Ecological Study of the Variations in Tuberculosis Case Notification Rates Among the Namibian Health Districts.

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Abstract

Tuberculosis (TB) is one of the oldest public health problems worldwide. The Case notification rate in various countries around the world varies due to different ecological factors. The main objective of this study was to evaluate the ecological factors that are contributing to the variation in the TB Case Notification Rate (CNR) among the 34 health districts in Namibia.

Methods

The descriptive analysis and statistical modelling were applied; the Pearson correlation was also performed to test the strength of relationship between the variables. Ten independent and one dependent variable were used. In selecting the best model fit, a backward elimination method was used as the model selection criteria. In this case, all the potential predictor variables were entered in the model and then dropped from the model one by one if they were found not to be significant at a predetermined level of significance which is 5 per cent.

Results

The study observed that for every unit increase in the average maximum temperature, the TB CNR increases by approximately 27 cases. However, in contrast a unit increase in the average minimum temperature results in a decrease of about 77 cases in the district TB CNR.

Conclusion

The study found that although there were many predictor variables that could be interrelated to TB CNR, average minimum and maximum temperatures were the only variables that were found to have a significant association in terms of explaining the variation in TB CNR. The study concludes that more studies need to be conducted to further explore the possibility of the effect of global warming which has become a global phenomenon, as a possible precipitating factor to the TB pandemic.

Key words: TB, Case notification rate, District, Variation

Introduction

Tuberculosis (TB) is one of the oldest public health problems worldwide. TB affects the health of millions of people and it was declared a global emergency in 1993 by the WHO [1]. Over two billion people were estimated to be infected by TB globally, 9.4 million new cases of TB were reported, while about 1.7 million people were estimated to have lost their lives to TB in 2013 [2,3].

By the end of 2013, 8.6 million incidences of TB were reported [3]. The report further states that, even though most TB cases and deaths occur among men, women are more burdened by the disease than men [4]. South Eastern Asia and West Pacific regions accounted for fifty eight percent (58%) of TB whereas the Africa region reported a quarter of the total cases [5]. The report further indicates that the African continent has the highest TB Case Notification Rate [5]. Sub-Saharan Africa accounted for 25% of all the reported cases of TB in 2013 and TB was reported to be the leading cause of death in Africa in spite of treatment [6].

Namibia remains among the countries with the highest per capita TB burden in the world [7]. The Case Notification Rate of TB in Namibia was 442 per 100,000 in 2014 data indicating [7]. According to the same report, Namibia was ranked as the fourth nation with the highest TB CNR in the world, just below Swaziland in the first place, South Africa in the second place and Sierra Leone in the third place [7]. The distribution of TB cases in the country is not uniform, with the majority of cases being reported in Khomas, Ohangwena and Erongo [7].

Although the country is rated fourth in the world and third in Southern Africa, there has been steady decline in TB CNR over the years.

The Namibian health system follows a decentralization system whereby all health activities have been decentralized at regional levels and further cascaded to the health districts. There are 34 health districts which are prominently present in all 14 regions. The districts catchment population is made up of the population of all constituencies served by the districts.[7]

Although, there has been a slight decline in TB CNR in Namibia, the rate remains very high at 566 across the health districts [7]. This has been more prominent in some districts in comparison to others. However, in its aim to curb TB, Namibia adopted the WHO's Directly Observed Treatment Short Course (DOTS) strategy which is the most cost-effective public health approach to TB control and management. The five elements of the DOTS strategy are to sustained political commitment to TB control expressed in terms of adequate human and financial resources, access to quality-assured network of sputum smear microscopy, standardized short-course chemotherapy for all cases of TB under proper case management conditions, including directly observed treatment, uninterrupted supply of quality-assured anti-TB medicines and recording and reporting system enabling treatment outcome assessment of all patients and assessment of overall programme performance [5]. This strategy is also incorporated in Tuberculosis Medium Term Plan II (MTP II) which is geared towards the reduction of TB in Namibia

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PROBLEM STATEMENT

Despite the progress made in the implementation of Tuberculosis (MTP1), TB remains a communicable disease of major public health concern in Namibia. In addition to its direct contribution to morbidity and mortality, TB also has a negative social, economic impact on individuals, families, and society at large since it primarily affects economically productive age groups. The existing high prevalence of TB and HIV co-infection as outlined in the National Tuberculosis report of 2013 by the MOHSS further aggravates the situation [7]. In Namibia, there is considerable district variation in TB CNR. The reasons for such variation have not been studied or explained. This therefore warranted an investigation to determine the causes of these district variations and their contributing factors as it could greatly assist in the control and management of TB in the country and successful implementation of TB-MTP II.

Aim of the study

The aim of this study was to evaluate the ecological factors that are contributing to the variation in the TB CNR among the 34 health districts in Namibia.

Research objectives

The objectives of the study were to:

- Evaluate the potential role of availability and quality of district TB services in explaining the variance in district CNRs.
- Evaluate the potential role of the socio-economic characteristics i.e. income, GDP, population under poverty line, degree of urbanization, population proportion living in informal settlements in relation to variation of district TB CNRs
- Evaluate the potential role of variation in behavioral factors of the population by district i.e. substance abuse, HIV, diabetes, smoking and malnutrition as contributing to the notified TB burden.
- Evaluate the potential role of cultural characteristics i.e. stigma, use of traditional medicine and migration in relation to variation of district TB CNRs
- Evaluate the potential role of climatic conditions in explaining the variation in district TB CNRs

Significance of the study

This study aims at exploring factors contributing to the variance of TB CNR at health district levels in Namibia. The findings of this study would assist in selecting TB control measures to reduce the burden of TB in Namibia. The findings will further enhance the implementation of efficient and effective management of TB cases at the district level. The implementation of the recommendations of the study will also assist the country in reaching its Sustainable

Development Goals. Furthermore, this study is the first of its kind and hence the resulting outcome can provide further opportunity for a more careful in depth designed studies.

METHODS

The research was an ecological study of a geographical design in nature as it is defined by the national health district as the unit of analysis. This study used quantitative method and in particular, the study compares one health district to another in terms of the variation in the TB CNR for the year 2011. As such, exposures at district level was measured and adjusted in the analysis as well as other potential confounding variables such as demographic and or socio-economic attributes. An advantage of the ecological study is that, it can be carried out to the lesser extend more quickly, easily and at low cost by using data that are generally routinely collected and readily available.[8]

Target population

The target population for this study comprised of all the district health catchment area populations, which is made up of the respective constituency level or regional populations.

Sampling and sample size

The study used secondary data sets from several sources among them the 2011/12 Namibia national annual TB Reports, 2011 Namibia population and Housing Census report as well as the Namibian Meteorological services. Data sets analyzed were for 2012. As a result, no sampling was involved as all the available statistics formed part of the analysis and all the 34 health districts in Namibia were included in the study. It is further important to point out that the study looked at a high level of aggregation, namely district level as opposed to the individual level as the preferred units of analysis.

Data collection procedure

The study used secondary data sets collected from the TB reports. Though the reports were officially published and were already in the public domain, prior approval to use the information from the reports was sought from the relevant authorities and stakeholders who are the custodians of this data.

Data analysis

The data collected were entered SPSS version 23 respectively. In analyzing the data, several approaches such as the descriptive analysis and statistical modeling were implemented. In particular it is important to note that all the variables selected for the study were scale variables. As such, the descriptive analysis was used in describing the distribution of the independent variables in terms of the measure of central tendency such as the average and their 95% confidence intervals, distributions based on the histograms as well as the scatter plots matrix that relates the district TB CNR to a set of predictor variables in order to determine the existing relationships.

Correlations test particularly the Pearson correlation was performed in order to ascertain the strength of the relationships. Let us denote the response variable by Y and the set of predictors by X , then the mathematical model for calculating the Pearson correlation (r_{XY}) between any two given variables is given by:

$$r_{XY} = \frac{n\sum XY - \left(\sum X \sum Y\right)}{\sqrt{n\left(\sum X^2\right) - \left(\sum X\right)^2}\sqrt{n\sum Y^2 - \left(\sum Y\right)^2}} \qquad [1]$$

In the evaluation of the predictors that are contributing to the variation in the TB CNR among the 34 health district in Namibia, a Univariate linear regression model was fitted. This model was used to evaluate the significance of each of the predictor in predicting the variation in the TB CNR. The Univariate model took on the following form:

$$\hat{y}_i = \beta_0 + \beta_1 x_i, \quad i = 1,2,\ldots,n \qquad [2]$$

Where y_i was the specific case notification rate in the health district i , β_0 represented the model intercept, while β_1 represented the slope of the regression line indicating the change in the case notification rate for every unit increase in the predictor x_i. Predictors with a significant value of 0.1 in the Univariate analysis were then entered in the multivariable models. The above model was then further expanded to incorporate multiple predictor variables to form a multivariate regression model, which took the following form:

$$\hat{y}_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \ldots + \beta_j x_{ij}, \quad j = 1,2,\ldots,k \qquad [3]$$

Where y and they $\beta^{'s}$ are as described in model 2 above, while the j represents the number of predictors in the model. In both equation [2] and [3], the errors were assumed to be normally distributed with a mean 0 and a variance σ^2 $\left(i.e. \quad \varepsilon_i \sim N\left(0, \sigma^2\right)\right)$ and the model parameters $\beta_i^{'s}$ were estimated from the data.

In selecting the best model fit, a backward elimination method was used as the model selection criteria. The resulting model was then assessed for the presence of multicollinearity and its resulting effects. Multicollinearity or inter-correlation is the situation that arises as a result of the correlation among the predictor variables. This occurs because aggregated socio-economic variables are likely to be more similar among districts, even if they do vary a lot within the district. Therefore, in testing for multicollinearity a variance inflation factor (VIF) measure was used, where the values of VIF approximately equal to 1 indicates no multicollinearity among the predictor variables left in the model.

Ethical consideration

Ethical clearance for the study was sought from the Mo HSS and the approval letter was forwarded to all 34 health districts in the country prior to the data collection process. Confidentiality and anonymity of the collected data was ensured at all times. To ensure anonymity, identifiers were removed from the data and codes were used. The collected statistics were entered in Epi Data and were password protected before exported into SPSS for analyses in order to ensure that no unauthorized persons access the information.

Results

The study had identified 39 variables, and the research team could only analyze data for 24 variables, representing about 62 percent of the total variables at district level. On the contrary, for the 15 variables that could not be analyzed 11 of them had data which were aggregated only at regional level. This made it difficult for the team to disaggregate them to district level. In addition, 4 variables had no data in general at any level.

Quality of health care

The result presents the outcome of the descriptive statistics for the variables of interest. In the table, the column entries describe the variables in terms of the mean occurring, the mode as well as the respective standard deviation of the mean.

Result from table 1, shows that on average most districts wait for about 6 days to get the results with most of them getting their results within 72 hours. Ninety five percent of facilities in the 34 health districts offer TB treatment whereas only 50 percent of facilities offer ART services. On average, the TB completion per district is 12.3 percent while the defaulter and failure rate is quite low at 3 and 4 percent respectively. This is within the WHO target which is set at 5 percent. The average prevalence rate of TB patients infected with the HIV virus was estimated to be around 17, while the TB treatment recorded an average success rate of close to 86 percent.

The study further investigated the relationship between TB CNR and the predictor variables of interest. A positive correlation was found between TB CNR and Cure rate with a borderline significant value of 0.058. Another positive correlation was found between TB CNR and facilities offering ARV (p-value = 0.014). Moreover, a negative correlation was found between TB CNR and TB patients on ARV (p-value = 0.025).

On the contrary there is a multi-correlation among some independent variables that had no significant relationship with TB CNR such as TB HIV prevalence and the following variables: MDR with a significant value of 0.046, trained staff with a significance value of 0.032. The correlation is between treatment success rate and defaulter rate with a high significance value of 0.000, failure rate with a significance value of 0.001, cure rate with a significance value of 0.000 and death rate with a high significance value of 0.001.

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Furthermore, a significance correlation is also observed between Cure rate and completion rate (p-value = 0.000), transfer out (p-value = 0.029) as well as death rate (p-value = 0 .016). Transfer out has a multi-correlation with MDR (p-value = 0.033) and trained staff (p-value = 0.001). Other uni-correlation exist between failure rate and MDR (p-value = 0.042), MDR and trained staff which is highly significant (p-value = 0.000) and finally facility offering ARV and death rate where the p-value was recorded to be a borderline significance value of 0.057.

Socio economic factors

Table 1 below presents the descriptive statistics of the socio economics variables of interest. The results indicates that 15 percent of the population in the health districts lives in shacks, while on average most of the households in the 34 districts are less overcrowded having an average of 2 persons per sleeping room. On average the Namibian health district serves a catchment population density of 11 persons per square kilometer.

Table 1: Descriptive statistics

Socio-economic factors	**Average**	**Mode**	**Std dev**	**Skewed**
Proportion of Shacks	14.695	-	11.8472	0.201
District Density	11.007	4	22.7412	3.390
Average Sleeping room	1.648	1.2	0.277	0.22

Furthermore, table 2 presents the evaluation of the associations between the socio economic variables in the study. The results showed a positive correlation between the proportion of shacks and TB CNR which was found to be highly significant (p-value 0.001). Other correlations between TB CNR and District density, average person per sleeping as well as among the variable were not found to be significant at the 5 percent level of significance.

Table: 2: Evaluation of associations among variables

	TBCNR	Proportion of Shacks	District Density	Average Person per room
TB CNR	1			
Proportion of Shacks	**.529** .001*****	1		
District Density	**-.056**	**-.205**	1	

	.755	.246		
Average Person per room	**.265** .130	**.175** .323	**-.177** .318	1

***** Correlation is significant at 5% level

Cultural and behavioural factors

The result indicates a high malnutrition rate among the under-five at an average of 77 percent which is observed among the districts. Moreover, about 16 percent of people in the districts suffer from diabetes whereas 12 percent of the population abuse substances.

For the association between the variables, the result indicates no significant correlation between TB CNR and the predictor variables (figure 1). The study however observed that there was a relationship between the proportion of people with Diabetic and Malnutrition which was significant as well as a high significant relationship was observed between the proportion of people with Diabetes per district and the proportion of substance abuse.

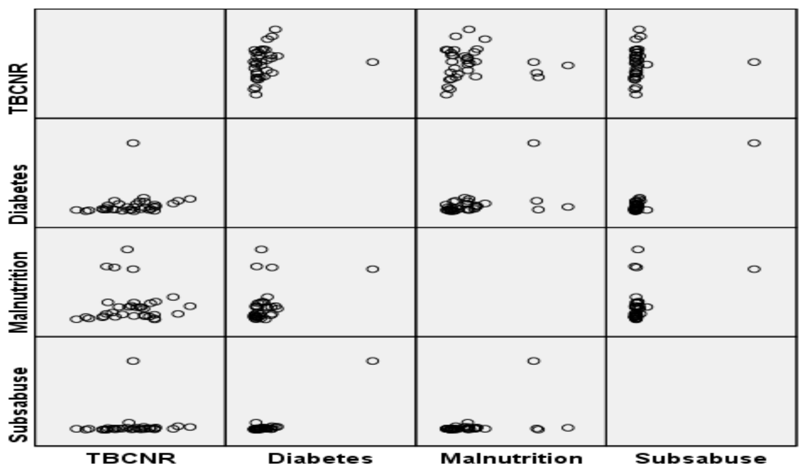


Figure: 1 Evaluation of associations among variables

Climatic conditions

The descriptive statistics of the climatic conditions showed that in terms of the environmental aspects, the average minimum temperature in the districts was 13^{o}C, which also appear to be the minimum temperature of most districts. Similarly, the average maximum temperatures recorded in districts during the period under study were 26^{o}C with 19^{o}C recorded in most districts. The results further show that most of the health districts in Namibia received an annual rainfall of 288 mm.

The associations between the variables in figure 2 below reveals that a positive correlation exists between average maximum temperature and TB CNR with a significant p-value of 0.015. The study further investigated the relationship between TB CNR and average minimum temperature and annual rainfall, where a negative correlation was observed, however in both cases it was found not to be significant.

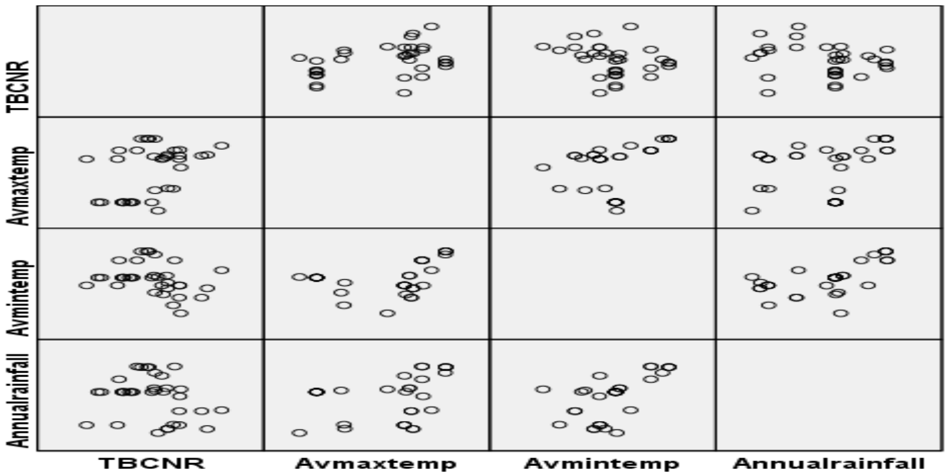


Figure: 2 Evaluation of associations among variables

Additionally, in evaluating the role of the annual rainfall in advancing the TB CNR among the health districts in Namibia, the results presented in the line graphs in figure 3 below confirm no significant correlation (p-value = 0.187) although a negative co-existence (r = -0.232) was observed. Furthermore, the resulting trend indicates a lack of linearity between the two variables, however, a fluctuating pattern which is consistent with inconsistent rainfall received in Namibia over the last couple of years is observed.

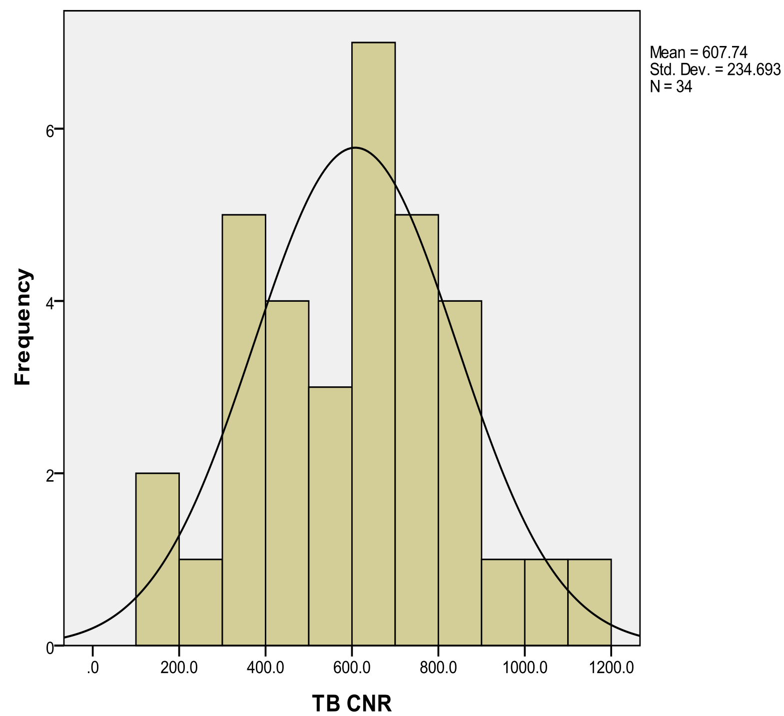
Figure 3**:** Line graph depicting the relationship between TB CNR and annual rainfall

Modeling the TB CNR

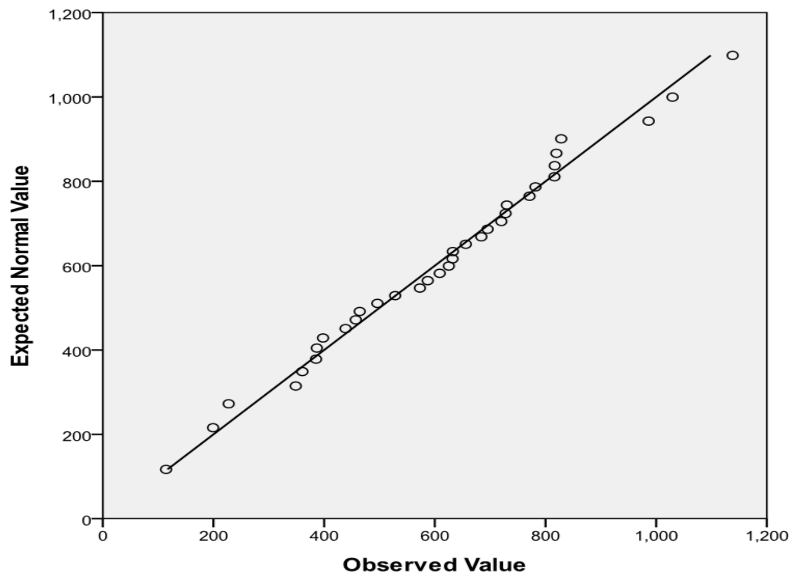
In determining the factors that are contributing to the variation in the district TB CNR, two approaches were implemented. These were the Univariate and multivariate modeling of TB CNR. However before the models were fitted, we first evaluated the response variable in order to determine if it is normally distributed, as one of the model assumption pertaining to linear modeling is that the distribution of the response variable should follow a normally distribution. Hence normality becomes a central aspect of the model.

Therefore, in doing so, three normality evaluation approaches were used namely by first plotting the histogram with a normal curve, secondly calculated and plotted the normal quartiles (Normal Q-Q Plot) based on the response variable and finally plotting the de trended Normal Q-Q plot of TB CNR. The resulting three graphs were presented in figure (i) to (iii) and 4 below.

(i) Histogram with the normal curve



(ii) Normal Q-Q plot of TB CNR



(iii)Detrended Normal Q-Q plot

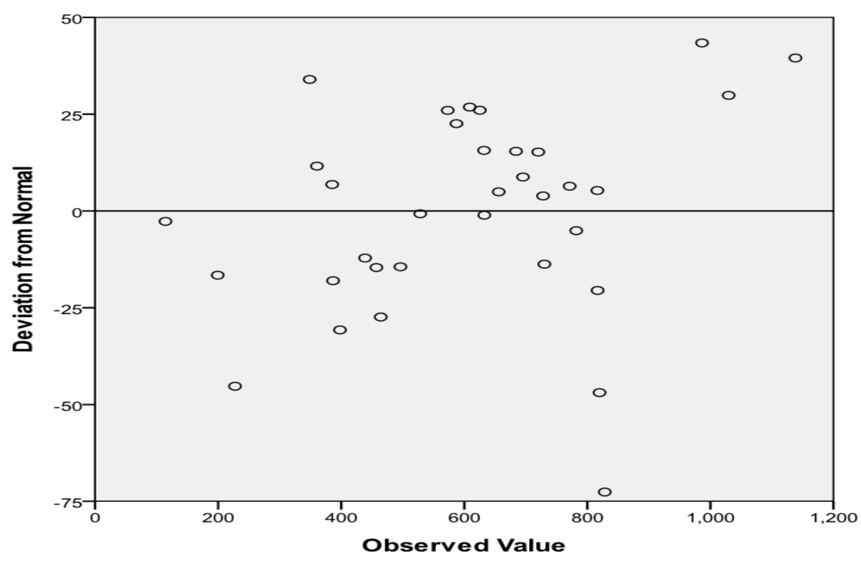


Figure 4: Normality evaluation for the response variable TB CNR

Both graphs collectively indicated that there is no serious deviation from normality for the TB CNR. In particular, the normal Q-Q plot show that the TB CNR quartiles are within the accepted normal band as the plotted points falls in close proximity of the normal line. Furthermore, the

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results of the detrended normal Q-Q plot show no serious deviation from normality as the plotted points are fairly equally distributed around the center line. Therefore, it is safe to conclude that the TB CNR variable is normally distributed.

The Univariate linear regression model was then fitted using the enter method, and the resulting outcome of the model fit was presented. In the table, the entries represent the variables of interest organized by the core objective areas and the corresponding significant values.

The result from the table shows that predictor variables such as the treatment completion rate, the percentage of facilities offering ART treatment, TB patients on ARV treatment, the proportion of shacks and the average maximum temperature were the variables that were found to be significantly contributing to the TB CNR in a Univariate case at the 5 percent level of significance. Furthermore, there were also borderline cases for variable such as cure rate (p-value = 0.058). This predictor was also included into the multivariate linear regression model. As a result of model selection process, the variables that were found to be significant in the multivariate regression model were the average maximum and minimum temperatures. The resulting test of the significance of the model fit is presented in the ANOVA table in table 6. The result indicates that the regression model with the two parameters appears to be a good fit having a p – value of 0.000.

Table 3: ANOVA table

Model	Sims of Squares	Df	Mean Squares	F	Sig
Regression	1162768.361	6	193794.727	7.990	0.000
Residual	654904.303	27	24255.715		
Total	1817672.665	33			

Furthermore, the resulting model parameter estimates were presented in Table 5 below. It is evident from the table that the two remaining variables were highly significant at the 5 percent level having the resulting p – values of 0.001 and 0.007 respectively.

Table 4: Model parameter estimates

Model parameter	Unstandardized Coefficients		Standardized Coefficients	Sig	95% C.I. for B	
	B	Std. Error	Beta		Lower bound	Upper bound
(Constant)	-781.225	235.835	-	0.003	-1265.118	-297.331

Cure rate	7.782	1.934	0.485	0.000	3.814	11.749
turn time	-12.473	4.947	-0.316	0.008	-22.623	-2.324
MDR	20.908	7.329	0.612	0.008	5.871	35.945
Trained staff	-9.497	3.271	-0.609	0.007	-16.208	-2.786
Facility offering ART treatment	5.542	1.266	0.619	0.000	2.944	8.140
Average maximum temperature	22.831	5.945	0.462	0.001	10.633	35.029

The resulting predictive regression model can therefore be written as follows:

TB_CNR^{i} = -781.225 + 7.782Cure_rate + 12.473Turn_time + 20.908MDR – 9.497Trained_staff + 5.542Facility_ART_treat + 22.831Ave_max_temp

It can be deduced from the model that TB CNR decreases by around 10 with every unit increase in the number of trained staff. In addition, cure rate, turnaround time, MDR, facility offering ART treatment and average maximum temperature results in increase in the TB CNR. The highest increase was observed for a unit change in the average maximum temperature and MDR which increase TB CNR by around 23 and 21 respectively. In contrast, cure rate has the least effect whereby a unit change results in about 8 points increase in the TB CNR.

The model summary presented in Table 5 below, shows that when the six predictor variables, cure rate, turnaround time, MDR, trained staff, facility offering ART treatment and average maximum temperatures total variation in the district TB CNR is reduced by 64 percent (R^2= 0. 640). It is also of note to point out here that adjusting for the number of predictor variables in the regression model accounts for slightly over half of the effect on the coefficient of multiple determination R^2 (Adjusted R^2 = 0.560).

Table 5: Model Summary

R	RSquare	Adjusted RSquare	Std. Error of the Estimate	Change Statistics	
				RSquare Change	F Change
0.800	0.640	0.560	155.743	0.640	7.990

Discussion

In our quest to explore the factors contributing to the variance in TB case notification among all health districts in Namibia, a correlation was observed between TB case notification and some predictor variables, in particular complete rate (p-value = 0.048), TB patients on ARV (p-value = 0.025), proportion of shacks (p=0.001) and average maximum temperature (p=0.015). Furthermore most of the 34 health districts were found to have an average of 15 percent of shacks. This means that a quarter of the population in most districts live in shacks according to the Namibia housing census report. Poor quality housing that are usually small in size and do not allow proper ventilation contribute to high TB transmission and progression. These results concur with the findings which indicated that poor quality housing and poor air quality within homes have been implicated in the spread and outcome of TB [9]. Although the average population density of districts is at 11 people per square kilometer, this is not relative to the setup of shacks in most of the districts that are densely concentrated in one area compared to quality structured houses. Moreover, although the national housing survey indicated that the average persons per sleeping room is 2 persons, this is more relevant to quality structured houses as opposed to shacks that are mostly smaller in size and poorly ventilated [10].

Namibia is a dry and semi-arid country mostly covered by the world driest desserts with fluctuating weather in some areas. The weather vary from the coastal town that experience misty and sand wind to other parts of the country that get either very cold or sometimes very hot which could probably be linked to global warming. During the period under study, the average of maximum temperature recorded was 26ºC [11]. It is a well-known fact that when the temperatures are hot, people tend to remain indoors to escape from the heat [12]. The outdoor temperature leads to poor ventilation which has an effect on TB transmission as reported also in the study by Canada communicable disease report of 2012 [9]. The situation is however more precipitated by the dry and dessert areas in some districts especially in the Southern part of Namibia.

The study also found a significant relationship between the maximum temperature and the average number of people per sleeping room which influence the TB CNR. However no direct association was found between the numbers of people per sleeping room and the high case notification rate.

On the contrary the study found that TB cases were associated with low temperature and wind speed [12]. This could elucidate the high TB rates in the western part of Namibia such as the coastal towns that are mostly cold with wind. Additionally our study found a significant relation between minimum temperature and annual rainfall. This however needs further study to substantiate these findings.

Similarly, a significant correlation was observed between minimum temperature and treatment success rate. The average minimum temperature that was recorded was 13ºC. This is a moderate temperature that allows for mobility, such as outdoor activities and adhering to TB follow up dates and other TB treatment related activities. This in turn does not only reduce the transmission of TB but it also contributes to a good treatment success rate. The study found that the average treatment success rate is 86% per district. This means that Namibia has to intensify efforts to attain and or surpass the WHO target set at 90% [13].

The study further found that there is negative relationship between treatment success rate and defaulter rate. This is highly expected since treatment success rate is expected to rise as defaulter rate decreases and vice versa. This finding affirms with a study that who found a high treatment success rate in areas where there was a high rate of TB defaulters [14].

The outcome of the multivariate linear regression model using the model selection criteria revealed that minimum and maximum temperatures were the only significant predictors of TB CNR among the 34 districts in Namibia. Although preliminary results have indicated that proportion of shacks was contributing to TB CNR in the Univariate case, it was found to be not significant in the presence of other predictor variables. These results further confirm the findings of the study which indicated that TB cases were associated with low temperature and wind speed [11].

Conclusions

In conclusion the study found that although there were many predictor variables that could be interrelated to TB CNR, average minimum and maximum temperatures were the only variables that were found to have a significant association in terms of explaining the variation in TB CNR. A unit increase in average maximum temperature increases the TB CNR by 27 while a unit rise in the average minimum temperature was found to decrease the TB CNR by 77. Furthermore, the study found no significant relationship between poor housing, overcrowding and TB CNR although the proportion of shacks which was a measure of poor housing in the study, was found to be significant at the Univariate level. The study also did not find any significant relationship between higher annual rainfall and high TB CNR.

Limitations of the study

The investigators faced limitations in the sense that the unit of analysis was at health district level however, most of the data were either not available at all, or were only available at regional level which made it difficult to disaggregate data to district level.

The researchers could not find latest literature on the use of traditional medicine to treat Tuberculosis. Moreover, on either the records on the number of traditional healers or activities carried out by them were not available.

Of the above mentioned variables that were removed from the data set, although most of them had data at regional level that could not be disaggregated at district or constituency levels, the following four indicator had no data capturing tools at any level thus no data at all: number of people who smoke, number of alcohol outlets, number of traditional authorities and number of people who were stigmatized against for having contracted Tuberculosis.

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