Demographic and socio-economic risk factors associated with self-reported tuberculosis in Gauteng, South Africa

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ABSTRACT

Background: Mycobacterium tuberculosis' (TB) infectiousness is known to be shaped by the human environment with research showing positive associations with poverty, homelessness, and overcrowding, among other factors. In this study the focus is primarily on environmental health risks for TB, particularly on those associated with socio-demographic and household living conditions in South Africa.

Methods: Data for this study were collected between 2014 and 2019 from a number of sites implementing community oriented primary care (COPC) in the Gauteng province of the country. Community Health Workers (CHWs) used AitaHealth™, a custom-built mobile information management application, to obtain data on the TB status and environmental conditions of households. Statistical models were used to determine associations between various demographic, socio-economic and environmental risk factors, and TB.

Results: Approximately 12,503 TB cases were reported among 7,769 households. Substance use and male-headed households were found to have significant associations in households with at least one individual with TB. Overcrowding as well as lack of access to piped water and adequate sanitation were also found to be positively associated with a 'TB-household.'

Conclusion: Improvements in housing and services, particularly the provision of piped water and reticulated flush toilets are needed to control and prevent TB in South Africa.

Keywords: community oriented primary care; respiratory disease; risk factors; harmful substance use; housing

TB is endemic in post-apartheid South Africa. According to the World Health Organization (WHO)[1] the country has the sixth highest annual incidence of TB in the world and accounts for approximately three percent of global TB prevalence. Although TB mortality rates in South Africa have fallen substantially over the past decade,[2] the disease burden of TB in South Africa has been exacerbated by HIV. HIV is known to increase susceptibility for new TB infection[3] as well as increase progression from latent TB infection to active TB disease.[4] Notwithstanding the substantial reduction in TB mortality rates - due mainly to Combined Anti-Retroviral Therapy (cART) roll-out to individuals living with HIV[2] - TB transmission remains largely unchecked.

Cure rates remain low (50%) and the disease still the leading cause of death.[1] The high TB disease burden is compounded by healthcare system and policy challenges, including an historical legacy of neglect,[5] on-going poor management,[6] fragmented health services,[7] as well as a truncated, facility-centric approach to primary healthcare delivery.[8] The multiplicity of these intersecting factors has resulted in often limited access to, and dire quality of public healthcare services in the country.

Similar to other countries, a number of individual-level factors such as age, gender and ethnicity have been found to contribute towards the persistent high rates of TB in South Africa.[9-11] Being young, male, black African, and immuno-suppressed have all been identified as significant independent risk factors for TB in the country.[12-14] Gender of the head of the household has also been found to be a factor at play in risk for TB, with female-headed households at significantly higher risk compared to male-headed households due specially to their greater socio-economical vulnerability.[15] Structural socio-economic as well as other behavioural factors have also found to increase TB risk at the individual level in South Africa. These include, among others, unemployment,[16] lower educational attainment,[17] and harmful alcohol and cigarette use.[9]

In addition to the above, a growing body of ecological research on risk prediction for TB has identified 'spatial' risk factors that arise from the social and/or structural composition of neighbourhoods. From an endogenous spatial perspective increased risk of TB has been found to be associated with local poverty,[18] overcrowding and/or non-standard housing,[4] limited health care access,[19] and recent immigrant status.[20]

Notwithstanding the plethora of studies investigating the epidemiology of TB in South Africa, few have focused on the combination of environmental health, demographic and socio-economic risk factors of TB using large-scale health surveys. While environmental tobacco smoke exposure[21] and indoor air pollution[22] have been considered, we are unaware of any study that has specifically examined the association between a range of risk factors and TB with such a sizeable dataset of almost 500 000 households. This study aims to fill this gap by identifying any possible household and/or community-level environmental health factors that may be associated with self-reported TB. This knowledge can provide vital insight on how to address household-level conditions unsupportive of healthy living environments. At a time when South Africa may start to see a slow increase in TB,[23] these findings could not be more relevant.

DATA AND METHODS

In 2013, the City of Tshwane, a metropolitan municipality located in the Gauteng province of South Africa, committed to implementing the Ward Based Outreach Teams (WBOT) approach to healthcare in the municipality. This approach to healthcare is built on the principles of epidemiology, primary care, preventive medicine and health promotion and has been used in several parts of the world (Bongongo, Ndimande et al. 2019). The initiative was assisted by the University of Pretoria, Department of Family Medicine, the City of Tshwane, and the Tshwane District Health (Gauteng Provincial Department of Health) as part of a national government drive to reform primary healthcare services in South Africa. The main aim was to collect health data that would provide essential information to enable WBOTs to provide community oriented primary care (COPC) that is specific to the needs of communities. In this case, the COPC programme was implemented at ward level, these are geopolitical subdivisions of municipalities used for electoral purposes. Data were collected between 2014 and 2019 mainly in Gauteng. Some sites were located in other provinces including Limpopo, Mpumalanga and North-West however these comprised less than 0.1% of the dataset. COPC site selection was informed by existing levels of poverty and high disease burden with a priority on informal settlements. Data were collected at both household and individual level. The household questionnaire was administered to a consenting adult to collect data on the household and all household members. If household members who should be referred for immediate healthcare were identified during the household questionnaire, they were provided with a questionnaire to further assess health at an individual level. The data used in this study was obtained from the initial household questionnaire. Data were collected using AitaHealth™, a mobile community healthcare management application developed by the University of Pretoria in South Africa. AitaHealth™ is routinely used by community health workers to register households, determine basic household environmental and socio-economic status, and record, respond to, and report on individual and household health. The collected health care information is most often used to support service delivery, facilitate local and district decision making through monitoring and evaluation, and for research. Other than health status, demographic, socio-economic and environmental data obtained through AitaHealth™ included household identifying data, health information of household members (including children under five years of age), demographics, household characteristics, socio-economic information and environmental data.

Statistical analyses

Multivariable logistic regression analyses was performed to examine the associations between the various risk factors and the self-reported presence of TB in each household. The dependent variable was the outcome (i.e., presence or absence of TB) and was coded as 0 for households where no cases were reported and 1 if any cases were reported for a given household. Households were coded as 1 if respondents answered yes to any of the following questions 1) Has anyone in the household been on TB treatment at any point in the past 12 months, or 2) Is anyone in the household currently on TB treatment at the time of the survey, or 3) Was anyone in the household diagnosed with TB within the past 12 months but defaulted on treatment or 4) Was anyone in the household diagnosed with TB within the past 12 months but not on treatment. A total of 403,339 households were recruited into the study and 7,769 of these had one or more individuals whose TB status matched the definitions outlined above. The following independent variables were included in the analyses: gender of head of household, size of household, harmful substance use (drugs or alcohol), food insecurity, member of household members employed, dwelling type, water source, toilet type, energy source for cooking and heating. There were nine independent variables in total. The regression also accounted for clustering within each ward and the clustering standard errors (Cluster SE) are presented. Collinearity of variables included in the model was assessed by using the variance inflation factor (VIF). Variables were considered to be statistically significant if $p<0.05$. Results are reported as odds ratios (ORs), 95% confidence intervals and p-values. STATA version 15 was used for data analysis. The study protocol was approved by the University of Pretoria's Faculty of Health Science's Research Ethics Committee, Pretoria, South Africa. The ethics committee complies with ICH-GCP guidelines and has US Federal wide assurance. Informed consent was provided by all study participants.

RESULTS

Descriptive statistics of risk factors for households that had a case of TB reported compared to those that did not report a case of TB are presented in Table S1. Results of the multivariable analysis are presented in Table 1. Collinearity of variables included in the model was ruled out because the VIF values were all below 10. Male-headed households (OR = 1.46, 95% CI = 1.31 – 1.64, $p <0.001$) and households where harmful substance use was reported were significantly more likely to have TB (OR = 5.26, 95% CI = 3.94 – 7.03, $p <0.001$) (Table 1). Households where meal

size had to be reduced and people went to bed hungry were also more likely to have individuals with TB (OR = 2.61, 95% CI = 2.08 – 3.26, p <0.001). In terms of environmental health risks, overcrowding (considered as more than two or more people per room in a dwelling) was found to be a statistically significant risk factor for a household with TB (OR = 2.15, CI = 1.66 – 2.78, p <0.001). We found strong evidence in favour of the final model as the observed difference in model fit was highly statistically significant, the goodness of fit test for the model produced a p-value <0.001.

Table 1: Multivariable regression analysis of demographic, socio-economic and environmental health determinants of TB

Risk Factors		OR (95 % CI)	P-value	VIF	Clustered SE
Gender	Female	*			
	Male	1.46 (1.31 – 1.64)	<0.001	1.72	0.38
Substance use	No	*			
	Yes	5.26 (3.94 – 7.03)	<0.001	1.02	1.66
Type of dwelling	House	*			
	Flat	0.44 (0.18 – 1.04)	0.061	1.02	-0.83
	Shack	0.75 (0.58 – 0.98)	0.032	1.46	-0.29
	Room	0.96 (0.71 – 1.29)	0.768	1.10	-0.05
	Hut	0.95 (0.40 – 2.24)	0.901	1.01	-0.05
Overcrowding	<= 2 people per room	*			
	> 2 people per room	2.15 (1.66 – 2.78)	<0.001	1.16	0.76
Is a member of the household employed	Yes	*			
	No	0.67 (0.57 – 0.78)	<0.001	2.44	-0.40
Type of toilet	Flush toilet connected to sewage system	*			
	Flush toilet with septic tank	1.01 (0.77 – 1.31)	0.930	1.12	0.01
	Chemical toilet	1.33 (0.84 – 2.08)	0.150	1.17	0.28
	Pit toilet	0.91 (0.74 – 1.11)	0.190	2.86	-0.09
Source of water	Piped water in house	*			
	Piped water in the yard	0.92 (0.64 – 1.32)	0.670	3.13	-0.07
	Piped water outside yard	1.40 (0.95 – 2.05)	0.087	2.26	0.33
	Borehole/well	1.24 (0.78 – 1.98)	0.361	1.17	0.21
	Spring/stream/river/dam	1.70 (0.96 – 3.00)	0.067	1.06	0.53
	Rainwater tank	1.45 (0.86 – 2.41)	0.160	1.26	0.36
	Water tank	1.16 (0.76 – 1.77)	0.501	2.24	0.14
Source of energy used for cooking/heating	Electric	*			
	Non-electric	1.06 (0.91 – 1.24)	0.456	2.96	0.05
Does any member of this household ever cut the size of his/her meal or go to bed at night without food?	No	*			
	Yes	2.61 (2.08 – 3.26)	<0.001	1.11	0.96

Notes: * = Reference category; Percentages are expressed relative to total number of available records for each risk factor; # = This study used the United Nations HABITAT (UN-HABITAT) definition of overcrowding which is more than two people per room (UN-Habitat 2020).
OR = Odds Ratio; 95% CI = 95% Confidence Interval; VIF = Variance inflation factor; Cluster SE = Clustering standard errors

DISCUSSION

Four risk factors, namely, substance use, living in male-headed households, overcrowding and food insecurity were shown by our study findings as being positively associated with households in which individuals with TB reside. In fact, of all potential risk factors substance use had the highest odds ratio of the presence of TB in a household. While there is no national data on harmful use of substances in South Africa, all available evidence points to it being a common practice that is growing in scale and expanding in scope. More than 13% of the population have used substances harmfully during their lifetime.[24] A study of drinking in Tshwane – the capital city of South Africa - found that more than half of those who drink, drink heavily; seven in ten of heavy drinkers are male; and heavy drinkers consume 94% of the absolute alcohol sold.[25] Moreover, the illicit substance bouquet has expanded in South Africa to include dangerous opioids, such as nyaope - a low-grade heroin derivative that is smoked with cannabis – which has spread ever deeper into urban and rural socially disadvantaged communities.[26.] Abusing these substances can lead to an increase in the risk of defaulting on TB treatment. In fact, a recent South African study found that recent alcohol (Hazard Ratio = 2.1, 95% CI = 1.1- 4.0) and drug use (Hazard Ratio = 2.0, 95% CI = 1.0 - 3.6) were statistically significantly associated with increased risk of default.[27]

Several previous international studies have similarly found a causal relationship between TB and heavy alcohol consumption and alcohol use disorders[28,29] while a number of other local studies have also found that increased alcohol consumption is associated with treatment default among TB patients.[30,31] Further evidence of the negative effect of alcohol on TB is provided by Lönnroth et al.[28] who found that alcohol use disorder had a pooled relative risk of 3.50 (95% CI: 2.01 – 5.93) for the development of TB. Possible reasons for the increased risk of TB due to alcohol consumption are social destabilization caused by alcoholism and the magnification of medication toxicities commonly caused by alcohol.[32] Our study confirm that actions aimed at combating the issue of substance abuse may have an effect on the prevalence of TB in South Africa. Male-headed households had increased risk for TB in the household. This notable finding contradicts previous research which has found that female-headed households had higher risk than male-headed households for TB.[15] This contradictory finding may reflect several behavioural and structural gender inequalities inherent in South Africa including a greater propensity among men to engage

in episodic heavy or binge drinking,[33] higher treatment default rates among men compared to women[32] and increased male exposure to high-risk-for-TB occupations, especially mining.[35]

In our multivariable analysis, we also found that male headed households and overcrowding were significant risk factors for TB. The incidence of TB could be higher in male headed households because males often have more frequent external interactions thus increasing risk of exposure and there are differences in health seeking behaviour between males and females (Stevens, Ximenes et al. 2014). Smaller studies have found that overcrowding[9,37] was associated with higher risks of exposure to TB through the lack of proper construction of homes and poor ventilation or quality of indoor air.[38] Similar findings exist in other low-income countries including Uganda[39] and Nigeria[40] where overcrowding increased TB transmission (prevalence ratio 1.22, p = 0.09) and had a statistically significant adjusted OR of 4.8 (CI: 1.8, 13.1), respectively. Outside Africa, a Brazilian study found that household crowding was a potential mediator of two socio-economic determinants of TB incidence, namely income inequality and poverty.[41] About 28% of the households in our study lived in informal dwellings. However, with a high unemployment rate, many likely do not have jobs, or end up taking low-paying jobs making adequate housing unaffordable. Given the findings of local and international studies that overcrowding increases the risk of TB, actively intervening to improve housing quality is a critical disease control measure given our study findings.

Our study found that food insecurity was a significant risk factor for TB. Previous studies have also shown that poor nutrition is associated with increased risk of TB (Van Lettow, Kumwenda et al. 2004, Lönnroth, Williams et al. 2010, Duarte, Lönnroth et al. 2018). This could be because malnutrition increases the risk of progression of TB from infection to disease (Lönnroth, Williams et al. 2010).

Limitations

Self-reported morbidities may be biased due to the subjectivity in responses therefore, it is possible that the self-reported TB diagnosis in our study could have led to an under-estimation of the true prevalence of TB in the study sites. Furthermore, we were unable to register all households in the wards in which COPC fieldworkers recruited participants and collected data therefore the incidence of TB reflected in our study could be a biased representation of TB within the sampled

communities. There was a statistically significant association between whether there was an individual employed in the household and whether there was a person with TB in the household. This finding is deemed spurious and therefore it is not possible to interpret. It is not possible to connect the question showing that if there was an unemployed person in the household (as indicated by the protective OR) with the person with TB. In future, the question would be more helpful if the question about employment asked about the person in the household with TB.

CONCLUSION

The results of this study indicate that environmental risk factors, particularly inadequate water provision, absent or inappropriate sanitation and overcrowding increase the risk for active TB. As such, they need to be considered an integral component of any solutions to TB transmission prevention and control which, by definition, require coordinated general, community and individual public and personal social, economic and health interventions. An additional knowledge gap which this study has fulfilled was showing the value of using data such as those collected by WBOT. National level health surveys are costly and can therefore not be conducted over extended periods, hence the use of community level surveys is essential for assessing the state of health of communities and to provide evidence for targeted and impactful interventions, particularly in developing contexts. Therefore, our study shows the feasibility of using community level health surveys such as COPC programmes to better understand TB and its environmental, demographic and socio-economic risk factors hence similar studies can implemented across the country as part of comprehensive health programmes. By extending health and care services from and to people in their homes in geographically defined communities through COPC it becomes possible to first, identify, and second, proactively respond to individual and family specific health needs in context.

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