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Eleanor Mary Kerr Date

THE IMPACT OF TARGETED INTERVENTIONS ON PREVALENCE AND PREDICTORS OF TB AWARENESS AND LTBI TESTING AMONG THE HOMELESS DURING A LARGE TB OUTBREAK, 2015-2016

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An abstract of

A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University

in partial fulfillment of the requirements for the degree of
Master of Public Health
in Epidemiology

2017

Abstract

THE IMPACT OF TARGETED INTERVENTIONS ON PREVALENCE AND PREDICTORS OF TB AWARENESS AND LTBI TESTING AMONG THE HOMELESS DURING A LARGE TB OUTBREAK, 2015-2016

By Eleanor Mary Kerr

Introduction: Tuberculosis (TB) outbreaks continue to affect people experiencing homelessness in the US. The homeless also suffer greater consequences of TB disease. A resurgent outbreak of TB occurred among homeless persons in a large US metropolitan city from 2014-2016. In response, active case finding was implemented to find and treat TB cases, and halt disease transmission. A TB testing mandate was enacted that required regular TB testing of persons entering homeless facilities. Educational campaigns were designed to alert the homeless population of the ongoing outbreak and encourage testing. Using novel data, we evaluated the impact of these citywide interventions on TB awareness and compliance with the testing mandate among the homeless.

Methods: Data from a cross-sectional survey of homeless persons in Atlanta, GA in January 2016 were analyzed to determine patient characteristics that could best predict non-compliance with the TB testing mandate and lack of awareness of the current TB outbreak. Bivariate analysis was performed among demographic and medical history variables. Logistic regression was performed to build models to predict a person's odds of non-compliance with the testing mandate and to predict a person's odds of unawareness of the TB outbreak.

Results: Compliance with the testing mandate and awareness of the outbreak rose from 2015 to 2016. Non-compliance with the testing mandate was significantly lower among persons who resided in homeless shelters (aOR: 0.48; 95%CI: 0.32, 0.72) and among persons who were aware of the current TB outbreak (aOR: 0.28; 95%CI: 0.20, 0.40). Lack of awareness of the outbreak was associated with living outside a shelter (aOR: 0.55; 95%CI: 0.40, 0.76), non-compliance with the TB testing mandate (aOR: 0.28; 95%CI: 0.20, 0.41), and being male (aOR: 0.58; 95%CI: 0.39, 0.85).

Conclusions: Active case finding through mandated TB screening and educational outreach efforts were able to target a large portion of the homeless people who reside in homeless facilities in Atlanta. Widespread implementation of administrative controls in other cities could help reduce TB outbreaks in the homeless population. Public health efforts targeting unsheltered homeless persons may improve the reach of future interventions aimed at TB control in these communities.

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Chapter I: Background/Literature Review

Introduction

For many decades now, tuberculosis (TB) has been a serious concern worldwide, with 10.4 million cases of TB disease in 2014 and a case fatality rate greater than 15% (1). Great strides have been made in reducing the number of new cases, yet TB still remains one of the top ten causes of mortality globally (1). Compared to high-burden countries in southeast Asia and sub-Saharan Africa, the epidemiology of TB is vastly different in the United States, where 9,421 cases of TB were reported in 2014, of which 6% were fatal (1). While the rate of TB in the US is relatively low, reports show that there is still ongoing transmission of disease among certain groups of people, including the homeless (2-8). TB persists in the US without prospect of elimination however because of contained transmission particularly among vulnerable groups of people in the population, including racial and ethnic minorities, persons living with HIV/AIDS, those with history of alcohol and/or substance abuse, persons experiencing homelessness, and incarcerated persons (6, 8-12).

Throughout recent years, there have been many documented outbreaks of TB in homeless populations in the US, mainly in urban areas (8, 13-15). In response to these outbreaks, public health agencies have developed programs that aim to increase detection of TB among the homeless by implementing active case finding programs. Additionally, educational campaigns have been designed that aim to increase the knowledge of TB in the homeless population, as well as among staff and volunteers at homeless shelters.

In response to a recent TB outbreak, a program was launched in Atlanta to detect TB among homeless persons and increase knowledge of TB among the population. A mandate that every homeless individual be evaluated for TB prior to entering a homeless shelter was enacted, as well as administrative controls and various educational programs targeted at the homeless, particularly those who resided in homeless shelters. The impact of these efforts on the testing practices and TB knowledge among the homeless have not yet been studied. Using novel data from a cross-sectional survey of homeless persons in Atlanta, we will examine the impact of these efforts on TB testing practices and outbreak awareness among the homeless. Predictors of non-compliance with the TB evaluation mandate and of ignorance of the outbreak will be analyzed in both sheltered and unsheltered homeless persons. Additionally, subgroups among the homeless population that have low knowledge of the TB outbreak or have high rates of non-compliance with the TB testing mandate will be identified for future educational outreach efforts.

Tuberculosis Disease

Tuberculosis disease (TB disease) is an infectious disease caused by the bacterium *Mycobacterium tuberculosis* (*M. tuberculosis*) (1, 16-19). TB disease occurs when a person is infected with *M. tuberculosis* and the body's immune system cannot keep the bacteria from multiplying, allowing the bacteria begin to attack body tissues (17, 18). TB disease most commonly affects the lungs, causing pulmonary TB (17). The most common symptoms of pulmonary TB are pain in the chest, a productive cough with or without blood, and a persistent cough that lasts for at least three weeks (1, 17, 18).

TB disease is primarily spread when a person with pulmonary TB coughs and releases TB bacteria into the air for others to inhale. If a person breathes this air in, they can become infected with *M. tuberculosis*, which can result in latent tuberculosis infection (LTBI) or TB disease. LTBI occurs when a person is infected with *M. tuberculosis* but does not show signs of disease because the bacteria have been walled off by the person's immune system (16, 18). Since the bacteria are kept under control by the body's immune system, patients with LTBI are not able to infect other persons (16, 20).

Estimates for the prevalence of LTBI are hard to gather because patients show no signs of disease, however it is estimated that between a quarter and a third of the world's population have LTBI (1, 20, 21). Despite the high number of people living with LTBI, a very small percentage, estimated to be between 5% and 15%, will develop TB disease (1, 16, 22). It is crucial to treat persons with LTBI in order to prevent them from developing TB disease (16).

Diagnosis of LTBI and TB disease can be done in a variety of ways. LTBI can be diagnosed using TB skin tests or TB blood tests (16, 17). TB disease can be diagnosed via chest x-ray, sputum smear, or culture methods (16, 17). Both TB disease and LTBI can be treated with antibiotics, which typically must be taken for at least six months to clear the bacteria from the body (1, 17, 23).

Tuberculosis Among the Homeless

The US Department of Housing and Urban Development (HUD) estimates that in 2016, there were approximately 550,000 homeless persons in the 50 states, territories,

Puerto Rico and District of Columbia (24). While homeless persons make up less than 1% of the US population, they disproportionally contribute to 6% of the annual cases of TB in the United States (3, 25). TB primarily affects those with weakened immune systems, and is more likely to be spread when a person is in close contact with an infected person for extended periods of time (17). This leaves the homeless particularly vulnerable to infection, who are often subject to overcrowding and poor ventilation in homeless shelters, as well as malnutrition and poor access to health care (11, 14, 26). The risk factors for TB overlap with many conditions that are very common among the homeless, including alcohol abuse, drug abuse, and mental illness (27, 28). TB is also more likely to be outbreak-associated among the homeless than the general population, highlighting the need for rapid response by the public health sector to implement infection control measures to prevent singular cases from becoming large outbreaks (4-6, 9).

Homelessness has been cited as a risk factor for failure in timely TB treatment completion (25, 29). Directly observed therapy (DOT) is recommended for homeless patients undergoing treatment for LTBI or TB disease, as it is associated with higher rates of treatment completion and treatment success (9, 25, 29). Patients enrolled in DOT meet with a health care worker several times a week or even daily to ensure that a patient is adhering to their treatment regimen (17).

Prioritizing TB prevention among the homeless (compared to only providing treatment for those who become very sick) is wise from not only a public health standpoint, but also from an economic standpoint. In addition to being more prone to

infection, homeless TB patients in the US are also more likely to be hospitalized due to infection than the general population, leading to higher health care costs (30). As health care for the homeless is generally paid for by the public, preventative measures to reduce the burden of TB among the homeless would decrease these costs (30, 31).

Screening of high risk populations for LTBI and subsequent enrollment in treatment is critical to reduce the risk of new and resurgent TB outbreaks among vulnerable populations (8, 20, 23, 32). Unfortunately, financial and logistic constraints on local health departments often do not allow for the prioritization of LTBI treatment among homeless persons (8). Resources are mainly spent on active case finding and contact investigations to contain TB outbreaks, often passing over homeless persons with LTBI (8). Evidence of resurgences in TB rates among homeless populations as TB control efforts have declined has been documented in many urban areas in the US (8, 33, 34).

Due to the highly transient nature of the homeless population, it is very hard to identify, screen, locate, and treat those who have LTBI or TB disease (2). There have been various TB outbreaks among homeless populations in the past years, during which many public health agencies have developed testing programs and educational outreach programs. These programs have been shown to be effective in finding and treating persons with TB disease and LTBI in the homeless population, therefore reinforcing the importance of proactive steps that reduced the burden of the outbreak (2, 11, 14, 15, 35). Along with infection control practices for homeless shelters to abide by, the developed programs contain TB evaluation mandates for homeless persons presenting for shelter

services, in order to identify potential cases of LTBI and TB disease (2, 14, 15). These mandates generally require that a homeless person be evaluated for TB before entrance to a homeless shelter, and provide a clearance card or letter as proof of testing upon shelter entry (14). It has also been recommended that greater emphasis be placed on recordkeeping at homeless shelters so that public health agencies can work with homeless shelters to locate persons who may have been exposed to TB during an outbreak (13).

In countries with high-income and low TB incidence such as the US, efforts should be focused on increased screening and treating of persons with LTBI in populations who are most at risk, including those who are incarcerated, people living with HIV/AIDS, and homeless persons (1, 6, 7, 9, 12, 36). Previous studies have shown that the general population in the US has a low level of knowledge and understanding about TB disease, diagnosis and treatment and that accurate knowledge is lowest in the groups most at risk, including the homeless (37). Educational efforts for the highest risk groups are critical to improve TB knowledge among vulnerable populations and reduce the burden of disease. TB screening programs and educational campaigns to increase knowledge about TB have been implemented in many cities and are critical to halting the spread of TB in the homeless population (2, 15).

Tuberculosis Outbreak in Atlanta, 2014

In the first months of 2014, resurgence of a prior outbreak of TB disease among residents in homeless shelters in Atlanta was detected (26, 33). From January through March, nine cases of TB disease were found in homeless persons in Atlanta, indicating

the need for rapid public health intervention. Public health stakeholders in Atlanta, including Fulton County Department of Health and Wellness (Fulton County) and the Centers for Disease Control and Prevention (CDC), began to coordinate an outbreak response.

CDC launched an Epi-Aid investigation into the TB outbreak to produce recommendations for how to contain the outbreak. The results of the Epi-Aid investigation produced recommendations for how best to handle the current TB outbreak and similar ones in the future. Specifically, the public health agencies were advised to diagnose and treat patients with LTBI, create and implement administrative controls in homeless shelters, and focus on active case finding (38). To allow for active case finding, lists of persons who were in contact with TB cases at homeless shelters were generated so that they could be located and evaluated for TB disease or LTBI. Shelters that did not keep electronic registries of guests were to take part in mass screenings to identify and treat persons who had TB disease or LTBI.

In March 2014, homeless shelter directors and local emergency departments were notified of the current TB outbreak occurring among the homeless. The county health department focused on finding infected persons by conducting mass TB screenings at the shelters where initial TB cases had been identified. There were various informational sessions about TB that were conducted at soup kitchens and homeless shelters to alert the population of the outbreak, improve understanding of signs and symptoms of TB, and inform the homeless of the resources available to persons that may have TB (35, 38, 39). Furthermore, homeless service providers were targeted for educational sessions that

emphasized infection control measures to reduce the spread of TB (35). Teaching posters were distributed to homeless service providers along with the educational sessions so that the knowledge could be disseminated to new staff members (35).

In the second quarter of 2014, 12 additional outbreak-associated cases of TB were found among homeless persons in Atlanta (38). The need for collaboration between the public health agencies and the homeless service providers was clear, which led to the initiation of the TB Task Force. The TB Task Force, which involved homeless service providers, state and county public health agencies, a large health care system for the homeless, and TB physicians from a local academic center, served as a way for open communication between different stakeholders and as a way to foster a trustworthy relationship between involved parties.

The TB Task Force came together to collectively design and implement policies in homeless shelters to control and prevent TB outbreaks among the homeless (26, 35, 38). Through the work of the TB Task Force, an agreement between the county and the shelter administrators was reached on the implementation of a TB testing mandate for homeless persons who utilize homeless shelter services. For a homeless person to be allowed to stay in a homeless shelter under the new testing mandate, a resident had to produce documentation within seven days of arrival at a facility of a negative TB test in the past 6 months or documentation that they were actively undergoing treatment for LTBI. Furthermore, all persons were screened at entry to the homeless shelter for symptoms that indicate TB disease and referred to care facilities for further evaluation if they were suspected to have TB.

A survey of homeless shelters in the area was also conducted, which found that there was a want and need for TB educational training resources for both staff members and clients (38). Infection control procedures for homeless shelters, including administrative controls, symptom screening guidelines, information about the TB testing mandate, and general information about TB, were outlined in a document for homeless shelter staff in August 2014 and finalized into a set of guidelines in early 2015 (38, 40). The medical school of a local university was also engaged in a citywide educational campaign to improve infection control practices (35).

By the summer of 2015, outbreak-associated TB cases were declining (33). The next step for the stakeholders is to decide how to proceed with TB infection control among the homeless in the future years to prevent outbreaks from reoccurring. Infection control programs among the homeless are typically assessed by looking at disease counts over time, with lower case counts being attributed to successful program implementation. While widely used, these trends in case counts can be explained by other factors, such as particularly warm winters in which homeless shelter services are less utilized or low influx of new persons into the homeless community.

There are currently no available analyses of the knowledge of TB among the homeless in Atlanta, nor has the impact of the TB testing mandate and educational campaigns been assessed. We had a unique opportunity to evaluate the impact of the TB control programs in Atlanta using data that have not been collected among any other homeless population to date. A cross-sectional survey was conducted in January 2016 among the homeless population in Atlanta that contained questions on demographic

information about persons of the homeless population, their medical conditions and history, as well as their TB knowledge and testing practices. The data from this survey will be used in the study to evaluate the general knowledge of TB among the homeless population in Atlanta and better understand who is most likely to be compliant with the testing guideline, as well as who is most likely to be unaware of the current TB outbreak in the homeless. Using these outcome measures to assess the impact of the TB control measures in Atlanta allows for a more implementation-oriented analysis that specifically addresses program performance. Positive support for the TB program implementation by these metrics gives more weight to the impact of these interventions on the declining rate of TB among the homeless.

Point In Time Dataset

The data for this study come from the annual Point-In-Time (PIT) count conducted in Atlanta on the night of January 25th, 2016 by the Atlanta Homeless Continuum of Care (CoC). The US Department of Housing and Urban Development (HUD) requires all CoCs in the US to conduct an annual PIT count to gather a count of homeless individuals, as well as information on how many homeless individuals are sheltered versus unsheltered (41). Additional information on patient demographics, medical conditions, and socioeconomic situations are also collected, which are then used by the CoCs to better serve the homeless (41). For the first time in any US city, data were collected on TB knowledge and testing practices among the homeless population beginning with the 2015 PIT count in Atlanta. Information on TB knowledge and testing practices were collected by the Atlanta CoC using the following three questions:

1. Have you been tested or evaluated for tuberculosis (TB) in the last 6 months?
2. Are you aware that there is currently an outbreak of tuberculosis (TB) in the downtown Atlanta homeless population?
3. Do you currently have a persistent cough that has lasted for more than 3 weeks?

While these questions were first asked of homeless persons in Atlanta's 2015 PIT survey, the 2016 PIT survey in Atlanta is the first to link the responses to these three TB-related questions to the rest of the survey responses. This lends major strength to the dataset, as it gives a unique opportunity to better understand who among the homeless are the least likely to have been recently tested for TB and which groups have the lowest knowledge of TB. The complete 2016 PIT dataset contains survey responses from 1370 homeless people in Atlanta.

The answers to the first two TB questions were used as outcome variables in bivariate and multivariate analyses. The answer to the first question will tell whether a person is compliant with the TB testing mandates set forth by the county health department for all homeless individuals. The second question will be used to assess knowledge of the recent TB outbreak among the homeless population, which would indicate that a person has likely been reached by the various educational programs to promote awareness of TB in this population. The third question will be used to define a subgroup of persons who are symptomatic for TB.

Study Purpose/Specific Aims

This study will provide baseline data on the TB knowledge and testing practices of the homeless population in Atlanta. It is important to understand who among the homeless are most likely to be non-compliant with the testing mandate and who should be targeted for future educational campaigns to reduce the incidence of TB in the homeless population in Atlanta. Further, determining which groups of people among the homeless population are the most in need of TB education will allow the various shareholders in Atlanta to allocate resources and funding to have a stronger impact.

The following analysis intends to address the following specific aims:

1. To describe the impact of local TB control efforts among the homeless on improving awareness of TB in the community and compliance with a recent TB evaluation mandate using the data from the 2015 and 2016 PIT counts
2. To describe predictors of compliance with the testing mandate among persons experiencing tuberculosis symptoms
3. To describe the relationship between residence in a homeless shelter (versus being unsheltered) and having had a recent TB evaluation
4. To describe the relationship between residence in a homeless shelter and awareness of the current TB outbreak in Atlanta's homeless population
5. To describe predictors of unawareness of the local TB outbreak and with absence of recent TB evaluation

Chapter II: Manuscript

Abstract

Introduction: Tuberculosis (TB) outbreaks continue to affect people experiencing homelessness in the US. The homeless also suffer greater consequences of TB disease. A resurgent outbreak of TB occurred among homeless persons in a large US metropolitan city from 2014-2016. In response, active case finding was implemented to find and treat TB cases, and halt disease transmission. A TB testing mandate was enacted that required regular TB testing of persons entering homeless facilities. Educational campaigns were designed to alert the homeless population of the ongoing outbreak and encourage testing. Using novel data, we evaluated the impact of these citywide interventions on TB awareness and compliance with the testing mandate among the homeless.

Methods: Data from a cross-sectional survey of homeless persons in Atlanta, GA in January 2016 were analyzed to determine patient characteristics that could best predict non-compliance with the TB testing mandate and lack of awareness of the current TB outbreak. Bivariate analysis was performed among demographic and medical history variables. Logistic regression was performed to build models to predict a person's odds of non-compliance with the testing mandate and to predict a person's odds of unawareness of the TB outbreak.

Results: Compliance with the testing mandate and awareness of the outbreak rose from 2015 to 2016. Non-compliance with the testing mandate was significantly lower among persons who resided in homeless shelters (aOR: 0.48; 95%CI: 0.32, 0.72) and among

persons who were aware of the current TB outbreak (aOR: 0.28; 95%CI: 0.20, 0.40). Lack of awareness of the outbreak was associated with living outside a shelter (aOR: 0.55; 95%CI: 0.40, 0.76), non-compliance with the TB testing mandate (aOR: 0.28; 95%CI: 0.20, 0.41), and being male (aOR: 0.58; 95%CI: 0.39, 0.85).

Conclusions: Active case finding through mandated TB screening and educational outreach efforts were able to target a large portion of the homeless people who reside in homeless facilities in Atlanta. Widespread implementation of administrative controls in other cities could help reduce TB outbreaks in the homeless population. Public health efforts targeting unsheltered homeless persons may improve the reach of future interventions aimed at TB control in these communities.

Introduction

Tuberculosis (TB) is an infectious disease that ranks as a top cause of mortality worldwide (1). While relatively rare in the United States among the general population, TB is found disproportionally in certain groups of people, including the homeless (3, 9). Along with being more likely to have TB, homeless persons are more likely to have poor treatment outcomes than the general population, which leads to a higher mortality rate among this population (12, 29). Programs that focus on active TB case finding among the homeless can greatly reduce the burden of TB on the homeless population (6, 11, 13-15, 23).

Homelessness, alcohol and drug abuse, incarceration, and HIV/AIDS are among the most commonly reported risk factors for TB in countries with a low prevalence of TB

(8, 10, 12, 25). Persons experiencing homelessness are particularly vulnerable to TB infection due to their living conditions – most homeless shelters are crowded and poorly ventilated, perfect environmental conditions for TB transmission (11, 14). Outbreaks are particularly difficult to control among the homeless due to the transient nature of the population and poor access to health care (2). Infection control practices are therefore very critical for this population to prevent outbreaks from occurring, as well as to reduce burden of unavoidable illnesses.

In the early months of 2014, resurgence of an outbreak of tuberculosis was detected in Atlanta, which eventually grew to infect around fifty persons (33). Most cases occurred in residents of four homeless shelters in downtown Atlanta, however there were also infected shelter volunteers. Members of Fulton County Department of Health and Wellness, CDC, Emory University, and shelter directors came together to mount a cohesive response to the outbreak. The public health agencies began to take part in active case finding by implementing a testing mandate and performing contact investigations. The testing mandate required all homeless persons seeking to enter a shelter to have proof of a negative TB test from the prior six months within the first seven days of a shelter stay (26, 38, 40). Additionally, the TB Task Force was formed, which involved various stakeholders in the creation of guidelines that outlined TB testing practices for shelter residents, administrative controls, and infection control practices to be used by shelter staff.

In the summer of 2015, the number of outbreak-associated TB cases in the homeless population were declining (33, 38). The impact of the active case finding and

educational outreach efforts of the stakeholders have not yet been measured. Typically, program performance is measured by showing a decrease in new disease cases that coincides with an intervention, however there are often other factors that could explain these trends in the data. For example, fewer homeless persons seek shelter services in particularly mild winters, which leads to less overcrowding and lower potential for disease transmission.

We had the unique opportunity to use novel data from a cross-sectional survey of homeless persons in Atlanta to determine how the educational campaigns and administrative controls have impacted TB testing practices and TB awareness among the homeless population. The following analysis aimed to understand who among the homeless are most likely to be non-compliant with the TB testing mandate and if certain sub-groups in the homeless population are more likely to be unaware of the TB outbreak, necessitating targeted educational outreach in the future.

Methods

Data source and variables

The data for this study come from the annual Point-In-Time (PIT) count conducted in Atlanta on the night of January 25th, 2016 by the Atlanta Homeless Continuum of Care (CoC). The US Department of Housing and Urban Development (HUD) requires all CoCs in the US to conduct an annual PIT count to gather a count of homeless individuals, as well as information on how many homeless individuals are sheltered versus unsheltered (41). Additional information on patient demographics, medical conditions,

and socioeconomic situations are also collected, which are then used by the CoCs to better serve the homeless (41). The Atlanta PIT count includes three questions relation to TB testing practices, awareness, and symptoms that have never been asked in another city. Beginning in 2015, information on TB knowledge and testing practices were collected by the Atlanta CoC by using the following questions:

1. Have you been tested or evaluated for tuberculosis (TB) in the last 6 months?
2. Are you aware that there is currently an outbreak of tuberculosis (TB) in the downtown Atlanta homeless population?
3. Do you currently have a persistent cough that has lasted for more than 3 weeks?

The answer to the first question was used to assess non-compliance with the TB testing mandate (people who answered 'no' were non-compliant). The answer given for the second question was used to assess if a person was unaware of the TB outbreak (those who answered 'no' were unaware). These variables give an opportunity to better understand who among the homeless are the least likely to have been recently tested for TB and which groups have the lowest knowledge of TB. The third question was used to capture information on persons who were symptomatic for TB. These persons were individually evaluated to determine predictors of compliance with the TB testing mandate among symptomatic persons.

The main exposure variable of interest in this analysis was whether a person resided in a homeless shelter ("sheltered"). For analysis purposes, study subjects were considered to be "sheltered" if they spent the previous night at an emergency shelter or

domestic violence shelter, and "unsheltered" if they spent the previous night elsewhere (for example, on the street, in an abandoned building, etc.).

Participants were asked separately if they were currently experiencing any of a list of chronic medical conditions, or if they had ever experienced any of the same conditions. To reduce the amount of incomplete data in the dataset, the answers to these questions were collapsed into a single category for each chronic condition. The resulting set of variables indicated that a person either had previously experienced or was currently experiencing a condition, or that they had no history of the condition.

Analysis

Subject characteristics, including information on demographics, homelessness, and medical conditions, were summarized to describe the members of the cohort. The answers to the three questions relating to TB on the PIT survey were compared across 2015 and 2016 using two sample Z-tests to compare sample proportions. Demographic characteristics and testing compliance of subjects with reported TB symptoms were summarized. Participants were stratified by shelter status, and characteristics between the two groups were compared using chi-square tests. Risk factors for being non-compliant with the TB testing mandate and for being unaware of the current TB outbreak were analyzed by calculating conditional maximum likelihood estimation prevalence odds ratios (ORs), corresponding 95% confidence intervals (CIs) and mid-exact p-values.

Demographics, health conditions, and information on a person's homelessness experience were assessed for associations with the outcome variables using logistic

regression. Backwards elimination was used to obtain final models that only contained terms that were significant. Crude and adjusted odds ratios (cORs and aORs, respectively) were calculated for all predictors in the final models. A significance level of 0.05 was used in all analyses.

All analyses were performed using SAS v. 9.4 (Cary, NC) and OpenEpi.

Results

Impact of infection control programs on TB knowledge and testing practices

Answers to the TB related questions are summarized in Table 1. The proportion of the homeless population that was aware of the TB outbreak increased from 2015 to 2016 (68% vs 75%; p=0.01). The percent of homeless persons who reported being compliant with the TB testing mandate also increased over the same period (81% vs 86%; p=0.03). While fewer person reported being symptomatic for TB in 2016 than 2015 (7% vs 10%), the decline was not significant (p=0.11).

Overall cohort characteristics:

On the night of January 25th, 2016, volunteers with the Atlanta CoC were able to interview 1370 homeless persons. Patient characteristics are displayed in Table 2. Among the participants in the study, 741 (54%) were sheltered on the night of January 25th. There were 629 (48%) persons who had never been homeless before, and 648 (54%) had been homeless only one time over the past 3 years. Participants were on average 49 years old (IQR: 38, 56), mainly black (86%), and male (84%). Information

on current and past medical conditions was available for 1046 (76%) of the participants. Mental illness, drug abuse, alcohol abuse, physical disabilities, PTSD, and other chronic medical conditions were commonly reported by members of the study. When stratifying on shelter status, sheltered participants were more likely to be black ($p=0.01$), men ($p<0.01$), with a history of mental illness ($p=0.01$), alcohol abuse ($p<0.0001$), and drug abuse ($p<0.001$).

Among the 98 persons who reportedly were symptomatic in 2016, half were sheltered, 85 (87%) were compliant with the testing mandate, and 62 (67%) were aware of the current TB outbreak. Persons who were non-compliant with the testing mandate did not differ from those who were compliant across any demographics or medical characteristics (Table 3).

Predictors of non-compliance with the TB testing mandate

When asked if they had been evaluated for TB in the past six months, 185 (14%) of persons in the study said they had not been evaluated, indicating that they were non-compliant with the TB evaluation mandate. Table 4 shows the results of bivariate analysis, which revealed that persons who were sheltered ($p<0.0001$), black ($p<0.001$), or living with HIV/AIDS ($p=0.032$) were all more likely to be compliant with the testing mandate (i.e., they were more likely to have been evaluated for TB in the past 6 months). Those who were sheltered, and therefore held to the TB testing mandate by the shelter staff, had over three times the odds of being compliant with the testing mandate than those who were not sheltered ($p<0.0001$).

The results of the logistic model built to predict the odds of being non-compliant with the TB evaluation mandate are shown in Table 5. Only shelter status and awareness of the TB outbreak were found to be significant predictors of non-compliance after controlling for HIV/AIDS status, drug abuse, alcohol abuse, mental illness, and chronic medical conditions. Persons who were sheltered had lower odds of being non-compliant (aOR: 0.48; 95% CI: 0.31, 0.72). Similarly, those who said they were aware of the TB outbreak also had lower odds of non-compliance (aOR: 0.28; 95% CI: 0.20, 0.40).

Predictors of TB outbreak awareness

Overall, 25% of the people in the study said they were unaware that there was a TB outbreak in the homeless population in Atlanta (Table 6). Persons who were sheltered, and therefore more likely to be reached by the educational outreach efforts made by various shareholders in Atlanta, had more than twice the odds of being aware of the outbreak compared to persons who were unsheltered ($p<0.0001$). Compared to women, men had lower odds of being unaware of the TB outbreak (OR: 0.54; 95% CI: 0.39, 0.75; $p<0.001$).

The resulting model that was built to predict the odds of being unaware of the current TB outbreak contained three significant terms after controlling for HIV/AIDS status, drug abuse, alcohol abuse, mental illness, and chronic medical conditions: shelter status, compliance with the TB testing mandate, and sex (Table 7). Persons who were sheltered were about half as likely to be unaware of the current TB outbreak compared to unsheltered persons (aOR: 0.55; 95% CI: 0.40, 0.76). Those who were compliant with

the TB testing mandate were also less likely to be unaware of the outbreak (aOR: 0.29; 95% CI: 0.20, 0.41). Men were less likely to be unaware than women (aOR: 0.58; 95% CI: 0.39, 0.85).

Discussion

The implementation of the administrative controls and educational efforts coincided with an increase in compliance with the TB testing mandate and a rise in awareness of the TB outbreak among homeless persons in Atlanta. These findings, in conjunction with declining TB cases, indicate that the efforts have successfully targeted homeless persons and encouraged screening for LTBI among this population. Residence in a homeless shelter was associated with lower odds of non-compliance with the TB testing mandate, as well as being unaware of the current TB outbreak among the homeless population in Atlanta. Consistent with findings of similar TB programs in other cities, the TB testing mandate and educational outreach efforts have been followed by a decrease in the number of active TB cases among the homeless population in Atlanta (11, 14, 33). Persons residing in a homeless shelter were more likely to be aware of the TB outbreak and more likely to have been recently tested for TB compared to those who were unsheltered.

Compared to the general population, there was an increased prevalence of drug abuse and alcohol abuse in this population, consistent with findings of other studies that report heightened rates of these conditions in the homeless (28, 34). These conditions were also more common among those who were unsheltered than those who were

sheltered. As alcohol and drug abuse are known risk factors for both TB disease and poor treatment adherence, efforts to educate, screen and treat persons with these conditions should be made (9, 28, 42).

There were several limitations to this study. Firstly, the homeless are a highly transient and dynamic population, and our data were collected on a sample of people at a single point in time. There are greater than 4000 estimated homeless persons in Atlanta, and our interviews sampled only 1370 (34%) people without information on the larger cohort to evaluate generalizability (43). This study is not unique however in being challenged by homeless persons not being fully represented in the study cohort. Information on medical history was unavailable for nearly a quarter of the participants in the study, which could bias results. The study is also limited by self-reported outcomes, and the possibility that patients could inaccurately report their answers to the outcome questions relation to TB knowledge and testing practices.

Although it is hard to determine the representativeness of this sample, there is strength to this study, as it is the first analysis of its kind in a large US city and the results can be used to better direct program efforts and funds in the future. The results of this analysis provide baseline data on TB knowledge and testing practices among the homeless, and can be used in conjunction with data from future PIT counts to assess trends in TB knowledge and testing practices. These findings lend support to broader implementation of administrative controls on homeless shelters across the US to improve and maintain TB control practices. Further, there was very complete information on the main exposure variable (being housed in an emergency or domestic violence shelter) and

outcome variables (compliance with TB evaluation mandate, awareness of TB outbreak). The completeness of this data gave us the ability to say with confidence that persons who are housed in an emergency or domestic violence shelter were more likely to be aware of the TB outbreak in the homeless population, and that they were more likely to be compliant with the TB evaluation mandate.

The results of this study indicate that the educational efforts to inform the homeless population in Atlanta of the recent TB outbreak have reached the majority of those living in homeless shelters. The implementation of administrative controls and educational campaigns have been shown to have positive impacts on the percentage of homeless persons who are aware of the outbreak and are compliant with the testing mandate, however there still remains a significant portion of the unsheltered who remain unaware of the TB outbreak. Consistent screening for LTBI among the homeless should continue in order to ensure the current outbreak subsides and future outbreaks are prevented (9). Educational efforts to better inform homeless persons, shelter staff, and shelter volunteers of infection control practices should continue in order to reduce the incidence of TB in the homeless population (15, 35).

There are a significant number of cities that continue to have TB outbreaks among the homeless populations because they do not embrace administrative controls. Our study shows that implementing administrative controls to tuberculosis control efforts leads to higher rates of testing compliance and higher TB awareness among homeless persons. The results of this study support the widespread implementation of administrative controls in tuberculosis control programs as a sustainable and strategic

way to reduce new and resurgent TB outbreaks among homeless persons living in urban areas.

Chapter III: Summary, Public Health Implications, and Possible Future Directions

Summary

Non-compliance with the TB testing mandate and lack of awareness of the current TB outbreak were significantly lower in homeless persons who were sheltered rather than unsheltered. Demographics were relatively similar between the sheltered and unsheltered, although drug and alcohol abuse were more prevalent in the unsheltered. Shelter status and knowledge of the current TB outbreak were the strongest predictors of non-compliance with the TB testing mandate. Being unaware of the TB outbreak in the homeless population was predicted by non-compliance with the testing mandate, shelter status, and gender. Taken together, these results indicate that being sheltered, and therefore being more likely to have been upheld to the TB testing mandate and to receive education on TB, has had a positive impact on testing practices and general TB knowledge on homeless persons in Atlanta.

Public Health Implications

The results of this analysis indicate that the efforts of the various public health stakeholders and the TB Task Force have produced positive results among the sheltered portion of the homeless population in Atlanta from 2015 to 2016, as referenced by the increased awareness of the TB outbreak (67% vs. 75%; $p=0.01$) and the increasing rate of compliance (81% vs 86%; $p=0.03$). There are large gaps between the sheltered and

unsheltered homeless persons in terms of these measures, which highlights an opportunity for future efforts.

In 2016, there were only nine cases of TB among the homeless in Atlanta. Of these, one person was found to have never entered a homeless shelter (44). From an infection control standpoint, this was beneficial, as this person did not have contact with a high number of persons in a shelter. However, this situation reinforces the fact that these programs have generally targeted homeless persons who are sheltered, leaving those who are unsheltered more at risk. The unsheltered represent a large proportion of the homeless population that cannot be ignored in programs designed for this population. Implementing programs specifically to reach the unsheltered homeless are needed to further reduce the incidence of TB in the homeless population. Potential points of contact with the unsheltered persons in the homeless population, such as soup kitchens, churches, and homeless service organizations, should be investigated to determine how best to reach this sub-group (35).

Possible Future Directions

Possible future research directions could include using this baseline data conjunction with the data gathered during future PIT counts to analyze the impact of continued educational efforts among the homeless. Trends in non-compliance with the TB testing mandate could be assessed over time for various sub-groups of people within the homeless population. Additionally, trends in knowledge of TB among the lowest-

knowledge groups can be observed over time to assess whether programs meant to target these individuals are reaching their intended audiences.

The three tuberculosis-related questions that were analyzed in this study have not been collected in any other PIT counts in other cities. These questions offer a unique opportunity to assess TB control program effectiveness in the highly transient and hard-to-reach homeless population. As the PIT count is an assessment that is required annually by the federal government, no additional resources are required to collect this very important data. Incorporating these questions into PIT counts in other cities with TB control programs will allow for comparison of program effectiveness, providing evidence for best practices in TB control among the homeless.

Table 1: Comparison of responses to tuberculosis related questions on the 2015 and 2016 PIT counts

	2015	2016		
	N (%)	N (%)	Z	p
Tested or evaluated for tuberculosis in last 6 months	240 (81%)	1118 (86%)	2.17	0.03
Aware of current TB outbreak in homeless population	201 (68%)	994 (75%)	2.54	0.01
Currently have a persistent cough that has lasted more than 3 weeks	30 (10%)	98 (7%)	-1.61	0.11

Table 2: Characteristics of participants in the 2016 PIT count in Atlanta

	Total (N=1370)		Sheltered (N=741)		Unsheltered (N=628)		
	N	%	N	%	N	%	p
Experience of Homelessness							
Sheltered	741	54%					
First time homeless	629	48%	330	47%	298	49%	0.62
Homeless two or more times in last 3 years	561	46%	325	48%	239	45%	0.30
Demographic Characteristics							
Age							
<18	2	0%	2	0%	0	0%	0.08
18-24	57	4%	35	5%	22	4%	
25-34	197	15%	115	16%	82	13%	
35-44	244	18%	126	17%	118	19%	
45-54	453	34%	229	31%	224	37%	
55-64	324	24%	185	25%	138	23%	
65+	67	5%	43	6%	24	4%	
Race							
Black/African American	1147	86%	645	89%	501	83%	<0.01
Other/Multi-racial	80	6%	41	6%	39	6%	
White	109	8%	42	6%	67	11%	
Ethnicity: Hispanic	37	3%	17	2%	20	4%	0.24
Sex: Male	1154	85%	646	88%	507	82%	<0.01
Veteran	160	12%	81	11%	79	13%	0.24
Current or Past Medical Conditions (N=1046)							
Mental illness	233	22%	79	18%	154	25%	0.01
HIV/AIDS	31	3%	10	2%	21	3%	0.31
Drug abuse	175	17%	51	12%	124	20%	<0.001
Alcohol abuse	202	19%	51	12%	151	25%	<0.0001
Chronic medical condition	238	23%	95	22%	143	23%	0.66

Table 3: Predictors of non-compliance with the TB testing mandate among homeless persons symptomatic of TB, 2016

	Total (98)		Non-complaint (13)		Compliant (85)				
	N	%	N	%	N	%	OR*	95% CI*	p*
Experience of Homelessness									
Sheltered	49	50%	4	31%	45	53%	0.40	(0.10, 1.38)	0.15
First time homeless	43	45%	4	31%	39	47%	0.51	(0.13, 1.75)	0.29
Homeless two or more times in last 3 years	44	49%	5	56%	39	49%	1.31	(0.31, 5.85)	0.72
Aware of TB outbreak	62	67%	5	45%	57	70%	0.36	(0.09, 1.33)	0.12
Demographic Characteristics									
Age									
18-24	6	6%	1	8%	5	6%	1.97	(0.04, 11.3)	0.90
25-34	8	8%	0	0%	8	9%	0	(0.00, 3.67)	0.32
35-44	13	13%	1	8%	12	14%	0.47	(0.02, 4.21)	0.57
45-54	26	27%	4	31%	22	26%	*Ref.*	--	--
55-64	35	36%	7	54%	28	33%	1.37	(0.35, 5.95)	0.67
65+	10	10%	0	0%	10	12%	0	(0.00, 2.88)	0.25
Race									
Black/African American	77	80%	11	85%	66	80%	0.84	(0.17, 6.26)	0.80
Other/Multi-racial	7	7%	0	0%	7	8%	0	(0.00, 5.98)	0.39
White	12	13%	2	15%	10	12%	*Ref.*	--	--
Ethnicity: Hispanic	3	3%	0	0%	3	4%	0	(0.00, 10.91)	0.63
Sex: Male	75	100%	9	100%	66	100%	1.54	(0.37, 5.52)	0.51
Veteran	17	18%	3	25%	14	17%	1.63	(0.32, 6.65)	0.50
Current or Past Medical and Social Conditions (N=78)									
Mental illness	27	35%	6	55%	21	31%	2.59	(0.68, 10.21)	0.16
HIV/AIDS	2	3%	0	0%	2	3%	0	(0.00, 21.74)	0.74
Drug abuse	15	19%	4	36%	11	16%	2.86	(0.64, 11.73)	0.16
Alcohol abuse	20	26%	3	27%	17	25%	1.10	(0.21, 4.55)	0.87
Chronic medical condition	44	56%	6	55%	38	57%	0.92	(0.24, 3.56)	0.89

**Conditional maximum likelihood estimated odds ratios, 95% confidence intervals, and corresponding p-values*

Table 4: Predictors of non-compliance with TB evaluation mandate among homeless persons, 2016 (bivariate analysis)

	Non-compliant (n=185)		Compliant (n=1148)				
	N	%	N	%	OR*	95% CI*	p*
Experience of Homelessness							
Sheltered	56	30%	666	58%	0.31	(0.22, 0.44)	<0.0001
First time homeless	85	47%	529	48%	0.94	(0.69, 1.29)	0.72
Homeless two or more times in last 3 years	78	50%	469	46%	1.17	(0.83, 1.63)	0.37
Demographic Characteristics							
Age							
<18	0	0%	2	0%	0	--	0.79
18-24	11	6%	44	4%	1.94	(0.90, 3.97)	0.09
25-34	28	15%	165	15%	1.32	(0.79, 2.17)	0.28
35-44	22	12%	215	19%	0.80	(0.46, 1.34)	0.40
45-54	59	32%	381	34%	*Ref.*	--	--
55-64	51	28%	263	23%	1.51	(0.99, 2.31)	0.06
65+	12	7%	55	5%	1.69	(0.82, 3.33)	0.15
Race							
Black/African American	147	80%	981	87%	0.40	(0.26, 0.65)	<0.001
Other/Multi-racial	8	4%	70	6%	0.31	(0.13, 0.70)	<0.01
White	29	16%	78	7%	*Ref.*	--	--
Ethnicity: Hispanic	2	1%	33	3%	0.38	(0.06, 1.35)	0.16
Sex: Male	148	80%	982	86%	0.67	(0.45, 1.02)	0.06
Veteran	27	15%	128	11%	1.41	(0.89, 2.19)	0.14
Current or Past Medical and Social Conditions (N=1017)							
Mental illness	45	27%	178	21%	1.43	(0.98, 2.09)	0.07
HIV/AIDS	1	1%	30	4%	0.17	(0.01, 0.90)	0.03
Drug abuse	35	21%	139	16%	1.39	(0.91, 2.10)	0.12
Alcohol abuse	39	24%	161	19%	1.34	(0.89, 1.99)	0.15
Chronic medical condition	40	24%	193	23%	1.10	(0.74, 1.62)	0.62

**Conditional maximum likelihood estimated odds ratios, 95% confidence intervals, and corresponding p-values*

Table 5: Analysis of risk factors for non-compliance with the TB testing mandate among homeless persons in 2016 using univariate and multivariate logistic regression

Variable	cOR	cOR 95% CI	aOR*	aOR 95% CI
Residence in a homeless shelter	0.3135	(0.22, 0.44)	0.4756	(0.32, 0.72)
Aware of the TB outbreak in the homeless	0.2497	(0.18, 0.35)	0.2828	(0.20, 0.40)

**controlling for HIV/AIDS status, mental illness, chronic medical conditions, drug abuse, alcohol abuse*

Table 6: Predictors of being unaware of TB outbreak among homeless persons, 2016 (bivariate analysis)

	Unaware of outbreak (n=330)		Aware of outbreak (n=994)				
	N	%	N	%	OR*	95% CI*	p*
Experience of Homelessness							
Sheltered	126	38%	591	60%	0.42	(0.33, 0.54)	<.0001
First time homeless	161	50%	448	47%	1.11	(0.86, 1.43)	0.43
Homeless two or more times in last 3 years	128	44%	416	47%	0.88	(0.67, 1.15)	0.34
Demographic Characteristics							
Age							
<18	0	0%	2	0%	0.00	--	0.56
18-24	20	6%	35	4%	1.67	(0.91, 3.00)	0.1
25-34	48	15%	142	15%	0.99	(0.66, 1.46)	0.95
35-44	69	21%	168	17%	1.20	(0.84, 1.71)	0.32
45-54	112	35%	327	33%	*Ref.*		
55-64	57	18%	252	26%	0.66	(0.46, 0.94)	0.02
65+	15	5%	51	5%	0.86	(0.45, 1.57)	0.64
Race							
Black/African American	267	81%	851	87%	0.59	(0.39, 0.91)	0.02
Other/Multi-racial	25	8%	54	6%	0.88	(0.47, 1.63)	0.68
White	37	11%	70	7%	*Ref.*	--	
Ethnicity: Hispanic	12	4%	23	2%	1.56	(0.74, 3.15)	0.23
Sex: Male	260	79%	865	87%	0.54	(0.39, 0.75)	<0.001
Veteran	45	14%	111	11%	1.26	(0.86, 1.82)	0.23
Current or Past Medical and Social Conditions (N=1008)							
Mental illness	59	21%	166	23%	0.92	(0.65, 1.28)	0.61
HIV/AIDS	9	3%	22	3%	1.08	(0.47, 2.33)	0.84
Drug abuse	47	17%	127	17%	0.97	(0.66, 1.39)	0.86
Alcohol abuse	57	21%	142	19%	1.07	(0.75, 1.50)	0.7
Chronic medical condition	66	24%	168	23%	1.04	(0.75, 1.44)	0.8

**Conditional maximum likelihood estimated odds ratios, 95% confidence intervals, and corresponding p-values*

Table 7: Analysis of risk factors for unawareness of the TB outbreak among the homeless in 2016 using univariate and multivariate logistic regression

Variable	cOR	cOR 95% CI	aOR*	aOR 95% CI
Residence in a homeless shelter	0.42	(0.33, 0.54)	0.55	(0.40, 0.76)
Evaluated for TB in past 6 months	0.25	(0.18, 0.35)	0.29	(0.20, 0.41)
Sex: Male	0.54	(0.39, 0.75)	0.58	(0.39, 0.85)

**controlling for HIV/AIDS status, mental illness, chronic medical conditions, drug abuse, alcohol abuse*

Appendix A: Letter of IRB Exemption

EMORY UNIVERSITY

Institutional Review Board

August 30th, 2016

Eleanor Kerr
Rollins School of Public Health

RE: Determination: No IRB Review Required
Title: *Post outbreak analysis of TB knowledge among Atlanta's homeless population*
PI: Eleanor Kerr

Dear Ms. Kerr,

Based on our review of the materials you provided, we have determined that it does not require IRB review because it does not meet the definition of research with human subjects as set forth in Emory policies and procedures and federal rules, if applicable. Specifically, in this project, you will not be interacting with any subjects and will only be using data from which identifiers have already been removed. The data collected from the Department of Housing and Urban Development will be responsible for removing these identifiers before disclosing datasets.

Please note that this determination does not mean that you cannot publish the results. This determination could be affected by substantive changes in the study design or identifiability of data. If the project changes in any substantive way, please contact our office for clarification.

Thank you for consulting the IRB.

Sincerely,

Emilie Scheffer
Emory University Institutional Review Board

Emory University
1599 Clifton Road, 5th Floor - Atlanta, Georgia 30322
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