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Risk Factors and the Evolution of Tuberculosis Cases in the Laayoune and Tarfaya Provinces of Morocco

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Abstract

Background: Tuberculosis remains a major public health concern in Morocco. The main objective of this study was to evaluate its prevalence and analyze how risk factors influence the development of the disease and treatment failure rates in the Laayoune and Tarfaya provinces of Morocco.

Methods: This research took the form of a retrospective study of 1,333 tuberculosis cases, with all forms being combined, that were reported to the Center for the Diagnosis and Treatment of Respiratory Diseases in Laayoune between 2006 and 2012. We utilised the chi-square/Fisher's test for categorical analysis. Following this, a multivariate logistic analysis was undertaken to discern factors linked to Pulmonary/ extrapulmonary tuberculosis, presenting findings through odds ratios (OR) accompanied by 95% confidence intervals (CIs). Post-estimation analyses using the 'Lincom' command were executed to compute adjusted ORs and 95% CIs, amalgamating effects from preceding logistic models.

Results: This study found that 61.2% of patients were diagnosed with a form of pulmonary tuberculosis, while 38.8% presented extrapulmonary tuberculosis, including 12.2% lymph node cases and 15.9% pleural cases. In terms of treatment outcomes, 36.5% managed to complete their treatment, while 24.8% of pulmonary tuberculosis patients were cured. Nevertheless, 21.1% of patients needed to be transferred to other cities, 14.3% were lost to follow-up, and 3.2% died during treatment. 38.7% of patients had unfavourable outcomes, while 61.3% had favorable outcomes. A multivariate logistic analysis identified the risk factors associated with pulmonary and extrapulmonary tuberculosis and any adverse outcomes. Patients in some age groups had a significantly higher risk of pulmonary tuberculosis, when adjusted for diabetes (aOR=13.16, 95% CI[4.54-38.12]), more so once smoking was also taken into account (aOR=31.49, 95% CI [9.55-103.8]). Additionally, this study highlights how the high prevalence of pulmonary tuberculosis can be linked to smoking and a rural origin, with it underscoring a greater vulnerability among younger (aOR =7,16, 95% CI[2,34-21,83]) and elderly adults (aOR= 7,78 95% CI [2,24-27,00]), particularly those with diabetes.

The study identifies challenges in terms of diagnostic delays and providing access to healthcare in rural areas. The study's findings help improve our understanding of tuberculosis and will inform the development of more effective preventive strategies.

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Introduction

Tuberculosis (TB) is a major public health challenge around the world. Before the COVID-19 pandemic, it ranked ninth among the leading causes of death globally (Ben Ayed et al., 2018). According to a 2021 report on global tuberculosis by the World Health Organization (WHO), TB remains the leading cause of mortality among various infectious diseases (Chakaya et al., 2022) so it remains a serious threat to global public health and constitutes a major public health problem. Nevertheless, unlike the common concerns about pulmonary tuberculosis (PTB), extrapulmonary tuberculosis (EPTB) has received less attention. EPTB involves mycobacterium tuberculosis (MTB) infecting organs and sites outside the respiratory system. Indeed, it can affect various organs, leading to unusual symptoms and imaging findings. Diagnosing and managing EPTB is problematic because of the difficulty in obtaining samples and the low etiological positivity (Rodriguez-Takeuchi et al., 2019) Compared to PTB, however, there has been a significant increase in EPTB. The Global TB Report 2020 revealed that in 2019, 16% of all TB patients had EPTB (OMS, 2020, p. 202) In the United States and Europe, the share of EPTB cases has been found to vary from 20% to 53% (Rowińska-Zakrzewska et al., 2013, pp. 1974–2010)

The prevalence of tuberculosis and the deaths attributed to it remain particularly high in low- and middle-income countries (Harling et al., 2008; Költringer et al., 2023, pp. 2005–2015) Several factors can influence the risk of developing tuberculosis, such as sociodemographic factors

like age, sex, and occupation; environmental factors like indoor air pollution; practices and conditions that hinder the body's immune system (e.g., smoking, malnutrition, alcohol consumption, HIV, diabetes); and therapeutic challenges associated with the emergence of drug-resistant tuberculosis (Gelaw et al., 2019; Lönnroth et al., 2009). Morocco has not been spared the burden of tuberculosis. In 2019, the WHO estimated around 35,000 new cases and 2,900 deaths were linked to this disease, which is equivalent to a mortality rate of 8.1 per 100,000 inhabitants. In 2020, the total number of recorded cases was 29,018 once all forms were combined. In the same year, 240 cases of tuberculosis–HIV co-infection were identified (MSM, 2020) Faced with this alarming situation, we urgently need to increase the awareness of tuberculosis and improve measures to combat it. In Morocco, studies investigating TB and its associated factors are still limited.

Our study acknowledges the global context of TB while emphasizing the specific relevance to Laayoune and Tarfaya. According to the statistical report published by the Moroccan Ministry of Health in 2021, the issue of tuberculosis persists in the provinces of Laayoune and Tarfaya (MSPM, 2021). Furthermore, the study conducted in Laayoune, Morocco, revealed a higher prevalence of tuberculosis in males, predominantly in its pulmonary form (70.90%), while EPTB was more common in females (61%). The highest morbidity burden was observed in individuals aged ≥15 years (92.40%). Key risk factors influencing the defence against tuberculosis included HIV infection and smoking (Eddabra & Neffa, 2020).

This research therefore seeks to deepen our understanding of tuberculosis as a persistent global public health problem. We analyze the prevalence of the disease in detail together with the risk factors (e.g., age, diabetes, smoking, family history) and assess their impact on the risk of developing the disease. In addition, we examine how these same factors influence the risk of TB treatment failing. These obtained findings should contribute to developing better prevention and treatment strategies for combatting this persistent disease in the Laayoune and Tarfaya provinces of Morocco.

Sample and Methods

Research Design and Study Population

This study focused on two provinces in the Laayoune-Sakia El Hamra region, namely Laayoune and Tarfaya, which are located on the Atlantic coastline. In 2012, these two provinces had a total population of 260.000 inhabitants. In terms of their exact geographical locations, Laayoune is located at a latitude of 27°09'44" North and a longitude of 13°12'11" West, while Tarfaya is located at a latitude of 27°56'22" North and a longitude of 12°55'34" West.

This research is based on a retrospective study of 1,333 cases of tuberculosis of all types that were reported to the Center for Diagnosis and Treatment of Respiratory Diseases (CDTRD) in Laayoune over seven years from January 2006 to December 2012. During this study, all cases were consecutively included over time. Data collection was based on systematically filled medical records. These reported cases originated from various sources in the two provinces, such as a military hospital, various public health centres, public sector pulmonologists, and general practitioners and specialists in the private sector.

All parameters relating to reported cases—including age, sex, affected organs, results of biological and radiological examinations, treatment administered, clinical condition of patients, and so on—were carefully recorded in the medical records. The individual treatment of patients was also recorded in a register kept at the CDTRD. These individual patient records, which were systematically updated, comprised the main source of data for our study. During the study period, we identified 1,333 cases of tuberculosis that were managed and treated at the CDTRD in Laayoune. In this study, the rural-urban classification of participants was determined based on their residential status at the time of enrollment. Urban origin was assigned to participants residing in urban areas, while rural origin was designated for those residing in rural areas. The determination of rural or urban status was made considering established geographic and administrative criteria. This

classification provides a basis for assessing the potential impact of residence on tuberculosis outcomes, allowing for a comprehensive analysis of the influence of rural or urban origin on the study parameters.

Case Selection: Inclusion and Exclusion Criteria

To ensure a good representation and minimize any potential sampling bias, we included all TB cases that were diagnosed and reported during the study period.

Operational definitions

- **Classification of tuberculosis**: This encompasses categories of tuberculosis PTB and EPTB —for which the patients were diagnosed and subsequently administered treatment.
  TB relapse was characterized by the appearance of a new episode of TB in a previously treated patient who was considered "cured" upon completing treatment.
- **Cured**: This outcome applies to patients with pulmonary tuberculosis where the infection was bacteriologically confirmed at the start of treatment. To be considered cured, a patient must have negative test results (e.g., a smear examination or culture) in the last month of treatment and at least once before this.
- **Treatment completed**: This category covers TB patients who completed their treatment without any evidence of failure. However, data may be lacking to indicate that the test results for a smear examination or culture were negative during the last month of treatment and at least once before this, either because the tests were simply not carried out or because the results were unavailable.
- **Treatment failure**: This outcome applied to TB patients who continued to have positive test results from a smear examination or culture after five or more months of treatment.
- **Death**: This applies to TB patients who died for various reasons before, or during, treatment.
- **Lost to follow-up**: Patient was considered lost to follow-up if they failed to start treatment or their treatment was interrupted for two or more consecutive months because this indicates irregular follow-up for the recommended treatment.
- **Favorable treatment outcomes** fall into two categories, namely patients who completed their treatment and those who were deemed to be cured.
- **Adverse treatment outcomes** include cases of death, transfer to other cities, and patients lost to follow-up.

Statistical Analysis

We used Stata version 14 to perform our statistical analysis, with categorical variables being analyzed using the chi-square test and Fisher's exact tests. Variables with a P value less than 0.10 in the univariate analysis were included in a multivariate analysis, which used the multiple logistic regression method to identify independent variables associated with the transition from PTB to EPTB. Variables with a P value < 0.05 were considered independent risk factors, and the results were presented as odds ratios (OR) with a 95% confidence interval (95% CI). We also performed additional post-estimation analyses using the "Lincom" command to calculate the adjusted ORs at 95% CIs for the combined effects of factors from the previous multivariate logistic models.

Ethical Considerations

This work followed the ethical principles outlined in the Declaration of Helsinki for medical research involving human subjects. The necessary authorizations were obtained from the Regional Directorate of the Ministry of Health in Laayoune and the CDTRD in Laayoune to obtain access to the records required to conduct the study for the seven years from January 2006 to December 2012. In addition, the participants provided oral consent before any interviews when appropriate.

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Results

Sociodemographic characteristics of patients with tuberculosis and clinical manifestations

This study considered a total of 1,333 cases of TB. It should be highlighted that a clear gender disparity emerged, with 1.73 men being diagnosed for each woman.

Among the studied cases, 817 (61.2%) had PTB, while 517 (38.8%) had EPTB. The latter category included 163 cases (12.2%) of lymph node tuberculosis and 212 cases (15.9%) of pleural tuberculosis. In terms of treatment outcomes, 330 (24.8%) of the PTB patients were cured, while 486 (36.5%) completed their treatment. Among the cases studied, however, 281 (21.1%) were transferred to other cities, 191 (14.3%) were lost to follow-up, and 43 (3.2%) died during treatment. Overall, 515 patients (38.7%) had unfavourable outcomes, while 816 (61.3%) had favorable ones (figure 1, Table 1).

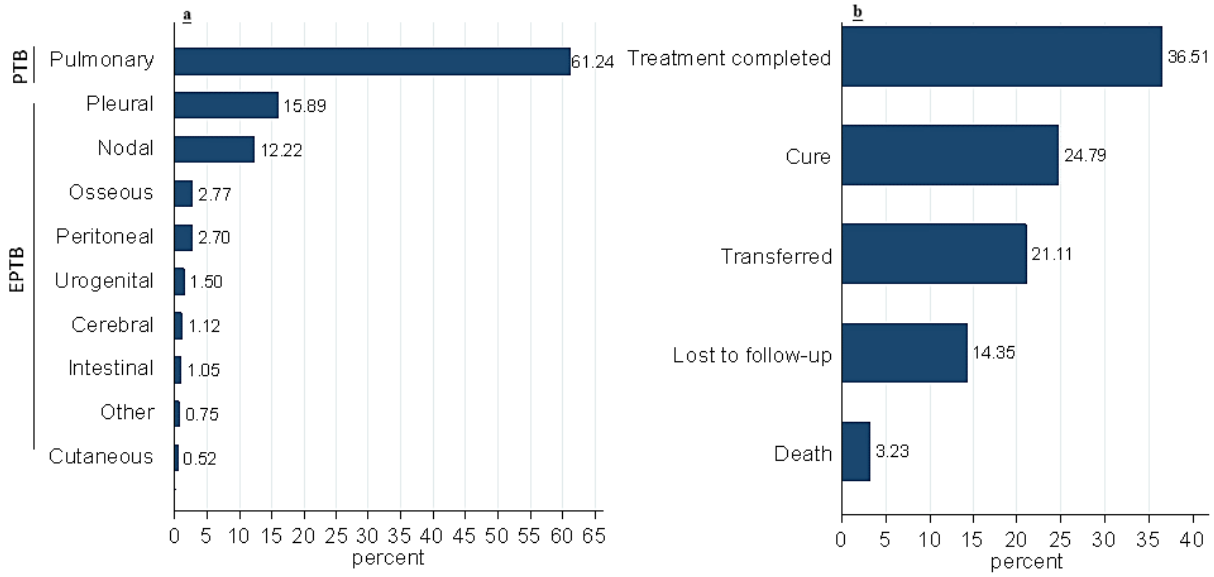

Figure 1: Tuberculosis Epidemiology: PTB vs. EPTB Distribution (a) and Case Progression (b).

Analysis of risk factors associated with PTB and EPTB

Compared to patients with EPTB aged younger than 15 years, a significantly higher risk was observed in patients with PTB in the age groups of 15–24 years, 25–34 years, 35–44 years, 45–54 years, 55–64 years, and 65 years or older, as shown in **Table 1**. This risk is 13 times higher (95% CI: 4.54 to 38.12) when adjusted for diabetes, and it reaches 31 times higher (95% CI: 9.55 to 103.8) when adjusted for both diabetes and smoking. Similarly, patients with a history of relapse, a male gender, a rural origin, diabetes, a family history, and a smoking habit were significantly and positively associated with a greater risk of developing PTB compared to patients with EPTB.

Multivariate logistic modelling of risk factors associated with adverse outcomes

The results of this analysis revealed that patients from rural areas have a greater risk of unsuccessful treatment outcomes when compared to patients from an urban setting, with the aOR being 2.66 (95% CI: 1.23–5.75). Once this rural origin is combined with smoking, however, it rises to 3.52 (95% CI: 1.45–8.52). Moreover, the association between a rural origin, smoking, and unsuccessful treatment outcomes is particularly strong among younger age groups, particularly among patients aged 25–34 years with an aOR of 7.16 (95% CI: 2.34–21.83) and patients aged over 64 years old with an aOR of 7.78 (95% CI: 2.24–27.00).

Table 1: The results of the univariate analysis and logistic multivariate analysis of risk factors associated with PTB and EPTB (N=1333).

	Location of	p-value	Multivariate analysis

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	tuberculosis			Univariate analysis	[a] OR (95% CI) [p-value]
	PTB N (%)	EPTB (%)		[c] OR (95% CI) [p-value]	
Age (years)					
<15	19 (2.3)	41 (7.9)		Ref	Ref
15-24	178 (21.8)	115 (22.2)		3.34(1.84-6.03) ***	**3.25(1.61-6.56)** **
25-34	255 (31.2)	153 (29.6)		3.59(2.01-6.42) ***	**2.95(1.48-5.91)** **
35-44	151 (18.5)	86 (16.6)	***	3.78(2.06-6.93) ***	**3.50(1.70-7.22)** **
45-54	113 (13.8)	55 (10.6)		4.43(2.35-8.34) ***	**3.55(1.66-7.59)** **
55-64	53 (6.5)	39 (7.5)		2.93(1.48-5.80) **	**2.42(1.06-5.52)** *
≥65	48 (5.9)	28 (5.4)		3.69(1.80-7.57) ***	**5.57(2.27-13.63)** ***
≥65[a]					**13.16(4.54-38.12)** ***
≥ 65[b]					**31.49(9.55-103.8)** ***
Episode of tuberculosis					
New case	744 (91.1)	499 (96.5)		Ref	Ref
Relapse	68 (8.3)	12 (2.3)	***	3.08(2.03-7.09) ***	**3.80(1.81-8.00)** ***
Failure	5 (0.6)	6 (1.2)		0.55(0.16-1.84)	**0.49(0.04-6.02)** NS
Sex					
Male	578 (70.7)	266 (51.7)	***	Ref	Ref
Female	239 (29.3)	249 (48.3)		0.44(0.35-0.55) ***	**0.49(0.37-0.65)** ***
Origin					
Urban	733 (96.6)	475 (98.5)	*	Ref	Ref
Rural	26 (3.4)	7 (1.5)		2.40(1.03-5.58) *	**2.55(1.05-6.18)** *
Diabetes					
No	632 (93.2)	403 (96.4)	*	Ref	Ref
Yes	46 (6.8)	15 (3.6)		1.95(1.07-3.54) *	**2.36(1.24-4.48)** **
Family history					
No	623 (91.9)	393 (94.0)	NS	Ref	Ref
Yes	55 (8.1)	25 (6.0)		1.38(0.85-2.26)	**1.96(1.14-3.37)** *
Smoking					
No	591 (87.0)	399 (95.5)	***	Ref	Ref
Yes	88 (13.0)	19 (4.5)		3.12(1.87-5.21) ***	**2.39(1.40-4.09)** **

a: Combined effect of age ≥ 65 and diabetes; b: Combined effect of age ≥ 65, diabetes and smoking; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

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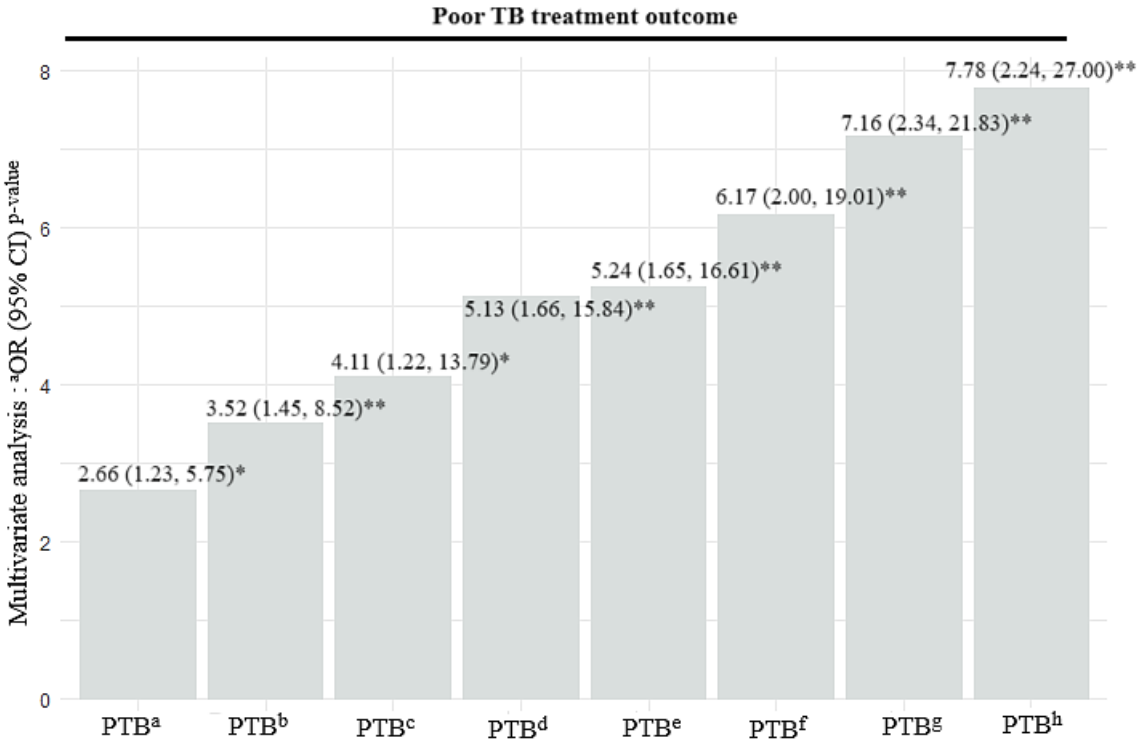

Figure 2: The multivariate model of risk factors associated with poor TB treatment outcomes (PTB: pulmonary tuberculosis).

a: The effect of a rural origin in tuberculosis patients; b: The combined effect of a rural origin and smoking in tuberculosis patients; c: The combined effect of a rural origin and smoking among tuberculosis patients aged 55–64 years; d: The combined effect of a rural origin and smoking among tuberculosis patients aged 35–44 years; e: The combined effect of a rural origin and smoking among tuberculosis patients aged 15–44 years; f: The combined effect of a rural origin and smoking among tuberculosis patients aged 45–54; g: The combined effect of a rural origin and smoking among tuberculosis patients aged 25–34 years; h: The combined effect of a rural origin and smoking among tuberculosis patients aged 65 and over. In addition, a, b, c, d, e, f, g, and h were adjusted according to the episode of tuberculosis, sex, diabetes, and family history. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Discussion

Tuberculosis stands as a significant global health concern. In developing countries, major global health organizations view TB as a serious public health challenge, making substantial investments to mitigate TB-related mortality and morbidity (WHO, 2023). In the present study, the prevalence of PTB was found to be 61.4%, which is much higher than that for EPTB at 36.6%. This is consistent with the findings of several previous research efforts (Arnedo-Pena et al., 2019; Chahboune et al., 2022; Chakaya et al., 2022; Eddabra & Neffa, 2020)Indeed, a TB infection usually starts in the respiratory tract, but it can spread to the blood and lymph nodes if the immune response is insufficient for containing the bacteria in the lungs. Nevertheless, the pathogenesis of tuberculosis is not fully understood. Studies have shown that women may be more prone to active EPTB, which would be consistent with our observations (Min et al., 2023; Sbayi et al., 2020; Tahseen et al., 2020).

Age is linked to the risk of PTB. We found that while children younger than 15 years have a lower risk of developing PTB, they are more likely to develop lymph node and pleural tuberculosis, regardless of sex, which is consistent with previous research (Dubois et al., 2022; Ramos et al., 2019). Additionally, another study conducted in Northwest Morocco revealed that younger patients are preferentially affected by lymph node tuberculosis (Sbayi et al., 2020). Similarly, a study carried out

in the Casablanca-Settat region found that extreme age groups were more prone to pleural and lymph node tuberculosis (Chahboune et al., 2022). Some pathophysiological and diagnostic factors have been suggested for young patients, but the mechanisms that underlie the varying prevalences of pleural tuberculosis between sexes remain unknown, so this requires further research (Alpert et al., 2020; Carr, 2015; Jmaa et al., 2020). The lower prevalence of PTB among children may be partly due to neonatal BCG vaccination. Nevertheless, among those aged 15–64 years, the risk of PTB increases significantly, with it peaking at 70.4% among those aged 15–44 years, which is consistent with data from the Ministry of Health in Morocco (MSM, 2015).

This increased risk may result from cumulative exposure to MTB, air pollution, smoking, and other age-related risk factors. On the other hand, the increased risk of PTB among younger people could be mainly attributed to the transmission of the disease within the community being facilitated by frequent gatherings in school and other social activities, thus increasing the risk of exposure. Furthermore, our study revealed a significantly higher prevalence of EPTB among women, especially for lymph node and pleural tuberculosis, regardless of age. This observation is consistent with the results of studies conducted in Spain (Rolo et al., 2023) and Pakistan (Tahseen et al., 2020) all also reported a higher prevalence of lymph node tuberculosis in women, although unlike in our results, pleural tuberculosis was found to be more common in men. The underlying reasons for women's increased predisposition to EPTB remain unknown, but biological factors like sex hormones and genetic elements may well be playing a role in influencing the immune system (Gupta et al., 2022(Gupta et al., 2022).

Smoking and diabetes are two factors that were independently associated with the risk of PTB, and this risk increases significantly for people aged over 64 with diabetes (a 2.36 times higher risk) and especially for those with diabetes who smoke simultaneously (5.65 times higher risk). This correlates with the findings of Yorke et al. (2017) in highlighting how smoking and diabetes worsen the severity of TB. This has already been reported by a Moroccan Multicenter National Study, indicating that diabetes and smoking are independent risk factors for tuberculosis (Aachari et al., 2022). Furthermore, numerous studies have reported that 5–30% of tuberculosis patients also have diabetes, especially in developing countries where tuberculosis is more widespread, thus favouring the co-occurrence of tuberculosis and diabetes (Berbudi et al., 2020; Niazi & Kalra, 2012; World Health Organization, 2017). Some interesting research has also found that hyperglycemia is associated with an increased risk of delayed diagnosis for PTB, which can have serious implications for ongoing community TB transmission and disease outcomes at treatment clinics (Wang et al., 2017). Furthermore, the combination of tuberculosis and diabetes may interfere with therapeutic interventions for tuberculosis, as well as diabetes management, and this may influence the course of the disease (Bisht et al., 2023).

Underlying immune mechanisms that could be responsible for the increased susceptibility to tuberculosis in diabetic patients include defects in bacterial recognition, reduced phagocytic activity, slow migration of macrophages and antigen-presenting cells, alterations in chemokine/cytokine secretion, and an impaired T lymphocyte response. Such factors compromise the immune response, thus increasing the burden and disease pathogenicity of MTB in various organs, including the lungs and liver (Alim et al., 2020; Vallerskog et al., 2010). To reduce this risk, diabetic patients need to maintain good metabolic control. The impaired immune mechanisms that result from hyperglycemia highlight the importance of using diabetes management to prevent the complications of tuberculosis. Indeed, a joint effort to manage both diabetes and tuberculosis is needed to improve patient health outcomes and reduce the overall burden of tuberculosis in at-risk populations.

It comes to smoking, significantly increases the risk of MTB infection in several ways: For example, it reduces the activity of the alveolar macrophages, disrupts mucociliary clearance, weakens the immune response of pulmonary lymphocytes, affects the activity of the pulmonary dendritic cells, and decreases the effectiveness of natural killer cells (Underner & Perriot, 2012). Indeed, previous studies have reported higher mycobacterial loads in the sputum of smoking

patients (Adegbite et al., 2020). Our results also highlight the important role that smoking plays in the positivity of tuberculosis bacilli in the sputum of patients with PTB. It is therefore imperative to promote smoking cessation to strengthen the immune response, reduce smokers' vulnerability to tuberculosis, and improve the overall health of smokers' lungs.

Our study of reported cases between 2006 and 2012 consisted of 93.2% new cases and 6% relapses. In 2020, Eddabra and Neffa conducted a similar study in the same province and noted a very similar trend, with 93.40% being new cases and 6.60% being retreatments (Eddabra & Neffa, 2020). Taking these two results together, the prevalence of tuberculosis cases in the region over several years shows a certain stability in the epidemiological situation of the disease.

Tuberculosis relapse was identified as a significant factor contributing to the onset of the disease in individuals in this study. Although most patients with tuberculosis can be cured with standard combination therapeutic regimens, there is still a risk of a subsequent episode or recurrence of the disease in some patients after completing their initial treatment (Zong et al.(Zong et al., 2018). Patients with recurrent TB often require longer treatment cycles with the use of more toxic drugs, and overall, it reduces the chance of treatment success, promotes further transmission of mycobacterium tuberculosis (MTB), and increases the TB burden (Liu et al., 2020). TB recurrence can arise from two distinct origins, namely a relapse in the form of an endogenous reactivation of the initial infection or an exogenous reinfection with a new MTB strain (Ruan et al., 2022; Ruan et al., 2022). High relapse rates typically result from insufficient treatment of TB, while high reinfection rates suggest poor case management and the presence of many undetected cases circulating in the community (Du et al., 2021; Du et al., 2021; Folkvardsen et al., 2020)

Our study found that men had a greater tendency to develop PTB than women did with a prevalence of 61.2%. This male predominance for TB cases has been noted in Morocco, where men constitute the majority of adult TB patients (Chahboune et al., 2022; Eddabra & Neffa, 2020). Several reasons have been put forward to explain this gender disparity in tuberculosis prevalence. For example, in many countries, women have limited access to health care, which can lead to greater numbers of undiagnosed TB cases. Furthermore, screening and diagnostic strategies for women that are potentially less sensitive can lead to the prevalence of tuberculosis among females being underestimated.(Citro et al., 2021).

Family history is also considered a risk factor for PTB, with the prevalence of TB among patients with PTB and family history being 8% in our study, which is consistent with the findings of a Moroccan study (Sabri et al., 2019). This figure reflects the findings of another study conducted in sub-Saharan Africa (7.8%) (Shah et al., 2014) but it is somewhat higher than that reported by a study in Nepal (1.6%) (Gyawali et al., 2012). On the other hand, it is far lower than the value reported in a previous study carried out in Peru (34%) (Otero et al., 2016).

These wide variations may be attributed to differences in the study population, living conditions, and population density, which are important risk factors for respiratory diseases like tuberculosis (Citro et al., 2021; Kampala et al., 2013), as well as to each study's diagnostic methods (Federal Ministry of Health, 2012). Additionally, disparities in household contacts, socioeconomic status, lifestyle, and dietary habits could also explain these differences (Chandrasekaran et al., 2017).

The prevalence of active PTB is 2.55 times higher in rural areas than it is in urban areas, suggesting that there are diagnostic delays in rural areas due to several factors, such as limited access to health facilities, a lack of diagnostic services close to villages, long distances to the nearest health centre, and a lack of monitoring among health workers (Citro et al., 2021; Belay et al., 2012). What is more, rural populations often have limited knowledge of TB's symptoms and frequently underestimate its severity, leading to delays in diagnosis and treatment (Aljassim & Ostini, 2020). Thus, it is imperative to implement specific strategies that are tailored to local circumstances to improve the public health system and better meet the needs of TB patients in rural areas.

Patients from rural areas are also at greater risk of treatment failure than those from urban areas, and this observation is consistent with research that has shown geographic disparities in TB

management due to limited access to health care in rural areas (Abubakar et al., 2008; Nidoi et al., 2021). Although TB recurrence is lower in rural than it is in urban areas, adverse outcomes are more common in rural areas, thus increasing the risk of spreading multidrug-resistant tuberculosis. Likewise, most studies identify urban areas as having better outcomes thanks to more efficient patient monitoring systems and easier access to health services (Adatu et al., 2003; Cattamanchi et al., 2015). Thus, barriers to accessing diagnostics and treatment can influence TB treatment outcomes.

The results suggest that the association between a rural origin, smoking, and treatment failure is more marked in patients aged over 64 and younger adults, particularly those aged 25–34. A Moroccan study also found a high risk of treatment failure among smokers aged over 50 years, with the variation in risk being due to confounding factors for which adjustments were made (Tachfouti et al., 2011).

Smoking is associated with lower cure rates, faster progression, and increased severity of TB. Indeed, a clear immunopathological connection has been established between smoking and tuberculosis (Maurya et al., 2002). In this study, when combined with a rural origin and age, smoking lowers the treatment success rate. Previous work has also established a significant association between smoking as a predictor and risk factor for poor adherence, as well as a higher rate of treatment discontinuation, in TB care settings (Chang et al., 2004; Khan et al., 2020). This is particularly significant because untreated patients are at high risk of developing drug-resistant tuberculosis and spreading the disease in the community (Shamaei et al., 2009). Smoking is therefore a modifiable risk factor that can have a major impact on PTB outcomes (El Hamdouni et al., 2019). Indeed, reducing the prevalence of smokers in the general population could reduce the incidence of PTB and poor treatment outcomes like treatment failure (Khan et al., 2020). It therefore seems appropriate to include tobacco interventions when designing tuberculosis-control strategies, such as offering smoking cessation treatment at the time of diagnosis to improve the chances of a successful TB treatment.

Limitations

This study has its limitations, most notably its retrospective nature. To strengthen the validity of the cause-and-effect relationships identified in this study, diverse multicenter studies are required. Furthermore, it is important to recognize that our results may have been influenced by potential confounding factors that were unaccounted for, given that the study is based on medical records, and this limited the analysis to a small number of factors. Future research is therefore needed to search for such factors.

More specifically, some potential confounders like HIV infection, obesity, alcohol/drug abuse, and so on were not documented in the data we used for this study. It is therefore essential to consider these variables in future research to obtain a more complete picture. Finally, some caution should be taken when generalizing our results to a larger population, given that our data is derived from the two provinces of Laayoune and Tarfaya in the south of Morocco.

Conclusion

In conclusion, this in-depth study of tuberculosis analyzed 1333 cases and revealed vital information about the prevalence, risk factors, and distribution of tuberculosis cases according to the origin of the disease. It confirms that PTB is particularly prevalent in men and highlights the role that rural origin, age, diabetes, smoking, and family history play in determining the risk of developing tuberculosis.

The results highlight that younger adults and elderly people are more vulnerable, particularly smokers with diabetes. This study also reveals the significant role that smoking plays as an independent factor associated with PTB, thus highlighting the importance of taking measures to encourage smoking cessation among the population, especially for high-risk groups.

In addition, this study demonstrates that a rural origin is associated with an increased risk of TB treatment failure, particularly for smoking patients of all ages. Smoking has a major impact on tuberculosis outcomes by weakening the immune system, so smoking interventions, including smoking cessation treatment at the time of diagnosis, are essential for improving TB treatment outcomes and reducing the disease's prevalence, thereby promoting better public health.

There are also challenges related to diagnostic delays in rural areas, so we call for improved access to health care and campaigns to increase awareness of TB symptoms in these regions. Overall, this research provides crucial data to better understand tuberculosis and develop prevention and treatment strategies that will be more effective. It highlights the complexity of the disease's progression in society and the need to address multiple risk factors to reduce its burden on public health.

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