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Association Between Staff Experience and Effective Tuberculosis Contact Tracing in North Carolina, 2008–2009

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Abstract

BACKGROUND—Effective investigation of tuberculosis (TB) contacts is essential for continued progress toward TB elimination. As the incidence of TB declines, staff experience will also decline. Little is known about the association between the experience level of public health TB staff and the quality of contact investigations.

METHODS—Contact investigations involving fewer than 30 contacts during the period 2008–2009 were included in this analysis. Multivariable models were used to examine associations between staff TB experience (assessed by a standardized survey) and measures of contact investigation quality: time from case identification to contact identification and number of contacts identified per case investigated.

RESULTS—A total of 501 cases and 3,230 contacts met the inclusion criteria. Data were stratified by the number of cases in the county and whether the case was smear-positive or smear-negative. For contacts of smear-positive cases, greater staff experience was associated with more

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rapid contact identification both in counties with high case counts (hazard ratio [HR] = 2.43; 95% CI, 1.79–3.31) and in counties with low case counts (HR = 1.142; 95% CI, 0.95–1.37). However, for smear-negative cases, staff in counties with low case counts identified contacts more slowly as years of experience increased (HR = 0.82; 95% CI, 0.62–1.07). For contacts of smear-negative cases, more contacts (relative risk [RR] = 1.20; 95% CI, 1.07–1.35) were identified per case in high case-count counties (more than 20 cases during 2008–2009). Conversely, in low case-count counties, fewer contacts were identified per case (RR = 0.94; 95% CI, 0.82–1.08); however, this finding was not significant.

DISCUSSION—Speed of identification and number of contacts are imperfect surrogates for the most important outcome of contact investigations—that is, the rapid identification and treatment of infected contacts.

CONCLUSION—More TB experience was associated with more rapid and thorough TB contact investigations. Retaining experienced staff and mentoring staff new to case management should be high priorities for TB control programs.

Tuberculosis (TB) remains a persistent public health threat both in the United States (case rate of 3.0 per 100,000 in 2013) and in North Carolina (case rate of 2.2 per 100,000 in 2013) [1]. With the number of cases declining gradually, public health expertise in controlling TB is also declining [2]. Further, resources for TB control are diminishing disproportionately to the reduction in caseload, resulting in less capacity. Declining public health infrastructure and workforce, particularly of those with TB expertise, is a threat to TB programs, especially those serving low-morbidity areas [3, 4].

The first priority for TB control programs is identification and treatment of persons who have active TB. The second priority is finding and screening persons who have been in contact with TB patients to determine whether they have TB infection or disease [5]. As the second priority of TB control programs, contact investigations are essential to detect secondary active TB cases and to prevent disease spread. To achieve these goals, contact investigations should be both timely (performed soon after identification of a potentially infectious TB patient) and thorough (structured to identify all contacts) [6, 7].

A smear-positive pulmonary case is defined as a patient with at least 2 initial sputum smear examinations (direct smear microscopy) that are positive for acid-fast bacilli (AFB), one sputum examination that is AFB-positive and radiographic abnormalities consistent with active pulmonary TB as determined by a clinician, or one sputum specimen that is AFB-positive and a culture positive for *Mycobacterium tuberculosis*. A smear-negative pulmonary case is defined as a patient with pulmonary TB who does not meet the aforementioned criteria for smear-positive disease. Diagnostic criteria should include at least 3 sputum smear examinations negative for AFB, radiographic abnormalities consistent with active pulmonary TB, no response to a course of broad-spectrum antibiotics, and a decision by a clinician to treat with a full course of antituberculosis chemotherapy; or positive culture but negative AFB sputum examinations [8]. Smear-positive patients are typically at a higher risk of spreading disease and are typically the highest priority in an investigation. However, smear-negative patients should also be investigated, in accordance with the algorithm from the Centers for Disease Control and Prevention (CDC) [9]. It is uniformly recommended that contact investigations across all of North Carolina be conducted in accordance with the North Carolina Tuberculosis Manual [10].

Counties in North Carolina receive funding from the state for their TB control programs based on a formula that considers the county's population size and the number of TB cases in the county in previous years. As of the 2000 census, the population of North Carolina was slightly more than 8 million people, with 65 of 100 counties considered to be rural. Almost half of the TB cases in 2008 and 2009 occurred in 6 counties. All of these counties, with the exception of one, are considered to be nonrural areas. Typically North Carolina's urban counties have more TB cases, receive more funding, and have larger TB control programs. Several of the rural, less populated counties belong to health districts with combined local health departments, so there are 85 local health directors for the 100 local health departments.

North Carolina is a "home rule" state, so TB treatment and contact investigation for a case residing in a given county are the direct responsibility of that county, although consultation is available from the state TB control program as needed. While the state TB manual provides guidance for risk stratification of contacts and recommended timing of testing based on risk strata, the onus for implementation of contact investigations rests entirely with local health department staff.

Various measures have been used to assess the quality of contact investigations, but the majority of them have focused on patient and contact characteristics [11, 12]. Less is known about the association between investigators' experience levels, years working for a TB program, and contact investigation measures. Shrestha-Kuwahara and colleagues reported that suboptimal contact investigation interviews were associated with fewer contacts being identified and evaluated. Their research demonstrated that interviewer education and effective communication are critical components of adequate contact investigations [13]. Sprinson and colleagues also noted the importance of effective contact elicitation methods, which require experienced interviewers [14]. With communicable diseases generally, nursing experience has been reported to lead to higher quality of care, regardless of whether nurses have earned a baccalaureate degree [15].

Although these studies indicate that training improves the quality of contact investigations, the experience of the nursing staff at the health department was not examined as a factor that might contribute to successful investigations. One might expect that increasing nursing experience in contact investigations would correlate with higher quality investigations (ie, more contacts identified more quickly), but this expectation has not been systematically examined.

The objective of this assessment was to determine whether staff experience in TB is associated with 2 measures of contact investigation quality: time from case identification to contact identification and number of contacts identified per case investigated. These measures were selected because both are necessary to meet state and national TB objectives for contact investigations and treatment initiation, which include the following: increasing the proportion of TB patients with positive AFB sputum-smear results who have contacts elicited to 100%; increasing the proportion of contacts to sputum AFB smear-positive TB patients who are evaluated for infection and disease to 93%; increasing the proportion of contacts to sputum AFB smear-positive TB patients with newly diagnosed latent TB infection (LTBI) who start treatment to 88%; and, for contacts to sputum AFB smear-positive TB patients who start treatment for newly diagnosed LTBI, increasing the proportion who complete treatment to 79% and increasing the proportion of TB patients with positive AFB sputum-smear results who initiate treatment within 7 days of specimen collection [16], as well as quickly identifying and testing contacts as recommended at the state and national level [17]. In brief, high-priority contacts (eg, close contacts to smear-positive cases) should be identified and evaluated within 7 days of when the health department is notified of the source case, and medium-priority contacts (eg, close contacts to smear-negative cases) should be identified and evaluated within 14 days of source case notification.

In 2010, the institutional review boards (IRBs) of the CDC and North Carolina reviewed the evaluation plan, deemed this research to be part of routine program activities, and exempted it from IRB review.

Methods

Survey Data

As part of North Carolina's TB control program activities, we evaluated the quality of contact investigations by surveying North Carolina county health department TB control program staff. Although there are 85 local health agencies in the state, TB data is collected at the county level, so 100 surveys were distributed to the 100 county TB nurses in each of the local health departments. In North Carolina, there are 4 state TB control nurse consultants who provide technical assistance to counties in the region of the state each services. These nurse consultants assist with contact investigations and assist county-level TB programs in meeting the state TB requirements. In 2009, state TB control nurse consultants distributed and administered the survey—which addressed program staffing, TB program work experience, 2009 contact investigations, and county needs and resources—to the 100 counties either in person during regular visits to the county or by phone.

Each survey was completed by self-report by the county nurse who manages the TB program. County nurses provided information on the number of individuals on their staff, the percentage of each individual's time that is dedicated to working on TB, and how long each person had been working in the field of TB. The county nurse was able to verify any information with their program staff, as needed. Information was also provided on their smallest and largest contact investigations in 2009, the type of investigations they had performed in the past year (eg, school, workplace, homeless shelter, etc.), and whether they had performed an investigation with a non–English-speaking population. This survey included individual measures such as the percentage of time dedicated to the TB program and the number of years individuals in the program had worked in TB, as well as group measures such as the number, type, and size of contact investigations completed by the county. The survey was pilot tested with several nurses and reviewed by the state nurse consultants to ensure it was easy to understand and complete. No incentives were offered for those completing the survey.

Case Information Data

The survey data were combined with case and contact data from 2008–2009 obtained from several sources: the North Carolina Electronic Disease Surveillance System (NC EDSS) and the Report of Verified Case of Tuberculosis (RVCT), an in-house data collection system used to manage TB data from 2008. The RVCT database was used prior to 2008 by the North Carolina TB control program to document TB cases, and it contained patients' medical and personal information. In 2008, North Carolina began using the online system NC EDSS to collect data on TB and other diseases. NC EDSS did not contain all 2008 contact data; therefore, the RVCT system, an in-house data system, was used to complete certain data sets. All patient and contact data were obtained from these data sets.

Outcomes

The examined data included all confirmed, pulmonary TB cases with documented AFB smear status from 2008–2009 and all contacts from small contact investigations, defined as investigations with at least 1 and fewer than 30 identified contacts. Based on these criteria, 501 cases with 3,230 contacts were included, and 84 cases with 3,798 contacts were excluded. Small contact investigations were selected for study because larger contact investigations often involve mass screenings in places such as schools and workplaces, in which the timing and numbers of contacts are less likely to relate to staff efforts. Counties with high case counts were defined as those with more than 20 cases of TB during the 2-year period January 1, 2008 to December 31, 2009. Six counties fell into this category. The final data set included contacts identified within 100 days after case identification. Contacts identified more than 100 days after the source case were excluded because these contacts are usually not identified during the initial investigation, and their identification is less likely to relate directly to staff members' efforts.

Explanatory Variables

The explanatory, or independent, variable of interest in this study was the quartile of average years of staff experience working in the field of TB. The average number of years of experience of the county health department staff working in TB (defined as the average number of years the nurses in the county's TB program had been working in TB) was grouped into quartiles (0–2.5 years, 2.6–6.9 years, 7.0–8.3 years, and 8.4 years or more), because the distribution of this variable was markedly non-normal. The average number of years of TB experience was analyzed as a continuous variable, meaning that the hazard ratio represents the result of going up 1 quartile.

The dependent variables were the rate of contact identification per case and the number of contacts identified per case. These measures were selected because both are necessary to meet state and national TB objectives for contact investigations and treatment initiation. Other variables that were included in the model to predict the rate of contact identification and the number of contacts identified included county- and case-level variables. The county-level variable was the average time the county TB nurses had to dedicate to the TB program.

The case-level variables were whether the TB case reported substance abuse (defined as injection drug use or excessive alcohol use); the sex, race, and age of the case; whether the case was homeless in the year prior to diagnosis; and whether he or she was born in a foreign country.

Data Analysis

Data were analyzed by county case count (high or low) and by the sputum AFB smear status of the patient (smear-positive or smear-negative). Continuous measures, the number of contacts identified, and county demographic variables were described with medians and ranges. Wilcoxon rank-sum (nonparametric) tests were used to make comparisons for continuous measures. Chi-square tests for independence were used to describe relationships between categorical variables, such as patient demographic characteristics by county type. The associations between staff TB experience and time from case to contact identification were examined by a multivariate Cox regression analysis. The associations between number of contacts identified per case investigated and staff TB experience were examined by negative binomial regression in a multivariate model. Clustering within counties was included in both models, with county variables entered as random variables; other variables were treated as fixed parameters. A significant interaction between case count and smear status was noted, so we elected to perform the analyses stratified by case count and smear status. Both analyses were completed using SAS version 9.2. Dependent variables were individually added to the model and checked for interactions. A statistical significance level of $P = .05$ was used for all statistical tests.

Results

We received survey responses from 98 of 100 (98%) of North Carolina local health departments, which covered 98.6% of the TB cases reported in North Carolina in the period 2008–2009. Staff reported a median of 5 years of experience working in a TB program; the median amount of experience did not differ between high case-count counties (median, 6 years; interquartile range [IQR], 2–11) and low case-count counties (median, 5 years; IQR, 2–10; see Table 1). On average, staff reported dedicating 52.5% of their time to TB control, with a significantly greater fraction of time dedicated to TB in high case-count counties (76.5%; IQR, 56.4–81.6) versus low case-count counties (20.0%; IQR, 9.25–32.4; $P < .0001$).

The majority of county nurses reported that they had the materials they needed to perform contact investigations among foreign-born persons (76.9%). The majority of local TB programs reported not having a doctor regularly in their TB clinics (72.5%); however, virtually all of the responding programs reported having a doctor available for consultation at all times (90.7%). The majority of North Carolina TB program staff in local health departments self-identified as non-Hispanic (98.1%), white (89.0%), and female (96.7%).

Counties in North Carolina conducted 249 contact investigations in 2009. The median numbers of contacts in the smallest and largest investigations in each county were 1 (IQR, 0–3) and 4 (IQR, 0–15), respectively. Eighteen counties, including all 6 of the high case-count counties, reported performing a contact investigation in some type of facility (eg, school, workplace, skilled nursing facility) in 2009. Differences were seen between counties with high and low case counts when comparing TB cases by various demographic characteristics (see Table 2). Statistically significant differences were seen in the number of foreign-born cases ($P < .0001$), homeless cases ($P = .030$), and cases of various races ($P < .0001$).

The average total case count during the 2008–2009 period was 3 cases per county. Of the 585 cases and 7,028 contacts identified during this period, 501 cases (86%) and 3,230 contacts (46%) met the inclusion criteria. Thirty-six cases did not meet the inclusion criteria because they had more than 30 contacts, and 48 cases had no contacts. Of the 36 cases with more than 30 contacts, 23 cases were located in high case-count counties, and 13 cases were located in low case-count counties.

In cases with fewer than 30 contacts, contacts were identified a median of 6 days (IQR, 3–16) after case identification. Overall, contacts were identified later in high case-count counties (median, 7 days) compared with low case-count counties (median, 6 days; $P < .0001$). A median of 4 contacts per case were identified (IQR, 1–8), and there was no difference between high and low case-count counties in terms of the median number of contacts identified ($P = .417$). High case-count counties participated in a mean of 11 contact investigations in 2009, which was significantly more than the number of contact investigations in low case-count counties (mean, 2; $P < .0001$)

A total of 465 cases had all relevant data available and were included in the primary analysis. The median number of contacts identified for smear-positive cases was 7 (IQR, 3–12); 79 cases came from high case-count counties, and 101 cases came from low case-count counties. For smear-negative cases, a median of 3 contacts (IQR, 2–6) were identified per case; 142 cases were from high case-count counties, and 143 cases were from low case-count counties. Differences were also seen in the number of contacts identified for cases reporting substance abuse; specifically, there were a median of 6 contacts (IQR, 2–12) versus 4 contacts (IQR, 2–8) for cases reporting substance abuse versus cases reporting no substance abuse, respectively (see Table 3).

The number of days until contact identification and the number of contacts identified per case were associated with staff experience in TB and with the sputum smear status of the patient. In high case-count counties, contacts of smear-positive patients were identified significantly faster as the years of experience in TB increased (see Table 4). For smear-negative patients, however, low case-count counties identified contacts slower as the years of staff experience in TB increased (see Table 4). High case-count counties identified contacts of smear-negative patients quicker as years of experience increased, while low case-count counties identified contacts to smear-negative patients slower; however, this trend was not statistically significant (see Table 4).

The average number of years of experience working in the field of TB did not affect the number of contacts identified per case for smear-positive patients (see Table 5). For smear-negative patients, however, a significantly higher average rate of contacts per case was revealed in high case-count counties as TB staff experience increased (see Table 5).

Conversely, in low case-count counties, fewer contacts per smear-negative patient were identified, although this association was not significant (see Table 5).

Of all the contacts included in this data analysis, 6,600 contacts were tested for TB: 3,220 in high case-count counties and 3,380 in low case-count counties. A total of 1,048 contacts were found to have LTBI (15.9%); this included 15.2% of contacts in high case-count counties and 16.5% of contacts in low case-count counties. Of the contacts with LTBI, 74.4% started treatment (73.6% in high case-count counties and 75.1% in low case-count counties). Of those who started LTBI treatment, 65.5% completed treatment (63.3% in high case-count counties and 67.4% in low case-count counties). A total of 109 cases of TB were found in the contacts tested (1.7%).

Discussion

Our results demonstrate that the amount of time until contact identification was associated with the number of years of TB experience of the staff; however, this variable was also associated with the county case count and with the smear status of the patient. Years of experience of the staff was not associated with the number of contacts identified per case for smear-positive cases; however, it was associated with the number of contacts identified for smear-negative cases. These results demonstrate that, not only are the years of experience working in TB important, but the practical experience of the staff (defined as the number of investigations in which the individual has participated) needs to be considered. There is a lack of research comparing high and low case-count areas to determine if years of experience in TB affects performance, but our results indicate this should be studied for low-incidence areas. Other studies have examined training and hospital nurse experience in relation to TB contact investigations [13, 14] and quality of care [15], but this study is the first to explore contact investigation measures in relation to county health department experience.

There are several possible explanations for the differences observed in high and low case-count counties. As years of experience increase in high case-count counties, staff members increase their skills in performing contact investigations and therefore might have a greater understanding of the importance of certain aspects of these investigations. In low case-count counties, staff will have more years of experience as time passes, but they might not be performing contact investigations on a regular basis. In addition, more staff members are typically available in high case-count counties, allowing these counties to find contacts who might be lost in low case-count counties, where resources are often limited and less time is available for TB control activities.

One limitation of this study is that the data collected from the local health department survey were self-reported, which can lead to bias or inaccuracies. However, the majority of the surveys were completed with a state nurse consultant present to assist staff, which hopefully helped to remove inaccuracies. The survey was also reviewed by the North Carolina TB nurse consultants to ensure it was understandable and addressed questions related to program staff expertise and knowledge of their program.

A second limitation is the use of a surveillance data set to assess contact identification, as this data set is retrospective and has the potential for inaccuracies caused by both data entry errors and omissions, particularly in counties with fewer resources (and thus less time devoted to data entry). We attempted to verify data accuracy through our 2 systems to reduce errors.

Another limitation is the use of an average for the number of years of TB experience. This only allowed us to compare the average number of years across an entire county's TB program and does not take into account the difference between, for example, having 4 staff members with 2.5 years of experience each versus 1 staff member with 10 years of experience. Averages were used because, in certain programs, multiple staff members care for a single patient, making it difficult to determine the experience level of the staff member performing the contact investigation for each case.

Our use of the number of contacts as a measure of the quality of contact investigations is also a limitation of this study. While this measurement is a standard quality measure for contact investigations [16], identifying a greater number of contacts could simply indicate that a staff member is identifying more persons who had limited exposure to a source case and are at relatively low risk for TB infection. Unfortunately—because of variability in source case infectiousness, contact demographic characteristics, and exposures—limiting the analysis to only infected contacts is probably a worse reflection of contact investigation quality than is analyzing the total number of contacts, as was done in the present analysis. Limiting the analysis to smaller contact investigations partially addresses this limitation by excluding contact investigations of large numbers of persons who often have more limited exposure to the source case. However, we found an average of 12 contacts per case, when including all cases, which aligns with the estimated 10 contacts per case expected based on previous research. In addition, based on the number of contacts with LTBI or TB that we found among our contacts, the number of contacts identified appears to be in agreement with the average numbers discussed by the CDC and by Jereb and colleagues, demonstrating that the number and the exposure of the contacts identified is as expected for contact investigations [9, 17].

Another limitation of this study is that cases in different parts of the state may have individual differences in clinical characteristics (eg, more extensive disease) and/or behaviors (eg, being more social and outgoing, or working in close proximity with a larger number of persons). Such differences may have systematically varied between low and high case-count counties, as employment opportunities and social milieu certainly differ between rural counties with fewer cases and more urban counties with more cases. Furthermore, given that a small number of high case-count health departments accounted for a large proportion of contact investigations, there may well have been clustering of patient variables, provider variables, or both by health department. We did not account for such clustering in our analysis and were unable to quantify the individual differences in case characteristics listed above because they are not captured in any systematic fashion. Ignoring clustering may have underestimated variability in our effect estimates, but attempting to account for clustering in such a small proportion of counties would have likely produced imprecise estimates of variability, so we chose not to pursue this approach.

Conclusion

North Carolina TB control programs should work to retain experienced staff, and mentoring new staff should be a priority. Focus should be placed on the importance of training staff in both low- and high-incidence areas to maintain contact investigation proficiency. More emphasis on the training of TB staff regarding the importance of contact tracing for smear-negative patients is needed.

Prior studies in the United States have demonstrated that formal contact investigation training is limited in public health TB control programs [18], but recommendations for standardization and implementation of such training do exist [19]. We recommend that North Carolina TB control programs routinely implement formal contact investigation training with periodic updates to maintain this skill. In particular, given the diverse nature of persons with TB, contact investigation training should include effective communication and cultural competency [12]. We recommend identifying individual staff who perform investigations and tracking their years of experience to determine if the association is still valid at the level of the individual; however, a more refined measure of experience based on the exact number of cases investigated in a lifetime would be needed to perform such an analysis.

Although it can be difficult to make changes to programs that already have limited resources, modifications to contact tracing practices might be necessary to achieve highly efficient and effective investigations. The number of cases of TB in the United States is declining gradually, and future cases might be the missed contacts of persons who are being treated for TB today. Thoroughly trained TB staff members are needed to successfully identify TB contacts (and treat them, if necessary) and to move toward the goal of TB elimination in the United States.

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TABLE 1

Median County Health Department Characteristics, by County Case Count, North Carolina, 2009

Variable	High case-count county mean (IQR)	Low case-count county mean (IQR)
Percentage of time spent working for the TB program	76.5 (56.4–81.6)	20.0 (9.3–32.4)
Years of experience working for a TB program	6.0 (2.0–11.0)	5.0 (2.0–10.0)
Number of contact investigations in 2009	11.0 (6.0–16.0)	2.0 (0.0–3.0)
Number of FTEs in the county TB program	4.0 (1.0–7.0)	0.0 (0.0–0.0)
Number of staff working for the county TB program (FTEs and PTEs)	8.0 (6.0–10.0)	2.0 (1.0–3.0)
Number of TB cases	39.0 (27.0–62.0)	2.0 (0.0–5.0)

Note. FTE, full-time employee; IQR, interquartile range; PTE, part-time employee; TB, tuberculosis.

TABLE 2

Demographic Characteristics of Tuberculosis Cases, by County Case Count, North Carolina, 2008–2009

Variable	**High case-count county (No.)**	**Low case-count county (No.)**	***P*-value**
Foreign-born case	127	87	<.0001
HIV-positive case	27	19	.081
Substance-using case	63	62	.246
Smear-positive case	93	113	.196
Homeless within the last year	20	11	.030
Race/ethnicity of case			**<.0001**
White	25	84	
Black	106	128	
Hispanic	62	74	
Other	66	22	
Sex			**.725**
Male	167	202	
Female	101	115	

TABLE 3

Median Number of Contacts Identified per Tuberculosis Case, by Case Demographic Characteristics, North Carolina, 2008–2009

Variable	Median	IQR	*P*-value
Foreign-born case			**.918**
Yes	4.0	2–9	
No	4.0	2–9	
HIV-positive case			**.873**
Yes	4.0	2–11	
No	4.0	2–9	
Substance-abusing case			**.003**
Yes	6.0	2–12	
No	4.0	2–8	
Sputum smear status of case			**<.001**
Positive	7.0	3–12	
Negative	3.0	2–6	
Case homeless within the previous year			**.532**
Yes	5.5	3–8	
No	4.0	2–9	
Race/ethnicity of case			**.421**
White	4.0	2–7	
Black	5.0	2–9	
Hispanic	4.0	2–11	
Other	4.0	2–7	

Note. IQR, interquartile range.

TABLE 4

Rate of Contact Identification, by County Case Count and Patient Smear Status, North Carolina, 2009

Smear-positive	**High case-count county**			**Low case-count county**		
Variable	**Hazard ratio**	**Confidence interval**	***P*-value**	**Hazard ratio**	**Confidence interval**	***P*-value**
Staff-level variables						
Quartile of TB experience	2.43	1.79–3.31	<.001	1.14	0.95–1.37	.160
Time dedicated to TB	1.92	1.42–2.59	<.001	1.01	0.69–1.49	.956
TB case-level variables						
Substance abuse	1.65	0.86–3.15	.1322	0.68	0.33–1.42	.306
Sex (male versus female)	3.38	1.90–6.02	<.0001	1.49	0.84–2.63	.171
Black versus white	0.66	0.40–1.10	.1093	2.13	1.00–4.51	.049
Hispanic versus white	0.61	0.36–1.05	.073	1.66	0.74–3.73	.219
Other race versus white	0.48	0.16–1.50	.210			
Smear-negative	**High case-count county**			**Low case-count county**		
Variable	**Hazard ratio**	**Confidence interval**	***P*-value**	**Hazard ratio**	**Confidence interval**	***P*-value**
Staff-level variables						
Quartile of TB experience	1.16	0.85–1.60	.345	0.82	0.62–1.07	.142
Time dedicated to TB	2.00	1.02–3.92	.045	0.87	0.68–1.10	.247
TB case-level variables						
Substance abuse	0.60	0.26–1.36	.220	0.88	0.62–1.25	.481
Sex (male versus female)	2.31	1.42–3.78	.001	1.45	0.82–2.59	.205
Black versus white	1.47	0.38–5.68	.574	1.16	0.64–2.10	.620
Hispanic versus white	1.01	0.28–3.66	.984	0.67	0.41–1.09	.108
Other race versus white	1.95	0.51–7.49	.329	1.61	0.59–4.35	.349

Note. TB, tuberculosis.

Hazard ratios greater than 1 indicate a relatively higher rate of contact identification.

TABLE 5

Number of Contacts Identified per Tuberculosis Case, by County Case Count and Patient Smear Status, North Carolina, 2008–2009

Smear-positive	**High case-count county**			**Low case-count county**		
Variable	**Rate ratio[a]**	**Confidence interval**	***P*-value**	**Rate ratio[a]**	**Confidence interval**	***P*-value**
Staff-level variables						
Quartile of TB experience	0.95	0.82–1.11	.516	1.02	0.91–1.14	.784
Time dedicated to TB	1.13	0.88–1.44	.341	0.94	0.78–1.14	.540
TB case-level variables						
Foreign-born patient	0.91	0.76–1.08	.288	2.12	1.43–3.15	.000
Substance abuse	1.62	1.20–2.20	.002	1.30	0.92–1.84	.131
Case homeless within the previous year	0.36	0.23–0.58	<.001	0.46	0.22–0.97	.042
Black versus white	0.92	0.61–1.40	.703	1.39	0.88–2.22	.161
Hispanic versus white	1.74	1.32–2.30	<.001	1.03	0.59–1.80	.907
Other race versus white	0.82	0.53–1.26	.359	0.55	0.27–1.13	.105
Sex (male versus female)	0.96	0.77–1.20	.740	1.03	0.71–1.49	.869
Age	1.00	0.99–1.01	.920	1.01	1.00–1.01	.183
Smear-negative	**High case-count county**			**Low case-count county**		
Variable	**Rate ratio[a]**	**Confidence interval**	***P*-value**	**Rate ratio[a]**	**Confidence interval**	***P*-value**
Staff-level variables						
Quartile of TB experience	1.20	1.07–1.35	.002	0.94	0.82–1.08	.362
Time dedicated to TB	1.01	0.82–1.24	.914	0.88	0.68–1.12	.300
TB case-level variables						
Foreign-born patient	0.64	0.40–1.03	.064	0.67	0.27–1.67	.389
Substance abuse	1.38	0.75–2.55	.303	0.90	0.51–1.59	.722
Case homeless within the previous year	1.28	0.75–2.18	.359	3.72	1.74–7.95	.001
Black versus white	1.59	0.84–2.99	.154	0.76	0.48–1.19	.233
Hispanic versus white	2.09	1.24–3.52	.006	1.39	0.50–3.83	.527
Other race versus white	2.20	1.59–3.05	<.001	1.25	0.46–3.41	.666
Sex (male versus female)	0.82	0.63–1.05	.117	1.35	0.91–2.02	.138

Smear-positive	High case-count county			Low case-count county		
Variable	**Rate ratio[a]**	**Confidence interval**	***P*-value**	**Rate ratio[a]**	**Confidence interval**	***P*-value**
Age	1.01	1.00–1.01	.005	1.00	0.99–1.01	.856

Note. TB, tuberculosis.

[a]The rate ratio represents the adjusted (for all other variables listed in the table) change in the number of contacts identified for each unit change in the independent variable. For example, a nurse in the second quartile of experience in a high case-count county would be expected to identify on average 25% more contacts to smear-negative cases than a nurse in the first quartile of experience in the same county.