# Conversion and Reversion of Tuberculin Skin and QuantiFERON Gold-in-tube Tests Among Persons Experiencing Homelessness During a Multi-Shelter Screening Effort in Atlanta, Georgia (2008-2018)

ABSTRACT

CONVERSION AND REVERSION OF TUBERCULIN SKIN AND QUANTIFERON GOLD-IN-TUBE TESTS AMONG PERSONS EXPERIENCING HOMELESSNESS DURING A MULTI-SHELTER SCREENING EFFORT IN ATLANTA, GEORGIA (2008-2018)

by

RISHIKA MOHNISH PARIKH

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**Background:** The aim of this study was to determine the proportion of persons experiencing homelessness (PEH) who converted or reverted a tuberculin skin test (TST) or QuantiFERON Gold-in-tube test (QFT) and examine the risk factors associated with prevalence of latent tuberculosis infection.

**Methods:** We performed a retrospective cohort study of all PEH screened for latent tuberculosis infection (LTBI) by TST or QFT from 2008-2018 in Fulton County, Georgia.

**Results:** Out of 16,444 PEH in the study cohort who were screened by TST or QFT, 1603 (9.7%, 95% Confidence Interval [CI] 9.2 – 10.1%) had a positive TB screening. Factors associated with positive results were older age, being male, being Asian, HIV co-infection and history of incarceration. Of those initially negative with a second test (n=3491), 8.5% became positive during a total follow-up period of 102521 person-months, corresponding to an incidence rate of 2.9 cases per 1000 person-months. The rate of conversion was higher among male, older adults and PEH with HIV. Of those initially positive with a second test (n=241), 36.5% reverted to negative during a total follow-up period of 6655 person-months, corresponding to reversion rate of 13.2 cases per 1000 person-months. The rate of reversion was highest among older adults.

**Discussion**: We found higher rates of QFT/TST conversion and reversion. Targeted QFT/TST screening and LTBI treatment among PEH should be an active strategy to reduce TB morbidity.

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by

RISHIKA MOHNISH PARIKH

B.S., UNIVERSITY OF GEORGIA

A Thesis Submitted to the Graduate Faculty
of Georgia State University in Partial Fulfillment
of the
Requirements for the Degree

MASTER OF PUBLIC HEALTH

ATLANTA, GEORGIA
30303

APPROVAL PAGE

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RISHIKA MOHNISH PARIKH

Approved:

**Heather Bradley, Ph.D., MHS**
Committee Chair

**Matthew J. Magee, Ph.D., MPH**
Committee Member

**December 9, 2019**
Date

# ACKNOWLEDGEMENTS

I would like to express my special appreciation and thanks to my committee members, Dr. Matthew Magee and Dr. Heather Bradley. I am gratefully indebted for their patience, continuous support, motivation and participation in my thesis writing process. Dr. Magee's expertise on TB research has greatly help me structure my research.

I would also like to express my deepest thanks and sincere appreciation to Dr. Udodirim Onwubiko from the Fulton County Board of Health, for her encouragement, creative, and comprehensive advice until this work came to existence.

Finally, I must express my very profound gratitude to my parents for providing me with unfailing support and continuous encouragement throughout my years of study. This accomplishment would not have been possible without them.

Author's Statement Page

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Rishika Mohnish Parikh
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# CHAPTER I

# INTRODUCTION

## 1.1 Background

Tuberculosis (TB) disease is an infectious disease caused by the bacillus *Mycobacterium tuberculosis* that typically affects the lungs. The infection causes a binary condition that is either active TB disease or latent infection. One third of the global population is estimated to be latently infected by *Mycobacterium tuberculosis* (Houben & Dodd, 2016). Most of the infected people do not show any signs or symptoms of TB disease and are not infectious. While this fragment of the population may not be infectious, but they are at a risk of developing active TB disease and becoming infectious. However, the progression of latent tuberculosis infection (LTBI) to active TB disease depends on bacterial, host, and environmental factors (Getahun et al., 2015).The global annual incidence is estimated to be 10 million, with an estimated 1.5 million deaths in 2018 (WHO, 2019). TB disease has been a leading cause of death worldwide and has been a major public health concern for the last several centuries. Even though the global incidence is projected to decline 1.6% each year (Furin, Cox, & Pai, 2019), the risk of TB disease at least 10 folds higher in person experiencing homelessness (PEH) than the general population (Bamrah et al., 2013).

The overall rate of homelessness in the United States at any given night in 2018 was 0.2% i.e. 17 persons per 10,000 people (*The 2018 Annual Homeless Assessment Report (AHAR) to Congress*). They are exposed to numerous behavioral, social and environmental risks that leads to increased communicable infections and are one of the

reasons of an outbreak which become serious public health concern. The prevalence of these communicable diseases depends greatly on the living conditions. PEH are at a higher risk for latent and active TB (Nyamathi, Sands, Pattatucci-Aragón, Berg, & Leake, 2004). Substance abuse, incarceration, and human immunodeficiency virus (HIV) are also the risk factors associated with TB (Bamrah et al., 2013). They are more likely to spread TB and cause an outbreak due to compromised immunocompetency and delay in seeking health care and treatment. PEH who sleep in shelters are majorly men, but they also include women and families with children. The overcrowded conditions in the homeless shelters expose them to airborne infections, especially TB is a primary health concern for this population at risk (Badiaga, Raoult, & Brouqui, 2008). More than 5% of TB cases reported to the National TB surveillance System have experienced homelessness in the preceding year (Parriott et al., 2018).

TB was recognized as a disease that was associated with homelessness as early as 1914 (Bamrah et al., 2013). The spread of TB among PEH is related to person-to-person transmission where TB is transmitted by droplet nuclei when a person with active TB coughs or sneezes. Thus, this population are at a higher risk of progressing to active TB. There is a necessity for interventions to control the spread of TB among such high risk population by early detection of cases and outbreaks in shelters, screening of those patients who has had contact with an infectious person, and effective treatment of TB patients (Badiaga et al., 2008).

Our study was conducted in Fulton County of Atlanta, Georgia, where an outbreak investigation for Drug-Resistant Mycobacterium tuberculosis was conducted

among the homeless people during the period from 2008-2015. The majority of outbreak associated patients had stayed overnight or volunteered at a homeless facility (Powell et al., 2017).

## 1.2 Gap and Purpose of Study

Previous studies about LTBI in the homeless population or high-risk populations have focused on the risk factors of LTBI and the performance of the screening test for TB disease (Bagheri Amiri, Saifi, Gouya, Rohani, & Mostafavi, 2015; Getahun et al., 2015; Laurenti et al., 2012). To our knowledge very few studies have examined the conversion or reversion of a TB screening tests in the context of an active TB outbreak among PEH in the United States (Doshi et al., 2012; Sivapalasingam et al., 2009). Given that 13 million people in the US have LTBI (CDC, 2019), it is important to describe the risk factors of LTBI among PEH. Our study focused on determining rates of conversion and reversion of TST and QFT screening tests.

The specific objectives of this study were to:

1. To examine risk factors associated with prevalence of positive QFT or TST at the time of initial screening.

2. To determine the proportion of persons experiencing homelessness who converted a tuberculin skin test (TST) or QuantiFERON Gold-in-tube test (QFT) from negative to positive.

3. To determine the proportion of persons experiencing homelessness who reverted a tuberculin skin test (TST) or QuantiFERON Gold-in-tube test (QFT) from positive to negative.

# CHAPTER II

# REVIEW OF LITERATURE

## 2.1 Tuberculosis

Primary tuberculosis occurs when the body is unable to defend against Mycobacterium tuberculosis bacterium (MTB) infection. The lung is the most involved organ, although the gastrointestinal system, the musculoskeletal system, the lymph reticular system, skin, liver, and the reproductive system may also become infected. The organism is spread primarily as an airborne aerosol from an individual infected with tuberculosis. The deposition of the organism can lead to primary disease (i.e. immediate onset of active disease), latent infection or reactivation of the disease. The body's ability to effectively restrict the infective bacteria id dependent on the individuals' immune system, genetics and whether the exposure is primary or secondary (Jilani, Avula, Gondal, & Siddiqui, 2019).

LTBI is characterized by a state of persistent immune response to stimulation by antigens without any clinical evidence of active tuberculosis (WHO, 2018). The lifetime risk of reactivation TB for any person with documented LTBI is estimated to be 5-15%, with the majority developing the TB disease within the first 5 years after initial infection (Bamrah et al., 2013).

Amongst the many diagnostic tools used for screening tuberculosis infect, Tuberculin skin test (The Mantoux test) and interferon-gamma release assay assist in diagnosis (Jilani et al., 2019). In addition to these screening methods, proper diagnosis of LTBI requires that the presence of active TB infection be excluded. A chest radiography

or in certain circumstances, sputum examinations should be performed to eliminate the possibility of active TB infection should be performed to eliminate the possibility of active TB infection (CDC, 2019; Kim & Kim, 2018). The treatment regimens for LTBI can be given under directly observed therapy (DOT) or self-administered therapy (SAT). The treatment regimens are decided based on severity and patient attributes. They include a 12-dose regimen of Izoniazid (INH) and Rifapentine (RPT), a 4- month regimen of Rifampin (RIF), a 9/6- month regimen of INH or 4-month regimen of INH and RIF (CDC, 2019; WHO, 2018)

**2.2 Risk factors for LTBI**

While we make efforts to control and eliminate TB globally, the foremost challenge there exists is the large often overlapping socially and medically vulnerable population among whom the LTBI subgroups have a significantly higher risk of progression into active TB disease due to a compromised immune or nutritional status (Nandini Sharma, Saurav Basu, & Kamal K. Chopra, 2019).

The current established risk factor for LTBI is close contacts with active tuberculosis patients. It poses as a higher risk for both active and latent TB infections. A close contact is defined as living in the same household or frequent contact with a source case with sputum smear positive. Cases who are sputum smear negative but culture-positive are also infectious, but to a much lesser extent ("Guidance for National Tuberculosis Programmes on the management of tuberculosis in children. Chapter 1: introduction and diagnosis of tuberculosis in children," 2006). A close contacts of culture positive TB patients who visited Gyeongsang National University Hospital in South Korea, were prospectively enrolled to identify the predominant risk factors of contracting

LTBI when in close contact with active TB patients. The enrolled subjects were household or work contacts of patients with active TB. Out of the 308 subjects, 38% were tuberculin skin test (TST) positive and 28.6% were QuantiFERON-TB Gold test (QFT) positive. The TST positivity was significantly associated with the male gender (p=0.049), history of TB (p=0.008), and household contact (p=0.01). The prevalence of LTBI among close contacts of active TB was high, and prior TB history and household contact were risk factors for LTBI (S. J. Lee et al., 2014). Another study conducted in a tertiary hospital in South Korea, observed a prevalence of LTBI to be 15.8% among the 499 health care workers (HCWs). Additionally, the prevalence of exposure to pretreatment TB patients was higher among HCWs in TB-related departments, than among HCWs working in a Tb-unrelated department (Park, 2018). These findings indicate that close contacts with active TB patients has a higher chance of acquiring LTBI.

Demographics that were associated with increased risk of LTBI include increasing age, lower educational and socio-economic status, and alcohol use (Yap et al., 2018). Risk factors for LTBI were significantly associated with living with a relative with TB, history of incarceration, diabetes (Martínez-Aguilar et al., 2015), and Smoking (Amere, Nayak, Salindri, Narayan, & Magee, 2018), There is evidence of increased risk of LTBI and active TB among people living with HIV, substance abuse, and smokers (Getahun et al., 2015). Chronic exposure to silica, undernutrition with low BMI in adults and malnutrition in under-5 children were reported to increase the risk of LTBI (N. Sharma, S. Basu, & K. K. Chopra, 2019). People with Hepatitis C virus (HCV) infection were also found to be at a higher risk for LTBI and active TB disease (Armenta et al., 2017).

A few studies have been conducted in the United States and other countries, investigating diabetes as a risk factor for LTBI. A cross-sectional analysis was performed using National Health and Nutrition Examination Survey data for 2011-2012 determining the association between prediabetes and diabetes with LTBI. Out of the 9756 participants, 793 eligible participants had diabetes, 513 had LTBI and 127 had both diabetes and LTBI. Prevalence of diabetes among adults in the United States population was 11.4% and the prevalence of prediabetes was 22.1%. Prevalence of LTBI was seen to be significantly higher among adults with diabetes (11.6%) compared to those without diabetes (4.6%). LTBI prevalence was also higher among those participants with prediabetes (7.0%) (Barron, Shaw, Bullard, Ali, & Magee, 2018). Another study was conducted to estimate the population-level impact of diabetes on the incidence of pulmonary tuberculosis in India. The country of India was chosen for the study for its large population size and availability of the required data. The study estimated that diabetes accounted for 14.8% of incident pulmonary tuberculosis in India in 2000. While, the proportion of incident smear-positive tuberculosis due to diabetes was estimated to be 20.2%. The study also predicted that the prevalence of pulmonary tuberculosis in patients with diabetes in India is 18.4 %, and that in the smear-positive group diabetes prevalence is 23.5% (Stevenson et al., 2007).

A study conducted in San Diego County, CA investigated the LTBI prevalence by birth regions and clinical risk factors. It identified the demographic and clinical risk factors associated with LTBI treatment among newly arrived refugees from January 1, 2010, through October 1, 2012. The prevalence of LTBI was the highest among the refugees from Saharan Africa (43%) and was associated with current smoking status and

having other clinical comorbidity which in turn increases the risk of active TB. Even though the prevalence of LTBI was high amongst this specific group of refugees, they were found to be less likely to initiate treatment than other refugees from the Middle East. The study also found that refugees who had a post-secondary education were more likely to initiate a treatment for LTBI (Bennett, Brodine, Waalen, Moser, & Rodwell, 2014).

World Health Organization in 2018 reported tuberculosis as the most important co-infection in HIV epidemic, with an estimated 0.8 million TB cases attributable to HIV. HIV is not only found to increase the risk of reactivating LTBI, but also increases the risk of rapid TB progression soon after infection of reactivation of LTBI. A review study for 6 WHO regions and 22 high burden countries was conducted by obtaining the data from the Joint United Nations Program on HIV/AIDS (UNAIDS) to understand the increasing global burden of TB liked to HIV. Tuberculosis incidence rates were the highest in the WHO African Region (265/100,000 population, in addition to the annual rate of increase in the number of cases (6%). Out of all the new TB cases, 9% (7%-12%) of the cases in adults were attributable to HIV infection. The study also estimated 1.8 million deaths from TB, out of which 12% (226,000) were attributable to HIV. The prevalence of LTBI-HIV co-infection was estimated to be 0.36% (11 million people). The high prevalence of HIV and TB co-infection presents a massive challenge to global TB control (Corbett et al., 2003). Another study conducted in southern Brazil, aimed to identify the prevalence of LTBI in persons living with HIV/AIDS (PLWHA) and progression to active tuberculosis among the identified cases. Among the 690 individuals in the sample with HIV, 9.6 % of the sample were diagnosed with LTBI presenting a prevalence of 7.5 cases

observed for every 100 patients. 47 (6.7%) of the identified LTBI cases progressed to active tuberculosis among PLWHA (Santos et al., 2017). These findings for the research reinforce the risk of LTBI among high risk group of people living with HIV/AIDS.

**2.3 Homelessness and risk of LTBI**

Homelessness is recognized to be an economic and social issue that is relevant to the society. A retrospective study was conducted in Houston, Texas where they aimed to calculate the rate of TB disease among the homeless population. The study cohort included 4312 TB cases from October 1995 to September 2004. The average rate of TB was found to be 9.5 among housed persons and 411 among homeless persons per 100,000. The univariate analysis revealed that the homeless were more likely than housed participants to belong to the Beijing family. The study found that being White, male, unmarried or unemployed; reporting a military service; engaging in transactional sex; reported history of incarceration or injection or non-injection drug use; and belonging to the genotyping clusters p1, p3, p16, p22, or p33 all remained positively associated with homelessness (OR>1.4) (Feske, Teeter, Musser, & Graviss, 2013).

Another cross-sectional study was conducted in Seoul metropolitan city, South Korea that aimed to explore the prevalence rate of LTBI and active TB among homeless, and to compare the TB burden among homeless people with that of the control group. Out of the 313 participants, 309 (98.7%) were male, 17 % had a history of previous TB, bacille Calmette-Guerin (BCG) scars were present among 68.8 % participants. 5.8 % participants had active pulmonary TB that were identified by chest x-ray (CXR), and the prevalence rate of active TB among homeless was much higher than that in general population. 206 out of 258 (79.8%) were TST positive and 224 out of 295 (75.9%) were

GFT positive, therefore, positive rates of QFT and TST screening for LTBI were much higher for the homeless participants compared with the controls. The higher prevalence rate of active TB and LTBI among the homeless in South Korea was 25 times and 6 times higher as compared with the US and Japan respectively (C.-H. Lee et al., 2013).

**2.4 Persons experiencing homelessness and other comorbidities**

Previous research has been done on PEH that have demonstrated their elevated risk of asymptomatic TB infection, active TB and multi-drug resistant TB. Substance abuse, incarceration, and HIV have been established as conditions that more frequently affect PEH and are risk factors for TB infection (Bamrah et al., 2013). There is multiplicity of factors among the homeless population that have contributed to the resurgence of TB, such as increasing poverty, budget-constraints on local health, illicit drug use, immigration from high prevalent countries, and non-compliance among TB patients. Bamrah et al., examined the demographic information and TB outcomes among the homeless persons with TB during 1994-2010. The prevalence of reported HIV coinfection was found to be higher among both US born and foreign-born homeless with TB than in the non-homeless (22% vs 9% and 15% vs 5%, respectively). Additionally, substance abuse was strongly associated with homeless than the non-homeless. The odds of substance abuse were 8.3 (95 %CI 8.0-8.7) among US-born homeless TB patients and 12.3 (95% CI 11.5-13.2) among foreign-born homeless TB patients (Bamrah et al., 2013).

Another study conducted in Argentina to determine the main comorbidities, associated conditions, clinical and microbiological characteristics of adult TB patients. With a median age of 37 years, males were associated with extrapulmonary TB, hospitalization, smoking, drug addiction and alcoholism. TB and AIDS (22.6%) was

related to drug use, admission into hospital, extrapulmonary TB, non-addiction to tobacco, non-pathological radiology, and negative sputum smear microscopy. The study also estimated that patients who were less than 40 years of age had a higher rate of drug addiction and low weight, while those who were 40 years of age and older had a higher proportion of diabetes, alcoholism, and chronic pulmonary disease (COPD) (Echazarreta et al., 2018).

These aforementioned risks established by previous research, not only help to recognize the characteristics and comorbidities, but also help to influence the development of social and community-based strategies.

**2.5 Screening and diagnosis of LTBI among persons experiencing homelessness**

The sequence of steps diagnosing TB are identify the population to be tested, test with-γ release assays (IGRAs) or TST (including evaluation to exclude active tuberculosis if test is positive), initiate treatment in the people to test positive for LTBI, and complete treatment. People who fail to complete any of these diagnostic steps results in transmission of disease that has multiplicative effects (LoBue & Mermin, 2017).

A study was conducted in Denver, Colorado that described the implementation of a mandatory screening program consisting of symptom screening and TST testing in homeless shelters and evaluate its effect on TB incidence and transmission. The screening test were provided at some overnight shelters, at a day shelter, and a clinic for the homeless. The data for this study was collected between January 1995 and December 1998. The estimated number of homeless increased from 3,330 in 1995 to 5,792 in 1998, largely attributable to the growing metropolitan area. The number of homeless

individuals who were screened for LTBI increased from 893 in 1995 to 3,897 in 1998. The screening ration increased from 26.7 to 67.3 per 100 persons during that period. They also found that the proportion of positive TST decreased during the study period. Although the number of homeless people increased, the incidence of active TB decreased from 510 to 121 per 100,000 persons during the study period. The screening program had successful outcomes in early identification of LTBI, however, the treatment of LTBI had low acceptance and completion rates (Kong et al., 2002).

An interesting qualitative cross-sectional study was conducted as a result of the large TB outbreak involving homeless shelters in Atlanta, Georgia. It involved in dept interviews with 10 PEH with active TB disease. The goal was to inform the ongoing TB control efforts and contribute hypothesis-generating data for further research on TB elimination in this setting. The perspective of LTBI and active TB is underrepresented among PEH, thus, the study also aimed to explore how these participants who belong to a high-risk population, experience illness and shelter-based interventions. Out of the 10 PEH, 50% previously completed TB treatment, 50% were infected with HIV, 70% self-reported substance abuse, and all had history of substance abuse. A few participant testaments: *Everybody keeps it (health status) quiet. They don't want to (disclose symptoms or seek help)—they feel like they'll be discriminated against and stuff like that. (Participant 7); I would rather be hung from a tree than to sleep in there … again. (Participant 6); I don't want to go back to the shelter. It's worse than jail without the bars. (Participant 1).* The stressful and unpleasing shelter environment appeared to reduce the impact of public health interventions. The health was de-prioritized and delayed care was observed among these shelter homes. Shelter related stress was

observed to be an important implication for the prevention and control of TB outbreak (Connors et al., 2017).

### 2.6 Summary of literature review

- The association between person experiencing homelessness and latent tuberculosis infection have been established through previous studies.
- Majority of the studies with regards to the homeless population have examined the risk factors associated with latent tuberculosis infection, however the adherence to treatment and tuberculosis management for this high-risk population is under studied.
- Very few studies have been found examining the test conversion and a reversion among persons experiencing homelessness.

## CHAPTER III

## MANUSCRIPT

### Introduction

Although great improvements have been made in reducing the rate of tuberculosis (TB) outbreaks, active TB remains a public health concern in the US, especially among populations at high-risk [1, 2]. One population at high-risk of TB in the US includes persons experiencing homeless (PEH). Homelessness has been linked to major outbreaks of TB in the US in the past [1, 3]. In 2018 an estimated 553,000 people in the US were experiencing homelessness including individuals who slept in homeless shelters, on the streets or in other locations [3, 4]. For PEH, the risk of acquiring TB infection is 10 times higher than the risk among the general population [5]. In addition, PEH experience who acquire TB disease have worse disease outcomes and are more likely to be hospitalized than the general population [6] [7].

The US Centers for Disease Control and Prevention (CDC) guidelines indicate targeted screening for LTBI among at-risk populations including PEH. Expanded LTBI screening efforts among PEH in the US led to a decrease in TB incidence rates from 1,502 cases per 100,000 in 1992 to 171 cases per 100,000 in 2004. [9]. Nonetheless PEH present many challenges for TB control regarding LTBI screening and treatment [5]. Social stigma, isolation and secrecy associated with diagnosis of LTBI pose additional barriers to accessing health care [12].

Facilities serving PEH have increased risk of TB transmission due to congregate nature of the housing in the shelters. Concurrent risk factors for LTBI among PEH exist include co-morbidities, mental illness, inadequate food supply, concurrent substance use, and increased history of incarceration [7, 13-15].

One of the largest TB outbreaks among homeless persons in recent history occurred in Atlanta, Georgia. It started in March 2008 at one homeless facility and spread to other shelters within the metro Atlanta areas. [16]. In Fulton County, one of the jurisdictions that comprise the metropolitan Atlanta, the outbreak resulted in a 3-fold increase in the number of active TB cases among PEH in 2014 [17, 18]. The Fulton County health department in response to the outbreak began sporadic screening of individuals who use transitional housing facilities within the metro Atlanta area. However, a resurgence of the outbreak in 2014 led to the implementation of a targeted screening program at all Atlanta shelters in mid-2015, requiring mandatory screening of all individuals accessing all homeless housing facilities located in the metro-Atlanta area within seven days of initial contact with the shelter. This effort was aimed at identifying new, untreated LTBI, reinforcing environmental control measures at the shelters and linking individuals with untreated LTBI to treatment. During the initial year of implementing the screening program, participants were screened using Tuberculin Skin Test (TST) onsite at the health department, as well as off site at the homeless shelters. QuantiFERON-TB Gold-in-Tube (QFT; QIAGEN Inc, Germantown, MD) screening test was introduced in subsequent years and was used as the primarily method of screening offsite at the homeless shelters [18]. Several studies have described various aspects of this Atlanta TB outbreak [18-20]. However, there has not been any study evaluating TB screening conversions and reversions among the individuals screened during this major TB screening effort in Atlanta. The primary objective of this study was to examine the proportion of PEH who screened positive for TST/QFT after an initial negative screening during the targeted program in Fulton County, Georgia. We also describe the proportion of PEH who reverted to a negative after a positive TST/QFT screening test. We also

aimed to describe the socio-demographic factors associated with the prevalence of LTBI among PEH.

## Methods

### *Setting and study design*

We conducted a retrospective cohort study of PEH screened for LTBI by Fulton County Board of Health (FCBOH) between 2008 and 2018. During the initial and quiescent phases of the outbreak (2008 – 2014), the Fulton County health department conducted sporadic TB screening exercises at affected homeless facilities, screening individuals who agreed to be screened [19]. A resurgence of the outbreak in 2014 led to the establishment of a collaboration between the health department and Mercy Care, a local federally qualified health center, to create the Metro Atlanta TB task force which encompassed representatives from public health centers, homeless shelters, and other community service providers within the metro Atlanta area [20]. In addition, new screening guidelines were also enacted in 2015, making TB screening mandatory for all users of homeless facilities. All new and intending shelter residents were required to get screened for TB within seven days of shelter entry and every six months thereafter [18, 20]. PEH were screened by TST or QFT at both the shelter locations and at TB clinic at the health department. The screening tests were analyzed and interpreted according to the Centers of Disease Control and Prevention (CDC) guidelines [18, 21, 22].

### *Study Population*

Eligible participants included 16,444 individuals who were attained by excluding participants less than 18 years of age (N=301), screening with TST or QFT test results that were missing (N=135), indeterminate and not read test results (N=2341) (Figure 1). The study population initially included a total of 19,221 unique PEH who were screened between 2008 and 2018.

Unique identifiers were created to determine individuals who had repeat screenings during the 10-year period. To determine prevalence of LTBI among the PEH screened during the entire duration, we used the first screening on record as the entry LTBI status. [18].

*Study Outcomes and Variables*

There were two primary outcomes in this study – 1) time to conversion (TTC) from a negative to a positive TB screening test and 2) time to reversion (TTR) from a positive to a negative TB screening test. Among PEH who had negative TB screening results at the entry screening, TTC was defined as the duration between the date of the entry screening (i.e. date of initial TB screening) and the date of first positive TB screening test (if conversion was observed). Among PEH who had a positive TB screening result at entry screening, TTR was defined as the duration between the date of entry screening and the first negative TB screening (if reversion was observed). Participants at entry screening or follow-up screening were screened either by TST or QFT. They were necessarily given identical tests during the entry and follow-up screenings. Thus, conversion of TB screening test was defined by TST or QFT positivity irrespective of the type of test administered at entry screening.

Other variables included in the analysis are demographic characteristics (Race/ethnicity, gender, and age), year of entry screening, social history (incarceration), behavioral history (substance use defined by alcohol, and injection or non-injection drug use) and personal medical history (HIV and diabetes). Social and personal medical histories were all self-reported. The year of entry screening was characterized by before (pre-2015) and after (post-2015) the new screening guidelines were enacted. The data for history of incarceration in the past 2 years was added to the questionnaire in 2016, there is no available data prior to 2016. These independent variables in the analysis were included based on previous literature review.

*Statistical Analysis*

Unadjusted logistic regression analyses were conducted to explore socio-demographic characteristics associated with LTBI prevalence at entry screening. Incidence rates and incident rate ratios were calculated to examine conversion and reversion among PEH who were negative and positive at entry screening. Kaplan Meier curves were used to examine time to conversion and reversion. Patients were censored if they were lost to follow up for rescreening for LTBI. A two-sided p-value <0.05 was considered significant in all analyses. All statistical analyses were performed using SAS version 9.4 and Open Source Epidemiologic Statistics (OpenEpi) version 3.01.

*Ethical Approval*

This study has been reviewed and approved by Institutional Review Board at the Georgia Department of Public Health and Georgia State University.

**Results**

Between 2008 and 2018, there were 16,444 homeless individuals with viable TB screening results at initial screening (Figure 1). The median age was 45 years (IQR=20), 78.3% were male, and 85.5% were non-Hispanic Blacks/African Americans. At entry screening, 1603 (9.7%, 95% Confidence Interval [CI] 9.2 – 10.1%) PEH among the 16,444 PEH screened had a positive TB screening.

Odds of having LTBI at entry was higher among PEH who were over 65 years old (Crude Odds Ratio (cOR) 9.1; 95% CI 5.9-14.1; p<0.001) and those aged between 45 and 64 years old (cOR 5.9; 95% CI 4.1-8.4; p<0.001) compared to younger PEH (Table 1). The odds of being positive at baseline was significantly higher among male PEH (cOR 2.1; 95% CI 1.8-2.5, p<0.001) compared to female PEH. PEH who were Asians had higher odds of being positive at

baseline as compared to other races (cOR 3.7, 95% CI 1.9-7.3; p<0.001). PEH who were screened pre-2015 had higher odds of being positive at baseline TB screening compared to those screened post-2015 (cOR 12.3; 95% CI 10.7-14.2, p<0.0001). Although, large portion of HIV data was missing for this cohort (68.8%), PEH who were HIV positive had an increased odd of LTBI at baseline (OR 1.5; 95% CI 1.3 – 2.4, p<0.05). PEH who had a history of recent incarceration were also observed to have higher odds of being positive at baseline compared to those who did not report incarceration history (cOR 1.3; 95% CI 0.7-2.2)

Among the 14,841 unique persons with a negative TB screening test at baseline, 3491 (23.5%) participants had at least one subsequent TB screening within the study period and 298 (8.5%) of those became positive during the follow-up period (Table2). Overall rate of incident QFT or TST conversion was 2.9 cases per 1,000 person-months (95% CI 2.6-3.2).

The rate of QFT/TST conversion was higher among male PEH (Incident Rate Ratio [IRR] 2.7; 95% CI 1.7 – 4.4; p<0.001) compared to the female PEH. Rate of conversion of TST or QFT was significantly higher among older PEH, 65+ years old (IRR 3.8; 95% CI 1.5 – 9.4, p<0.01) compared to younger age groups. Additionally, PEH who had diabetes were also observed to have a higher rate of conversion (IRR 1.2; 95% 0.7-2.0) compared to those who did not have diabetes. Participants who had 1 to 3 follow up screenings in addition to the entry screening were observed to have a conversion rate of 3.3 cases per 1000 person months. The rate of conversion was higher among PEH screened post-2015 (IRR 1.4, 95% CI 1.1-1.8; p<0.01) compared to those who were screened pre-2015. Figure 2 describes the factors associated with the conversion IRR.

Among those 1,603 participants who had a positive TB screening result at entry screening, 241(15%) participants had at least one subsequent TB screening. Of those 241

persons, 88 (37%) PEH reverted from a positive to a negative result during the follow-up period (Table 3). Overall rate of reversion from positive to negative was 13.2 per 1000 person months (95% CI 10.7-16.2). Reversion rate was observed to be higher in females and male PEH (17.9 per 1000 person months). The PEH belonging to the older age group (65+ years) had a higher rate of reversion (30.8 per 1000 person months; 95% CI 2.3-907.6) as compared to the other young age groups. Reversion rate was higher among those screened using TST at baseline (90.9 per 1000 person months) than among those screened using QFT at baseline (35.2 per 1000 person months). Reversion rate was also observed to be higher in Non-Hispanic Whites (30.0 per 1000 person months) as compared to Non-Hispanic Blacks (12.4 per 1000 person months) and Asians (17.5 per 1000 person months). Participants who had 7 to 15 follow up screenings in addition to the entry screening were observed to have a reversion rate of 15.4 cases per 1000 person months.

Table 4 describes the demographic characteristics for PEH with and without follow-up screenings. In this study, 12,712 PEH were lost to follow-up after the first screening. This may have occurred due to PEH not returning for TST reading, or continued instability in housing may have led to frequent patient relocation. Out of the individuals who were screened at baseline without any follow up screenings, 76% were male, and 84 % were Non-Hispanic Blacks. Even though, we observed significant associations between gender, race, age-groups and LTBI, it would have been beneficial to manage transmission of TB if we had more persons with follow-up screenings.

**Discussion**

Overall, we found that being male, older and Asian were independent risk factors for prevalence of LTBI. Our findings also suggested that of the 16,444 screened participants, 70% were screened post-2015 i.e. after mandatory screening at shelters was implemented. Overall prevalence of LTBI was also found to be higher among PEH who HIV were positive. The high incident rates among people who had follow-up screening were associated with being male, Non-Hispanic Blacks, old (65+) and having diabetes (Figure 2). While, the high reversion rates were associated with being female, Non-Hispanic Whites, old (65+), and being screened by TST at baseline screening.

Homelessness is recognized to be an economic and social issue that presents a great challenge to achieve the national goal of TB elimination. They represent a plausible source of increased transmission of TB across socially diverse populations [7, 23]. Overall, we found a TST/QFT positivity prevalence of 9.7% among PEH in Atlanta, GA. Consistent with previous studies [24-26], diagnosis of LTBI among PEH was significantly associated with male gender, older age and Non-Hispanic Blacks. The prevalence of LTBI may be higher in men as compared to women because of behavioral factors associated with mobility and social crowding [24, 25]. However, another possible explanation for lower prevalence in women is associated with diagnostic delays and subsequent delays in seeking health services [27]. This also supports our finding, that rate of incident TB infection was higher among male PEH as compared to female PEH. There is evidence that when women are enrolled in health care, they are more likely than men to adhere to treatment resulting in better treatment outcomes [28]. Additionally, we observed that women had a higher rate of reverting from positive to negative TST or QFT.

The global population is ageing quickly and represents a large reservoir of TB infection. Few studies have reported that TB incidence is higher among older age groups [29, 30]. Consistent with this study's finding, a longitudinal study conducted in China reported higher total incidence and mortality among older (aged 65 years and older) people (193.0 cases per 100,000 people and 18.7 deaths per 100,000 people, respectively) [31]. A cross-sectional study conducted of Zambian residents reported TB prevalence of 0.7% among those who aged ≥55 compared to those who belonged to the 15-54 age group (0.3%) [32].

Consistent with our findings that Asians, Hispanics and Non-Hispanic Blacks were more likely to be diagnosed with LTBI at entry screening, a cross-sectional study conducted on 2011-2012 NHANES data also found Asians had the highest LTBI prevalence (21.3%) followed by Hispanics (11.7%) and Non-Hispanic Blacks (6.3%) [33]. A cross-sectional study of TB surveillance data conducted Michigan also found that among the clustered TB cases, the average incidence rate among Blacks was 25 times and among Asians was 19 times higher than White, after controlling for nativity, gender, and age [26], this was not supported by our finding for incidence rate ratio stratified by race/ethnicity. However, our findings were consistent with a prospective cohort analysis conducted in New York City, where they observed that Asian ethnicity were at increased risk for conversion [34].

TST is currently the widely used method for identifying tuberculosis infection in person who do not have TB disease [21] followed by QFT [22]. QFT is preferred in detection of LTBI as compared with TST, not only because it has greater specificity but also a follow-up visit is not required for the reading of the test [35]. There is also evidence that implies adherence with follow-up visit for TST reading is poor amongst PEH [3, 18]. Although, this was not entirely supported by our finding where PEH who had at least one subsequent follow-up visit were

initially screened by TST (75%), which indicated increased adherence to follow-up with TST as compared to QFT (Table 4). In addition to this finding, we also found that the reversion rate was higher among those who were screened using TST at baseline than among those who were screened using QFT.

PEH who have been incarcerated or who use drugs are at a high risk of HIV. HIV is a known greatest risk factor for TB disease and greatest risk factor for progression of LTBI to active TB disease [23, 36, 37]. Although, incarceration history was not captured until 2016, our findings were yet consistent with previous studies that PEH with history of incarceration or HIV were more likely to be diagnosed with LTBI. Prevalence of diabetes is increasing globally and presents a three-fold risk of TB among those with diabetes [38]. We did not observe any significant association between diabetes, substance use and TB prevalence for PEH who were tested at entry screening, almost certainly because 77% of data for diabetes and 79 % data for substance use was missing. Therefore, we may be underestimating the risk for TB transmission among PEH with diabetes or substance use. This may be a result of recall bias where individuals may less accurately remember history of diabetes or not report substance use (alcohol use, injection or non-injection drug use, and smoking pattern).

**Limitations**

This study was also subject to several limitations. The study had many individuals who did not return for TST reading, but we assumed the LTBI prevalence in those lost to follow-up to be the same as those who remained in the study [18]. In addition, the TST and QFT screening interventions were implemented over different time period and different settings ( clinic or field), so it is possible that the consistency in  administration of same TB screening test (i.e. > = 2 TST or QFT tests) may have accounted for  some difference in concordance among these tests.

Although interferon-γ release assays (IGRAs) (such as QFT) and TST may be used in the diagnosis of LTBI, they do not give equivalent information and often have discordant results [33, 34, 39-46]. In high-income, low TB incidence countries the QFT is especially suited due to better specificity and in older persons due to its superior sensitivity [47, 48]. Additionally, foreign birth [46], belonging to African ancestry [41], variable immune response like medications, stress and previous infection [42] are associated with discordance. IGRA is a dynamic test that tend to fluctuate according the variable status of TB infection [49] while its limitation is its inability to differentiate between recent or remote infection [50]. Therefore, it seems that knowledge of exposure is critical in assessing TB infection. It is also important to be note that the individuals who consented for LTBI screening were given an incentive, which may have led them to falsely report their homelessness and may not have any intensions to follow-up causing selection bias. The Fulton County health department did not collect data for history of incarceration from 2008-2015, this may have therefore underestimated the transmission of TB amongst this at-risk population. Most of the PEH who were lost to follow-up could not be reached and its reasons are not completely evaluated. Non-reporting/response bias of HIV, substance use and diabetes status led to increased proportion of missing data which may be because of unique stigma attached to HIV, fear of reprisal connected to substance use, or unawareness of diabetes status. Thus, in this population-based study misclassification bias may be enforced. There would be a biased estimate of proportion of population with above exposure resulting into LTBI. Finally, some of these predictors in the analysis were self-reported and may have resulted in misclassification. However, previous studies have reported high validity of self-reported health risk behaviors [51], therefore we believe the misclassification may not have led to substantial bias in our reported measure of association.

## Conclusion

In summary, among the PEH in Atlanta, we found a high conversion rate of 2.9 per 1000 person-months. Being male, 65 years and older, HIV co-infected and having a history of incarceration within the prior two years were independent risk factors for conversion. Additionally, we found a high reversion rate of 13.2 per 1000 months. This implies that the screening program more likely resulted in early diagnosis and treatment of LTBI [52]. PEH are at increased risk for TB infection and therefore, to prevent future TB outbreaks, health departments should continue routine screening and re-screening among this high-risk populations of persons experiencing homelessness [36].

**REFERENCES**


1. Haddad, M.B., et al., *Characteristics of tuberculosis cases that started outbreaks in the United States, 2002-2011.* Emerging infectious diseases, 2015. **21**(3): p. 508-510.
2. CDC, *Reported Tuberculosis in the United States, 2018*. 2018, Center for Disease Control and Prevention
3. Parriott, A., et al., *Care Cascade for targeted tuberculosis testing and linkage to Care in Homeless Populations in the United States: a meta-analysis.* BMC public health, 2018. **18**(1): p. 485-485.
4. *The 2018 Annual Homeless Assessment Report (AHAR) to Congress*, The U.S. Department of Housing and Urban Development.
5. Bamrah, S., et al., *Tuberculosis among the homeless, United States, 1994-2010.* The international journal of tuberculosis and lung disease : the official journal of the International Union against Tuberculosis and Lung Disease, 2013. **17**(11): p. 1414-1419.
6. Marks, S.M., et al., *Hospitalization of homeless persons with tuberculosis in the United States.* Am J Public Health, 2000. **90**(3): p. 435-8.
7. Badiaga, S., D. Raoult, and P. Brouqui, *Preventing and controlling emerging and reemerging transmissible diseases in the homeless.* Emerg Infect Dis, 2008. **14**(9): p. 1353-9.
8. Gupta, V., et al., *Tuberculosis among the Homeless — Preventing Another Outbreak through Community Action.* New England Journal of Medicine, 2015. **372**(16): p. 1483-1485.

9. John, M.M., et al., *Latent Tuberculosis and Active Tuberculosis Disease Rates among the Homeless, New York, New York, USA, 1992–2006.* Emerging Infectious Diseases, 2009(7): p. 1109.

10. Alsdurf, H., et al., *The cascade of care in diagnosis and treatment of latent tuberculosis infection: a systematic review and meta-analysis.* The Lancet Infectious Diseases, 2016. **16**(11): p. 1269-1278.

11. Nwana, N., et al., *Treatment of latent Mycobacterium tuberculosis infection with 12 once weekly directly-observed doses of isoniazid and rifapentine among persons experiencing homelessness.* PloS one, 2019. **14**(3): p. e0213524-e0213524.

12. Nyamathi, A., et al., *Tuberculosis Knowledge, Perceived Risk and Risk Behaviors Among Homeless Adults: Effect of Ethnicity and Injection Drug Use.* Journal of Community Health, 2004. **29**(6): p. 483-97.

13. Prevention, C.o.D.C.a. *TB in the Homeless Population*. 2018.

14. Moss, A.R., et al., *Tuberculosis in the Homeless.* American Journal of Respiratory and Critical Care Medicine, 2000. **162**(2): p. 460-464.

15. Lee, C.-H., et al., *Active pulmonary tuberculosis and latent tuberculosis infection among homeless people in Seoul, South Korea: a cross-sectional study.* BMC public health, 2013. **13**: p. 720-720.

16. Powell, K.M., et al., *Outbreak of Drug-Resistant Mycobacterium tuberculosis Among Homeless People in Atlanta, Georgia, 2008-2015.* Public health reports (Washington, D.C. : 1974), 2017. **132**(2): p. 231-240.

17. *2014 Georgia tubercuosis report* 2015, Georgia Department of Pubic Health: Atlanta, GA.

18. Collins, J.M., U. Onwubiko, and D.P. Holland, *QuantiFERON-TB Gold Versus Tuberculin Screening and Care Retention Among Persons Experiencing Homelessness: Georgia, 2015–2017.* American Journal of Public Health, 2019. **109**(7): p. 1028-1033.

19. Powell, K.M., et al., *Outbreak of Drug-Resistant Mycobacterium tuberculosis Among Homeless People in Atlanta, Georgia, 2008-2015.* Public Health Reports, 2017. **132**(2): p. 231-240.

20. Holland, D.P., et al., *Response to Isoniazid-Resistant Tuberculosis in Homeless Shelters, Georgia, USA, 2015-2017.* Emerging infectious diseases, 2019. **25**(3): p. 593-595.

21. *Diagnostic Standards and Classification of Tuberculosis in Adults and Children. This official statement of the American Thoracic Society and the Centers for Disease Control and Prevention was adopted by the ATS Board of Directors, July 1999. This statement was endorsed by the Council of the Infectious Disease Society of America, September 1999.* Am J Respir Crit Care Med, 2000. **161**(4 Pt 1): p. 1376-95.

22. Mazurek, G.H., et al., *Guidelines for using the QuantiFERON-TB Gold test for detecting Mycobacterium tuberculosis infection, United States.* MMWR Recomm Rep, 2005. **54**(Rr-15): p. 49-55.

23. Feske, M.L., et al., *Counting the Homeless: A Previously Incalculable Tuberculosis Risk and Its Social Determinants.* American Journal of Public Health, 2013. **103**(5): p. 839-848.

24. Bennett, R.J., et al., *Prevalence and treatment of latent tuberculosis infection among newly arrived refugees in San Diego County, January 2010-October 2012.* American journal of public health, 2014. **104**(4): p. e95-e102.

25. Liu, Y., et al., *The prevalence of latent tuberculosis infection in rural Jiangsu, China.* Public Health, 2017. **146**: p. 39-45.

26. Noppert, G.A., et al., *Race and nativity are major determinants of tuberculosis in the U.S.: evidence of health disparities in tuberculosis incidence in Michigan, 2004-2012.* BMC public health, 2017. **17**(1): p. 538-538.

27. Gosoniu, G.D., et al., *Gender and socio-cultural determinants of delay to diagnosis of TB in Bangladesh, India and Malawi.* Int J Tuberc Lung Dis, 2008. **12**(7): p. 848-55.

28. Van den Hof, S., et al., *A systematic review on the role of gender in tuberculosis control. 2010.*

29. Fernandes, P., et al., *Sex and age differences in Mycobacterium tuberculosis infection in Brazil.* Epidemiol Infect, 2018. **146**(12): p. 1503-1510.

30. Sorresso, D.J., et al., *Underutilization of Isoniazid Chemoprophylaxis in Tuberculosis Contacts 50 Years of Age and Older: A Prospective Analysis.* Chest, 1995. **108**(3): p. 706-711.

31. Li, J., et al., *The age-structured incidence and mortality of pulmonary tuberculosis reported in China, in 2005–15: a longitudinal analysis of national surveillance data.* The Lancet, 2017. **390**: p. S12.

32. Coffman, J., et al., *Tuberculosis among older adults in Zambia: burden and characteristics among a neglected group.* BMC Public Health, 2017. **17**(1): p. 804.

33. Mancuso, J.D., et al., *The Prevalence of Latent Tuberculosis Infection in the United States.* American Journal of Respiratory and Critical Care Medicine, 2016. **194**(4): p. 501-509.

34. Cook, S., et al., *Prevalence of tuberculin skin test positivity and conversions among healthcare workers in New York City during 1994 to 2001.* Infect Control Hosp Epidemiol, 2003. **24**(11): p. 807-13.

35. Mahomed, H., et al., *The tuberculin skin test versus QuantiFERON TB Gold® in predicting tuberculosis disease in an adolescent cohort study in South Africa.* PloS one, 2011. **6**(3): p. e17984-e17984.

36. *Targeted tuberculin testing and treatment of latent tuberculosis infection. American Thoracic Society.* MMWR Recomm Rep, 2000. **49**(Rr-6): p. 1-51.

37. *Guidelines for the investigation of contacts of persons with infectious tuberculosis. Recommendations from the National Tuberculosis Controllers Association and CDC.* MMWR Recomm Rep, 2005. **54**(Rr-15): p. 1-47.

38. Lönnroth, K., G. Roglic, and A.D. Harries, *Improving tuberculosis prevention and care through addressing the global diabetes epidemic: from evidence to policy and practice.* The Lancet Diabetes & Endocrinology, 2014. **2**(9): p. 730-739.

39. Ghassemieh, B.J., et al., *Latent Tuberculosis Infection Test Agreement in the National Health and Nutrition Examination Survey.* American journal of respiratory and critical care medicine, 2016. **194**(4): p. 493-500.

40. Leung, C.C., et al., *Poor agreement between diagnostic tests for latent tuberculosis infection among HIV-infected persons in Hong Kong.* Respirology, 2016. **21**(7): p. 1322-9.

41. Porsa, E., et al., *Comparison of a new ESAT-6/CFP-10 peptide-based gamma interferon assay and a tuberculin skin test for tuberculosis screening in a moderate-risk population.* Clin Vaccine Immunol, 2006. **13**(1): p. 53-8.

42. Bagheri Amiri, F., et al., *Comparison of an interferon-gamma release assay and the tuberculin skin test for diagnosis of latent tuberculosis in homeless people in Iran: a cross-sectional study.* Infect Dis (Lond), 2015. **47**(8): p. 536-41.

43. Dorman, S.E., et al., *Interferon-gamma release assays and tuberculin skin testing for diagnosis of latent tuberculosis infection in healthcare workers in the United States.* Am J Respir Crit Care Med, 2014. **189**(1): p. 77-87.

44. Monárrez-Espino, J., et al., *Serial QuantiFERON-TB Gold In-Tube assay and tuberculin skin test to diagnose latent tuberculosis in household Mexican contacts: conversion and reversion rates and associated factors using conventional and borderline zone definitions.* Memorias do Instituto Oswaldo Cruz, 2014. **109**(7): p. 863-870.

45. Perez-Porcuna, T.M., et al., *Mycobacterium tuberculosis infection in young children: analyzing the performance of the diagnostic tests.* PLoS One, 2014. **9**(5): p. e97992.

46. Weinfurter, P., et al., *Predictors of discordant tuberculin skin test and QuantiFERON(R)-TB Gold In-Tube results in various high-risk groups.* Int J Tuberc Lung Dis, 2011. **15**(8): p. 1056-61.

47. Denkinger, C.M., K. Dheda, and M. Pai, *Guidelines on interferon γ release assays for tuberculosis infection: concordance, discordance or confusion?* Clinical Microbiology and Infection, 2011. **17**(6): p. 806-814.

48. Nienhaus, A., A. Schablon, and R. Diel, *Interferon-gamma release assay for the diagnosis of latent TB infection--analysis of discordant results, when compared to the tuberculin skin test.* PloS one, 2008. **3**(7): p. e2665-e2665.

49. Pai, M., A. Zwerling, and D. Menzies, *Systematic review: T-cell-based assays for the diagnosis of latent tuberculosis infection: an update.* Ann Intern Med, 2008. **149**(3): p. 177-84.

50. Chandrasekaran, P., 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**(8): p. e0199360-e0199360.

51. Brener, N.D., J.O.G. Billy, and W.R. Grady, *Assessment of factors affecting the validity of self-reported health-risk behavior among adolescents: evidence from the scientific literature.* Journal of Adolescent Health, 2003. **33**(6): p. 436-457.

52. Kong, P.M., et al., *Skin-test screening and tuberculosis transmission among the homeless.* Emerg Infect Dis, 2002. **8**(11): p. 1280-4.

## TABLE - RESULT

Table 1. Distribution of demographic characteristics and tuberculosis (TB) screening positivity at initial encounters among persons experiencing homelessness in Atlanta, Georgia, 2008 – 2018

| Socio-demographic Characteristics | PEH who were diagnosed with LTBI during entry screening N (%)[1] | PEH who were not diagnosed with LTBI during entry screening N (%)[1] | Total N (%)[1] | Crude OR (95% CI) |
|---|---|---|---|---|
| | **N = 1603** | **N = 14841** | **N = 16444** | |
| **Gender** | | | | |
| Female | 194 (5.5) | 3345 (94.5) | 3539 (100.0) | Ref |
| Male | 1406 (10.9) | 11463 (89.1) | 12869 (100.0) | **2.1 (1.8-2.5) ***** |
| Transgender | 3 (8.3) | 33 (91.7) | 36 (100.0) | **1.6 (0.5-5.2)** |
| **Race** | | | | |
| Non-Hispanic Black | 1458 (10.4) | 12595 (89.6) | 14053 (100.0) | **1.9 (1.6-2.3) ***** |
| Non-Hispanic White | 119 (5.6) | 1999 (94.4) | 2118 (100.0) | Ref |
| Asian | 11 (18.0) | 50 (82.0) | 61 (100.0) | **3.7 (1.9-7.3) ***** |
| Hispanic | 7 (15.6) | 38 (84.4) | 45 (100.0) | **3.1 (1.3-7.1) **** |
| Other | 5 (4.5) | 106 (95.5) | 111 (100.0) | 0.8 (0.3-2.0) |
| Missing[2] | 3 | 53 | 56 | |
| **Age group** | | | | |
| 18-24 | 32 (2.7) | 1151 (97.3) | 1183 (100.0) | Ref |
| 25-44 | 396 (5.64) | 6623 (43.8) | 7019 (100.0) | **2.2 (1.5-3.1) ***** |
| 45-65 | 1104 (14.0) | 6787 (86.0) | 7891 (100.0) | **5.9 (4.1-8.4) ***** |
| 65+ | 71 (20.2) | 280 (79.8) | 351 (100.0) | **9.1 (5.9-14.1) ***** |
| **HIV[4]** | | | | |
| Negative | 497 (10.0) | 4460 (90.0) | 4957 (100.0) | Ref |
| Positive | 26 (14.6) | 152 (85.4) | 178 (100.0) | 1.5 (1.0-2.4) * |
| Missing[3] | 1080 (9.5) | 10229 (90.5) | 11309 (100.0) | |
| **Screening Type** | | | | |
| TST | 924 (9.5) | 8823 (90.5) | 9747 (100.0) | Ref |
| QFT | 548 (8.3) | 6018 (91.7) | 6566 (100.0) | 0.9 (0.8-1.0) * |
| Missing[2,3] | 131 | 0 | 131 | |
| **Screening Location** | | | | |
| Clinic | 841 (10.) | 7614 (90.0) | 8455 (100.0) | Ref |
| Field | 762 (9.5) | 7227 (90.5) | 7989 (100.0) | 0.9 (0.9-1.1) |
| **Year of entry screening** | | | | |
| Pre – 2015 | 549 (11.1) | 4410 (88.9) | 4959 (100.0) | **12.3 (10.7-14.2) ***** |
| Post – 2015 | 1054 (9.2) | 10431 (90.8) | 11485 (100.0) | Ref |
| **Diabetes[5]** | | | | |
| No | 337 (10.0) | 3027 (90.0) | 3364 (100.0) | Ref |
| Yes | 37 (9.6) | 350 (90.4) | 387 (100.0) | 0.9 (0.7-1.3) |

| | | | | |
|---|---|---|---|---|
| Missing[3] | 1229 (9.7) | 11464 (90.3) | 12693 (100.0) | |
| **Substance Abuse[6]** | | | | |
| No | 304 (9.6) | 2868 (90.4) | 3172 (100.00) | Ref |
| Yes | 25 (9.9) | 227 (90.1) | 252 (100.00) | 1.0 (0.7-1.6) |
| Missing[3] | 1274 | 11746 | 13020 (100.00) | |
| **Recent incarceration[7]** | | | | |
| No | 66 (8.6) | 697 (91.4) | 763 (100.0) | Ref |
| Yes | 18 (10.8) | 148 (89.2) | 166 (100.0) | 1.3 (0.7-2.2) |
| Missing[3] | 749 | 7381 | 8130 (100.0) | |

**Abbreviations:** LTBI – Latent Tuberculosis Infection; PEH – Persons Experiencing Homelessness; TST – Tuberculin Skin Test; QFT – QuantiFERON-Tuberculosis; HIV – Human Immunodeficiency Virus.
**[1]** Table displays the row numbers followed by row percentage in parenthesis.
[2] Missing data is not counted in calculating percentage since the missing value is relatively less.
[3] Odds ratio is not calculated for missing data.
[4] HIV was defined as any HIV screening test conducted and/or self-reported diagnosis.
[5] Diabetes was defined as a self-reported diagnosis.
[6] Any substance abuse was defined as self-reported excessive alcohol use or injection/non-injection drug use.
[7] Incarceration information was collected from patients only beginning of May 2016.
*p≤.05. **p≤.01. ***p≤ .001

Table 2. Rate of conversions from negative to positive tuberculosis (TB) screening result during subsequent TB screening encounters among persons experiencing homelessness who tested negative at initial TB screening encounters in Atlanta, GA, US Georgia, 2008-2018

| Socio-demographic Characteristics | Remained negative at subsequent TB screenings N (%)[1] | Became positive at subsequent TB screenings N (%)[1] | Person months | Rate of conversion per 1000 person months (95%CI) | Incident Rate Ratio per 1000 person months (95%CI) |
|---|---|---|---|---|---|
| All PEH N=3491 | 3193 | 298 | 102521 | 2.9 (2.6-3.2) | |
| **Gender[2]** | | | | | |
| Female | 498 (96.5) | 18 (3.5) | 14840 | 1.2 (0.7-1.9) | Ref |
| Male | 2695 (90.6) | 280 (9.4) | 87681 | 3.2 (2.8-3.6) | **2.7 (1.7-4.4) ***** |
| **Race** | | | | | |
| Non-Hispanic Black | 2822 (91.2) | 275 (8.8) | 93086 | 3.0 (2.6-3.3) | 1.1 (0.7-1.7) |
| Non-Hispanic White | 341 (93.7) | 23 (6.3) | 8691 | 2.6 (1.7-3.9) | Ref |
| Asian | 7 (100.0) | 0 (0.0) | 220 | 0.0 | |
| Hispanic | 3 (100.0) | 0 (0.0) | 51 | 0.0 | |
| Other | 14 (100.0) | 0 (0.0) | 385 | 0.0 | |
| Missing[3] | 6 (100.0) | 0 (0.0) | 88 | | |
| **Age group** | | | | | |
| 18-24 | 181 (94.8) | 10 (5.2) | 4575 | 2.2 (1.1-3.9) | Ref |
| 25-44 | 1323 (93.2) | 97 (6.8) | 44805 | 2.2 (1.8-2.6) | 1.0 (0.5-2.0) |
| 45-65 | 1639 (90.0) | 181 (10.0) | 51938 | 3.5 (3.0-4.0) | 1.6 (0.9-3.2) |
| 65+ | 50 (83.3) | 10 (16.7) | 1203 | 8.3 (4.2-14.8) | **3.8 (1.5-9.4) **** |
| **HIV[4]** | | | | | |
| Negative | 1972 (89.9) | 154 (10.1) | 45826 | 3.4 (2.9-3.9) | Ref |
| Positive | 49 (90.7) | 5 (9.3) | 1601 | 3.1 (1.1-6.9) | 0.9 (0.3-2.0) |
| Missing[3] | 1772 (92.7) | 139 (7.3) | 55094 | | |
| **Screening Type** | | | | | |
| TST | 2368 (89.9) | 265 (10.1) | 92749 | 2.9 (2.5-3.2) | Ref |
| QFT | 825 (96.2) | 33 (3.8) | 9772 | 3.4 (2.4-4.7) | 1.2 (0.8-1.7) |
| **Screening Location** | | | | | |
| Clinic | 1672 (91.7) | 152 (8.3) | 53593 | 2.8 (2.4-3.3) | Ref |
| Field | 1521 (91.2) | 146 (8.8) | 48928 | 3.0 (2.5-3.5) | 1.1 (0.8-1.3) |
| **Year of entry screening** | | | | | |
| Pre – 2015 | 1394 (87.3) | 202 (12.7) | 76575 | 2.6 (2.3-3.0) | Ref |
| Post – 2015 | 1799 (94.9) | 96 (5.1) | 25946 | 3.7 (3.0-4.5) | **1.4 (1.1-1.8) **** |
| **Diabetes[5]** | | | | | |
| No | 991 (90.5) | 104 (9.4) | 32884 | 3.2 (2.6-3.8) | Ref |
| Yes | 114 (88.4) | 15 (11.6) | 4163 | 3.6 (2.1-5.8) | 1.2 (0.7-2.0) |
| Missing[3] | 2088 (92.1) | 179 (7.9) | 65474 | | |

| | | | | | |
|---|---|---|---|---|---|
| **Substance Abuse[6]** | | | | | |
| No | 793 (90.2) | 86 (9.8) | 28338 | 3.0 (2.4-3.7) | Ref |
| Yes | 77 (92.8) | 6 (7.2) | 2931 | 2.0 (0.8-4.2) | 0.7 (0.3-1.5) |
| Missing[3] | 2323 (91.9) | 206 (9.1) | 71252 | | |
| **Number of Follow-up screenings[7]** | | | | | |
| 1-3 | 2735 (91.8) | 245 (8.2) | 75319 | 3.3 (2.9-6.7) | **1.5 (1.1-2.2) *** |
| 4-6 | 385 (89.5) | 45 (10.5) | 21432 | 2.1 (1.6-2.8) | Ref |
| 7-15 | 73 (90.1) | 8 (9.9) | 5770 | 1.4 (0.6-2.6) | 0.7 (0.3-1.4) |

**Abbreviations:** TST – Tuberculin Skin Test; QFT – QuantiFERON-Tuberculosis; PEH – Persons Experiencing Homelessness; HIV – Human Immunodeficiency Virus.

**[1]**Table displays the column numbers followed by row percentage in parenthesis.

[2] Table does not include Transgender race due to a small sample size of less than 5.

[3] Rate and rate ratio not calculated for missing data.

[4] HIV was defined as any HIV screening test conducted and/or self-reported diagnosis.

[5] Diabetes was defined as a self-reported diagnosis.

[6] Any substance abuse was defined as self-reported excessive alcohol use or injection/non-injection drug use.

[7] Follow-up screenings after the entry screening.

*p≤.05. **p≤.01. ***p≤ .001

Table 3. Rate of incident tuberculosis (TB) infection screening result reversion from positive to negative among persons experiencing homelessness in Atlanta, Georgia, 2008-2018

| Socio-demographic Characteristics | No. reversion observed During subsequent TB screening (%)[1] | Reverted to negative during subsequent screenings (%)[1] | Person months) | Rate of reversion per 1000 person months (95%CI) | Incident Rate Ratio per 100 person months (95%CI) |
|---|---|---|---|---|---|
| All PEH N = 241 | 153 | 88 | 6655 | 13.2 (10.7-16.2) | |
| **Gender[2]** | | | | | |
| Female | 12 (52.2) | 11 (47.8) | 615 | 17.9 (9.4-31.1) | Ref |
| Male | 141 (64.7) | 77 (35.3) | 6040 | 12.7 (10.115.8) | **7.1 (3.9-14.1)** |
| **Race[3]** | | | | | |
| Non-Hispanic Black | 145 (65.0) | 78 (35.0) | 6277 | 12.4 (9.9-15.4) | **4.1 (2.1-9.1) *** |
| Non-Hispanic White | 7 (46.7) | 8 (53.3) | 264 | 30.0 (14.1-57.5) | Ref |
| Asian | 1 (33.3) | 2 (66.7) | 114 | 17.5 (2.9-57.9) | **5.8 (0.8-25.0)** |
| **Age group** | | | | | |
| 18-24 | 0 (0.0) | 1 (100.0) | 1 | 1.0 (0.0-5.0) | Ref |
| 25-44 | 41 (63.1) | 24 (36.9) | 1853 | 12.9 (8.4-19.0) | 13.0 (2.4-269.2) |
| 45-65 | 102 (62.6) | 61 (37.4) | 4736 | 12.9 (9.9-16.4) | 12.8 (2.5-261.5) * |
| 65+ | 10 (83.3)) | 2 (16.7) | 65 | 30.8 (5.1-101.7) | **30.8 (2.3-907.6)** |
| **HIV[5]** | | | | | |
| Negative | 94 (65.7) | 49 (34.3) | 3543 | 13.8 (10.3-18.1) | Ref |
| Positive | 4 (66.7) | 2 (33.3) | 131 | 15.3 (2.6-50.4) | **11.0 (1.8-38.1)** |
| Missing[4] | 55 (59.8) | 37 (40.2) | 2981 | | |
| **Screening Type** | | | | | |
| TST | 101 (65.2) | 54 (34.8) | 5942 | 90.9 (68.9-117.7) | Ref |
| QFT | 47 (69.1) | 21 (30.9) | 596 | 35.2 (22.4-52.9) | **3.9 (2.3-6.3) ***** |
| Missing[4] | 5 (27.8) | 13 (72.2) | 117 | | |
| **Screening Location** | | | | | |
| Clinic | 83 (66.9) | 41 (33.1) | 3702 | 11.2 (8.0-14.9) | Ref |
| Field | 70 (59.8) | 47 (40.2) | 2953 | 15.9 (11.8-21.0) | **14.4 (9.4-21.9)** |
| **Year of entry screening** | | | | | |
| Pre – 2015 | 71 (67.0) | 35 (33.0) | 5506 | 6.4 (4.5-8.7) | Ref |
| Post – 2015 | 82 (60.7) | 53 (39.3) | 1149 | 4.6 (3.5-6.0) | **7.3 (4.7-11.2) ***** |

| | | | | | |
|---|---|---|---|---|---|
| **Diabetes[6]** | | | | | |
| No | 58 (63.7) | 33 (36.3) | 2521 | 13.1 (9.2-18.2 | Ref |
| Yes | 8 (53.3) | 7 (46.7) | 297 | 23.6 (10.3-46.6) | **18.0 (7.3-39.2**) |
| Missing[3] | 87 (64.4) | 48 (35.6) | 3837 | | |
| **Substance Abuse[7]** | | | | | |
| No | 38 (63.3) | 22 (36.7) | 1602 | 13.7 (8.8-20.5) | Ref |
| Yes | 2 (40.0) | 3 (60.0) | 118 | 25.4 (6.5-69.2 | **18.5 (4.4-56.2)** |
| Missing[3] | 113 (64.2) | 63 (35.8) | 4935 | | |
| **Number of Follow-up screenings[8]** | | | | | |
| 1-3 | 153 (64.8) | 83 (35.2) | 6463 | 12.8 (10.3-15.8) | **4.1 (1.6-13.1)** |
| 4-6 | 0 (0.0) | 4 (100.0) | 127 | 31.5 (10.-7.6) | Ref |
| 7-15 | 0 (0.0) | 1 (100.0) | 65 | 15.4 (0.8-75.9) | **24.5 (7.6-61.1)** |

**Abbreviations:** TST – Tuberculin Skin Test; QFT – QuantiFERON-Tuberculosis; PEH – Persons Experiencing Homelessness; HIV – Human Immunodeficiency Virus.

**[1]**Table displays the column numbers followed by percentage in parenthesis.

[2] Table does not include Transgender race due to a small sample size of less than 5.

[3] No observations for sub-categories of Race (Hispanic and Other).

[4] Rate and rate ratio not calculated for missing data.

[5] HIV was defined as any HIV screening test conducted and/or self-reported diagnosis.

[6] Diabetes was defined as a self-reported diagnosis.

[7] Any substance abuse was defined as self-reported excessive alcohol use or injection/non-injection drug use.

[8] Follow-up screenings after the entry screening.

*p≤.05. **p≤.01. ***p≤ .001

Table 4. Distribution of demographic characteristics and follow-up screening status among persons experiencing homelessness in Atlanta, Georgia, 2008 - 2018

| Socio-demographic Characteristics | PEH with follow-up screenings N (%)[1] | PEH without follow-up N (%)[1] |
|---|---|---|
| **Total** | **N=3732** | **N=12712** |
| **Gender** | | |
| Female | 539 (14.4) | 3000 (23.6) |
| Male | 3193 (85.6) | 9676 (76.1) |
| Transgender | | 36 (0.3) |
| **Race** | | |
| Non-Hispanic Black | 3320 (89.0) | 10730 (84.4) |
| Non-Hispanic White | 379 (10.1) | 1739 (13.7) |
| Asian | 10 (0.3) | 51 (0.4) |
| Hispanic | 3 (0.1) | 42 (0.3) |
| Other | 14 (0.4) | 97 (0.8) |
| Missing | 6 (0.1) | 50 (0.4) |
| **Age group** | | |
| 0-24 | 192 (5.1) | 990 (7.8) |
| 25-44 | 1485 (39.9) | 5532 (43.5) |
| 45-65 | 1983 (53.1) | 5908 (46.5) |
| 65+ | 72 (1.9) | 279 (2.2) |
| **Screening Type** | | |
| TST | 2788 (74.7) | 6958 (54.7) |
| QFT | 926 (24.8) | 5638 (44.4) |
| Missing | 18 (0.5) | 113 (0.9) |

**Abbreviations:** TST – Tuberculin Skin Test; QFT – QuantiFERON-Tuberculosis; PEH – Persons Experiencing Homelessness; HIV – Human Immunodeficiency Virus.
[1]Table displays the column numbers followed by percentage in parenthesis.

Figure 1. Study participant flowchart of total number of persons experiencing homelessness in the main cohort in Atlanta, Georgia, 2008 - 2018

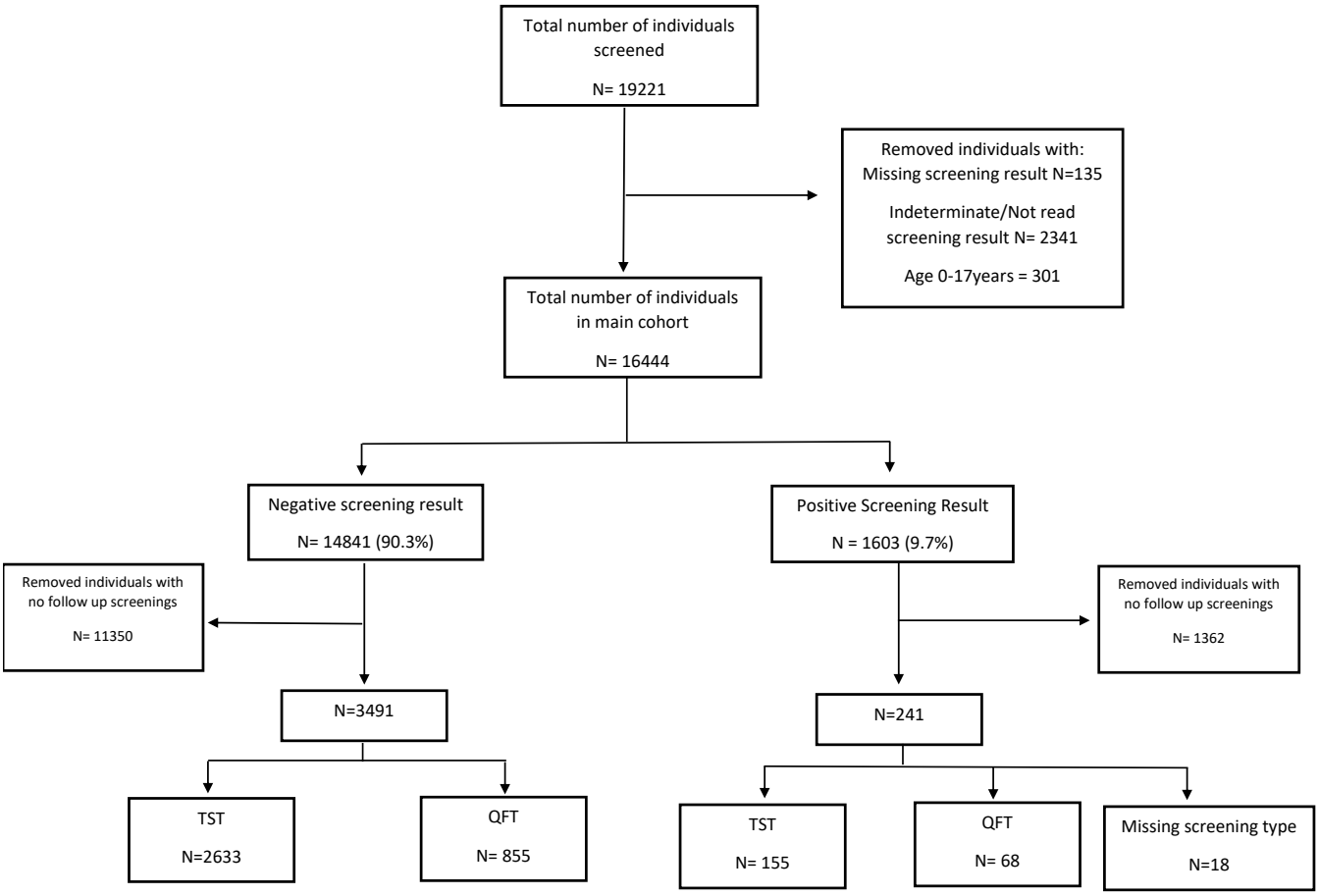
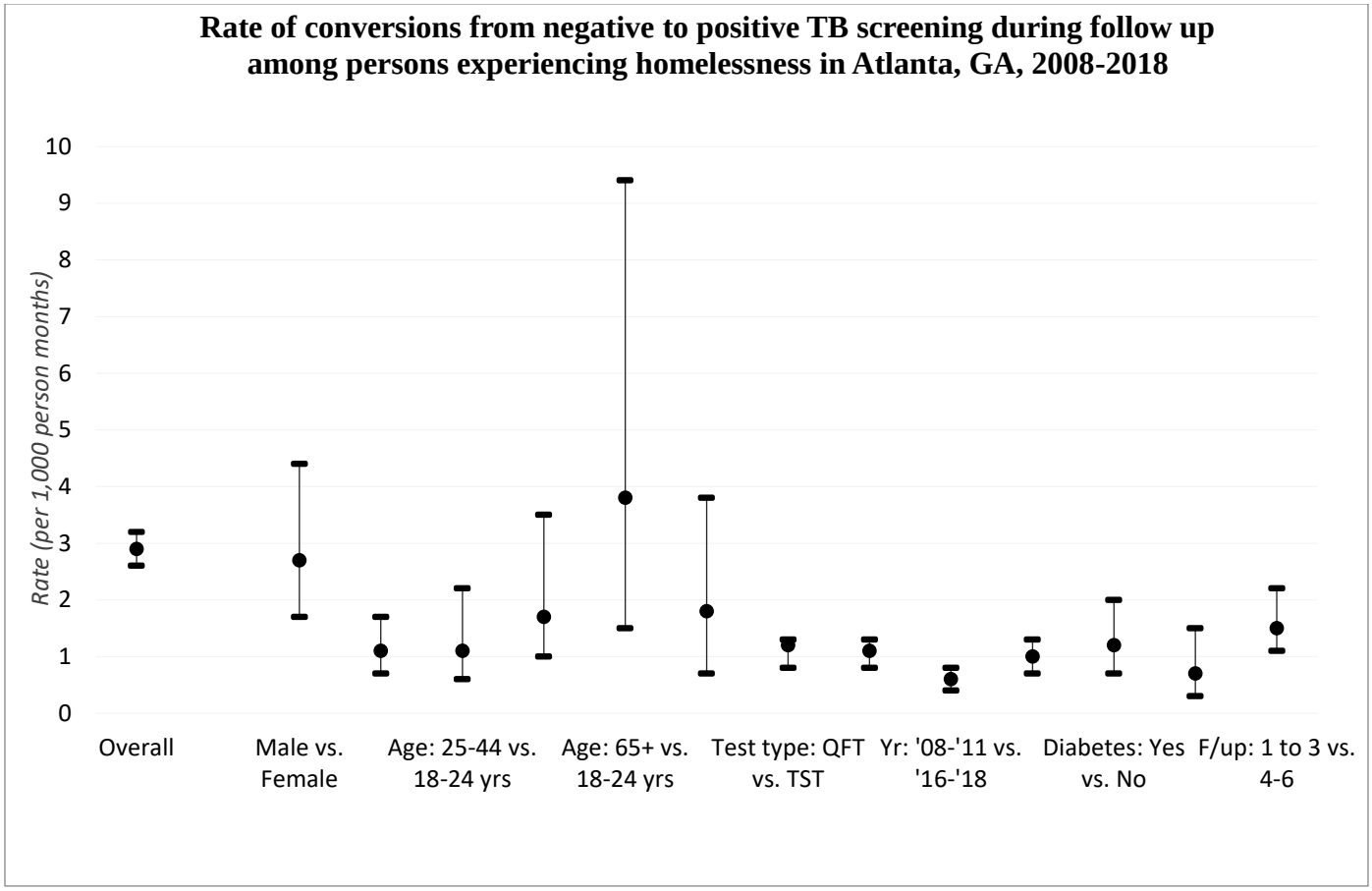


Figure 2. Rate of conversions from negative to positive TB screening during follow-up among persons experiencing homelessness in Atlanta, Georgia, 2008-2018.



**THESIS REFERENCES**

Amere, G. A., Nayak, P., Salindri, A. D., Narayan, K. M. V., & Magee, M. J. (2018). Contribution of Smoking to Tuberculosis Incidence and Mortality in High-Tuberculosis-Burden Countries. *American Journal of Epidemiology, 187*(9), 1846-1855. doi:10.1093/aje/kwy081

Armenta, R. F., Collins, K. M., Strathdee, S. A., Bulterys, M. A., Munoz, F., Cuevas-Mota, J., . . . Garfein, R. S. (2017). Mycobacterium tuberculosis infection among persons who inject drugs in San Diego, California. *International Journal of Tuberculosis and Lung Disease, 21*(4), 425-431. Retrieved from https://search.ebscohost.com/login.aspx?direct=true&AuthType=ip,shib&db=lhh&AN=20173140316&site=ehost-live&scope=site&custid=gsu1

Badiaga, S., Raoult, D., & Brouqui, P. (2008). Preventing and controlling emerging and reemerging transmissible diseases in the homeless. *Emerg Infect Dis, 14*(9), 1353-1359. doi:10.3201/eid1409.080204

Bagheri Amiri, F., Saifi, M., Gouya, M. M., Rohani, M., & Mostafavi, E. (2015). Comparison of an interferon-gamma release assay and the tuberculin skin test for diagnosis of latent tuberculosis in homeless people in Iran: a cross-sectional study. *Infect Dis (Lond), 47*(8), 536-541. doi:10.3109/23744235.2015.1026934

Bamrah, S., Yelk Woodruff, R. S., Powell, K., Ghosh, S., Kammerer, J. S., & Haddad, M. B. (2013). Tuberculosis among the homeless, United States, 1994-2010. *The international journal of tuberculosis and lung disease : the official journal of the International Union against Tuberculosis and Lung Disease, 17*(11), 1414-1419. doi:10.5588/ijtld.13.0270

Barron, M. M., Shaw, K. M., Bullard, K. M., Ali, M. K., & Magee, M. J. (2018). Diabetes is associated with increased prevalence of latent tuberculosis infection: Findings from the National Health and Nutrition Examination Survey, 2011–2012. *Diabetes Research and Clinical Practice, 139*, 366-379. doi:https://doi.org/10.1016/j.diabres.2018.03.022

Bennett, R. J., Brodine, S., Waalen, J., Moser, K., & Rodwell, T. C. (2014). Prevalence and treatment of latent tuberculosis infection among newly arrived refugees in San Diego County, January 2010-October 2012. *American Journal of Public Health, 104*(4), e95-e102. doi:10.2105/AJPH.2013.301637

CDC. (2019). Burden of TB in the United States. Retrieved from https://www.cdc.gov/features/burden-tb-us/index.html

CDC. (2019). Latent Tuberculosis Infection: A Guide for Primary Health Care Providers. Retrieved from https://www.cdc.gov/tb/publications/ltbi/treatment.html

Connors, W. J., Hussen, S. A., Holland, D. P., Mohamed, O., Andes, K. L., & Goswami, N. D. (2017). Homeless shelter context and tuberculosis illness experiences during a large outbreak in Atlanta, Georgia. *Public health action, 7*(3), 224-230. doi:10.5588/pha.17.0040

Corbett, E. L., Watt, C. J., Walker, N., Maher, D., Williams, B. G., Raviglione, M. C., & Dye, C. (2003). The Growing Burden of Tuberculosis: Global Trends and Interactions With the HIV Epidemic. *Archives of Internal Medicine, 163*(9), 1009-1021. doi:10.1001/archinte.163.9.1009

CSDH. (2008). *Closing the gap in a generation: health equity through action on the social determinants of health.* Retrieved from Geneva : https://www.who.int/social_determinants/thecommission/finalreport/en/

Doshi, S., Chen, T. F., Zapata, J., Holzman, R. S., Zapata, L. C., Aberg, J. A., & Sivapalasingam, S. (2012). Risk factors for tuberculin skin test conversion among HIV-infected patients in New York City. *International Journal of Infectious Diseases, 16*(7), e518-e521. doi:10.1016/j.ijid.2012.03.002

Echazarreta, A., Zerbini, E., De Sandro, J., Saenz, C., Yessi, L., Saad, R., . . . Cuello, M. (2018). [Tuberculosis and comorbidities in urban areas in Argentina. A gender and age perspective]. *Biomedica, 38*(2), 180-188. doi:10.7705/biomedica.v38i0.3904

Feske, M. L., Teeter, L. D., Musser, J. M., & Graviss, E. A. (2013). Counting the Homeless: A Previously Incalculable Tuberculosis Risk and Its Social Determinants. *American Journal of Public Health, 103*(5), 839-848. doi:10.2105/AJPH.2012.300973

Figueroa-Munoz, J. I., & Ramon-Pardo, P. (2019). *Tuberculosis control in vulnerable groups*. Retrieved from Geneva: https://www.who.int/bulletin/volumes/86/9/06-038737/en/

Furin, J., Cox, H., & Pai, M. (2019). Tuberculosis. *The Lancet, 393*(10181), 1642-1656. doi:https://doi.org/10.1016/S0140-6736(19)30308-3

Getahun, H., Matteelli, A., Abubakar, I., Aziz, M. A., Baddeley, A., Barreira, D., . . . Raviglione, M. (2015). Management of latent Mycobacterium tuberculosis infection: WHO guidelines for low tuberculosis burden countries. *The European respiratory journal, 46*(6), 1563-1576. doi:10.1183/13993003.01245-2015

Guidance for National Tuberculosis Programmes on the management of tuberculosis in children. Chapter 1: introduction and diagnosis of tuberculosis in children. (2006). *The international journal of tuberculosis and lung disease : the official journal of the International Union against Tuberculosis and Lung Disease, 10*(10), 1091-1097.

Houben, R. M. G. J., & Dodd, P. J. (2016). The Global Burden of Latent Tuberculosis Infection: A Re-estimation Using Mathematical Modelling. *PLOS Medicine, 13*(10), e1002152. doi:10.1371/journal.pmed.1002152

Jilani, T. N., Avula, A., Gondal, A. Z., & Siddiqui, A. H. (2019). *Active Tuberculosis*.

Kim, H. W., & Kim, J. S. (2018). Treatment of Latent Tuberculosis Infection and Its Clinical Efficacy. *Tuberculosis and respiratory diseases, 81*(1), 6-12. doi:10.4046/trd.2017.0052

Kong, P. M., Tapy, J., Calixto, P., Burman, W. J., Reves, R. R., Yang, Z., & Cave, M. D. (2002). Skin-test screening and tuberculosis transmission among the homeless. *Emerg Infect Dis, 8*(11), 1280-1284. doi:10.3201/eid0811.020306

Laurenti, P., Bruno, S., Quaranta, G., La Torre, G., Cairo, A. G., Nardella, P., . . . Ricciardi, G. (2012). Tuberculosis in sheltered homeless population of Rome: an integrated model of recruitment for risk management. *ScientificWorldJournal, 2012*, 396302. doi:10.1100/2012/396302

Lee, C.-H., Jeong, Y.-J., Heo, E. Y., Park, J. S., Lee, J. S., Lee, B. J., . . . Yim, J.-J. (2013). Active pulmonary tuberculosis and latent tuberculosis infection among homeless people in Seoul, South Korea: a cross-sectional study. *BMC public health, 13*, 720-720. doi:10.1186/1471-2458-13-720

Lee, S. J., Lee, S. H., Kim, Y. E., Cho, Y. J., Jeong, Y. Y., Kim, H. C., . . . Menzies, D. (2014). Risk factors for latent tuberculosis infection in close contacts of active tuberculosis patients in South Korea: a prospective cohort study. *BMC infectious diseases, 14*, 566-566. doi:10.1186/s12879-014-0566-4

LoBue, P. A., & Mermin, J. H. (2017). Latent tuberculosis infection: the final frontier of tuberculosis elimination in the USA. *The Lancet Infectious Diseases, 17*(10), e327-e333. doi:10.1016/S1473-3099(17)30248-7

Martínez-Aguilar, G., Serrano, C. J., Castañeda-Delgado, J. E., Macías-Segura, N., Hernández-Delgadillo, N., Enciso-Moreno, L., . . . Enciso-Moreno, J. A. (2015). Associated Risk Factors for Latent Tuberculosis Infection in Subjects with Diabetes. *Archives of Medical Research, 46*(3), 221-227. doi:https://doi.org/10.1016/j.arcmed.2015.03.009

Nyamathi, A., Sands, H., Pattatucci-Aragón, A., Berg, J., & Leake, B. (2004). Tuberculosis Knowledge, Perceived Risk and Risk Behaviors Among Homeless Adults: Effect of Ethnicity and Injection Drug Use. *Journal of Community Health, 29*(6), 483-497. Retrieved from https://search.proquest.com/docview/224052391?accountid=11226

http://galileo-usg-gsu-primo.hosted.exlibrisgroup.com/openurl/GSU/GSU_SP?url_ver=Z39.88-2004&rft_val_fmt=info:ofi/fmt:kev:mtx:journal&genre=article&sid=ProQ:ProQ%3Ahealthcompleteshell&atitle=Tuberculosis+Knowledge%2C+Perceived+Risk+and+Risk+Behaviors+Among+Homeless+Adults%3A+Effect+of+Ethnicity+and+Injection+Drug+Use&title=Journal+of+Community+Health&issn=00945145&date=2004-12-01&volume=29&issue=6&spage=483&au=Nyamathi%2C+Adeline%3BSands%2C+Heather%3BPattatucci-Arag%C3%B3n%2C+Angela%3BBerg%2C+Jill%3BLeake%2C+Barbara&isbn=&jtitle=Journal+of+Community+Health&btitle=&rft_id=info:eric/15587347&rft_id=info:doi/

Park, J. S. (2018). The Prevalence and Risk Factors of Latent Tuberculosis Infection among Health Care Workers Working in a Tertiary Hospital in South Korea. *Tuberculosis and respiratory diseases, 81*(4), 274-280. doi:10.4046/trd.2018.0020

Parriott, A., Malekinejad, M., Miller, A. P., Marks, S. M., Horvath, H., & Kahn, J. G. (2018). Care Cascade for targeted tuberculosis testing and linkage to Care in Homeless Populations in the United States: a meta-analysis. *BMC public health, 18*(1), 485-485. doi:10.1186/s12889-018-5393-x

Powell, K. M., VanderEnde, D. S., Holland, D. P., Haddad, M. B., Yarn, B., Yamin, A. S., . . . Ray, S. M. (2017). Outbreak of Drug-Resistant Mycobacterium tuberculosis Among Homeless People in Atlanta, Georgia, 2008-2015. *Public Health Reports, 132*(2), 231-240. doi:10.1177/0033354917694008

Santos, D. T. d., Garcia, M. C., Costa, A. A. N. F. d., Pieri, F. M., Meier, D. A. P., Albanese, S. P. R., . . . Dessunti, E. M. (2017). Infecção latente por tuberculose entre pessoas com HIV/AIDS, fatores associados e progressão para doença ativa em município no Sul do Brasil. *Cadernos de Saúde Pública, 33*.

Sharma, N., Basu, S., & Chopra, K. K. (2019). Achieving TB elimination in India: The role of latent TB management. *Indian J Tuberc, 66*(1), 30-33. doi:10.1016/j.ijtb.2018.10.006

Sharma, N., Basu, S., & Chopra, K. K. (2019). Achieving TB elimination in India: The role of latent TB management. *Indian Journal of Tuberculosis, 66*(1), 30-33. doi:https://doi.org/10.1016/j.ijtb.2018.10.006

Sivapalasingam, S., Klein, R. S., Howard, A., Qin, A., Tseng, C.-H., & Gourevitch, M. N. (2009). Housing insecurity and lack of public assistance are risk factors for tuberculin skin test conversion among persons who use illicit drugs in New York City. *Journal of addiction medicine, 3*(3), 172-177. doi:10.1097/ADM.0b013e31819eac4c

Stevenson, C. R., Forouhi, N. G., Roglic, G., Williams, B. G., Lauer, J. A., Dye, C., & Unwin, N. (2007). Diabetes and tuberculosis: the impact of the diabetes epidemic on tuberculosis incidence. *BMC public health, 7*, 234-234. doi:10.1186/1471-2458-7-234

*The 2018 Annual Homeless Assessment Report (AHAR) to Congress*

Retrieved from https://files.hudexchange.info/resources/documents/2018-AHAR-Part-1.pdf

WHO. (2018). *Latent TB Infection : Updated and consolidated guidelines for programmatic management*. Retrieved from Geneva: https://www.who.int/tb/publications/2018/latent-tuberculosis-infection/en/

Yap, P., Tan, K. H. X., Lim, W. Y., Barkham, T., Tan, L. W. L., Chen, M. I. C., . . . Chee, C. B. E. (2018). Prevalence of and risk factors associated with latent tuberculosis in Singapore: A cross-sectional survey. *International Journal of Infectious Diseases, 72*, 55-62. doi:https://doi.org/10.1016/j.ijid.2018.05.004