IJID Regions 4 (2022) 1–9

Contents lists available at ScienceDirect

IJID Regions

journal homepage: www.elsevier.com/locate/ijregi

Magnitude and associated factors of latent tuberculosis infection due to *Mycobacterium tuberculosis* complex among high-risk groups in urban Bobo-Dioulasso, Burkina Faso

Diakourga Arthur Djibougou[a,b], Gloria Ivy Mensah[c,*], Tani Sagna[d], Leon Tinoaga Sawadogo[e], Arsène Kiswensida Ouedraogo[b], Antoinette Kabore[b], Hervé Hien[b,d], Clément Ziemlé Meda[b,f], Adjima Combary[e], Adrien Marie-Gaston Belem[a], Kennedy Kwasi Addo[c], Roch Konbobr Dabiré[d], Matthieu Perreau[g], Jakob Zinsstag[h], Serge Potiandi Diagbouga[d]

[a] *Ecole Doctorale Sciences Naturelle et Agronomie, Université Nazi BONI, Bobo-Dioulasso, Burkina Faso*
[b] *Programme des Maladies Infectieuse, Centre MURAZ/Institut National de Santé Publique, Bobo-Dioulasso, Burkina Faso*
[c] *Department of Bacteriology, Noguchi Memorial Institute for Medical Research, College of Health Sciences, University of Ghana, Legon, Accra, Ghana*
[d] *Centre National de Recherche Scientifique et Technologique/Institut de Recherche en Sciences de la Santé, Ouagadougou, Burkina Faso*
[e] *Programme National Tuberculose, Ministry of Health, Ouagadougou, Burkina Faso*
[f] *Institut Superieur des Sciences de la Santé, Université Nazi BONI, Bobo-Dioulasso, Burkina Faso*
[g] *Faculty of Biology and Medicine, Université de Lausanne, Lausanne, Switzerland*
[h] *Department of Epidemiology and Public Health, Swiss Tropical and Public Health Institute, Basel, Switzerland*

ARTICLE INFO

Keywords:
TB high-risk groups
Latent tuberculosis infection
Magnitude
Interferon-gamma release assay
Tuberculin skin test
Burkina Faso
One Health

ABSTRACT

Objectives: To determine the prevalence and risk factors for latent tuberculosis infection (LTBI) among three high-risk groups – household contacts of TB index cases, healthcare workers and slaughterhouse workers – in Bobo-Dioulasso, Burkina Faso.

Methods: Participants were recruited to this cross-sectional study from March to July 2020 after giving informed consent. Sociodemographic, clinical and biological data were collected using a structured questionnaire. The QuantiFERON-TB Gold Plus test (QFT-Plus) and the tuberculin skin test (TST) were used for detection of LTBI. Bivariate and multivariate logistic regression analyses were performed to identify risk factors for LTBI.

Results: The prevalence of LTBI among 101 participants (age range 15–68 years) was 67.33% [95% confidence interval (CI) 57.27–76.33] and 84.16% (95% CI 75.55–90.66) based on QFT-Plus and TST results, respectively. Compared with healthcare workers and household contacts of TB index cases, the prevalence of LTBI among slaughterhouse workers was significantly higher for both QTF-Plus (96.8%; $P<0.001$) and TST (100%; $P=0.003$). Working in a slaughterhouse [adjusted odds ratio (AOR) 1.095, 95% CI 1.00–2.036], smoking (AOR 4.214, 95% CI 1.051–16.899), ≥15 years of exposure (AOR 5.617, 95% CI 1.202–32.198), having an animal at home (AOR 2.735, 95% CI 1.102–6.789) and protozoal infection (AOR 2.591, 95% CI 1.034–6.491) were significantly associated with LTBI on the QFT-Plus assay.

Conclusion: The prevalence of LTBI was high in all three groups, particularly slaughterhouse workers. The risk factors identified could form the basis of targeted intervention.

Introduction

Tuberculosis (TB) is among the top 10 causes of death in the world, despite being curable and preventable. There were 1.4 million deaths due to TB and 10 million cases of TB in 2019, and most of these cases were reported from African and Asian countries (World Health Organization, 2019). TB is caused by *Mycobacterium tuberculosis* complex (MTBC), and the disease is spread when the source expels bacteria into the air to a susceptible host, causing active TB disease or latent tuberculous infection (LTBI) without evidence of manifestation of symptoms of active disease (López de Goicoechea-Saiz et al., 2018).

An estimated 1.7 billion people are living with LTBI globally, and 5–10% of them are expected to develop active TB (Sadananda et al., 2020). The risk of active TB increases with occurrence of comorbidities

* Corresponding author. Department of Bacteriology, Noguchi Memorial Institute for Medical Research, College of Health Sciences, University of Ghana, Legon, Accra, Ghana.
E-mail address: gmensah@noguchi.ug.edu.gh (G.I. Mensah).

https://doi.org/10.1016/j.ijregi.2022.05.004
Received 17 January 2022; Received in revised form 9 May 2022; Accepted 12 May 2022

such as human immunodeficiency virus/acquired immunodeficiency syndrome (HIV/AIDS) or occupational exposure. High prevalence of LTBI has been reported in populations at risk, such as miners, healthcare workers (HCWs) due to their professional exposure, and individuals suffering from diabetes and malnutrition in high-incidence countries (Baussano et al., 2011; Basera et al., 2017; Qader et al., 2021). Similarly, household contacts of smear-positive TB patients are at risk for LTBI because they share the same environment (Eom et al., 2018). In addition, it has been well demonstrated in developed countries that people in close contact with infected animals, such as slaughterhouse workers (SWs), can contract TB from animals (zoonotic TB) (Mbugi et al., 2017). However, the situation in low-resource countries, where disease control in cattle is poor, remains poorly documented (Torres-Gonzalez et al., 2013). Individuals infected with TB pathogens present an increased risk of progression to active disease, and constitute a potential source of infection. A significant number of cases of active TB occur in people with LTBI within a short time following primary infection, suggesting the need for LTBI intervention (Wang et al., 2020). In view of this, the World Health Organization (WHO) has set up the End TB strategy, which aims to reduce the number of TB deaths by 95% and the number of new cases by 90% in 20 years (2015–2035) (MacNeil, 2020). In order to achieve these ambitious goals, it is important to use diagnostic strategies as a central element to promote the detection and early management of cases of TB (Uplekar et al., 2015). Use of the tuberculin skin test (TST) and interferon-gamma release assay (IGRA) contitutes a valuable approach for early identification of people at risk for TB infection (Carranza et al., 2020).

In Burkina Faso, the burden of TB is high, and all segments of the population are affected. The recent WHO report estimated that there were 9500 cases of TB in Burkina Faso, including HIV co-infection, with an incidence of 48 per 100,000 population (World Health Organization, 2019). An understanding of the factors associated with acquiring and transmitting MTBC is a prerequisite for TB control in Burkina Faso. Although the 2020 WHO consolidated guidelines on TB recommend systematic testing and treatment of LTBI in populations at risk, to the authors' knowledge, there is no data on LTBI in Burkina Faso. This study screened for LTBI among three groups at high risk for TB: household contacts of TB index cases, HCWs and SWs. The participants were recruited in urban Bobo-Dioulasso, screened for LTBI using the two WHO-recommended diagnostic tools, and factors associated with LTBI were identified.

Materials and methods

Study site

This cross-sectional study was conducted from March to July 2020 in Bobo-Dioulasso (11°10'42" N; 4°17'35" W); this city is the economical capital of Burkina Faso, and is located in the western part of the country. The study collection sites were the regional centre for TB control, the medical centre in Dafra, the medical centre in Do, and the slaughterhouse in Bobo-Dioulasso (Figure 1).

Study population and sample collection

The study participants were household contacts of TB index cases, HCWs and SWs who gave their informed consent. A stool sample, urine sample, 4-mL blood sample in a lithium heparin tube (for the IGRA test) and 4-mL blood sample in an ethylenediaminetetraacetic acid tube (for immuno-haematological tests) were collected from each participant. All samples were sent to Centre MURAZ for analysis. Sociodemographic, clinical and anthropometric parameters and biological data were collected.

Tests performed

QuantiFERON-TB Plus (QFT-Plus) test

To avoid the booster effect, a blood sample was collected from each participant by venipuncture into a 4-mL heparinized tube for QFT-Plus (Qiagen, Hiden, Germany), and then TST was performed.

QFT-Plus includes new antigens designed to increase the sensitivity of the test compared with the previous IGRA tool (QTF-GIT). In brief, 1 mL of blood was drawn directly into each of four separate tubes: nil control (negative control), mitogen control (positive control containing phytohemagglutinin), TB1 (containing MTBC-specific antigens ESAT-6 and CFP-10 modified for eliciting CD4+ T-cell responses) and TB2 (containing MTBC-specific antigens ESAT-6 and CFP-10 modified for eliciting CD8+ T-cell responses). After filling, the tubes were inverted slowly 10 times to coat the sides, and placed in an incubator at 37°C for 16–24 h. All tubes were centrifuged at 3000 × ***g*** for 15 min to separate the plasma, and were stored at -20°C before analysis. The QFT-Plus interferon-gamma enzyme-linked immunosorbent assay (ELISA) was performed with plasma on the EVOLIS machine (BIO-RAD, Hercules, CA, USA), an automated ELISA processor. Results were calculated using QFT-Plus Analysis Software Version 2.71.2, as described by the manufacturer (Bongomin et al., 2021; Qiagen: QuantiFERON-TB Gold Plus (QFT-Plus) ELISA... - Google Scholar, 2021 n.d.).

Results of LTBI were defined as an interferon-gamma concentration ≥0.35 IU/mL (calculated as either TB1 or TB2 antigen minus nil) according to the manufacturer's guideline. If antigen minus nil was <0.35 IU/mL or <25% of the nil value, when the mitogen value was ≥0.5 IU/mL, the result was considered negative. If (1) nil was >8 IU/mL or (2) antigen minus nil was ≥0.35 IU/mL and <25% of the nil value when nil was ≤8.0 IU/mL and the mitogen value was <0.5 IU/mL, the results were considered indeterminate (Qiagen: QuantiFERON-TB Gold Plus (QFT-Plus) ELISA... - Google Scholar, 2021 n.d.)

TST using Tubertest method

TST was performed with an intradermal 0.1-mL injection of tuberculin, equivalent to 5 IU Tubertest (Sanofi Pasteur, Paris, France), in the front side of the forearm. The diameter of the indurated area was measured 48–72 h later (Rieder et al., 2011), and was considered positive when the area was ≥5 mm, as indicated by the manufacturer.

Parasitological screening test

Each stool sample was prepared and treated using the Kato-Katz and formol ether concentration methods, as well as the direct saline/iodine method, in order to diagnose infections with intestinal parasites. In addition, urine samples were examined qualitatively to screen for *Schistosoma* spp. using the urinary sediment method, and by rapid point-of-care circulating cathodic antigen, as described previouly (Cisse et al., 2021).

Data management and statistical analysis

Data from questionnaires and laboratory analyses were first entered into Excel 2016 (Microsoft Corp., Redmond, WA, USA), then cleaned and exported to Stata 14 (Stata Corp., College Station, TX, USA) for analyses. Chi-squared or Fisher's exact tests were used for bivariate analyses. A univariate logistic regression was performed initially to identify potential factors associated with the occurrence of LTBI. Next, a multivariable logistic regression model was built using a stepwise backward model by including all independent variables with $P<0.2$ on univariate logistic regression in the model. The final model had an inclusion criterion of $P<0.05$ and an exclusion criterion of $P>0.10$. The conditions of fitness of the final model were verified. The results are presented as odds ratio (OR) and 95% confidence interval (CI). $P< 0.05$ was considered to indicate statistical significance.

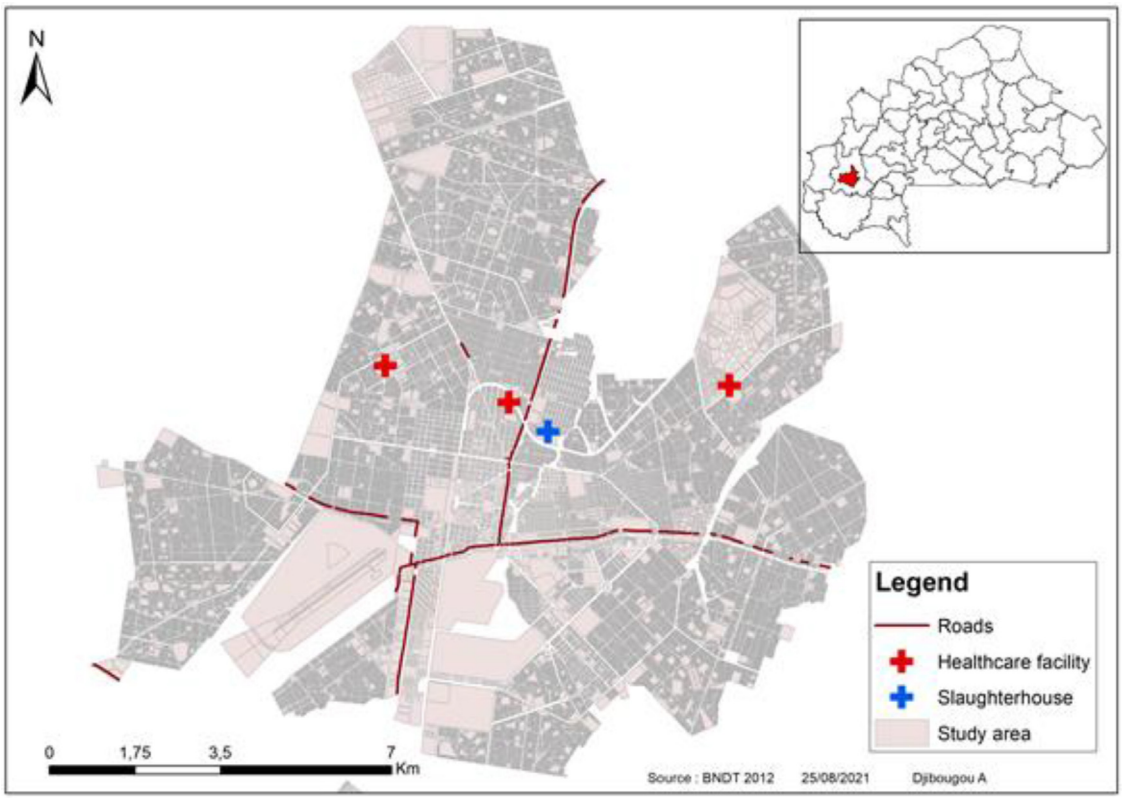

Figure 1. Map of study area.

This research involved human participants, human material and human data; all activities were performed in accordance with the Declaration of Helsinki 2018.

Results

Sociodemographic and biological characteristics of the study population

Study participants (n=103) were selected at random from slaughterhouses, healthcare facilities and households with TB index cases. Two household contacts were excluded because they had indeterminate results on the QTF-Plus assay. Baseline characteristics of the 101 subjects with reliable QTF-Plus and TST results are shown in Table 1 and Figure 2. Among these 101 subjects, 42 were HCWs, 31 were SWs and 28 were household contacts of TB index cases. The mean age was 38.52 (standard deviation 12.01) years. The sex ratio (male/female) was 1.97. Most participants (77%) had received the Bacillus Calmette-Guérin (BCG) vaccine, 52.48% of participants had a secondary education, and 61.39% were infected by intestinal protozoa.

Prevalence of LTBI based on test technique

The prevalence of LTBI among the 101 participants was found to be 67.33% (95% CI 57.27–76.33) using QFT-Plus and 84.16% (95% CI 75.55–90.66) using TST. The overall prevalence rate based on both tests was 63.36% (95% CI 52.18–71.82).

Compared with HCWs (50.0%) and household contacts of TB index cases (60.7%), the prevalence of LTBI among SWs was found to be significantly higher using QTF-Plus (96.8%; P<0.001). Based on TST results, the prevalence of LTBI among SWs (100%; P=0.003) was also higher compared with that in HCWs (83.3%) and household contacts of TB index cases (67.9%). A significant difference was observed with respect to origin of the participant and cohabitation with animals (P<0.05) for both QTF-Plus and TST. However, a positive result on QTF-Plus was significantly associated with a high frequency (61.39%) of protozoal infection in the participants (P=0.022), while TST positivity was significantly associated with gender (P<0.05), with 94.03% of cases being male (Table 2).

Factors associated with LTBI among the study population

Based on QTF-Plus positivity, univariate logistic regression analysis showed that working in a slaughterhouse [crude odds ratio (COR) 30.00, 95% CI 3.739–240.651; P=0.001], having an animal at home (COR 3.009, 95% CI 1.268–7.139; P=0.012) and protozoal infection (COR 2.685, 95% CI 1.140–6.326; P=0.024) were significantly associated with LTBI. On multivariate logistic regression, working in a slaughterhouse (AOR 1.095, 95% CI 1.00–2.036), smoking (AOR 4.214, 95% CI 1.051–16.899), years of exposure (AOR 5.617, 95% CI 1.202–32.198), having an animal at home (AOR 2.735, 95% CI 1.102–6.789) and protozoal infection (AOR 2.591, 95% CI 1.034–6.491) remained significantly associated with LTBI on QFT-Plus assay. Considering the LTBI status based on TST, being male (COR 8.590, 95% CI 2.507–29.429; P=0.001) and having an animal at home (COR 4.50, 95% CI 1.339–15.119; P=0.015) were significantly associated with LTBI. However, on multivariate logistic regression, being male (AOR 10.114, 95% CI 2.744–37.270; P=0.001) and having an animal at home (AOR 5.582, 95% CI 1.484–20.995; P=0.015) were the only risk factors associated with LTBI.

Meanwhile, age, body mass index, educational level, alcoholism, diabetes, history of hospitalization and BCG scar were not associated with LTBI (Tables 3 and 4).

Discussion

Prevalence of LTBI among three TB high-risk groups in Bobo-Dioulasso

To the authors' knowledge, this is the first study on the prevalence of LTBI in three TB high-risk groups using TST and QTF-Plus in Burk-

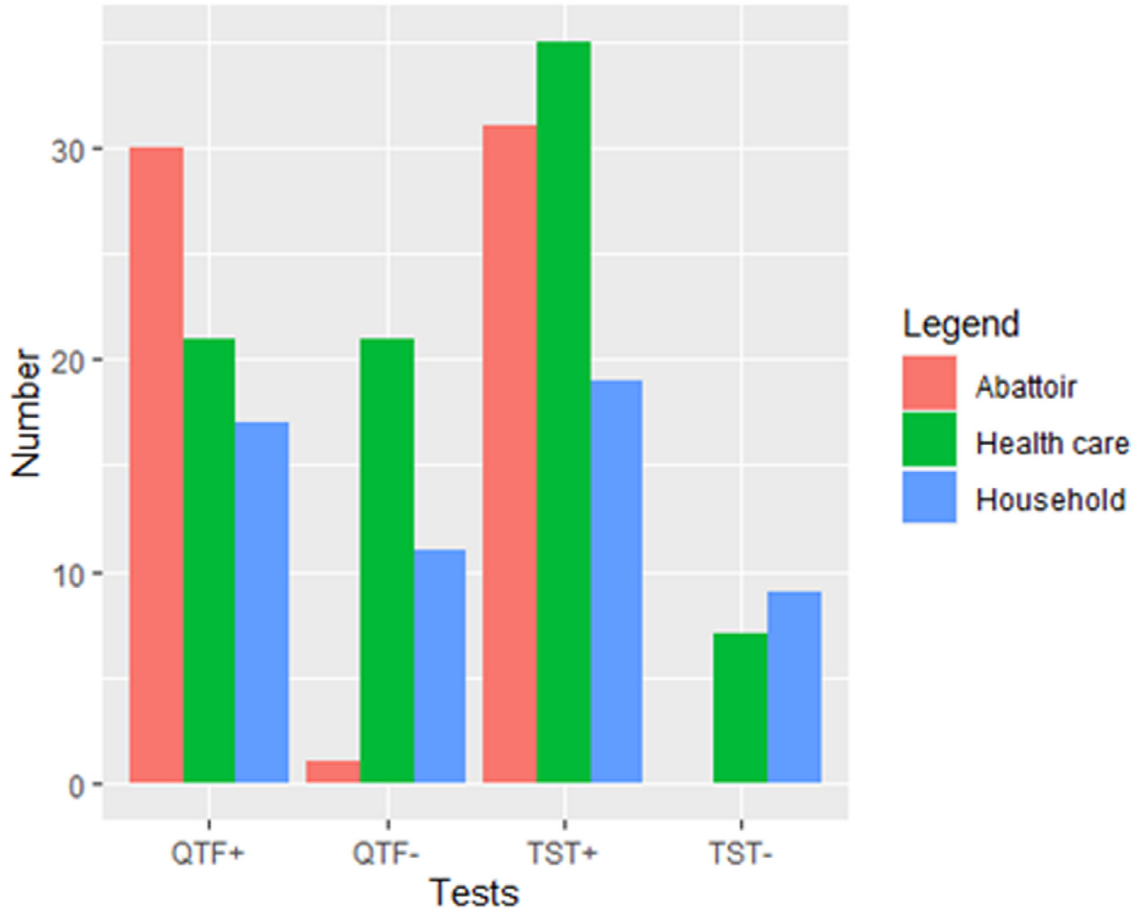

Figure 2. Distribution of latent tuberculosis infection (LTBI) according to the type of participant and LTBI test.

ina Faso, a low-income country with high incidence of TB (48/100,000 population).

The prevalence of LTBI among 101 participants was 67.33% (95% CI 57.27–76.33) using QFT-Plus and 84.16% (95% CI 75.55–90.66) using TST. The burden of LTBI in this urban city was high, with overall prevalence of 63.36% (95% CI 52.18–71.82) using both QFT-Plus and TST.

Based on IGRA, household contacts of index cases of TB in this study had relatively high prevalence of LTBI (60.7%). Similar rates have been reported in Ghana (Mensah *et al.*, 2017) and India (Kashyap *et al.*, 2014): 65% and 48%, respectively. In South Korea, Lee *et al.* (2014) reported a moderate rate of 28.6% in a similar population, while a relatively low rate (19.85%) has been estimated in Iraq (Abdulkareem *et al.*, 2020).

Among HCWs, the prevalence of LTBI was 50% in this study. In comparison, prevalence rates of LTBI in HCWs of 47% in Iran (using QFT-GIT), 40.7% in Morocco (using QFT-GIT), 33.6% in China (using T-SPOT.TB), 26% in South Africa (using QFT-GIF) and 61.6% in **Thailand (using QFT-Plus) have been reported (Li *et al.*, 2015; McCarthy et al., 2015; Keshavarz Valian *et al.*, 2019; Sabri *et al.*, 2019). These differences could be due to the incidence of TB, national income levels, and the type of IGRAs used in the studies. The rate of LTBI in SWs was significantly higher using QFT-Plus (96.8%; $P<0.001$). A moderately high rate of 58.5% was also found in Mexico (Torres-Gonzalez *et al.*, 2013). This may suggest that SWs are more exposed to TB infection due to manipulating infected carcasses and using knives, which may increase the risk of transmission via inhalation of aerosols produced by infected animals or from direct contact with a wound (de la Rua-Domenech, 2006).

Based on TST results, the prevalence of LTBI in this study was 84.16% (95% CI 75.55–90.66), which was much higher compared with results from Madagascar (78.6%) (Sadananda *et al.*, 2020) and India (55%) (Chandrasekaran et al., 2018). This could be due to the wide coverage of BCG immunization in Burkina Faso (Ouédraogo *et al.*, 2013), and the circulation of non-tuberculous mycobacteria (NTM) (Zida *et al.*, 2014) inducing false-positive TST results (Latorre *et al.*, 2010). However, prevalence rates varied depending on the specific risk group and technique. For TST, prevalence was 83.3% among HCWs, 100% among SWs, and 67.9% among household contacts of TB index cases. A study conducted in 2015 reported prevalence of 60% among HCWs in Kenya (Agaya *et al.*, 2015), 61.7% in Indonesia (Wardani *et al.*, 2021), 79% in Ivory Coast (Kassim *et al.*, 2000), 67% in Georgia (Mirtskhulava *et al.*, 2008), 57.6% in Iran (Keshavarz Valian *et al.*, 2019) and 52.1% in Morocco (Sabri *et al.*, 2019). These inconsistent findindgs could be due to false-positive results because NTM infections could affect the TST results (Andersen *et al.*, 2000) and TST characteristics.

For household contacts of TB index cases, the prevalence of LTBI was 67.9% on TST, which was higher compared with the results for similar populations in Taiwan (Huang *et al.*, 2010), Iraqi Kurdistan (Abdulkareem *et al.*, 2020) and South Korea (Lee *et al.*, 2014): 46%, 24.05% and 38%, respectively. These differences in prevalence, although relatively moderate, could be explained by disparity in the incidence of TB in these countries (Enos *et al.*, 2018; Chen *et al.*, 2019; Song *et al.*, 2019). In addition, in the context of high incidence of TB, the size of the induration of TST in a household contact could only be the corollary of exposure to a focus of mycobacteria strains from the family (MacPherson *et al.*, 2020).

Table 1
Sociodemographic and biological characteristics of the study population (n=101).

Variables	Category	n	Proportion (%)
Sex	Male	67	66.34
	Female	34	33.66
Age group (years)	15–30	28	27.72
	31–46	46	45.54
	≥47	27	26.73
Origin	Healthcare worker	42	41.58
	Household contact	28	27.72
	Slaughterhouse worker	31	30.69
Body mass index (kg/m^2)	<18.5	4	3.96
	18.5–24.9	53	52.48
	25–29.9	36	35.64
	>30	8	7.92
Educational level	Any	16	15.84
	Primary	12	11.88
	Secondary	53	52.48
	University	20	19.80
Marital status	Married	73	72.28
	Single	26	25.74
	Other	2	1.98
Smoking	Yes	20	19.80
	No	81	80.20
Alcoholism	Yes	32	31.68
	No	69	68.32
Diabetes	Yes	12	11.88
	No	89	88.12
Hospitalization	Yes	5	4.95
	No	96	95.05
Exposure (years)	<15	68	67.33
	≥15	33	32.67
BCG scar	Yes	77	77.00
	No	23	23.00
Chronic cough	Yes	10	9.90
	No	91	90.10
Presence of animal at home	Yes	55	54.46
	No	46	45.54
Helminth infection	Yes	15	14.85
	No	86	85.15
Protozoal infection	Yes	62	61.39
	No	39	38.61

BCG, Bacillus Calmette-Guérin.

The prevalence of LTBI among SWs was 100% in this study, and a similarly high result was obtained in Mexico (76.2%) (Torres-Gonzalez et al., 2013). This suggests that SWs are highly exposed to TB pathogens.

Regardless of the population group in this study, the TST positivity rate was higher than the QTF-Plus positivity rate. This was corroborated by other studies, including a meta-analysis of 24 studies showing the same outcomes from both tests in professional groups at risk for TB (Lamberti *et al.*, 2015).

Based on the results of both test methods (QFT-Plus/TST), the overall prevalence of LTBI in this study was 63.36% (95% CI 52.18–71.82). Similar results have been reported from Thailand (61.6%) and Georgia (55%) (Whitaker *et al.*, 2013; Gatechompol *et al.*, 2021). However, the prevalence found in the present study was higher compared with the prevalence in Morocco (45.2%) (Sabri *et al.*, 2019). This could be attributed to the inclusion of different categories of participants in the two studies. Also, the discrepancies in prevalence may be linked with the tools used for LTBI diagnosis, and the disproportionate distribution of TB worldwide.

This study found that the overall prevalence of LTBI was significantly higher in men (94.03%) compared with women (P<0.05). This may be due to the fact that the global burden of TB is higher among males than females (Mumpe-Mwanja *et al.*, 2015), and men are more susceptible to exposure to many sources of infection as well as TB due to their activities or sociocultural determinants (Neyrolles and Quintana-Murci, 2009). Also, the prevalence of LTBI in participants with an animal at home was significantly higher compared with that among those who did not have an animal at home (P<0.05). Animals provide many benefits to people, but they could carry harmful germs that can spread to people and cause zoonotic diseases, such as bovine TB (Centers for Disease Control and Prevention, 2021). In addition, the prevalence of LTBI was higher in participants with protozoal infections compared with those who were not infected with protozoal infections. Similar results were found in the USA among refugees (Board and Suzuki, 2016).

Factors associated with LTBI among the study population

Factors significantly associated with LTBI were identified using univariate and multivariate logistic regressions. These risk factors were: working in a slaughterhouse, having an animal at home, protozoal infection, smoking, being male and ≥15 years of exposure. Previous studies found that several factors are associated with positivity on both QFT-Plus and TST among people exposed to TB infection (Torres-Gonzalez et al., 2013; Lee et al., 2014; Agaya et al., 2015; McCarthy et al., 2015; Eom et al., 2018; Wardani et al., 2021).

In the logistic regression analyses (both univariate and multivariate) for QTF-Plus and/or TST, the prevalence of LTBI was approximately eight-fold higher among males than females. This corroborates results from South Africa (Ncayiyana et al., 2016) and Uganda (Mumpe-Mwanja *et al.*, 2015). This trend has been attributed to the fact that males practice more risky activities, such as pastoral activities, butchery, mining and agriculture (Horton *et al.*, 2016). Depending on the origin of the study population, SWs were at significantly higher risk of LTBI than HCWs and household contacts of index TB cases. Although few studies have been conducted on these three risk groups at the same time, this study supports the findings of Gompo *et al.* (2020) who found that SWs are at high risk due to their exposure to infected cattle. This finding highlights the need for screening of SWs at slaughterhouses where bovine TB is prevalent. It is important to note that SWs may also be exposed to TB that is not linked to *M. bovis* infection but linked to *M. tuberculosis*, as for HCWs and household contacts of TB index cases. A previous study on the prevalence of TB species in bovine carcases found that some isolated species were not *M. bovis* (Tarnagda *et al.*, 2014). A relationship was found between the occurrence of LTBI and having an animal at home, with the risk of LTBI increased 10-fold compared with not having an animal at home. This could be explained by the fact that animals may constitute mycobacterial reservoirs as well as representing a source for TB infection of humans [Gompo et al., 2020]. Three of every four known infectious diseases or emerging infectious diseases in humans come from animals, due to the close connection between people and animals (Centers for Disease Control and Prevention, 2021).

In the present study, the carriage of intestinal parasites, such as protozoa, was found to increase the risk of LTBI two-fold. Other authors have recorded similar results, and provided evidence that protozoal infection was significantly associated with LTBI (Board and Suzuki, 2016; Alemu et al., 2019; Tesfaye et al., 2022). These results are likely to be due to the fact that the study population lived in settings that are co-endemic for TB and parasite infection, with poor implementation of wa-

Table 2
Bivariate analysis according to QuantiFERON-TB Gold Plus test (QFT-Plus) and tuberculin skin test (TST) (n=101).

Variables	QFT-Plus–*n* (%)	QFT-Plus+*n* (%)	*P*-value	TST–*n* (%)	TST+*n* (%)	*P*-value
Sex			0.194			<0.001
Female	14 (41.2)	20 (58.8)		12 (35.29)	22 (64.71)	
Male	19 (28.4)	48 (71.6)		4 (5.97)	63 (94.03)	
Age group (years)			0.566			0.095
15–30	7 (25.0)	21 (75.0)		8 (28.57)	20 (71.43)	
31–46	17 (37.0)	29 (63.0)		5 (10.87)	41 (89.13)	
≥47	9 (33.3)	18 (66.7)		3 (11.12)	24 (88.88)	
Origin			<0.001			0.003
Healthcare worker	21 (50.00)	21 (50.00)		7 (16.67)	35 (83.33)	
Household contact	11 (39.30)	17 (60.70)		9 (32.14)	19 (67.86)	
Slaughterhouse worker	1 (3.20)	30 (96.80)		0 (0.0)	31 (100.00)	
Body mass index (kg/m^2)			0.143			0.320
18.5	3 (75.00)	1 (25.00)		0 (0.00)	4 (100.00)	
18.5–24.9	17 (32.08)	36 (67.92)		7 (13.20)	46 (86.80)	
25–29.9	9 (25.00)	27 (75.00)		6 (16.67)	30 (83.33)	
>30	4 (50.00)	4 (50.00)		3 (37.50)	5 (62.50)	
Educational level			0.842			0.880
Any	5 (31.20)	11 (68.80)		3 (18.75)	13 (81.25)	
Primary	3 (25.00)	9 (75.00)		1 (8.34)	11 (91.66)	
Secondary	17 (32.10)	36 (67.90)		9 (16.98)	44 (83.02)	
University	8 (40.00)	12 (60.00)		3 (15.00)	17 (85.00)	
Smoking			0.068			0.184
No	30 (37.04)	51 (62.96)		1 (5.0)	19 (95.0)	
Yes	3 (15.00)	17 (85.00)		15 (18.52)	66 (81.48)	
Alcoholism			0.263			0.770
No	25 (36.23)	44 (63.77)		12 (17.39)	57 (82.61)	
Yes	8 (25.00)	24 (75.00)		4 (12.50)	28 (87.50)	
Diabetes			0.199			0.685
No	17 (30.34)	62 (69.66)		15 (16.85)	74 (83.15)	
Yes	6 (50.00)	6 (50.00)		1 (8.33)	11 (91.67)	
Hospitalization			0.896			1.000
No	32 (33.33)	64 (66.67)		0 (0.00)	5 (100.00)	
Yes	1 (20.00)	4 (80.00)		16 (16.67)	80 (83.33)	
Exposure (years)			0.723			0.895
<15	11 (16.40)	56 (83.6)		23 (33.82)	45 (66.18)	
≥15	5 (14.70)	29 (85.3)		10 (30.30)	23 (69.70)	
BCG scar			0.836			0.847
No	8 (34.78)	15 (65.22)		3 (13.05)	20 (86.95)	
Yes	25 (32.47)	52 (67.53)		13 (16.88)	64 (83.12)	
Chronic cough			0.218			0.050
No	28 (30.77)	63 (69.23)		12 (13.19)	79 (86.81)	
Yes	5 (50.00)	5 (50.00)		4 (40.00)	6 (60.00)	
Presence of animal at home			0.011			0.013
No	21 (45.65)	25 (54.35)		12 (26.09)	34 (73.91)	
Yes	12 (21.82)	43 (78.18)		4 (7.27)	51 (92.73)	
Helminth infection			0.768			0.702
No	29 (33.72)	57 (66.28)		13 (15.12)	73 (84.88)	
Yes	4 (26.67)	11 (73.33)		3 (20.00)	12 (80.00)	
Protozoal infection			0.022			0.114
No	18 (46.15)	21 (53.85)		9 (23.08)	30 (76.92)	
Yes	15 (24.19)	47 (75.81)		7 (11.29)	55 (88.71)	

BCG, Bacillus Calmette-Guérin.

Table 3
Factors associated with positive QuantiFERON-TB Gold Plus test (QTF-Plus) (n=101).

Variables	QTF-Plus+	COR (95% CI; *P*-value)	AOR (95% CI; *P*-value)
Sex			
Female	58.82 (20/34)	1	
Male	71.64 (48/67)	1.768 (0.744–4.201; 0.197)	
Age group (years)			
15–30	75.00 (21/ 28)	1	
31–46	63.04 (29/46)	0.568 (0.200–1.615; 0.289)	
≥47	66.67 (18/27)	0.666 (0.206–2.150; 0.497)	
Origin			
Healthcare worker	83.33 (35/42)	1	
Household contact	60.71 (17/28)	1.545 (0.585– 4.077; 0.379)	
Slaughterhouse worker	96.77 (30/31)	30.00 (3.739–240.651; 0.001)	1.095 (1.00–2.036; 0.023)
Body mass index (kg/m^2)			
18.5	25.00 (1/4)	1	
18.5–24.9	67.92 (36/53)	0.157 (0.015–1.626; 0.121)	
25–29.9	75.00 (27/36)	1.416 (0.548–3.661; 0.472)	
≥30	50.00 (4/8)	0.472 (0.105–2.118; 0.327)	
Educational level			
Any	68.75 (11/16)	1	
Primary	75.00 (9/12)	1.363 (0.253–7.321; 0.718)	
Secondary	67.92 (36/53)	0.962 (0.288–3.209; 0.950)	
University	60.00 (12/20)	0.681 (0.170–2.723; 0.588)	
Smoking			
No	62.96 (51/81)	1	
Yes	85.00 (17/20)	3.333 (0.901–12.324; 0.071)	4.214 (1.051–16.899; 0.042)
Alcoholism			
No	63.77 (44/69)	1	
Yes	75.00 (24/32)	1.704 (0.666–4.358; 0.266)	
Diabetes			
No	69.66 (62/89)	1	
Yes	50.00 (6/12)	0.435 (0.128–1.472; 0.181)	
Hospitalization			
No	66.67 (64/96)	1	
Yes	80.00 (4/5)	2 (0.214–18.637; 0.543)	
Exposure (years)			
<15	65.7 (44/67)	1	
≥15	70.6 (24/34)	1.255 (0.521–3.155; 0.189)	5.617 (1.202–32.198; 0.036)
BCG scar			
No	65.22 (15/23)	1	
Yes	67.53 (52/77)	1.109 (0.415–2.960; 0.836)	
Chronic cough			
No	69.23 (63/91)	1	
Yes	50.00 (5/10)	0.444 (0.119–1.658; 0.228)	
Presence of animal at home			
No	54.35 (25/46)	1	
Yes	78.18 (43/55)	3.009 (1.268–7.139; 0.012)	2.735 (1.102–6.789; 0.030)
Helminth infection			
No	66.28 (57/86)	1	
Yes	73.33 (11/15)	1.399 (0.409–4.780; 0.592)	
Protozoal infection			
No	53.85 (21/39)	1	
Yes	75.81 (47/62)	2.685 (1.140–6.326; 0.024)	2.591 (1.034–6.491; 0.042) 0.042)

(*continued on next page*)

Table 3 (*continued*)

AOR, adjusted odds ratio; BCG, Bacille Calmette-Guérin; CI, confidence interval; COR, crude odds ratio.

Table 4
Factors associated with positive tuberculin skin test (TST).

Variables	TST+	COR (95% CI; *P*-value)	AOR (95% CI; *P*-value)
Sex			
Female	64.71 (22/34)	1	
Male	94.03 (63/67)	8.590 (2.507–29.429; 0.001)	10.114(2.744–37.270; 0.001)
Age group (years)			
15–30	71.43 (20/28)	1	
31–46	89.13 (41/46)	3.280(0.950–11.319; 0.060)	
≥47	88.88 (24/27)	3.20(0.747–13.690; 0.117)	
Origin			
Healthcare worker	83.33 (35/42)	1	
Household contact case	67.85 (19/28)	0.422(0.135–1.313; 0.136)	
Slaughterhouse worker	100 (31/31)	NA	
Body mass index (kg/m^2)			
18.5	100 (4/4)	1	
18.5–24.9	67.92 (36/53)	Omitted	
25–29.9	30.3 (30/36)	0.760 (0.232–2.484; 0.651)	
≥30	62.5 (5/8)	0.253 (0.049–1.304; 0.101)	
Educational level			
Any	81.48 (13/16)	1	
Primary	91.66 (11/12)	2.538(0.229–28.020; 0.447)	
Secondary	83.02 (44/53)	1.128(0.265–4.789; 0.870)	
University	85.00 (17/20)	1.307 (0.225–7.568; 0.765)	

(*continued on next page*)

Table 4 (*continued*)

Variables	TST+	COR (95% CI; *P*-value)	AOR (95% CI; *P*-value)
Smoking			
No	68.2 (66/81)	1	
Yes	95.00 (19/20)	4.318 (0.535–34.83; 0.170)	
Alcoholism			
No	82.61 (57/69)	1	
Yes	87.50 (28/32)	1.473(0.435–4.984; 0.770)	
Diabetes			
No	83.15 (74/89)	1	
Yes	91.67 (11/12)	2.229(0.267–18.594; 0.459)	
Exposure (years)			
<15	83.6 (56/ 67)	1	
≥15	85.30 (29/34)	1.139 (0.375–3.900; 0.824)	
BCG scar			
No	19.3 (20/23)	1	
Yes	64.7 (64/77)	0.738 (0.191–2.854; 0.660)	
Chronic cough			
No	76.6 (79/91)	1	
Yes	60 (6/10)	0.227 (0.055–0.927; 0.039)	
Presence of animal at home			
No	46.3 (51/55)	1	
Yes	38.7 (34/46)	4.50 (1.339–15.119; 0.015)	5.582 (1.484–20.995; 0.017)
Helminth infection			
No	72.4 (73/86)	1	
Yes	80.00 (12/15)	0.712 (0.176–2.877; 0.702)	
Protozoal infection			
No	76.92 (30/39)	1	
Yes	83.33 (55/62)	2.357 (0.797–6.963; 0.114)	

AOR, adjusted odds ratio; BCG, Bacille Calmette-Guérin; CI, confidence interval; COR, crude odds ratio.

ter and hygiene sanitation. Epidemiologic studies of co-infection with TB and intestinal parasites in humans are strongly recommended to draw a roadmap for the control of both endemic diseases.

In the study population, ≥15 years of exposure increased the risk of LTBI more than five-fold. This corroborates the findings of other studies conducted elsewhere (Pai et al., 2005; Anwar et al., 2019; Sedamano et al., 2020). On multivariate logistic regression, smoking was found to be associated with LTBI. Other studies in Morocco and Nepal found that smoking was a risk factor for LTBI when assessed by QFT-GIT and/or TST (Sabri et al., 2019; Gompo et al., 2020).

This study has a few limitations. First, the results cannot be generalized to other cities in Burkina Faso. Also, other well-known risk groups, such as people living with HIV, people with chronic renal failure, and migrants, were not included. Due to difficulties with acquiring the IGRA reagents, this study was performed on a small sample (101 participants), which was not ideal to investigate the prevalence of LTBI. However, this study is considered to be of value as it is the first study to investigate LTBI in Burkina Faso.

Conclusion

To the authors' knowledge, this is the first report of LTBI in Burkina Faso. The study found a high prevalence of LTBI among the three groups of individuals, especially SWs, and identified working in a slaughterhouse, having an animal at home, protozoal infection, smoking, being male and ≥15 years of exposure as risk factors for LTBI. These data highlight the need for targeted interventions for these risk groups to reach the end TB goals. These interventions must include pre-employment screening for SWs and HCWs, and routine screening for household contacts at high risk of TB, which will maximize opportunities to identify and treat LTBI.

Declaration of Competing Interest

None declared.

Acknowledgements

The authors wish to thank the field workers, staff at the slaughterhouses and health facilities, and TB patients and household contacts for their support.

Author contributions

DAD, GIM and SPD conceived and designed the study. DAD and KAO conducted the field study. DAD and KAO performed field data collection and performed the laboratory analysis. DAD analysed the data and wrote the manuscript. DAD, GIM, SPD, TS, KAO, LTS, ASK, MZC, HMH, AC, AMGB, KKA, RKD, PM and JZ critically revised the manuscript. All authors read and approved the final manuscript.

Funding

The field work, laboratory analyses and all other costs related to this study were funded through a PhD Fellowship to Djibougou Arthur for his PhD at the Université Nazi BONI. Afrique One-ASPIRE is funded by a consortium of donors including the African Academy of Sciences, Alliance for Accelerating Excellence in Science in Africa, the New Partnership for Africa's Development Planning and Coordinating Agency, and the Wellcome Trust (107753/A/15/Z).

Ethical approval

The protocol of the study was approved by the Ethics Committee for Health Research of Burkina Faso, known as Comité d'éthique pour la recherche en Santé (Ref. 2017-07-106/CERS). The study was conducted in accordance with the Declaration of Helsinki. Data collection authorizations were provided by the Ministry of Health and the Regional Directors of Health of Hauts-Bassins and Animal and Fisheries Resources. All participants and/or their parents/legal guardians provided written informed consent after explanation of the study procedure, risks and benefits. Participants with parasitic infections received appropriate treatment, as recommended by national parasitosis treatment guidelines.

Availability of data and materials

All data generated or analysed during this study are included in this published article

References

Abdulkareem FN, Merza MA, Salih AM. First insight into latent tuberculosis infection among household contacts of tuberculosis patients in Duhok, Iraqi Kurdistan: using tuberculin skin test and QuantiFERON-TB Gold Plus test. Int J Infect Dis 2020;96:97–104.

Agaya J, Nnadi CD, Odhiambo J, Obonyo C, Obiero V, Lipke V, et al. Tuberculosis and latent tuberculosis infection among healthcare workers in Kisumu, Kenya. Trop Med Int Health 2015;20:1797–804.

Alemu A, Kebede A, Dagne B, Amare M, Diriba G, Yenew B, et al. Intestinal parasites co-infection and associated factors among active pulmonary tuberculosis patients in selected health centers, Addis Ababa, Ethiopia: unmatched case control study. BMC Infect Dis 2019;19:407.

Andersen P, Munk ME, Pollock JM, Doherty TM. Specific immune-based diagnosis of tuberculosis. Lancet 2000;356:1099–104.

Anwar MM, Ahmed DM, Elareed HR, Abdel-Latif RA-R, Sheemy MS, Kamel NM, et al. Screening for latent tuberculosis among healthcare workers in an Egyptian hospital using tuberculin skin test and QuantiFERON-TB Gold In-Tube Test. Indian J Occup Environ Med 2019;23:106–11.

Basera TJ, Ncayiyana J, Engel ME. Prevalence and risk factors of latent tuberculosis infection in Africa: a systematic review and meta-analysis protocol. BMJ Open 2017;7.

Baussano I, Nunn P, Williams B, Pivetta E, Bugiani M, Scano F. Tuberculosis among health care workers. Emerg Infect Dis 2011;17:488.

Board AR, Suzuki S. The interrelation between intestinal parasites and latent TB infections among newly resettled refugees in Texas. Int Health 2016;8:67–72.

Bongomin F, Ssekamatte P, Nattabi G, Olum R, Ninsiima S, Kyazze AP, et al. Latent tuberculosis infection status of pregnant women in Uganda determined using QuantiFERON TB Gold-Plus. Open Forum Infect Dis 2021;8:ofab241.

Carranza C, Pedraza-Sanchez S, de Oyarzabal-Mendez E, Torres M. Diagnosis for latent tuberculosis infection: new alternatives. Front Immunol 2020;11.

Centers for Disease Control and Prevention. Zoonotic diseases. Atlanta, GA: CDC; 2021 Available at https://www.cdc.gov/onehealth/basics/zoonotic-diseases.html .

Chandrasekaran P, Mave V, Thiruvengadam K, Gupte N, Shivakumar SVBY, Hanna LE, et al. Tuberculin skin test and QuantiFERON-Gold In Tube assay for diagnosis of latent TB infection among household contacts of pulmonary TB patients in high TB burden setting. PLoS One 2018;13.

Chen Y-Y, Pan S-W, Shen H-S, Chuang F-Y, Feng J-Y, Su W-J. Declining trend in incidence of tuberculosis in adolescents and young adults in Taiwan. Eur Respir J 2019;53.

Cisse M, Sangare I, Djibougou AD, Tahita MC, Gnissi S, Bassinga JKW, et al. Prevalence and risk factors of *Schistosoma mansoni* infection among preschool-aged children from Panamasso village, Burkina Faso. Parasit Vectors 2021;14:185.

de la Rua-Domenech R. Human *Mycobacterium bovis* infection in the United Kingdom: incidence, risks, control measures and review of the zoonotic aspects of bovine tuberculosis. Tuberculosis 2006;86:77–109.

Enos M, Sitienei J, Ong'ang'o J, Mungai B, Kamene M, Wambugu J, et al. Kenya tuberculosis prevalence survey 2016: challenges and opportunities of ending TB in Kenya. PLoS One 2018;13.

Eom JS, Kim I, Kim W-Y, Jo E-J, Mok J, Kim M-H, et al. Household tuberculosis contact investigation in a tuberculosis-prevalent country: are the tuberculin skin test and interferon-gamma release assay enough in elderly contacts? Medicine 2018;97:e9681.

Gatechompol S, Harnpariphan W, Supanan R, Suwanpimolkul G, Sophonphan J, Ubolyam S, et al. Prevalence of latent tuberculosis infection and feasibility of TB preventive therapy among Thai prisoners: a cross-sectional study. BMC Public Health 2021;21:1206.

Gompo TR, Shrestha A, Ranjit E, Gautam B, Ale K, Shrestha S, et al. Risk factors of tuberculosis in human and its association with cattle TB in Nepal: a One Health approach. One Health 2020;10.

Horton KC, MacPherson P, Houben RMGJ, White RG, Corbett EL. Sex differences in tuberculosis burden and notifications in low- and middle-income countries: a systematic review and meta-analysis. PLoS Med 2016;13.

Huang Y-W, Shen G-H, Lee J-J, Yang W-T. Latent tuberculosis infection among close contacts of multidrug-resistant tuberculosis patients in central Taiwan. Int J Tuberc Lung Dis 2010;14:1430–5.

Kashyap RS, Nayak AR, Gaherwar HM, Husain AA, Shekhawat SD, Jain RK, et al. Latent TB infection diagnosis in population exposed to TB subjects in close and poor ventilated high TB endemic zone in India. PLoS One 2014;9:e89524.

Kassim S, Zuber P, Wiktor SZ, Diomande FV, Coulibaly IM, Coulibaly D, et al. Tuberculin skin testing to assess the occupational risk of *Mycobacterium tuberculosis* infection among health care workers in Abidjan, Côte d'Ivoire. Int J Tuberc Lung Dis 2000;4:321–6.

Keshavarz Valian S, Mahmoudi S, Pourakbari B, Abdolsalehi MR, Eshaghi H, Mamishi S. Screening of healthcare workers for latent tuberculosis infection in the low tuberculosis burden country: QuantiFERON-TB Gold in Tube test or tuberculin skin test? Arch Environ Occup Health 2019;74:109–14.

Lamberti M, Uccello R, Monaco MGL, Muoio M, Feola D, Sannolo N, et al. Tuberculin skin test and QuantiFERON test agreement and influencing factors in tuberculosis screening of healthcare workers: a systematic review and meta-analysis. J Occup Med Toxicol 2015;10:2.

Latorre I, De Souza-Galvão M, Ruiz-Manzano J, Lacoma A, Prat C, Altet N, et al. Evaluating the non-tuberculous mycobacteria effect in the tuberculosis infection diagnosis. Eur Respir J 2010;35:338–42.

Lee SJ, Lee SH, Kim YE, Cho YJ, Jeong YY, Kim HC, et al. Risk factors for latent tuberculosis infection in close contacts of active tuberculosis patients in South Korea: a prospective cohort study. BMC Infect Dis 2014;14:566.

Li X-X, Chen J-X, Wang L-X, Tian L-G, Zhang Y-P, Dong S-P, et al. Prevalence and risk factors of intestinal protozoan and helminth infections among pulmonary tuberculosis patients without HIV infection in a rural county in P. R. China. Acta Trop 2015;149:19–26.

López de Goicoechea-Saiz M, Sternberg F, Portilla-Sogorb J. Prevalence and associated risk factors of latent tuberculosis infection in a Spanish prison. Rev Esp Sanid Penit 2018;20:4–10.

MacNeil A. Global epidemiology of tuberculosis and progress toward meeting global targets — worldwide, 2018. MMWR Morb Mortal Wkly Rep 2020;69:281–5.

MacPherson P, Lebina L, Motsomi K, Bosch Z, Milovanovic M, Ratsela A, et al. Prevalence and risk factors for latent tuberculosis infection among household contacts of index cases in two South African provinces: analysis of baseline data from a cluster-randomised trial. PLoS One 2020;15.

Mbugi EV, Katale BZ, Lupindu AM, Keyyu JD, Kendall SL, Dockrell HM, Michel AL, Matee MI, van Helden PD, et al. Tuberculosis Infection: Occurrence and Risk Factors in Presumptive Tuberculosis Patients of the Serengeti Ecosystem in Tanzania. The East African health research journal 2017;1(1):19–30. doi:10.24248/EAHRJ-D-16-00319.

McCarthy KM, Scott LE, Gous N, Tellie M, Venter WDF, Stevens WS, et al. High incidence of latent tuberculous infection among South African health workers: an urgent call for action. Int J Tuberc Lung Dis 2015;19:647–53.

Mensah GI, Sowah SA, Yeboah NYA, Addo KK, Jackson-Sillah D. Utility of QuantiFERON tuberculosis Gold in Tube test for detecting latent tuberculosis infection among close household contacts of confirmed tuberculosis patients in Accra, Ghana. Int J Mycobacteriol 2017;6:27–33.

Mirtskhulava V, Kempker R, Shields KL, Leonard MK, Tsertsvadze T, del Rio C, et al. Prevalence and risk factors for latent tuberculosis infection among health care workers in Georgia. Int J Tuberc Lung Dis 2008;12:513–19.

Mumpe-Mwanja D, Verver S, Yeka A, Etwom A, Waako J, Ssengooba W, et al. Prevalence and risk factors of latent tuberculosis among adolescents in rural Eastern Uganda. Afr Health Sci 2015;15:851–60.

Ncayiyana JR, Bassett J, West N, Westreich D, Musenge E, Emch M, et al. Prevalence of latent tuberculosis infection and predictive factors in an urban informal settlement in Johannesburg, South Africa: a cross-sectional study. BMC Infect Dis 2016;16:661.

Neyrolles O, Quintana-Murci L. Sexual inequality in tuberculosis. PLoS Med 2009;6.

Ouédraogo N, Kagoné M, Sié A, Becher H, Müller O. Immunization coverage in young children: a study nested into a health and demographic surveillance system in Burkina Faso. J Trop Pediatr 2013;59:187–94.

Pai M, Gokhale K, Joshi R, Dogra S, Kalantri S, Mendiratta DK, et al. *Mycobacterium tuberculosis* infection in health care workers in rural India: comparison of a whole-blood interferon gamma assay with tuberculin skin testing. JAMA 2005;293:2746–55.

Qader GQ, Seddiq MK, Rashidi KM, Manzoor L, Hamim A, Akhgar MH, et al. Prevalence of latent tuberculosis infection among health workers in Afghanistan: a cross-sectional study. PLoS One 2021;16.

Qiagen: QuantiFERON-TB Gold Plus (QFT-Plus) ELISA... - Google Scholar. 2021. n.d. Available at: https://scholar.google.com/scholar_lookup?title=QuantiFERON%C2%AE-TB+Gold+Plus+(QFT%C2%AE-Plus)+ELISA+package+insert&publication_year=2017& (Accessed 10 August 2021).

Rieder HL, Chadha VK, Nagelkerke NJD, van Leth F, van der Werf MJKNCV Tuberculosis Foundation. Guidelines for conducting tuberculin skin test surveys in high-prevalence countries. Int J Tuberc Lung Dis 2011;15(1):S1–25 Suppl.

Sabri A, Quistrebert J, Naji Amrani H, Abid A, Zegmout A, Abderrhamani Ghorfi I, et al. Prevalence and risk factors for latent tuberculosis infection among healthcare workers in Morocco. PLoS One 2019;14.

Sadananda G, Knoblauch AM, Andriamiadanarivo A, Razafindrina K, Ambinintsoa I, Rabetombosoa RM, et al. Latent tuberculosis infection prevalence in rural Madagascar. Trans R Soc Trop Med Hyg 2020;114:883–5.

Sedamano J, Schwalb A, Cachay R, Zamudio C, Ugarte-Gil C, Soto-Cabezas G, et al. Prevalence of positive TST among healthcare workers in high-burden TB setting in Peru. BMC Public Health 2020;20:612.

Song J-H, Huh K, Chung DR. Modern history of tuberculosis in Korea. Infect Chemother 2019;51:414–26.

Tarnagda Z, Kanyala E, Zingué D, Sidibé S, Yougbaré I, Kagoné TS, et al. Prevalence of *Tuberculosis* spp. species in bovine carcasses in two slaughterhouses of Burkina Faso 2014. Available at: https://www.semanticscholar.org/paper/Prevalence-of-Tuberculosis-spp-.-species-in-bovine-Tarnagda-Kanyala/ea7f6df95df9e5647eb35fe84f24e44258f5464a (Accessed 19 June 2020).

Tesfaye S, Zerfu B, Desta K. Magnitude and associated factors of intestinal parasitosis and tuberculosis among tuberculosis suspected patients attending Kuyu General Hospital, North Shewa, Oromia, Ethiopia. PLoS Negl Trop Dis 2022;16.

Torres-Gonzalez P, Soberanis-Ramos O, Martinez-Gamboa A, Chavez-Mazari B, Barrios-Herrera MT, Torres-Rojas M, et al. Prevalence of latent and active tuberculosis among dairy farm workers exposed to cattle infected by *Mycobacterium bovis*. PLoS Negl Trop Dis 2013;7:e2177.

Uplekar M, Weil D, Lonnroth K, Jaramillo E, Lienhardt C, Dias HM, et al. WHO's new end TB strategy. Lancet 2015;385:1799–801.

Wang P-H, Lin S-Y, Lee SS-J, Lin S-W, Lee C-Y, Wei Y-F, et al. CD4 response of QuantiFERON-TB Gold Plus for positive consistency of latent tuberculosis infection in patients on dialysis. Sci Rep 2020;10:21367.

Wardani HR, Mertaniasih NM, Soedarsono S. Risk factors of latent tuberculosis infection in healthcare workers at hospitals in Jember City. Indonesia. Afr J Infect Dis 2021;15:34–40.

Whitaker JA, Whitaker J A, Mirtskhulava V, Kipiani M, Harris DA, Tabagari N, et al. Prevalence and incidence of latent tuberculosis infection in Georgian healthcare workers. PLoS One 2013;8:e58202.

World Health Organization. Global tuberculosis report 2019. Geneva: WHO; 2019.

World Health Organisation. WHO consolidated guidelines on tuberculosis. Module 1: prevention tuberculosis preventive treatment. Geneva: World Health Organization; 2020 Licence: CC BY-NC-SA 3.0 IGO.

Zida S, Tarnagda Z, Kaboré A, Zingué D, Hien H, Sanou A, et al. Etat des lieux des mycobactérioses atypiques au Burkina Faso: résultats d'une enquête régionale. Pan Afr Med J 2014;17:188.