Evaluation of Public Transportation as a Risk Factor for Active Tuberculosis in Lima, Peru

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Abstract
Public transportation is a potential source of community transmission of *Mycobacterium tuberculosis* (TB). We conducted an observational study in Lima, Peru to examine the association between use of public transportation by TB patients and by three matched control groups. For non-transportation workers, the risk of developing pulmonary tuberculosis increased 25% for each increase in quintile of time spent in public transportation per week, underscoring the importance of public health interventions to reduce transmission of TB in crowded public transportation environments.

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Introduction

Mycobacterium tuberculosis (TB) is an airborne respiratory infection transmitted in confined environments including prisons [1] [2], homeless shelters [3], refugee camps [4], and hospitals [5]. While household contacts are an important mode of transmission, particularly for multidrug-resistant tuberculosis (MDR-TB) [6] [7], previous research performed in Lima suggests that community transmission accounts for up to 7 of 10 incident infections [8]. Therefore, while contact tracing of household contacts is important [9], further investigation of community transmission is merited [10].

The risk of TB transmission is present wherever there is overcrowding, poor ventilation, and exposure to an infected individual [11]. Public transportation has been identified as a potential site for TB transmission, based on contact investigations and cross-sectional data [12]. In addition, TB is clustered in certain areas of Lima [13] and a higher risk for TB infection has been documented along specific bus routes traversing areas with clustered TB cases in other settings [14]. This suggests that public transportation may serve as a medium for spreading TB to surrounding neighborhoods. While public transportation workers in Lima have increased risk of tuberculosis infection [15] [16], evidence regarding risk of TB among people who use public transportation is not as robust. A previous study in Lima suggested an increased risk of tuberculosis among people who rode mini-buses for more than 1 hour, but this study lacked a control group, likely suffered from TB misclassification, did not have precise time variables, and had wide confidence intervals (OR= 4.9; 95% CI: 1.06, 23.09) [17]. The objective of this study was to assess the risk of TB transmission among commuters and determine if use of public transportation was an independent risk factor for TB.

Methods

We enrolled people with newly diagnosed tuberculosis (incident cases) from three peripheral health centers in the Lima metropolitan area in the districts of San Juan de Lurigancho, Villa el Salvador, and Ate-Vitarte during the months of June to December 2011. Three people without tuberculosis (controls) matched by age (±5 years) and gender were recruited for each incident case: a patient with symptomatic respiratory syndrome from the same clinic as the incident case, a person living in the same household as the case, and a person from the same neighborhood as the case. Due to the limited sample of household contacts, age and gender matching of household controls was done to the nearest age of the case. Neighborhood controls were selected using random number sampling of households on the block same block as the case.
Participants were 15 years of age or older, without a history of TB, HIV negative, not pregnant, and not currently living with anyone with active TB—with the exception of household controls. Incident cases had a history of TB symptoms and at least one positive sputum smear, and

symptomatic respiratory controls had one or more negative sputum smears. Solid (Ogawa) and liquid (microscopic-observation drug-susceptibility assay) culture techniques performed at a dedicated tuberculosis diagnosis laboratory at the Tropical Medicine Institute of the University of San Marcos [18] were used to confirm the positivity and negativity of incident cases of TB and symptomatic respiratory patients, respectively. The microscopic-observation drug-susceptibility (MODS) assay is a reliable and efficient liquid culture technique designed to test for resistance against isoniazid (0.1 µg/ml sensitivity: 97.7%, specificity: 95.8%) or rifampicin (sensitivity: 98.0%, specificity: 99.4%) [19]. Household and neighborhood controls were screened for TB symptoms and were excluded if they had recent weight loss, fever, night sweats, cough, or hemoptysis.

Each participant completed a survey assessing demographic and socioeconomic factors, risk factors for TB, and transportation habits during the past week and past year. Incident TB cases and symptomatic respiratory controls were asked about transportation usage the week before they experienced symptoms. Questions about transportation included duration, time of day traveling, and transportation type. Transportation options included taxi, combi (mini-bus), couster (larger mini-bus), omnibus (charter bus), and mototaxi (a two-seat attachment to motocycle). The results were analyzed by univariate and multivariate logistic regression using STATA11 (StataCorp LP, College Station, TX, USA) [20].

This study was approved by both the University of Washington Human Subjects Division and the University of San Marcos Institute for Tropical Medicine Ethics Committee in Lima, Peru.

Results

86 people with incident TB infection were recruited along with 85 symptomatic respiratory syndromes, 86 household, and 86 neighborhood controls matched by age and gender (Table 1). One person with respiratory syndrome was excluded because of subsequent positive MODS and Ogawa. Controls did not vary significantly from each other—except slightly by age in household controls—and were pooled in the analysis (data not shown). Drug resistance was detected in 11.8% (9/76) of samples that had MODS drug resistance data available, with 7.9% having resistance to isoniazid (6/76) and 3.9% (3/76) having resistance to isoniazid and rifampicin (MDR-TB). Compared to controls, incident TB cases had lower BMI, prior TB exposure from cohabitation, differing marital status and occupation, and more frequent travel between 15:00-18:59, but did not significantly vary by age, gender, education, income, or transportation type. Total time in transportation and time of day in transportation over the past year did not differ between cases and controls, possibly due to recall bias, and was not included in the data analysis. Transportation duration over the most recent week was quantified by quintiles due to public transportation workers recording >920 minutes in public transportation, skewing the mean to a higher value.

Multivariate logistic regression was used to assess the relationship between increased duration of exposure in public transportation and risk of pulmonary TB among all subjects and only non-transportation workers (Table 2). Public transportation workers, all of whom belonged to the 5th quintile: ≥920 minutes, were disproportionately represented in the control groups (2.3% cases, 8.6% controls). Since transportation duration was strongly correlated with public transportation occupation (corr=0.74), this attenuated the association between transportation duration and risk for pulmonary tuberculosis. Since public transportation work is an established risk factor for

TB [15] [16], a separate analysis for non-transportation workers was calculated. Prior cohabitation with a person infected with TB, marital status, and public transportation use during 15:00-18:59 were included as covariates in the analysis. BMI was not included in the logistic regression as it was deemed in the causal pathway. In the adjusted analysis, an increase in one quintile of time spent in public transportation increased the odds of contracting tuberculosis by 25% among non-transportation workers (OR=1.25; $P<0.05$), but this was not significant when comparing all subjects (OR= 1.14; $P>0.05$). This suggests a dose response relationship between increasing time spent in transportation and the risk for contracting active pulmonary tuberculosis among commuters.

Discussion

Our study demonstrates that increased time spent in public transportation confers an increased risk for developing active pulmonary tuberculosis: each quintile increase of time spent in public transportation resulted in a 25% higher odds of TB (each quintile increase: OR= 1.25; $P<0.05$). This study expands on previous research demonstrating the risk of developing active tuberculosis and using public transportation [15] [16] [17]. The study design is an improvement from previous investigations as it had a larger sample size, utilized culture techniques to reduce TB misclassification, included three types of controls, and utilized a detailed survey of public transportation parameters. The finding that past cohabitation with a person infected with TB is a strong risk factor for tuberculosis is consistent with previous findings [6] [7] [8] [9], and was accounted for in the analysis unlike previous investigations. These attributes increase the precision in the finding that public transportation is a risk factor for the spread of TB. Limitations of the study include an underpowered sample size to demonstrate significant risks within each quintile and the inability to demonstrate a significant association without removing public transportation workers from the adjusted analysis. Public transportation workers tended to be controls rather than cases. Due to their long duration of public transportation use, this diminished the association between increased time in public transportation duration and risk for TB. The use of a stratified analysis of non-transportation workers is justified to eliminate this confounding, but limits its applicability to commuters. Finally, our study did not have the power to detect any differences in type of transportation work or type of commuter transportation used. The data presented in the context of previous research suggests the relationship between public transportation and increased risk of contracting TB. However, it is possible community transmission of TB happens primarily outside of public transportation and public transportation is merely a proxy measure for degrees of community exposure to an unknown TB reservoir. In order to assess this possibility, further research is needed to refine the temporal relationship between public transportation and risk of TB, identify whether specific routes or transportation types have higher risks, and assess the efficacy of interventions to mitigate the risk of TB in public transportation.

An immediately available intervention is establishing adequate ventilation in public transportation. Previous research suggests that simply opening windows and doors in hospitals allows for natural ventilation sufficient to be protective against TB [21] and this could be applied to the various modes of transportation in Lima. Currently, it is common practice to ride with the windows closed due to security concerns, and to some extent, cultural beliefs about wind-borne illness in minority populations in Peru [22]. An effort to improve ventilation in public transportation has the potential to reduce the risk of contracting TB. However, short term interventions should be jointly pursued with long-term investments in road conditions, enforcing vehicle standards, and fostering economic development outside of city centers to promote local resource growth, which have benefits including and beyond public health.

Disclaimers
The authors state no conflicts of interest.

Biographical Sketch

Nathan Furukawa is completing an MD/MPH degree at the University of Washington School of Medicine and School of Public Health in Seattle, WA. His primary research interests include infectious diseases, preventative medicine, and social determinants of health.

Tables

Table 1: Demographics and Baseline Characteristics of Study Participants in Lima at Enrollment

Characteristics	Baseline Demographics: TB(+) Cases (n=86)		TB(-) Controls (n=257)		p-value*
Age, years (SD)	25.3	(8.6)	27.3	(9.1)	0.128
Male, n (%)	53	(61.6%)	144	(56.0%)	0.364
BMI, kg/m^2 (%)	21.7	(2.9)	23.9	(3.3)	<0.001
Education, years (%)	10.2	(2.6)	10.4	(2.8%)	0.488
Prior TB Exposure from Cohabitation, n (%)	41	(47.8%)	65	(25.3%)	<0.001
Marital Status, n (%)					<0.001
Single	55	(64.0%)	130	(50.6%)	
Married	3	(3.5%)	28	(10.9%)	
Cohabitation	18	(20.9%)	91	(35.4%)	
Divorced	10	(11.6%)	7	(2.7%)	
Widowed	0	(0%)	1	(0.4%)	
Occupation, n (%)					0.005
Professional	2	(2.3%)	32	(12.5%)	
Commercial	20	(20.3%)	42	(16.3%)	
Domestic	8	(9.3%)	37	(14.4%)	
Laborer	27	(31.4%)	70	(27.2%)	
Public Transportation	2	(2.3%)	22	(8.6%)	
Student	21	(24.4%)	45	(17.5%)	
Unemployed	6	(7.0%)	9	(3.5%)	
Monthly Income, n (%)					0.201
<$75 USD	2	(2.3%)	6	(2.3%)	
$75-187 USD	29	(33.7%)	51	(19.8%)	
$187-374 USD	37	(43.0%)	148	(58.6%)	
$374-747 USD	16	(18.6%)	46	(17.9%)	
>$747 USD	2	(2.3%)	6	(2.3%)	
Transportation Type, n (%)					0.331
None	3	(3.5%)	10	(3.9%)	
Taxi	3	(3.5%)	7	(2.7%)	
Combi	27	(31.4%)	71	(27.6%)	
Couster	20	(23.3%)	56	(21.8%)	
Omnibus	21	(24.4%)	48	(18.7%)	
Mototaxi	12	(14.0%)	65	(25.3%)	
Time Spent in Transportation per Week, n (%)					0.201
<120 minutes	15	(17.4%)	62	(24.1%)	
120-279 minutes	13	(15.1%)	48	(18.7%)	

280-539 minutes	23	(26.7%)	54	(21.0%)	
540-919 minutes	18	(20.9%)	42	(16.3%)	
≥920 minutes	17	(19.8%)	51	(19.8%)	
Time of Day in Public Transportation†, n (%)					
Before 7:59	52	(62.7%)	156	(63.2%)	0.934
8:00-11:59	17	(20.5%)	78	(31.6%)	0.053
12:00-14:59	19	(22.9%)	76	(30.8%)	0.170
15:00-18:59	41	(49.4%)	90	(36.4%)	0.037
After 19:00	32	(38.6%)	103	(41.7%)	0.614

*Paired T-test of continuous variables; Pearson chi-square test for dichotomous categories; Fisher's exact test for categorical variables with small numbers; score test for linear trend for ordinal variables

†Multiple answers were possible, therefore, each time increment was treated independently

Table 2: Association between time spent in public transportation and active pulmonary tuberculosis adjusting for past household exposure, marital status, and travel between 15:00-18:59 in Lima, Peru.

	All subjects n= 343			Non-transportation workers n= 319		
Characteristic	OR	95% CI	P value	OR	95% CI	P value
Past Household TB Exposure*	2.47	(1.43, 4.28)	0.001	2.62	(1.48, 4.63)	0.001
Marital Status						
Single	1.00	Reference		1.00	Reference	
Married	0.28	(0.08, 1.01)	0.052	0.28	(0.08, 1.01)	0.051
Cohabitation	0.52	(0.28, 0.98)	0.045	0.60	(0.32, 1.14)	0.118
Divorced	3.77	(1.16, 12.3)	0.027	3.48	(1.42, 16.3)	0.012
Travel between 15:00-18:59	1.50	(0.89, 2.55)	0.131	1.62	(0.93, 2.80)	0.087
Time in Transportation per Week †			0.173‡			0.026‡
<120 minutes	1.00	Reference		1.00	Reference	
120-279 minutes	1.09	(0.44, 2.72)	0.849	1.27	(0.50, 3.28)	0.615
280-539 minutes	1.80	(0.77, 4.18)	0.172	1.40	(0.58, 3.36)	0.449
540-919 minutes	1.88	(0.76, 4.65)	0.173	2.28	(0.95, 5.50)	0.066
≥920 minutes	1.51	(0.61, 3.69)	0.371	2.21	(0.91, 5.38)	0.081
Each Quintile	1.14	(0.94, 1.37)		1.25	(1.03, 1.51)	

*Past TB exposure from living with someone who had tuberculosis previously.
† Quintile ranges list represent all subjects. Quintile ranges for non-transportation workers were >120, 120-239, 240-479, 480-899, and >900 minutes.
‡ P value for the linear trend

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