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ORIGINAL RESEARCH

Magnitude and Determinants of Latent Tuberculosis Among Inmates of Saudi Correctional Facilities: A Cross-Sectional Study

Abdulmajeed Alshowair[1], Abdullah M Assiri[2], Abdullah Hussein Balfas[3], Rakan Alkhattabi[3], Tilal Abdalla Eltegani[3], Sara Altowairib[3], Abdullah Hamed Almalki[3], Eman Ahmed Alharbi[3], Suad Alotai[3], Fahad Alobaid[3], Najeeb Saud S Altowiher[3]

[1]Community Health Excellence, Riyadh First Health Cluster Ministry of Health, Riyadh, Saudi Arabia; [2]Preventive Health, Ministry of Health, Riyadh, Saudi Arabia; [3]Public Health Directorate, Riyadh First Health Cluster Ministry of Health, Riyadh, Saudi Arabia

Correspondence: Abdulmajeed Alshowair, Community Health Excellence, Riyadh First Health Cluster Ministry of Health, Riyadh, Saudi Arabia, Tel +966547135224, Email dr.a.majeed@gmail.com

Purpose: To estimate the prevalence and determinants of latent tuberculosis (LTBI) among inmates of four correctional facilities in Saudi Arabia.

Methods: This is a retrospective review of health records. All inmates of four correctional facilities in Saudi Arabia were screened for tuberculosis in 2022. Their LTBI status was defined as more than 10mm Mantoux test result and negative X-ray chest result. The prevalence of LTBI and their determinants like age, gender, country of origin, location of the prison, and human immunodeficiency viruses (HIV) status were studied.

Results: We reviewed screening data of 10,042 inmates in four Saudi prisons. The prevalence of LTBI was 7.4%. The risk difference of LTBI was significantly higher in males compared to female inmates ($P < 0.001$). The highest prevalence of LTBI was noticed among males (7.7%), those older than 60 years old (26.9%), and African expatriates (12.1%). None of the female inmates or those with HIV had LTBI. The binomial regression analysis revealed a highly significant effect of older age on the risk of having LTBI.

Conclusion: The prevalence of LTBI was low among inmates at Saudi correctional facilities. The males, old age, and persons from African and Asian countries had a higher risk of LTBI. The prevalence of LTBI among inmates of Saudi prisons could be predicted by knowing their age group.

Keywords: tuberculosis, latent tuberculosis, inmate screening

Introduction

Tuberculosis, caused by the bacterium *Mycobacterium tuberculosis* (MTB), is a significant global health concern, contributing to a substantial number of deaths and illnesses worldwide. MTB infection is the only causative agent of human tuberculosis, and it is responsible for a high mortality and morbidity rate.[1] The disease presents in two forms: active tuberculosis, which manifests with clinical symptoms, and latent tuberculosis infection (LTBI), where individuals have a silent infection without clinical symptoms.[2,3] However, despite the absence of symptoms, individuals with LTBI still face the risk of reactivation of tuberculosis.[4] This reactivation can occur when the dormant bacteria become active, leading to the development of active tuberculosis.[5] The global prevalence of latent tuberculosis infection (LTBI) was estimated to be 24.8% (95% CI: 19.7–30.0%) using Interferon-γ release assays (IGRA) as a diagnostic tool.[6] Alternatively, when a 10-mm tuberculin skin test (TST) cut-off was employed, the estimated global prevalence was 21.2% (95% CI: 17.9–24.4%).[6] These findings indicate a significant burden of LTBI on a global scale.

In the specific regions of the Middle East and Africa, the prevalence of LTBI was notably higher, reaching 41.8. This suggests a greater risk of latent tuberculosis infection in these countries.[7]

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Furthermore, Barry[7] in the same study revealed that certain demographic factors were associated with a higher prevalence of LTBI. Populations older than 45, males, individuals residing in eastern provinces, and those with limited literacy exhibited a higher prevalence of LTBI. These findings underscore the importance of considering demographic characteristics when assessing the risk and prevalence of LTBI.[7] The demographic encompassing individuals from vulnerable groups, including the elderly, individuals, diabetes, people with HIV infection, and those who are immunocompromised, face an escalated risk of latent tuberculosis infection (LTBI) progressing to active tuberculosis (TB)[8–10] In line with the overarching objective of global tuberculosis elimination, member countries must prioritize implementing comprehensive screening initiatives to identify latent and active TB cases within these high-risk cohorts. A population-based survey in Saudi Arabia, encompassing 1369 participants, revealed the prevalence of LTBI at 9.3%.[11] This finding underscores the importance of addressing and detecting latent TB infections within specific regions, such as Saudi Arabia, to effectively combat the overall burden of tuberculosis. Active tuberculosis (TB) and latent tuberculosis infection (LTBI) pose significant public health challenges within prison settings worldwide. The prevalence of LTBI and TB is considerably higher among incarcerated individuals than the general population.[12] Prisons are often referred to as reservoirs of tuberculosis patients, posing a significant threat to inmates and staff members.[13] Several factors contribute to the heightened risk of infectious diseases, including tuberculosis, among prisoners, such as poor nutrition, chronic stress, substance abuse, and associated underlying health conditions.[14] Furthermore, factors such as overcrowding, inadequate ventilation, and the presence of human immunodeficiency virus (HIV) further increase the risk of tuberculosis transmission among both prisoners and staff members.[15]

A meta-analysis examining LTBI prevalence among prisoners found that 44.4% of 60,808 prisoners from published articles were affected by LTBI.[16] Additionally, the study reported a prevalence rate of 43.8% among prisoners from high-income countries and 49.4% from middle- and low-income countries. These findings underscore the significant burden of LTBI within prison populations across various socioeconomic settings. In the context of prisons, the prevalence of latent tuberculosis infection (LTBI) is significantly high in certain countries. For instance, in Spain, the prevalence of LTBI among prisoners was 54.6%.[17] This signifies a substantial burden of latent tuberculosis within the prison population in Spain. Similarly, in Iran,[18] the prevalence of latent tuberculosis based on tuberculin skin test (TST) was exceptionally high, reaching 62.3% among prisoners. This finding emphasizes the substantial proportion of Iranian prisoners exposed to *Mycobacterium tuberculosis* and at risk of developing active tuberculosis. These figures highlight the urgent need for effective tuberculosis screening, prevention, and management strategies within prison settings. Timely identification and treatment of latent tuberculosis among incarcerated individuals are essential for preventing the spread of tuberculosis within prisons and the broader community.

The World Health Organization (WHO) has provided guidelines outlining a public health approach for managing latent tuberculosis infection (LTBI) in high-risk individuals. According to the WHO task force, systematic testing and treatment of LTBI are strongly recommended for high-risk groups. These include individuals living with HIV, adult and child contacts of pulmonary tuberculosis (TB) cases, patients initiating anti-tumour necrosis factor treatment, patients undergoing dialysis, patients preparing for organ or hematological transplantation, and patients with silicosis.

In the case of prisoners, healthcare workers, expatriates from countries with a high burden of TB, homeless individuals, and illicit drug users, systematic testing and treatment of LTBI are conditionally recommended.[19] The decision to implement these measures is based on factors such as local TB epidemiology and the availability of resources.

The detection of latent tuberculosis infection (LTBI) has become increasingly crucial due to the emergence of drug resistance in active tuberculosis (TB) cases.[20] Effective treatment options for LTBI include a combination of regimens such as 6 months of daily isoniazid, 9 months of daily isoniazid, 3-month weekly rifapentine plus isoniazid, 3–4 months of daily isoniazid plus rifampicin, or 3–4 months of daily rifampicin alone.[21] However, there is expanding interest in a new LTBI treatment called hydrazones, which have shown promise in minimizing adverse effects and reducing the risk of antibiotic resistance that can occur when using the same drug to treat both latent and active tuberculosis.[22]

This study presents the prevalence and risk factors associated with latent tuberculosis among inmates in four correctional facilities in Saudi Arabia. The findings from this study provide valuable insights into the burden of LTBI within these distinct populations. Based on these results, we recommend implementing policies to strengthen healthcare provisions for incarcerated individuals, addressing their unique tuberculosis prevention and screening challenges. By

prioritizing the healthcare needs of this vulnerable population, we can contribute to the overall control and reduction of tuberculosis transmission within penitentiary settings and the broader community.

Methods

The approval of the ethical committee of King Saud Medical City (KSMC), Saudi Arabia was obtained to undertake this study. KSMC is the largest medical city in Riyadh First Health Cluster (RFHC) and the assigned central institution from MOH to provide IRB for research that will be conducted either by Investigators working in RFHC or those who will conduct research collecting data from RFHC. As data were collected retrospectively with no human interview or intervention, only written consent was obtained from the correctional facilities' administrators for using the previously collected health data of inmate screening without disclosing their identity. Tenants of the Helsinki Declaration were strictly abided by during all the stages of research.

This cross-sectional study was a retrospective review of health records of inmates from four Saudi prisons (allocated in RFHC catchment area) that were previously screened for active and latent tuberculosis in 2022. Their demographic and health screening records at the screening process were reviewed. All inmates of four Correctional facilities (Three for male and one for female inmates) were included. The demographic information including age, gender, HIV and the screening data of tuberculin skin test that was conducted by trained professionals using a standard syringe with a 27-gauge needle to inject five tuberculin units of purified protein derivative (PPD) or two tuberculin units of RT-23 intradermally following the Mantoux method.[23] The induration at the injection site was measured after 72 hours in the transverse direction. If it was more than 10 mm in a person without immunocompromised conditions like HIV, the test was considered positive. However, for those with HIV, the test was considered positive if the induration was more than 5 mm. Those found positive were requested chest X-rays. If the chest X-ray revealed evidence of pulmonary tuberculosis-like apical opacities, enlarged broncho pulmonary hilar shadow, pneumothorax, and pleural effusion, the inmate was further subjected to a sputum test to review the presence of gram-negative tuberculous bacilli using sputum culture. Participants with signs suggestive of LTBI tuberculosis (positive TST with negative chest radiography) but not showing symptoms were labeled as LTBI.[23–25]

The data was entered into the spreadsheet of Microsoft MS Excel. As the data was collected retrospectively, some inmates' data were missing regarding age. After consistency, excluding missed data and duplication checks, data was transferred into the spreadsheet of Statistical Package for Social Studies (SPSS 25, IBM, NY, USA). The qualitative data were presented as number and percentage proportions. The normally distributed quantitative variable was presented as the mean and the standard deviation. To estimate the prevalence of LTBI, we used the total number of inmates screened as the denominator. Those with and without LTBI were associated with different independent determinants and presented as odds ratio, 95% confidence interval, and two-sided P value. Binomial regression analysis was carried out to estimate the adjusted odds ratio (model adjusted for gender), its 95% confidence interval, and two-sided p-value.

Results

We reviewed the screening data of 10,042 inmates from four prisons in Riyadh City, Saudi Arabia. Their mean age was 33.8 ± 9.1 years (Range 18 −91 years) and approximately three-fourths of them 7617 (75.9%) were under 40 years of age. The majority of studied inmates were males 9595 (95.5%) distributed over 3 prisons, and only 447 (4.5%) were females from one prison. About two-thirds of participants were of Saudi nationality 5955 (59.3%) and 207 (2.1%) were of the displaced tribe but Saudi residents. However, one-third was non-Saudi (African expatriates 14.1%, Asian expatriates 12.6% and from other Gulf countries 7.3% respectively). A total of 743 (7.4%) inmates were identified as LTBI and had more than 10mm tuberculin test results. The prevalence of LTBI was higher among males (7.7%), while none of the female inmates had LTBI. The highest prevalence of LTBI is noticed among those older than 60 years old (26.9%). The prevalence of LTBI in inmates of other Gulf countries (11.9%), African countries (12.2%), and Asian countries (9.3%) was significantly higher than that in Saudi nationals (5.5%) and displaced tribes (3.9%). Despite 19 cases of HIV (0.2%) detected among the studied inmates, no case of LTBI was identified among such HIV cases. The prevalence of LTBI among all inmates and in subgroups is displayed in Table 1.

Table 1 Prevalence of Latent Tuberculosis (LTBI) Among Studied Inmates in Saudi Arabia (n = 10,042)

Variable		Screened N. (%)	Detected as LTBI	Prevalence %	p-value
Gender	Male	9595 (95.5%)	743	7.74	<0.001*
	Female	447 (4.5%)	0	0.00	
Age-group	18 to 39	7617 (75.9%)	513	6.7	<0.001*
	40 to 59	2099 (20.9%)	142	6.8	
	60 years and more	326 (3.2%)	88	26.9	
Nationality	Saudi	5953 (59.3%)	329	5.53	<0.001*
	Displaced Tribes	207 (2.1%)	8	3.86	
	Gulf countries	729 (7.3%)	87	11.93	
	African expatriates	1414 (14.1%)	172	12.16	
	Asian expatriates	1269 (12.6%)	118	9.30	
	Others	470 (4.6%)	29	6.17	
Prison	1	2784 (27.7%)	200	7.18	<0.001*
	2	3363 (33.5%)	399	11.86	
	3	3448 (34.3%)	144	4.18	
	4	447 (4.5%)	0	0.00	
HIV status	Positive	19 (0.2%)	0	0.0	P=0.231
	Negative	10,023 (99.8%)	743	7.4	
Total		10,042 (100%)	743	7.4	–

Note: *P ≤ 0.05 is significant.

As shown in Table 2, we performed binomial regression analysis to study the factors influencing latent tuberculosis (LTBI) among inmates in Saudi Arabia. The highest prevalence of LTBI was detected among elderly inmates aged more than 60 years and the regression model revealed a highly significant effect of age on the risk of having LTBI. The variation in the prevalence of LTBI among inmates of Saudi prisons could be explained and predicted by knowing their age group.

Table 2 Factors Influencing Latent Tuberculosis (LTBI) Among Inmates in Saudi Arabia

Determinants		Crude Odds Ratio	Adjusted Odds Ratio	95% Confidence Interval	P value
Age- group	18 to 39	2.90	0.06	0.038; 0.081	<0.001*
	40 to 59	2.94	0.05	0.035; 0.08	<0.001*
	60 years and more	2.49	0.08	0.042; 0.166	<0.001*
Nationality	Saudi	1.24	3.5	0.4; 26.9	0.2
	Displaced tribes	0.83	2.3	0.3; 20.0	0.5
	Gulf countries	1.34	3.8	0.4; 34.5	0.2
	African	1.41	4.1	0.5; 37.1	0.2
	Asian	1.01	2.7	0.3; 24.8	0.4
	Other	1.01	2.7	0.3; 25.4	0.4
Prison	1	19.7	3.4		0.99
	2	20.3	6.5		0.99
	3	19.3	2.3		0.99
	4		1		0.002*
Constant	−20.7				0.99

Note: *P ≤ 0.05 is significant.

Discussion

The prevalence of latent tuberculosis infection (LTBI) among the studied inmates, based on a tuberculin skin test and the subsequent chest x-ray, was 7.4%. This rate was notably lower compared to the published data on LTBI among inmates in neighboring countries and in Asian, African, and South American countries (Table 3). Interestingly, the LTBI rate observed in our study was similar to the published rate from Italy.[26] The relatively lower LTBI rate among inmates in Saudi correctional facilities, with approximately one in fourteen inmates affected, suggests a lower prevalence of risk factors within these facilities. Notably, none of the female or HIV-positive inmates were found to have LTBI, which is an important observation. Despite the TST test is acceptable for use in HIV people, the possibility of false negative results should be considered, as it is known that HIV can affect the outcome of the TST test.

Additionally, inmates of Saudi and displaced tribes had the lowest rate of LTBI, while inmates of African, Asian, and Gulf countries nationality had a higher prevalence of LTBI. Furthermore, there was a significant variation in the LTBI rate among the four correctional facilities under study. This can be explained by the nature of the 4th prison, which was for females and no cases of LTBI were detected among females. However, these findings highlight the unique epidemiological profile of LTBI within Saudi correctional facilities, characterized by lower overall prevalence and distinct patterns based on inmate demographics. The observed differences in LTBI rates among prisons underscore the need for targeted interventions and tailored strategies to effectively address the burden of latent tuberculosis within each correctional facility.

To the best of our knowledge, this study represents one of the first attempts to investigate latent tuberculosis infection (LTBI) among inmates in Gulf Council Corporation (GCC) countries. The inmate population in these countries exhibits unique characteristics, influenced by a substantial number of working-class expatriates from various developing nations, which can impact the epidemiology and dynamics of LTBI among inmates.

The prevalence of LTBI (7.4%) among four correctional facilities in Saudi Arabia was much lower than that reported in Iran, Brazil, Chile, Ethiopia, and Thailand.[18,27–31] Even a meta-analysis of published literature on this issue revealed a very high prevalence of LTBI.[16] The prevalence of LTBI (4.1%) published in Italy was lower than that reported in the present study. The authors noted in this study that inmates from *non-European countries* had a higher risk of LTBI.

Table 3 Prevalence of Latent Tuberculosis (LTBI) Among Inmates in Saudi Arabia (Present Study) and Other Countries

	Country	Authors	Year	Sample	Prevalence	Remarks	Reference
1	Saudi Arabia (present study)	AlShowair et al	2022	10,042	7.4%	Higher rates in male	
2	Prisoners' data published till 2021 "metanalysis"	Placeres et al	2023	60,808	44.37% [30.0; 59.7%]	High-income countries 43.8% [28.6; 60.2] Middle-and low-income countries 49.4% [45.9; 52.9]	[16]
3	Iran	Mamani et al	2013	1208	62.6%	Smokers and HIV positives risk factors	[18]
4	Italy	Izzo et al	2022	381	4.2%	History of drug addiction, non-European risk factors	[26]
5	Thai prisoners	Gatechompol et al	2019	1002	36% by TST 61.6% by QFTP	Past incarceration, prior active TB & long duration in prison risk factors.	[27]
6	Brazil (central west)	Estevan et al	2013	1261	49%		[28]
7	Ethiopia	Chekesa et al	2020	2620	51.2%	Longer duration and overcrowding risk factors	[29]
8	Columbia	Rueda et al	2014	1014	77.6% TST	Previous incarceration, long-duration risk	[30]
9	Chile	Aguilera et al	2016	26,644	33.2%	Gamma interferon method	[31]
10	Brazil	Carbone et al	2015	3380	22.5% in male 11.7% in female	8.6% rate in new inmates	[32]

A study in Brazil by *Carbone* et al noticed that the prevalence of LTBI in screened inmates was 8.6% among newly incarcerated inmates.[32] Although health screening is mandatory for workers joining the workforce in Saudi Arabia from Asia, and Africa, and those transferring jobs from other Gulf countries, the likelihood of previous infectious diseases in non-symptomatic stages, and getting infections in labor camps within the Kingdom causing LTBI cannot be completely ruled out. Thus, the findings of the present study not only reflect the TB status of inmates screened but also points to the status of the expatriate's workforce in the Kingdom.

The LTBI rate was higher in inmates of 60 years and older age group in our study. This was also noted in a study of inmates in a Spanish prison.[17] The confounding effect of comorbidities like diabetes, drug addiction, and HIV in older inmates should be noted before recommending age as the risk for LTBI among inmates and formulating policies accordingly.

In our study, all LTBI cases noted in the screening were males. The risk of LTBI was seven-fold higher among males compared to female inmates in the present study. This higher risk of LTBI among male inmates was also reported in Brazil, Chile, and Ethiopia.[29,31,32] The females were less than 5% of the total inmates and were in separate prisons. No LTBI was detected among females in the present study, which is encouraging but needs further confirmation before concluding.

For instance, a study conducted in Iran utilized a tuberculin skin test (TST) and reported that 62.6% of screened inmates exhibited an induration size of more than 10mm.[18] In Thailand, a study involving the use of both TST and QuantiFERON-TB Gold Plus (QFTP) tests found that TST alone yielded a positive result in 36% of inmates, while the combined positive rate with either TST or QFTP was 61.6%.[27] Conversely, the prevalence of LTBI among inmates in Malaysia was notably higher, reaching 87.6% when cases with a history of tuberculosis or treatment were included as positive TST results.[33]

Multiple studies focusing on LTBI among inmates in South American countries, utilizing TST as the screening test, reported high prevalence rates.[12,26,28,31,32] Similarly, studies conducted in African countries such as Ethiopia and Nigeria noted a nearly 40% prevalence rate of LTBI among inmates.[27,34] The high prevalence of LTBI in developing countries can be attributed to poor nutrition, overcrowding, and comorbidities associated with compromised immune function. Migration, whether legal or illegal, to seek a better lifestyle poses a significant threat to both Middle Eastern and European countries regarding tuberculosis transmission from individuals with LTBI. Data from studies conducted on prisoners in Italy indicated both a low prevalence of LTBI and a risk of tuberculosis transmission from non-European inmates to others.[26] Regional differences in tuberculosis control initiatives, nutritional status, risk factors for LTBI, overcrowding in labor camps housing immigrants, and access to health services are likely responsible for the observed variation in LTBI prevalence rates. These findings highlight the complex nature of LTBI prevalence among inmate populations across different regions and underscore the need for region-specific interventions and strategies to effectively address the burden of latent tuberculosis infection within correctional settings.

We had nearly one in four inmates of more than 40 years of age. Information on their diabetes status was not available. The risk of LTBI among diabetes mellitus patients is 60% higher than among nondiabetic patients.[35] In Saudi Arabia, the prevalence of diabetes is noted to be 32.8% in 2015 and is projected to rise to 40.4% in 2025.[36] Therefore, opportunistic screening of inmates in the kingdom for LTBI should also have included a review of diabetes status.

There was no association between HIV status and LTBI in our study. This was also noted in inmates of Italy.[26] HIV was significant comorbidity among inmates with LTBI in Iran[16.] Screening of LTBI among people living with the human immunodeficiency virus (PLHIV) and periodic monitoring and if needed preventive treatment of LTBI is recommended strategy to avoid reactivation of TB among persons with LTBI.[37]

In our study, tuberculin skin test (TST), X-ray chest, and sputum culture were performed to define and identify active cases and LTBI. As the TST is affected by the BCG vaccination and several other conditions that can reduce the skin reactivity, it may not be an ideal screening test. Therefore, interferon-gamma release assays (IGRAs) are preferred especially in countries with a low burden of TB.[38] The latter was also recommended in correctional facilities in the USA due to its cost-effectiveness.[39] We recommend the adoption of this screening test and compare the rates of LTBI noted in the present study.

Although LTBI may not be contagious, reactivation of TB among them due to high-risk factors is possible in such facilities. It is not only a health risk to other inmates but also to staff working in such facilities.[24,40] LTBI carries a 5–15% risk of progression to active TB in the first 2 years from the infection.[41] In prisoners, healthcare workers, immigrants from high TB burden countries, homeless persons, and illicit drug users, systematic testing and treatment of LTBI are conditionally recommended, according to TB epidemiology and resource availability.[19] Because of cost-effectiveness,

Kowada recommended interferon-gamma release assay for early tuberculosis screening for inmates in developed countries and countries with a low burden of tuberculosis.[42]

The Kingdom of Saudi Arabia has made significant strides toward tuberculosis control and elimination within correctional facilities by emphasizing regular screening, comprehensive treatment, and tailored interventions. This concerted effort not only protects the health of inmates and staff but also contributes to the broader goal of reducing tuberculosis transmission in the community. That may explain the low prevalence of LTBI detected in our study.

Limitations of the Study

There were a few limitations in our study. One limitation is being a retrospective review of health records, so missing information bias may influence some of the determinants associated with the LTBI. In addition, Information on a few known risk factors like previous incarceration, duration of imprisonment, history of diabetes, and immune-related systemic diseases was not available. However, the prevalence and demographic determinants of LTBI presented in the present study were based on reliable information and screening data from a large sample. Another limitation is the effect of HIV infection on the result of the TST test, so the possibility of false negative results among such inmates should be considered. Moreover, IGRA appears to exhibit better specificity than the TST and may be preferred as the standard of care for detecting LTBI in such immigrants.[43] However, taking into account the cost, and other logistics, TST remains the most preferred method for LTBI diagnosis in resource-limited settings.[44] In addition, despite the important role of chest radiography (CXR) in the diagnostic flow chart for LTBI, the recent findings stated that CXR for diagnosis of pulmonary TB has good sensitivity, but poor specificity.[45]

Conclusion

This pioneering study aimed at estimating the prevalence of latent tuberculosis infection (LTBI) among marginalized populations, specifically inmates of correctional facilities, represents a significant step towards achieving the World Health Organization's global goal of tuberculosis control and elimination. The observed low prevalence of LTBI in this population is encouraging and indicates the potential for effective interventions. To sustain this progress and further mitigate the burden of tuberculosis, it is essential to implement regular and periodic screening protocols for LTBI among newly admitted inmates. This screening should be complemented by timely and supervised treatment of active tuberculosis and LTBI cases. Moreover, extending these screening efforts to include the staff working within these facilities is crucial, ensuring their health and well-being and preventing the spread of tuberculosis within the correctional setting.

During periodic assessments, special attention should be given to known risk factors associated with LTBI, such as the original country of inmates, male gender, and older age groups. By focusing on these risk factors, targeted interventions can be developed to address the specific needs of high-risk individuals and reduce the overall burden of LTBI within the inmate population.

Abbreviations

GCC, Gulf Council Corporation; IGRAs, Interferon-Gamma Release Assays; LTBI, Latent Tuberculosis Infection; QFTP, QuantiFERON-TB Gold Plus; TST, Tuberculin Skin Test.

Ethical Statement

The approval of the research and ethical committee of King Saud Medical City, Saudi Arabia was obtained to undertake this study. Written consent was obtained from correctional facilities administrators for using the health data of inmate screening without disclosing their identity. Tenants of the Helsinki Declaration strictly abided during all the stages of research.

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Disclosure

The authors declare that they have no conflicts of interest in relation to this work.

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