The spatial relationship between tuberculosis and alcohol outlets in the township of Mamelodi, South Africa

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Abstract

Background: The availability of alcohol in society is known to increase the risk of a range of negative health outcomes.

Objectives: The aim of this research is to determine if there is a spatial association between tuberculosis and alcohol outlets in Mamelodi, South Africa. We also aim to examine whether the socio-economic characteristics of the neighbourhood in which an alcohol outlet was located was related to the magnitude of tuberculosis in the immediate vicinity of the alcohol outlet.

Methods: Location quotient analysis is used to compare the extent of tuberculosis within a series of buffer intervals (100m, 200m, 300m) immediately surrounding alcohol outlets with tuberculosis across the township of Mamelodi as a whole.

Results: The density of tuberculosis around alcohol outlets in Mamelodi at all buffer distances was found to be substantially higher than across the township as a whole. These findings indicate that the risk of tuberculosis in Mamelodi is higher around alcohol outlets. Alcohol outlets located in more deprived areas of Mamelodi were significantly associated with higher density of tuberculosis relative to alcohol outlets located in more affluent neighbourhoods.

Conclusion: Despite alcohol outlets forming an integral part of the urban landscape in townships in South Africa, they may facilitate the transmission of tuberculosis.

Keywords: Tuberculosis and alcohol outlets; Mamelodi; South Africa.

Introduction

Tuberculosis is a preventable and curable disease that affects roughly one-third of the global population. African countries are, however, disproportionately affected with tuberculosis rates well above the global average. Within Africa, South Africa has the highest annual incidence of tuberculosis with a rate of approximately 520 incidents per 100,000 population. The reason for the high rates of tuberculosis in South Africa are myriad and have previously been attributed to factors such as poverty, pollution, overcrowding, malnutrition, the remoteness of health facilities, poor health care programmes and the co-occurrence with other diseases such as HIV/AIDS. Although some research has been done examining the risk factors associated with tuberculosis in South Africa, very little is known how the prevalence of the disease in the country is impacted by the availability of alcohol. Alcohol usage has been identified as one of the key risk factors for a number of communicable diseases including tuberculosis, yet the specific spatial linkage between tuberculosis and the presence of alcohol outlets in South Africa has yet to be empirically determined. The main aim of this research is to determine if there is a spatial association between tuberculosis and alcohol outlets in one township community in the city of Tshwane of South Africa, namely Mamelodi. Specifically, we are interested in examining whether tuberculosis spatially clusters around alcohol outlets in the township and aim to determine whether the underlying socio-demographics of the neighbourhood in which the alcohol outlet occurs influences this association. We use point

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level tuberculosis data and a novel geospatial technique to examine the diffusion of tuberculosis around alcohol outlets in this unique post-apartheid setting.

**Risk factors for tuberculosis**

Similar to international studies, factors influencing tuberculosis prevalence in South Africa span the social, economic, health/lifestyle and built environments. In terms of the social environment common risk factors include overcrowding\(^{10,11}\), roof leakage\(^{12}\), air pollution\(^{13}\), and smoking\(^{14}\), among numerous others. From an economic perspective, the poor\(^{5}\), deprived\(^{15}\), and unemployed\(^{16}\) are at a greater risk of tuberculosis in South Africa as well as those with the least access to healthcare facilities\(^{17}\). Indeed, the provision of adequate healthcare facilities in South Africa is a major challenge especially in the most remote areas. This is especially problematic given the fact that individuals who live in remote areas most often have to travel long distances which means the patient has to pay more out-of-pocket costs to seek medical treatment and care\(^{18}\). Other related factors such as the lack of education and health-related knowledge have also been considered risk factors for tuberculosis in South Africa\(^{19,20}\) together with various other health and lifestyle factors\(^{5,14}\). This is especially true for communities such as Mamelodi, a South African township that was developed under apartheid. Apartheid spatial planning laws separated people based on race and resulted in areas that were historically designated as a black African being under-serviced and under-resourced - a problem that continues to the current day.

Although less common, a growing body of research on risk prediction for tuberculosis has identified significant relationships between various built environment factors and tuberculosis\(^{21-23}\). The notion here is that certain facilities in the built environment may facilitate the spread of the disease either through poor design (i.e., housing\(^{23}\)) or due to the fact that they promote social gatherings (i.e., churches\(^{22}\)). Like churches, alcohol outlets are places where people congregate in large numbers over several hours increasing the risk of transmission. The density of alcohol outlets in a neighbourhood has previously been found to be associated with a range of harms including crime\(^{24}\), domestic violence\(^{25}\), and risky sexual behaviour\(^{26}\). Previous public health research has also found that the increased availability of alcohol in an area can lead to a range of other negative physical and mental health outcomes including liver disease\(^{27}\), anxiety\(^{28}\), injuries\(^{29}\), depression\(^{30}\) and tuberculosis\(^{21-22,31}\). In terms of the latter a study by Munch\(^{21}\) found significant associations between tuberculosis and the number of shebeens (informal alcohol outlets) at the neighbourhood level in Cape Town while Murray et al.\(^{22}\) also found that shebeens posed a significantly high transmission risk for tuberculosis in Cape Town, particularly if located in overcrowded and impoverished areas of the city. Similar spatial associations between drinking outlets and the risk of tuberculosis infection have been found the United States\(^{8}\). While it is increasingly clear that access to alcohol has harmful effects on the population what is less clear is the extent to which geographic access and/or proximity to alcohol outlets is related to tuberculosis at the micro-level. Moreover, most prior research investigating this linkage in South Africa has also been confined to the Western Cape province and has been undertaken at an aggregate level. In this study we aim to employ a number of geospatial techniques to determine the point-based spatial association between alcohol outlet locations and tuberculosis. We also aim to determine whether the underlying socio-demographics of the areas influences this association in any way.

**Methods**

Data on the location of tuberculosis incidents in Mamelodi was obtained from the University of Pretoria’s (UP) Department of Family Medicine. The Department of Family Medicine obtained point-based tuberculosis information for Mamelodi through their collaboration with the City of Tshwane Metropolitan Municipality’s implementation of a Community Oriented Primary Care (COPC) system in the city. The so-called COPC system involves defining geographic areas, otherwise known as wards, and having community health workers collect health-related information pertaining to individuals in each ward with the ultimate aim to use the information obtained to develop and implement community-based health interventions. COPC is a proven approach to primary healthcare that has been successfully implemented throughout the world\(^{32-35}\). In 2013, the City of Tshwane in collaboration with the Department of Family Medicine at UP initiated COPC by rolling out 23 Ward Based Outreach Teams (WBOT). The first household visits were conducted in August 2014 using a mobile-based health application. In total, the WBOTs collected information of 310,844 individuals across Tshwane including Mamelodi – the study site for this research. The points that fell within the boundaries of Mamelodi were clipped
from the total dataset resulting in a total of 115,188 indi-
viduals used in the study. After removing null entries and
entries which had no GPS coordinates, the total sample
of citizen information collected by the WBOTs in Ma-
melodi was 114,348 individuals. From the survey, three
questions were identified as being relevant for the pur-
poses of this research
1) Is anyone in the household currently taking tubercu-
losis medication?
2) Has anyone in the household been diagnosed with
tuberculosis but is not yet taking tuberculosis medicine?
3) Does anyone in the household exhibit symptoms of
tuberculosis?
A total of 1742 individuals answered ‘yes’ to any one of
these questions. In instances where respondents answered
yes to more than one question, only one data point was
recorded. The 1742 points were extracted and mapped.
Ethical approval for this research was obtained from the
University of Pretoria’s Faculty of Natural and Agricul-
tural Sciences research ethics committee (approval num-
ber EC170612-128).

Data on alcohol outlets in Mamelodi were collected
during a number of field trips to the township. An ex-
haustive data capture exercise resulted in the geo-location
of 138 alcohol outlets being captured using a mobile web
mapping application. The socio-demographic data used
to construct a deprivation index for Mamelodi was ob-
tained from Statistics South Africa. The most recent cen-
sus for South Africa was undertaken in 2011 and the data
recorded in this census was used in the study to construct
a deprivation index for the township at the sub-place lev-
el of aggregation. This level of aggregation is the fin-
est level at which census data is publicly and exhaustively
released; each sub-place consists of between 150 – 300
households.

In this study location quotients (LQs) were employed to
compare the extent of tuberculosis around alcohol outlets
and their immediate surrounding areas, relative to other
areas across the township. Location quotients provide a
measure that indicates how different an individual area
of interest is relative to the total area under investigation.
In the context of this study, a LQ would show the extent
to which tuberculosis incidences surrounding an alcohol
outlet depart from the overall proportion of tuberculosis
occurring throughout Mamelodi as a whole. For example,
if an alcohol outlet or the area surrounding an alcohol
outlet in Mamelodi has a LQ of 1, then that area has

\[
\text{LQ}_{Ge} = \frac{Ge}{Ae} \div \left( \sum Ge \div \sum A \right)
\]

where \( Ge \) is the count of tuberculosis locations in each
research unit (e.g. alcohol outlet, or buffers around an
alcohol outlet), \( Ae \) is the area of the corresponding re-
search unit. \( \sum Ge \) indicates the total count of tuberculosis
incidents in the whole township, and \( \sum \) is the total area
of Mamelodi.

In the study, we calculated LQs for a series of buffer
intervals immediately surrounding alcohol outlets. This
was done in order to determine whether the impact of
alcohol outlets on tuberculosis in the areas immediately
adjacent to them. We were interested in determining
whether individuals that reside closer to an alcohol outlet
are at greater risk (spatial diffusion). Buffer intervals of
100 meters, 200 meters and 300 meters were constructed
around each alcohol outlet because that distance approx-
imates on average the length of a city block in Mamelodi
although these can vary considerably. The density of tu-
berculosis in these three zones (i.e., 100m; 200m; 300m)
are then compared to the density of tuberculosis for the
entire township of Mamelodi and represented as a LQ.
We also conducted a sensitivity analysis to test our results
against the extent of tuberculosis around a randomly se-
lected set of 100 locations throughout the township. For
each of these 100 randomly selected point locations, we
constructed a 300-meter buffer (broadly approximating
a city block in Mamelodi) and calculated LQs for these
areas. A comparison of tuberculosis across this ‘control’
group of 100 random locations with the 138 alcohol out-
lets allows us to be more certain of our findings and pro-
vides additional validity to the study.

Finally, we were interested in determining whether the
socio-economic characteristics of the neighbourhood in
which an alcohol outlet was located was related to the
magnitude of tuberculosis in the immediate vicinity of the alcohol outlet. It could be, for instance, that alcohol outlets located in less affluent neighbourhoods are more likely to be have a greater risk of tuberculosis occurrence in surrounding areas and that by aggregating all the alcohol outlets together in our analysis we lose the ability to unmask this association. In order to do this, we constructed a deprivation index using principal components analysis (PCA) and ascribed a deprivation score to each neighbourhood (sub-place) in Mamelodi. The PCA was run on four variables commonly used to measure levels of neighbourhood-level deprivation, namely, 1) the number of people with no income, 2) the number of people who are unemployed, 3) the number of people without grade 12 and above and, 4) the number of people with one room per household. The PCA identified four components explaining roughly 95% of the variance. The first component explained 94% of the variance and was used as the deprivation score per neighbourhood. LQs for each alcohol outlet were then calculated and averaged per neighbourhood deprivation quintile.

**Results**

The results of the LQ analysis are presented in table 1. Overall, the density of tuberculosis around alcohol outlets in Mamelodi at all buffer distances was found to be substantially higher than across the township as a whole (range 1.37-1.47). These findings indicate that the risk of tuberculosis in Mamelodi is higher around alcohol outlets. Interestingly there is no gradient in tuberculosis incidence as the distance from an alcohol outlet increased; in fact, there is a slight decrease in tuberculosis at the 300-meter buffer (LQ = 1.37) compared with the 200-meter buffer (1.47).

| Environment          | LQ       |
|----------------------|----------|
| 100m buffer          | 1.41     |
| 200m buffer          | 1.47     |
| 300m buffer          | 1.37     |
| Random points (100m) | 1.05     |

**Table 1:** Location quotients of TB around alcohol outlets (n = 138)

An examination of the relationship between the socio-economic characteristics of the neighbourhood in which the alcohol outlet was located and LQ of tuberculosis shows no noticeable socio-economic gradient (see Table 2). The average LQ values in quintile 5 (most deprived) were lower than the average LQ values in quintile 4 but greater than the average LQ values in quintile 3 (middle class). Interestingly, the highest average LQ values were found in quintile 2 (affluent).

| Overall | Low | High | Q5:Q1 | p-value |
|---------|-----|------|-------|---------|
|         | Q1  | Q2   | Q3    | Q4      | Q5      |       |
| 100m buffer | 1.41| 0.00 | 2.55  | 0.99    | 1.60    | 1.06   | - 0.04*|
| 200m buffer | 1.47| 0.65 | 3.38  | 0.52    | 1.36    | 1.05   | 1.62  | 0.04*|
| 300m buffer | 1.37| 0.64 | 2.52  | 0.90    | 1.42    | 1.16   | 1.81  | 0.01*|

Note: *p<0.05, **p>0.05
NOTE: There were no incidences of tuberculosis within 100 metres of an alcohol outlet in neighbourhoods in quintile 1 – hence the zero value

Discussion
The results of our research show that there is a higher density of tuberculosis around alcohol outlets at all buffer distances than Mamelodi as a whole, although there was no monotonic increase nor decrease in tuberculosis as the distance from the alcohol outlet increased. We also found some evidence that the socio-economic background of the neighbourhood in which the alcohol outlet was located significantly associated with occurrence of tuberculosis. Specifically alcohol outlets located in neighbourhoods in quintile 2 exhibited the highest density of tuberculosis on average. It is difficult to compare the results of this research with past research given the limited amount of studies that have examined this association as well as the contextual differences between Mamelodi and other cities. Previous ecological research has however shown that neighbourhoods with higher rates of alcohol outlets consume more alcohol which may increase the risk of tuberculosis transmission\(^1\)\(^,\)\(^2\). This may occur because of increased interaction between people in drinking locations and/or because excessive drinking may lower the body’s immune system making infection more susceptible.

One possible reason for the increased density of tuberculosis incidents around alcohol outlets found in our study could be due to the increased mobility in settings such as Mamelodi which have experienced significant inter- and intra-migration since democracy as the associated intermingling of residents across income groups. Past research has found how these types of migration behaviours could increase the risk of tuberculosis\(^1\)\(^,\)\(^2\). Overall, however, there were in general higher rates of tuberculosis in alcohol outlets located in poorer neighbourhoods. This finding is supported past some research which has found an increase in tuberculosis in more deprived neighbourhoods\(^3\)\(^,\)\(^4\). In contrast, in this study however we found the association between tuberculosis and alcohol outlets is more pronounced in more deprived neighbourhoods, adding to the extant literature.

One notable limitation of our study was that we did not take the underlying environmental backcloth into account in our analysis. That is, it could be that the spatial clustering of tuberculosis around alcohol outlets may simply reflect the broader processes (encompassing built, social, cultural and other factors) that are playing out at the neighbourhood level and may not be related to the presence of alcohol outlets themselves. This concern has validity, however, much of the appeal of location quotients lies in its simplicity. The technique is not analytical but is a purely descriptive measure which allows users to determine more broadly where a phenomenon is spatially clustered. Using this technique we found that the density of tuberculosis is greater in the areas surrounding alcohol outlets when compared to Mamelodi as a whole. Future research can aim to incorporate additional confounders into subsequent analysis to supplement the work done in this study.

Conclusion
This study represents the first empirical attempt to investigate the spatial association between tuberculosis and alcohol outlets at the point-based level in South Africa. Previous literature has examined tuberculosis prevalence either at the aggregate level or examined the phenomenon in association to a number of places where individuals congregate such as community halls, or churches. Alcohol outlets in Mamelodi form an integral part of the informal economy and are an essential means by which a number of households earn a living. They are therefore a permanent and necessary feature of the urban landscape. The results of our research however indicate that they may facilitate the transmission of tuberculosis, at least in
Mamelodi, which may be exacerbated in more deprived
neighbourhoods. Further research could aim to investi-
gate whether it is the mere purchase of alcohol from out-
lets or the consumption of alcohol at these outlets that
increase the spatial risk. Studies in other contexts both
in South Africa specifically, and Africa more generally,
would also be of value.

Acknowledgements
None.

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