation, and residence. The distribution of both TB forms was consistent across educational levels. The bulk of pulmonary tuberculosis patients are gold miners, followed by conventional laborers and the unemployed, who account for 153/533 (28.7%), 139/533 (26%), and 118/533 (22%), respectively. The unemployed had the highest prevalence of extra pulmonary tuberculosis, followed by traditional workers and students, with 59/218 (27%), 56/218 (25.7%), and 34/218 (15.6%), respectively. Out of the 751 patients, 409/751 (54.5%) were urban, whereas 342/751 (45.5%) were rural.

## 5. Discussion

Tuberculosis is a serious health concern in many low-income countries, with rising incidence rates and a growing problem of treatment resistance worldwide. Although Sudan has a longstanding TB problem, it accounts for 11% - 15% of the tuberculosis burden in the Eastern Mediterranean Region [8]. However, the prolonged battle between 2023 and 2024 exacerbated the situation. As a result, this study examines the epidemiologic pattern of tuberculosis during this tough period typified by a serious breakdown of the healthcare system, the loss of basic necessities, extreme poverty, and the dire situation of the refugees.

The current study's findings revealed that the incidence of tuberculosis (both pulmonary and extrapulmonary) among patients who presented with TB symptoms was 63.3%, which is much higher than studies from other parts of Sudan.

Most of the research in this field took place in eastern and central Sudan. During our literature search, we found no studies from Western Sudan. Abdallah and Ali [9] conducted a study on the epidemiology of tuberculosis in Sudan and discovered that 73.4% of TB patients had pulmonary TB and 26.6% had extra-pulmonary TB. Another study from Sudan found a prevalence of pulmonary tuberculosis (36.9%) [8]. In a meta-analysis study, the pooled prevalence was 30.72% [CI: 30.64 - 30.81]. Furthermore, Khartoum State had the highest pooled prevalence of 41.86% [CI: 14.69, 69.02], based on a total sample size of 2737 participants [5].

Males dominated the current study (72.6%), which was greater than previously reported from Sudan (65.9%). The study population had a mean age of 37.7 ± 18.6, which was consistent with prior reported values of 37.7 (SD 21.5) years [8]. Notably, 10.9% of the patients in this study were pediatric (under 18 years old). TB is one of the major causes of death in children globally, but there are still considerable obstacles in detecting and treating the condition. Treatment of tuberculosis infection in children and adolescents is crucial to preventing progression of TB disease and preventing them from serving as a future reservoir for TB transmission [10]. Even today, we often overlook and undertreat childhood TB. Children in their initial years of life have a high risk of developing severe forms and dying if they do not receive antituberculosis therapy. These children often exhibit non-specific symptoms, which can easily confuse them with other infections of

bacterial, viral, or fungal origin, thereby complicating diagnosis [11]. We should target high-risk and socioeconomically deprived areas for tuberculosis control and combine this data with additional risk variables to develop more specific criteria for BCG vaccination [12].

The current study found that the risk of tuberculosis infection increases with particular jobs, including traditional workers, gold miners, and jobless people. These observations were previously reported [13]. In its most basic form, occupationally acquired disease refers to disease acquired while performing one's job. On the other hand, those concerned about tuberculosis transmission in the workplace concentrate on identifying individuals whose tasks could reasonably expose them to either 1) individuals with infectious tuberculosis or 2) air contaminated with *Mycobacterium tuberculosis* [14].

The vast majority of patients in this study began treatment two to six months after their symptoms initially emerged. People exposed to *Mycobacterium tuberculosis* may develop a latent infection, putting them at risk of developing tuberculosis (TB) disease for the rest of their lives, a condition known as TB infection (TBI). The goal of TB preventative treatment (TPT) is to treat TBI while also preventing the progression of active TB in an exposed or infected person. Currently, TBI cannot be confirmed microbiologically, but it can be detected indirectly using immune-based diagnostics [Tuberculin skin test (TST) and interferon-gamma release assays (IGRAs)]. It is critical to rule out active tuberculosis before starting TPT. TPT regimens have developed over time. The most commonly utilized regimen is six months of daily isoniazid (INH). Another regime in development for people over the age of two, but not yet generally available, is 3HP (3 months of weekly Isoniazid and Rifapentine). We must adjust TPT to contacts of drug-resistant tuberculosis (DR-TB) patients based on the resistance pattern in the index case and bacteriological validation. Regularly monitor individuals on TPT for any indications or symptoms of active tuberculosis [15].

Although the current study provides significant updates on the current state of TB epidemiology in Sudan during these critical times, it has some limitations, including a retrospective sampling design.

**In conclusion**, tuberculosis is prevalent in western Sudan and has surged significantly during the Sudan conflict. Tuberculosis predominantly impacts younger males. The increased operations of conventional gold mines, combined with escalating urban air pollution, have substantially contributed to the disease's elevated epidemiology in Sudan. A significant number of people receive late diagnoses and treatment, thereby facilitating the transmission of infection. Immediate measures are necessary to reduce the overall impact of tuberculosis in western Sudan.

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## Authors Contribution

-**Mohammed AKY**: Conceptual, Administration, Data collection, Analysis, Final approval.

-**Babker MKA**: Conceptual, Data collection, Methodology, Final Approval.

-**Ahmed EDM**: Methodology, Analysis, drafting, Final Approval.

-**Dafea HA**: Methodology, Analysis, drafting, Final Approval.

-**Adam TM**: Methodology, Analysis, drafting, Final Approval.

-**Monwer TAM**: Conceptual, Data collection, Methodology, Final Approval.

-**Ahmed MKM**: Conceptual, Data collection, Methodology, Final Approval.

-**Humida EHM**: Conceptual, Data collection, Methodology, Final Approval.

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-**Monawer TEM**: Methodology, Analysis, drafting, Final Approval.

-**Saror GAG**: Conceptual, Data collection, Methodology, Final Approval.

-**Ahmed AAM**: Conceptual, Methodology, administration, Final Approval.

-**Salem NAE**: Data manipulation, Analysis, Final Approval.

-**Ahmed HGA**: Conceptual, Consultation, Writing, critical revision, Final Approval.

## Conflicts of Interest

The authors declare no conflict of interest.

## Ethical Consideration

A permission was obtained from authorities in El-Obeid Teaching Hospital to get access to the notified information.

## Ethical Approval

The protocol of this study was approved by the Human Research Ethics Committee (HREC) at Prof. Medical Research Center-MRCC. Approval Number: HREC 0014/PMRCC.9/24).

## Data Availability

Data regarding this study is available from the corresponding author.

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