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GEOSPATIAL DISTRIBUTION OF TUBERCULOSIS CASES AND ACCESS TO HEALTHCARE IN BIRIM SOUTH DISTRICT

BY

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DECLARATION

I, **Kingsley Owusu** hereby declare that this dissertation is the results of my independent work under the supervision of Dr. Justice Moses K. Aheto. References to other works have been duly acknowledge. I take full responsibility for any shortcomings in this work.

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ABSTRACT

Introduction

Tuberculosis continues to be one of the communicable diseases which is associated with high deaths that usually affect people in developing countries. Tuberculosis, a disease cause by a bacterium known as *Mycobacterium tuberculosis* which can be transmitted from an infected person to another susceptible person through air. The disease is an important public health issue that does not have any respect for anybody because irrespective of where one resides whether in a developed country or developing county one can be infected. Tuberculosis can affect everyone but about 90% of the people who become infected with tuberculosis are usually adults.

Objectives

The main objective was to determine the spatial distribution of tuberculosis cases and access to healthcare in Birim South District of the Eastern Region with specific objectives of identifying clustering of tuberculosis cases in the district and to assess the geographical accessibility of healthcare for TB patients.

Methodology

A descriptive cross sectional study was used for this study. The study used census method since all patients who meet the inclusion criteria were used for the study. The study included all TB patients who were on treatment from January 2019 to July 2020. The pre-coded data were entered into excel, clean and later exported to STATA version 16 software for statistical analysis. Frequency distribution and percentages were used to compute the proportions for age, education level, sex, religion, and occupation. The mean age and mean distance in kilometers to health facilities and their respective standard deviations were computed. The spatial data (coordinates)

for place of residence and the health facilities was organized in excel and later exported to geographical information system (ArcGIS) version 10.7.1 software for spatial analysis.

Results

The findings reveal that the distribution of tuberculosis cases in the district was randomly distributed. The study also reveals that there was a substantial surge in the number of tuberculosis cases from 2017 to 2019. The study again shows that the geographical access to health care by tuberculosis patients was not a challenge as most 99.1%, 97.2% and 92.5% of the study participants were found within 5km, 3km and 2km radius respectively.

Conclusion

The district health directorate should conduct intensive health education on tuberculosis with emphasis on prevention in the district to decrease or reduce the spread of tuberculosis in the district. The district health directorate should conduct active case search in communities to detected and identify all possible cases in the communities for treatment

DEDICATION

I dedicate this piece of work to my wife, Ruth Anakwah Owusu, my lovely children Nana Adwoa Owusu-Apau and Ohene Nhyira Owusu-Nyarko, my siblings especially Diana Antwi Agyei, Elder Eric Kofi Peprah and Francis Sarkodie, my uncle Mr. Henry Awuah Gyau and to the memory of my late mother, Agnes Nyarko Serwaa.

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To my family and friends, thank you for your support and prayers. This research would not have been possible without the approval from the District Director of Health Services for Birim South District. I am grateful for giving me the opportunity to carry out this research in your district.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

AIDS	Acquired Immune Deficiency Syndrome
BCG	Bacillus Calmette Guérin
BMI	Body Mass Index
CHAG	Christian Health Association of Ghana
CHPS	Community Based Health Planning Service
DHMT	District Health Management Team
DOTS	Directly Observed Treatment Strategy
GIS	Geographical Information System
GPS	Global Positioning System
HIV	Human Immunodeficiency Virus
MBTC	Mycobacterium Complex
MDG	Millennium Development Goals
MDR-TB	Multi Drug Resistance Tuberculosis
RHD	Regional Health Directorate
TB	Tuberculosis
USA	United States of America
WHO	World Health Organization
XDR	Extensively Drug-Resistant

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the study

Tuberculosis continues to be one of the infectious diseases which has a high mortality that usually affect people in developing countries (Muniyandi et al., 2010). Tuberculosis is a disease cause by a bacterium known as *Mycobacterium tuberculosis* which can be transmitted from an infected person to another susceptible person through air and therefore described as airborne diseases. The disease even though can affect other parts of the body; it usually affects the lungs of the patients. It is reported that if tuberculosis is not identified early and treated, a single infected person who has active TB can spread the disease to 10-15 people every year leading to cycle of continuous infections(World Health Organization, 2019). It is estimated that every second, one person becomes infected with tuberculosis in the world. It is reported that 7 to 8 million persons fall sick and two million die from tuberculosis in the world yearly (WHO, 2019).

The disease is a major public health issue that has no respect for anybody irrespective of where one resides whether in a developed country or developing county. Tuberculosis can affect everyone in any part of the world but about 90% of the people who become infected with tuberculosis are usually adults. Universally, it is reported that about 10.0 million ranging from 9.0–11.1 million individuals became sick with TB in 2018, a number that is considered to be moderately steady presently. The occurrence of the infection differs tremendously among nations, ranging from less than five to about 500 new cases for every 100, 000 populace annually, with the worldwide average being around 130 (WHO, 2019).

The disease can affect individuals of both sexes of all ages however those who are affected most are the men who are more than 15 years who represented 57% of all tuberculosis cases that were recorded in 2018. By comparison, females represented 32% and children who are below 15 years accounted for less than 11%. Among all the TB cases, 8.6% were individuals who were positive for HIV (WHO, 2019). It is reported that majority of the population in the world are infected with *Mycobacterium tuberculosis* and about 10% are greater risk to developing active tuberculosis in their life (Ferrara et al., 2012).

Tuberculosis, considered as one of the significant worldwide charitable and developing issues resolved currently (Muniyandi & Singh, 2014). The disease is believed to be a disease of the poor in which most of the impact being felt by developing countries and the populations who are marginalized in the society. Whereas global occurrence is decreasing, the present percentage of reduction will not make it possible for countries to achieve the targets set by the World Health Assembly (Houben et al., 2016). It is reported that with an appropriate, timely diagnosis and early treatment, majority people who have the disease could be treated and therefore further transmission of the disease could be prevented. The disease symbolizes worldwide danger to public health with more than 9 million cases and 2 million deaths yearly. The number of new cases that occur yearly and the number of deaths related with TB can be reduced by preventing risk factors associated with tuberculosis (WHO, 2019). Reducing the impact of tuberculosis in the world is part of a wider developmental frameworks such as the Millennium Development Goals (MDGs). The Millennium Development Goals obviously stipulate that prevalence and deaths associated with TB must be resolved with a goal towards improvement in case detection rate and treatment success rate within directly observed treatment strategy (DOTS) (Muniyandi & Singh, 2014).

The emergence of HIV has actually increased the susceptibility of the people to the tuberculosis infections as it weakens the immunity of the infected person leading to the increase number of tuberculosis cases in the world. Human immunodeficiency virus (HIV) infection is a potential risk factor for deaths associated with people who have been infected with tuberculosis. It was reported that 30% of those who died in the course of being treated for tuberculosis were HIV positive patients. Timely HIV diagnosis is a significant step to prevent tuberculosis and deaths associated with HIV/TB. When HIV diagnosis are done early, it tells patients that they stand the risk of developing tuberculosis and therefore take appropriate measures to prevent the development of tuberculosis by taking prophylaxis (Kong, Watt, Marks, & Flood, 2014). In 2015, 10.4 million new tuberculosis cases were recorded in the whole world. Out of this number, 11.0% were co-infected with HIV and 22.2% of tuberculosis related deaths were reported to be TB–HIV co-infections (Aung et al., 2019).

Worldwide endeavors to reduce tuberculosis (TB) have been profoundly centered on further decreases in the occurrence and TB related mortality, just as the increases in the expenses on TB treatment (Kim et al., 2019). High drug-resistance levels have been reported by some countries with 3% and 12% in new and relapsed TB cases. Over the past decades, the world is on a strong cause towards reducing TB as a health problem. Nonetheless, global movement, labour migration and constant travel by people from endemic nations represent a continuous risk of importing TB and spread among community members (WHO, 2016).

The World Health Organization in 2014 accepted the End TB Strategy, an approach of getting rid of TB as a public health issue at the worldwide level by 2050. Significant progress in worldwide TB control will be accomplished just if profoundly viable, generally accessible preventive measures are in place as well as diagnostic methods and treatment of TB become accessible in a strengthen health system and are related with measures that focus on the social and other of the tuberculosis (WHO, 2016). Non availability of health care can cause delays in the diagnosis and ten (10) causes of mortality in the world and the key source of a single infectious agent (*Mycobacterium tuberculosis*), positioning above HIV/AIDS (WHO, 2019).

It is estimated that 1.7 billion individuals are infected with *Mycobacterium tuberculosis* and therefore have increased risk to develop active form of tuberculosis (WHO, 2016). There was an estimated 1.2 million tuberculosis related deaths among individuals who do not have HIV in 2018 which is a 27% decrease from 1.7 million since the year 2000 and an extra 251, 000 deaths among people who had HIV which is about 60% decrease from 620, 000 since 2000. Over 95% of tuberculosis deaths happen in developing countries (WHO, 2019). Continentally, majority of the tuberculosis cases reported in 2018 were from WHO districts of South-East Asia, Africa and Western Pacific with 44%, 24% and 18% respectively and lesser rates recorded in the Europe 3% the Americas 3% and Eastern Mediterranean 8%, (WHO, 2019).

Globally, tuberculosis affects the people who are mostly within the labour force. When an individual is suffering from tuberculosis, about three to four months of work time will be lost bringing about loss of around 20 to 30% of family unit income yearly. An average of 15 years of pay is lost if a person dies from the disease. In this way, the disease causes huge social and financial difficulties and impedes the progress of the nation (Muniyandi et al., 2010). The economic impact brought about by tuberculosis in the world is huge. There is no ambiguity that a debilitated workforce adds to an undesirable economy. On the average, the disease costs more than US$ 10 billion annually worldwide. Tuberculosis does not only reflect financial status, it propagates and worsen destitution. Poor workers and farmers stay poor in the event that they are unwell. Improving health is a solid and quantifiable method for decreasing neediness and disparity both at the nation and worldwide levels (Muniyandi et al., 2010).

Despite the various interventions being implemented by the local, international governments and other partners, tuberculosis continues to be a burden globally. In Ghana, report from Ghana Health Service indicates that 14,932 cases of tuberculosis were reported in the year 2016 representing 2.4% reduction when compared against the number of cases that were recorded in the year 2015 (Ghana Health Service, 2017). In the Eastern region of Ghana, the report from the regional health directorate indicates that 880 cases of smear positive TB cases were recorded in 2016 and 940 smear positive tuberculosis cases in 2017 with a defaulter rate of 4.2% and 3.9% respectively (Regional Health Directorate, 2018).

In Birim South, report from the district health directorate indicates that 45 TB cases were recorded in 2017, 62 cases recoded in 2018 and 76 cases recorded in 2019 representing an increase of 25%, 37.8% and 22.6% for 2017, 2018 and 2019 respectively (District Health Directorate, 2019). The statistics clearly indicate that the district continues to record a significant number of tuberculosis cases annually. This therefore requires specific strategies to be put in place to reduce the spread of the disease in the district. In order to come out with effective intervention that could curtail the spread of the tuberculosis, it would be appropriate to know where the tuberculosis cases are located in the district. However, the geographical distribution of tuberculosis cases in Birim South district that would provide evidence based data to support development of strategies to curb the spread of tuberculosis in the district has been studied. The distribution of tuberculosis in the district may vary geographically and therefore may require diverse approaches to tackle them and so knowing the areas where most of the tuberculosis cases are located in the district may influence the interventions development and allocation of resources to help curtail the spread of the disease in the district.

It was against this background that this study was conducted using the geographical information system (ArcGIS) to determine the geospatial distribution of TB cases and their accessibility to healthcare. Geographical information system has widely been used in various fields for investigations in many parts of the world particularly during disease outbreak investigations. However, only few studies have been able to use the geographical information system (GIS) to determine the distribution of tuberculosis cases in Ghana. This study therefore aims to use GIS to identify population at risk and high risk areas for tuberculosis so that interventions that are meant to reduce or prevent the incidence of tuberculosis can be channeled to these areas and also provide appropriate information for policy development.

1.3 General Objective

- To determine the geospatial distribution of tuberculosis cases and accessibility to healthcare in Birim South District of the Eastern Region

1.3.1 Specific Objectives

- To determine the spatial pattern of tuberculosis cases in Birim South District
- To determine whether there are clustering of tuberculosis cases in the district
- To assess the geographical accessibility of treatment centers for TB patients

1.4 Justification and Significance of the Study

The distance to treatment centers affects compliance to treatment and the compliance to treatment in turn affects treatment outcomes. The compliance to anti-tuberculosis treatment has been a major concern for some years now in many parts of the world. Poor compliance to tuberculosis treatment usually leads to poor treatment outcomes such as treatment failure, relapse of TB cases and high rate of treatment defaults and has therefore been reported to be a major hindrance in the global efforts to reduce the incidence of TB (Cutler & Everett, 2010). The consequence of this is the development of drug-resistant tuberculosis and extensible drug-resistant tuberculosis which is the complicated form of the disease. Drug-resistant tuberculosis (TB) cases are now being reported on regular basis in many parts of the world and there has been increase in the degree of resistance making it difficult for patients to be cured and interfering the spread of tuberculosis (Lessem et al., 2015).

The occurrence and spread of drug resistance tuberculosis threatens the present situation of tuberculosis disease in Africa (Muniyandi et al., 2010). Over 480,000 cases of multi drug resistance tuberculosis (MDR-TB) and 100,000 of rifampicin resistant TB are posing a great challenge to health professionals globally as the duration for treatment is long, costly and difficult as a result of frequent adverse events. Probably the paramount risk to worldwide health is the rise of drug resistant tuberculosis. This has negative consequences on the health system, the patient, family members and country as a whole as it depletes the limited resources that are meant to finance the health system (Muniyandi & Singh, 2014). Drug-resistant TB remains a danger community health (D'Ambrosio et al., 2018).

In 2017, 33% of patients who were put on tuberculosis treatment were previously treated tuberculosis cases (WHO, 2018). The circumstance was high to such an extent that 24% new TB patients and 70% were those who had been treated before. Indeed, the overall picture is that we are recording a great deal of multidrug-resistance TB and rifampicin resistant TB and over the past two years alone, 684 new cases were recorded in 2017. Worldwide, patients who failed to follow tuberculosis treatment protocol are responsible for resistant TB strains development that the whole world is battling now (WHO, 2018).

In 2018, there were more than half a million new cases of rifampicin-resistant TB in which 78% were multi drug-resistant TB cases. Universally, 3.4% of new TB cases and 18% of cases that had been treated previously were multi drug resistant tuberculosis (MDR-TB) (WHO, 2016). Resistance to certain drugs which are considered to be effective for treatment of tuberculosis is a big challenge in most part of the world as it makes treatment more complicated and therefore increases deaths and morbidity (WHO, 2016). Management of multidrug resistant tuberculosis entails enormous funding with respect to governments budget which puts much pressure on the limited resources for the health sector in some countries of which Ghana is inclusive. Furthermore, the regimens accepted to manage drug-resistant TB have extreme adverse effects on patients. Moreover, success rate for drug-resistant TB is as low as 48% contrasted with ordinary TB diseases which can achieve 85% success rate (WHO, 2012b).

On the contrary, many countries are presently defenseless in handling the current condition as there is slight or almost nonexistence of data to prompt policy formulation. Therefore, knowing the spatial distribution and access to healthcare by TB patients may provide relevant information that may influence policy formulation which will go a long way to reduce or prevent drug resistant tuberculosis development and decrease the rate of new infections in the whole world. This study therefore aims to provide evidence-based data to support TB control activities in Ghana. This research will therefore be contributing to policy making, development of tuberculosis treatment guidelines and recommends some strategies to enhance TB control interventions and prevention. The study would also be contributing to the available body of knowledge on tuberculosis and its management.

1.5 Organization of the report

This report was organized into six chapters. Chapter one introduced the background of the study, problem statement, objectives of the study, significance of the study and the organization of the study. Chapter two presented the literature review of the study. Chapter three covered methodology of the study, data collection methods and the definitions of the key variables. The fourth chapter focused on data analysis especially spatial distribution of tuberculosis. Chapter five covered discussion of the findings of the study. The last chapter focused on the summary, recommendations and the conclusion of the study. In this chapter the key findings of the study and its implications as well as suggestions for future studies were presented.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

This section provides information on studies that have been carried out on tuberculosis which covers certain areas including global burden of TB, risk factors associated with TB, interventions to reduce TB and the geographical information system and health including tuberculosis.

2.2 Epidemiology of TB in the World

The incidence rate of tuberculosis has been reducing slowly globally since 2005. It is estimated that TB was responsible for loss of about 1.6 million people which includes 230,000 children worldwide (Rook, 2013). Various factors including malnutrition, smoking, diabetes, HIV/AIDS pandemic, the rise of multi-drug-resistant (MDR) and extensively drug-resistant (XDR) tuberculosis complicates the present tuberculosis situation in the world (Semba, Darnton-Hill, & De Pee, 2010).

According to WHO, it is estimated that more than 2 billion persons or about a third of the global population have been exposed to *M. tuberculosis* in which more than 8 million of these people are likely to developing the disease and 3 million will die from the disease yearly (WHO, 2012a). In 2011, a projected 8.7 million cases of tuberculosis were recorded worldwide which includes 1.1 million cases among people living with HIV. The incidence rate worldwide at the moment is 125 cases for every 100,000 population. The 22 high burden countries are responsible for about 82% of the world TB burden. Most of these nations are from developing countries. The total mortality related to tuberculosis recorded globally in 2011 was estimated to be 1.4 million (Rook, 2013). It is estimated that in the sub-Saharan Africa, South-East Asia, and the subcontinent of Indian, about half or a greater number of individuals have latent tuberculosis. Globally, it is reported that more than 9 million new cases of tuberculosis are recorded yearly of which most of these cases are found in the developing countries (Semba et al., 2010).

It is projected that about 33% of the population in the world who are positive with HIV are having tuberculosis and majority of these patients are at greater risk of developing the active form of tuberculosis. In 2010, 350,000 individuals were reported to have died as a result of HIV related TB. For people who have HIV and the same time infected with tuberculosis, it is critical to identify multi-drug resistant TB among these patients as a result of increased risk of death (Rook, 2013).

There has been an upsurge in the incidence of *M. tuberculosis* resistant to first-line drugs and the appearance of Extensively-Drug Resistant TB in 2006 throughout the world. Since 2006, many nations including Italy, Iran and India recorded TB strains with serious resistance to anti-tuberculosis drugs. The management of MDR-TB is challenging, costly and time consuming requiring as much as 18-30 months for treatment to be completed with less success rate (Rook, 2013).

Worldwide patterns in MDR-TB rates are not clear as a result of unavailability of information in many nations. Collective statistics revealed that averagely, multidrug-resistance TB occurs in 3.4% and 19.8% of new and TB cases that have been treated previously respectively. Information on XDR-TB is difficult to come by. However, it is approximated that 9.4% of all MDR-TB cases were extensive drug-resistant TB in the whole world with the high number of these cases recorded in Estonia, Latvia, Tajikistan and South Africa (Rook, 2013).

2.3 Risk factors of Tuberculosis

People whose immunity has been compromised are at greater risk to develop the active tuberculosis. Many things cause destruction to the defense mechanisms rendering the body vulnerable to tuberculosis organism. It is reported that individuals who smoke tobacco are susceptible to the development of the active TB. Certain conditions such as individuals who are being treated for cancer, diabetes, children, the aged, people with chronic conditions and malnourish people, smoker and others have increase danger to develop tuberculosis as these conditions increase their susceptibility to tuberculosis (WHO, 2017).

2.3.1 Malnutrition

Research has revealed that lack of both micro and macro nutrients has been established to increase the risk of TB because of a compromised immunity. TB disease itself can lead to malnutrition as a result of decrease appetite and variations in metabolic activities and therefore tuberculosis and malnutrition are said to have a bidirectional relationship. The relationship that exists between TB and malnutrition has been revealed through the vaccine trials involving BCG in the USA during the late 1960s that showed that children who were suffering from malnutrition were twice at risk of becoming infected with tuberculosis compared to their non-malnourished peers (Narasimhan, Wood, Macintyre, & Mathai, 2013). Other epidemiological studies that were carried out in the USA among grown-ups found an increased risk of TB from 6 to 10 times among individuals who were malnourished. However, other studies that have assessed the interaction among malnourishment and tuberculosis with existing epidemiological, ecological and other studies involving animals reported that though there exists some level of evidence to support the relationship between TB and malnutrition, the actual risk with respect to degrees of malnourishment should be well characterized (Narasimhan et al., 2013).

In a recent study to determine the relationship between nutrition, tuberculosis HIV and others risk factors, the authors reported that amongst all the various risk factors that were assessed, malnutrition was the highest risk factor to the development of tuberculosis as compared to the rest of the factors as malnutrition can impede the immune response to *M. tuberculosis* organism and thus make the infected individuals to develop active tuberculosis. The study therefore concluded that appropriate nutrition was a protective factors as far as prevention of tuberculosis is concerned as good nutrition improves individuals' immunity and are therefore able to fight against tuberculosis infections (Semba et al., 2010).

In a case control study carried out in Indonesia to determine factors associated with tuberculosis, it was found that most of the respondents who participated in the study were malnourished before the disease and therefore concluded that malnutrition was a critical factor which had independent relationship with tuberculosis. The study further indicated that body mass index (BMI) had strong association with tuberculosis as increase in BMI reduces the threat of developing tuberculosis (Pakasi, Karyadi, Dolmans, Van Der Meer, & Van Der Velden, 2011).

2.3.2 Diabetes

Diabetes has been revealed to be increasing the threat for the development of the active form of tuberculosis disease. It is approximated that there are about 70% individuals with diabetes presently who are living in developing countries and the rates keep increasing consistently in countries where TB is considered to be endemic which includes sub-Saharan Africa and India. A systematic review that compared 13 studies assessed the relationship among TB and diabetes found that patients with diabetes were 3 times at risk to develop TB as juxtaposed with those without diabetes (Narasimhan et al., 2013).

A similar systematic review on outcomes of treatment among patients with TB and diabetes reported that there was 1.89 times increase risk of dying as compared with non-diabetic people. There is biological evidence that corroborates that diabetes significantly impedes the adaptive and natural immunologic activities and thus hastening the propagation of TB (Baker, et al., 2011). The increase number of cases of diabetes globally poses difficult task for the control of TB for the years to come (Sen, Joshi, & Udwadia, 2014).

In a systematic review conducted to evaluate the implications of diabetes on tuberculosis, the study reported that diabetes was significantly associated with tuberculosis. The study further added that diabetic patients are at greater risk of developing drug resistant tuberculosis as those patients may have their immunity compromised and thereby reducing the effectiveness of immune system to eradicate mycobacterium from the body (Ruslami, Aarnoutse, Alisjahbana, Van Der Ven, & Van Crevel, 2010). Another systematic review carried to determine risk factors of tuberculosis reported that diabetes escalates the threat of an individual to developing tuberculosis. The study further indicated that diabetes hinders the capacity of macrophages, monocytes and lymphocytes which assume a critical role in fighting the tuberculosis organism (Harries et al., 2011).

In a recent study to determine the relationship between tuberculosis and diabetes, the study reported that current information from India has revealed that diabetes contribute significantly to the occurrence of tuberculosis. The study further stated that the present increases in diabetes may subsequently prompt a reappearance of tuberculosis in endemic countries like India. This has serious potential ramifications for tuberculosis control and preventive efforts and knowledge in diabetes should serve as priority to be utilized to start engaged and organized activity like active case search, treatment of dormant tuberculosis and new research in countries where diabetes is widespread to illuminate appropriate action (Sen et al., 2014).

2.3.3 HIV Infection

Human immunodeficiency virus (HIV) infection is believed to be a significant potential risk factor that predisposes an individual to tuberculosis infection and facilitate the reactivation of latent TB to active disease as the infection of HIV weakens a person immune system. This makes it possible for the opportunistic infections to take advantage of the weak immunity to cause many diseases (Pawlowski, Jansson, Sköld, Rottenberg, & Källenius, 2012). In a study to evaluate the risk factors of tuberculosis, it was reported that HIV infection significantly increases the reactivation of dormant tuberculosis and therefore escalates the rapid progression of tuberculosis after exposure to infection for the first time or reinfection with tuberculosis. The study further revealed that in countries where there is high prevalence of HIV, the spatial and temporal disparity in tuberculosis incidence is significantly associated with HIV infection prevalence. Additionally, the study reported that studies carried out by individuals in low and high burden HIV countries have contributed to the increases in incidence of tuberculosis infections (Narasimhan et al., 2013).

In a prospective cohort study in Eastern Europe to assess the management of MDR-TB in patients with HIV, the study reported that most of the people who were HIV positive developed MDR-TB and that included those who developed extensive drug resistance tuberculosis (Efsen et al., 2018). In a systematic review to determine the association HIV and tuberculosis coinfection, the study reported that HIV infection leads to a significant reduction of mucosal, peripheral and CD4 T cells in the gut few days after the infection by attacking activated CD4 T cells. The study further indicated that HIV infection can destroy about 60% of CD4 T cells in the gut within 10 days of infection and about 80% destruction of these cells by two (2) weeks post-infection. This results to a decline in the number and the functionality of the T cells leading to the compromised immunity and therefore makes it difficult for the HIV infected individuals to deal specifically with the presence *M. tuberculosis* and other opportunity infections (Diedrich & Flynn, 2011).

In another study to determine the effects of HIV in active tuberculosis, the study found that main effect of HIV infection was its ability to cause a decline in the constituents of immune responses that are responsible to prevent dangerous inflammation. The study further reported that in an advanced HIV infection, there could be a widespread absence of any immunological protection to tuberculosis with the exception of certain immune activity which usually forms part of the general defense against viruses which may also compromised immune response against tuberculosis (Bell et al., 2016).

2.3.4 Alcohol

Alcohol consumption has been perceived as one of the main reasons for the increasing number of tuberculosis infection and a current meta-analysis of epidemiological molecular assessment has found alcohol as a solid feature responsible for the increasing number of TB cases in most of the developing countries (Narasimhan et al., 2013). In a systematic review involving 3 cohort studies and 18 case control studies, it was reported that people who take more than 40g alcohol a day have a significant increase risk of developing active tuberculosis. The increasing risk involves changes in the defense mechanism of an individual especially changes in the molecules that are accountable for the production of cytokines (Narasimhan et al., 2013).

In a meta-analysis of case-control and cohort studies to determine the effects of alcohol use and tuberculosis, the study found that alcohol consumption was significantly related with tuberculosis and indicated that alcohol consumption increase the risk of developing tuberculosis. The study further indicated that alcohol consumption contributes significantly to the increasing number of tuberculosis in the world with the most extreme effects found in African Region. The study again stated that there is enough evidence to corroborate the dose response relationship between alcohol consumption and the development of tuberculosis (Imtiaz et al., 2017).

In another systematic review to assess the relationship between alcohol consumption and tuberculosis, the authors reported that alcohol was significantly associated with tuberculosis and therefore concluded that there was adequate proof to show that there is a link between substantial alcohol consumption and the occurrence of tuberculosis among both males and females and that the degree of consumption usually complicates the disease course (Rehm et al., 2009). In a retrospective cohort study which was carried out in South Africa to determine the relationship between alcohol consumption and tuberculosis, it was found that most of the tuberculosis patients had a history of alcohol abuse and further intimated that alcohol consumption was significantly related to the development of active tuberculosis in addition to inappropriate clinical outcomes (Kendall et al., 2013).

2.3.5 Smoking

The relationship among smoking and TB has been considered in various systematic reviews. Studies have established that the nicotine in the cigarette reduces the defense mechanism of an individual by impeding the clearing ability of mucosal secretions and reducing the ability of the phagocytes to fight foreign organisms and that has been responsible to render individuals who smoke vulnerable to tuberculosis (Narasimhan et al., 2013). In a recent study involving animals to assess the relationship between smoking and tuberculosis, the study found that cigarette smoke significant spikes the risk of tuberculosis as the mice that were exposed to *M. tuberculosis* after being exposed to cigarette smoke had an increase number of *Mycobacterium tuberculosis* in their system (Narasimhan et al., 2013).

In a systematic review involving 24 studies on the impacts of smoking on TB, it was found that the average risk of contracting tuberculosis infections was greater among smokers in contrast with those who do not smoke and that there was significant proof that smoking remains a serious risk factor for TB disease and an increased risk of mortality among people who have active form of tuberculosis (Narasimhan et al., 2013). In another systematic review involving 38 studies to determine the effects of smoking on tuberculosis, the authors reported that there was significant association between smoking and tuberculosis and therefore concluded that their analysis corroborate a linkage between exposure to smoking and an elevated risk of contracting TB with the prime effects of smoking resulting in increases in the risk of being infected with tuberculosis (Sen et al., 2014).

In a recent study in China to determine the cigarette smoking and tuberculosis, it was found that smoking was significantly associated with tuberculosis. The study further indicated that although the biological process behind this is not clear, solid relationship between tobacco smoking and tuberculosis have been demonstrated in many studies. The study further indicated that the findings from their study support the previous studies. The researchers further intimated that their study has been able to established dose response among cigarette smoking and TB with a daily increase in smoking equally increase the danger of developing tuberculosis (Wang & Shen, 2009).

In another study to estimate the projected effects of tobacco smoking on global tuberculosis disease, the study reported that smoking was significant associated with tuberculosis. The study further indicated that smoking could lead to an increase in the number of tuberculosis cases as well as mortalities associated with tuberculosis globally by the year 2050 and possibly serves as a hindrance to global efforts to reduce tuberculosis deaths if nothing is done about the current smoking patterns (Basu, Stuckler, Bitton, & Glantz, 2011).

2.4 Factors that affect compliance to TB treatment

Several factors have been found by many studies to affect TB treatment worldwide. These factors include access to healthcare, religious and cultural beliefs, inadequate knowledge, health education and counselling, poor knowledge of impacts of non-compliance, family support, age of the patients and among others. Some of these factors are briefly discussed in this section.

2.4.1 Access to healthcare

Access can normally be defined as a situation where an individual can enter or having the right to enter and utilize available health facility and its services. Spatial access on the other hand can be described as the capacity of an individual reaching the desire location or being able to easily locate another facility to access the services they may need. Variations in geographical access to healthcare emerge normally as a result of the course of action of certain parameters. Health facilities are usually situated at a specific location and are responsible to provide services to individuals who live within the catchment area of the health facilities (Asaah & Ussiph, 2017).

2.4.1.1 Distance

Proximity to health facility has been found by many studies to influence the health seeking behaviours of many people in the world. It impacts greatly on the diseases that burdens many nations particularly countries in Africa. Therefore measurement of proximity affects health system performance and influence policy development (Asaah & Ussiph, 2017). In a recent study to determine factors related with poor treatment outcome in Ethiopia, the study found that distance to the treatment centers was a major factors that affected treatment of tuberculosis in Ethiopia as most of these patients needed funds to travel to treatment centers for treatment (Muñoz-Sellart, Cuevas, Tumato, Merid, & Yassin, 2010). In another study carried out in Zambia to determine factors responsible non adherence to TB treatment, the study reported that majority of the respondents cited distance from their place of residence to the treatment sites as the reasons behind their poor treatment compliance as they had to cover more than 5 km to go for their drugs on routine basis (Ibrahim et al., 2014).

In another systematic that was carried out in Ethiopia to assess the determinants of anti-tuberculosis treatment compliance found that long distance of the place of residence of the patients from the treatment sites was significantly associated with non-compliance to anti-tuberculosis medication (Tola, Holakouie-Naieni, Tesfaye, Mansournia, & Yaseri, 2019). According a study conducted by Boateng, Kodama, Tachibana, & Hyoi (2010) to determine factors contributing to tuberculosis defaulter rate in the Eastern region of Ghana, majority of the respondents indicated that the main reason that was accountable for their inability to comply with their treatment had been the long distance they had to travel from their homes to the treatment sites.

2.4.1.2 Religious Beliefs

Religious beliefs of patients have been found by several studies to be an influential factor as far as compliance to treatment is concerned. A recent cross-sectional study to assess the influence of religion on compliance to tuberculosis treatment in Papua New Guinea found that religion was positively associated with TB treatment compliance. The study reported that traditional and religious beliefs influence demonstrated in different ways with some factors that facilitate patients' ability to adhere to their treatment as just having faith in God motivated people to ensure compliance to treatment. The study therefore suggested that religious leaders should be involved in the management of tuberculosis as this involvement could particularly concentrate on adherence to treatment, for instance with religious leaders serving as treatment supporters. Moreover, places of worship could serve as a medium where messages on TB are communicated to the populace, and also facilitating TB screening and tracing of contact in the communities (Diefenbach-Elstob et al., 2017).

A cross sectional study conducted in Ghana to determine factors that influence adherence to TB treatment reported that religion was statistically not significantly associated with compliance to tuberculosis treatment. The study however revealed that a significant number of respondents stated that tuberculosis is caused by witchcraft as a result of their beliefs and therefore can be cured after the necessary rituals are performed (Boateng et al., 2010).

In a similar cross sectional study conducted in Pakistan to determine factors that are responsible for delays in the initiation for the tuberculosis treatment found that most of the patients especially female patients who failed to initiate their treatment on time attributed their inability to start treatment on time to religious issues or beliefs (Munir et al., 2012).

2.4.2 Inadequate Knowledge

Adequate information on tuberculosis can help clarify issues concerning the disease. Evidence available on TB treatment recommends that, patients with some degree of knowledge on TB will comply to their treatment effectively. Patients with information on duration of treatment and adverse effects are likely to stick carefully to treatment regimens whereas patients who do not have adequate knowledge will have difficulties in adhering to their treatment (Salifu & Eliason, 2018). Inadequate knowledge has been established to be significantly related to poor tuberculosis treatment outcome. Findings from a study that was carried out in Kosovo found that patients who had some level of knowledge on tuberculosis will stick to treatment protocol when they are put on treatment. The study further indicated that people without adequate knowledge about the disease are likely not to comply with treatment protocol (Krasniqi et al., 2017).

Inadequate knowledge about tuberculosis treatment has a significant effect on adherence to treatment (Tola et al., 2019). In Morocco, a study conducted to assess the duration of treatment and the impacts of non-completing the treatment found that the significant factor for the respondents' inability to complete treatment was an inappropriate thought that they had been cured. The main reason that was indicated by most of the patients who were on treatment as being responsible for their inability to complete treatment was that most of them thought they have cured.

The findings from the study confirm that inadequate knowledge on the part of patients account to the inability of the clients to comply with the treatment regimens (Tola et al., 2019).

Another study to assess knowledge of TB and its treatment found that patients without adequate knowledge having observed some form of improvement thought they have been cured and therefore discontinue their treatment (Mekonnen & Azagew, 2018). A similar study that was conducted in Papua New Guinea to determine social determinants of treatment for tuberculosis found that adequate knowledge was significantly associated with compliance to tuberculosis treatment as patients who defaulted indicated that they did not receive adequate information about the disease and the treatment protocol (Diefenbach-Elstob et al., 2017).

2.4.3 Health Education and Counseling

Many studies have reported that proper counselling have significant influence on treatment compliance by TB patients. In a study to assess the effects of clinical counselling on TB treatment, the study found that clinical counselling can significantly influence patients' adherence to treatment resulting in strict compliance to treatment, change in the behaviour of patients, proper outcomes and faster cure (Adamo, Carollo, Di Giorgio, & Polidori, 2013). Adherence of patients to treatment usually relies upon the nature of messages that are given to them. Staff at the pharmacy unit ought to invest sufficient time to communicate the need for patients to take their recommended medicines to the patient and the effects for the failure to take their medication. This information when properly communicated, will significantly improve compliance to treatment (M'Imunya, Kredo, & Volmink, 2012).

In a systematic review to assess the interventions to improve compliance to tuberculosis treatment, it was reported that patients counselling, and health education was able to increase cure rate by 16%. The study further indicated that patients counselling, and health education were able to reduce defaulter rate by 49%. The study therefore recommended that tuberculosis patients should be given proper counselling prior to starting their anti-tuberculosis treatment (Efsen et al., 2018). According to a study carried out in Indonesia to determine factors that influence treatment compliance, it was reported that majority of the patients who defaulted or did not comply to treatment indicated that they were not given adequate education and counselling on the treatment and the side effects of the drug and therefore discontinued the treatment when they were feeling better (Widjanarko, 2010). In Uganda, an unmatched case-control study was conducted to determine factors that influence non-compliance to tuberculosis treatment. The study reported that one of the factors identified to be responsible to defaulting to anti-tuberculosis treatment was the absence of patient education and counselling that is patients being unaware of the period for the treatment and complications of non-compliance or to discontinue treatment (Elbireer, Guwatudde, Mudiope, Nabbuye-sekandi, & Manabe, 2011).

2.5 Strategies to reduce incidence of tuberculosis

For over two decades, directly observed therapy short-course (DOTS) which is a recommendation by the WHO has been the standard strategy by many countries in the world for the treatment or management of tuberculosis. The DOTS strategy implementation may have some variations from one place to another which may be influenced geographical location, demographic characteristics as well as socio-economic and cultural values of the countries. Management of tuberculosis entails accessibility to proper healthcare system and effective compliance to recommended treatment regimen that is available in the country (Munir et al., 2012).

In Ghana, tuberculosis is usually recognized in patients who come to facilities for health care. Individuals who have had coughs for some time are asked to undergo TB screening and those suspected to have the disease are referred for further sputum examination. Patients who are positive on the basis of sputum examination are assessed and put on TB treatment which ranges from 6 months to 2 years depending on the category of the case (National Tuberculosis Control Programme, 2012). Most of the patients are carefully observed on regularly during the intensive stage. Presently, WHO proposes that each patient is assign to at least one person which could be friend, a family member or a layman who serves as a treatment supporter during the treatment of the tuberculosis (WHO, 2017).

2.6 GIS Application and Healthcare

The geographical information system (GIS) has been used extensively in various field of study which includes environmental health, mapping of infectious diseases and health sector management. It has the ability to increase and enhance various fields of study and to display health conditions that may be affecting the health of the people in many countries in the world (Rakotosamimanana et al., 2014). The presence of computer application such as geographical Information System (GIS) is very important as it has a possibility to improve planning in health system organization as well as ensuring equal distribution of health facilities amongst the populace particularly in rural areas. The procedures for spatial investigation offers instruments that enhance the display and the comprehension of the spatial plan of health services and assess the association between access and health outcome in order to improve delivery of healthcare (Pakzad et al., 2018). The GIS as a computer base application can help in the analysis and integration of geographical data. It can process information gathered, store and retrieves information when required, do analysis and show information graphically as maps. This makes it possible for health conditions to be visualized so that new ideas could be generated. The application is usually used in epidemiological investigations in situations of disease outbreaks (Jr et al., 2013). The use of GIS innovation in healthcare can exactly display where cases are found during outbreak of disease just as determine the geographical inequalities in access to healthcare. Presently, the involvement of GIS in essential healthcare studies has been encouraged as a result of the advancement in GIS innovation, making it appropriate and reasonable for specialists in the healthcare (Salehi & Ahmadian, 2017).

Access to healthcare among individuals will continue to have some inequalities as a result of the present spatial distribution and available means of transportation. It is therefore important to monitor situations that impedes efforts to improve of access among community members and the location of health facilities during planning for the construction of health facilities (Hawthorne, 2012). Several investigations have displayed the outcome of hindrance in access to healthcare and its consequences for health results. These investigations are imperative to properly comprehend and to amend how healthcare system planning is conducted (Rakotosamimanana et al., 2014).

Despite the fact that various researches have been conducted on appropriate utilization of primary healthcare in many countries, only few studies have extensively assessed the potential accessibility to disease control, family planning, maternal and child welfare services by the target population (Rakotosamimanana et al., 2014). World Health Organization firmly recommends that these functions be integrated in the primary healthcare delivery. The utilization of Geographic Information system can help in the determination and improvement in the spatial distribution of healthcare. This should be possible in a logical and a reasonable method to enhance planning in healthcare system as well as allocation of resources in many middle income countries (Rakotosamimanana et al., 2014).

In a recent study in Iran to determine priority areas where maternal service and care by pregnant women are needed using geographical information technology, the study reported that most of the pregnant women had access to moderate level health facility within a desirable geographical area

(Salehi & Ahmadian, 2017). In another study to improve access to primary health care service in Atwima Mponua district in Ghana using geographical information system, the study reported that a substantial number of communities did not have access to health care within a radius of 8km. The study further indicated that a significant percentage of the population in the district had to travel long distance in their efforts to seek health care and that the people had to be travelling a minimum of 6.62km and a maximum of 21.02km to access health care (Asaah & Ussiph, 2017).

2.7 GIS Application and Tuberculosis

The geographical information system (GIS) has widely been used to determine the distribution of diseases in many parts of the world especially for investigation during outbreaks (Rakotosamimanana et al., 2014). Kolifarhood, Khorasani-Zavareh, Salarilak, Shoghli, & Khosravi, (2015) study to determine the non-spatial and spatial determinants of successful treatment of tuberculosis using GIS in Iran found three clusters of tuberculosis in which majority of the cases were more concentrated in the outskirts of the urban and deprived areas and therefore concluded that the cases were not randomly distributed. The study further added that tuberculosis cases who defaulted or interrupted in treatment were not residing far away from treatment centers. Wang, Xue, Chen, Ma, & Liu, (2012) in a spatial epidemiological study in China reported that 5 important clusters were identified in Linyi City when space distribution alone was used and that spatial dispersion of tuberculosis cases were not randomly distributed. The study however indicated that 1 significant cluster and 9 secondary clusters with higher occurrence of TB were detected when both time and space were used for analysis.

In another spatial and temporal distribution study in Mexico using geographical information system, the study reported that 9 clusters were significantly detected using spatial and space-time analysis. The study therefore concluded that tuberculosis cases in Mexico were not distributed randomly and that places which were near to Mexico City had higher concentration of cases and therefore concluded that tuberculosis cases occur most in urban communities as compared to rural communities (Zaragoza Bastida et al., 2012). In another spatial analysis to determine the distribution of tuberculosis in the USA using GIS, it was reported that there were some communities in the Houston County that had a higher concentration of tuberculosis. The study further indicated that persons who reside in these communities had an increased risk which is comparable to people living in countries with a high burden of tuberculosis (Feske, Teeter, Musser, & Graviss, 2011)

In The Gambia, GIS was used to show the distribution of tuberculosis. The study reported that based on the pure spatial and retrospective space-time analysis, significant clusters of tuberculosis cases were found in the capital Banjul. The study further indicated that actual spatial analysis revealed "hotspots" of tuberculosis in four communities whereas retrospective space-time analysis identified three out of four communities with high concentration of tuberculosis cases. Moreover, secondary cluster was identified by further spatial analysis in communities with high population density in which government and private facilities that are responsible for diagnosis of tuberculosis are found (Touray et al., 2010).

In another spatial study, GIS was used to evaluate the distribution of tuberculosis from 2002 to 2012 in Brazil. The study found that the disease was spatially dispersed all over the urban districts with no preponderance of the disease in a particular area. The study further indicated that majority of the cases were recorded in areas with high population density especially in areas where there was overcrowding and therefore concluded that densely population was a significant factor that may be related with an increase incidence of tuberculosis cases (De Silva, Di Lorenzo, Oliveira, Teixeira, & Camargos, 2016).

In a similar study in Portugal to determine the distribution of TB using GIS, the study reported that significant clusters of tuberculosis were identified in Porto and Lisbon Metropolitan areas. The study further indicated that high occurrence of tuberculosis cases were recorded in towns and cities which share border with Spain. Moreover, the study revealed that the geographical distribution of tuberculosis cases was not different from HIV/AIDS infection distribution and that high cases were recorded in Lisbon, Porto and other communities bordering the Spain as well as communities where with high population of foreigners (Couceiro, Santana, & Nunes, 2011). In Cameroun, GIS was to determine the tuberculosis cases distribution. The spatial analysis found three important clusters with varying number of cases were detected in the city of Douala. The study further stated that most of the cases were clustered in areas with high population density particularly the area in the city where the main market is located (Nana-Yakam et al., 2014).

Another study by Yeboah-Manu et al., (2016) to determine the distribution of Mycobacterium tuberculosis complex strains in Ghana using ArcMap analysis found *M. bovis* to be higher in Northern Ghana as compared to southern Ghana. The study further revealed that 7 clusters of M. bacterium complex (MBTC) were significantly detected when purely spatial and space time analysis were used. Another study in Ghana by (Abdul, Ankamah, Iddrisu, & Danso, 2020) to determine the prevalence rate of tuberculosis in the country reported that more tuberculosis cases were recorded in areas with higher population and thus concluded that tuberculosis cases seems to be higher in the populated regions of the country.

2.8 Summary

In summary, researches from other parts of the globe have shown that spatial analysis of diseases of public health importance using geographical information system have been helpful in identifying clustering of diseases and to generate hypothesis about factors which might be accountable to the distribution of the diseases. However, only few studies have been able to use the geographical information system to determine the distribution of tuberculosis cases in Ghana. It was on this basis that the study was conducted using geographical information system to identify high risk areas for tuberculosis for the formulation of policies.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Study Area

The study was conducted in the Birim South District (see Figure 1). The district is one of the 33 districts in the Eastern region of Ghana with Akim Swedru as its capital. The district covers an estimated land size of 345sq km. The district borders Birim Central Municipality in the North, Asikuma Odoben-Brakwa district in the East, Assin North Municipal in the South and Akyemansa toward the West. The estimated population for district for the year 2020 is 146,313 with a projected population growth rate of 2.1% based on the 2010 population census. The district is mainly rural with about 56% of population found in rural settlements

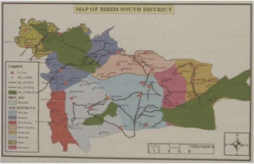

Figure 1: Birim South District Map

Source: Birim South District Health Directorate

3.1.1 Religion

For religion, most of the people representing about 93% of the populace in the district are Christians with the remaining 7% being Moslems and traditionalists. These structures could be utilized adequately to disseminate information about general health activities.

3.1.2 Education

The district has 3 Senior High Schools. There are 57 Junior High Schools in the district of which 14 are private schools. There are also 94 primary Schools of which 63 are public Schools and the rest being private. There are also 59 kindergarten schools in the district of which 19 are private schools.

3.1.3 Health

There are 27 functional health facilities in the district including 1 CHAG, 4 Health Centres and 22 CHPS that are widely distributed in the district.

3.2 Study Design

A descriptive cross sectional study was used for this study. The study conducted spatial analysis to determine the geographical distribution of tuberculosis cases and their access to healthcare in the district. The study included all TB patients who were treated and those who were being treated for tuberculosis from 2019 as well as those who were diagnosed as having tuberculosis in the course of the study until July 2020. All TB patients who were treated and those who were being treated for tuberculosis from 2019 as well as those who were diagnosed as having tuberculosis in the course of the study until July 2020 were traced to their place of residence (home) and spatial data (coordinates) for their homes taken and the distance in kilometers to the nearest health facility collected for this study. The other relevant information about the patients were obtained from TB registers at both the health facilities and the district health directorate.

3.3 Study Population

The study population for this study was all TB patients who were above 18 years whose details were captured in the TB registers at the health facilities and were being treated for tuberculosis from 2019 as well as those who were diagnosed as having tuberculosis in the course of the study until July 2020.

3.4 Sampling Technique and Sampling Size

The study used census method since all patients who met the inclusion criteria were included in the study. No sample size was calculated for this study since all subjects were studied.

3.5 Inclusion and Exclusion Criteria

3.5.1 Inclusion Criteria

Eligible patients for this study were;

1. TB patients who are more than 18 years and were being treated for tuberculosis from 2019
2. New clients who were diagnosed as having tuberculosis and were put on anti-tuberculosis drugs in the course of the study until July 2020

3.5.2 Exclusion Criteria

1. TB patients who were on treatment but did not reside in the study district
2. Tuberculosis patients who failed to consent to be part of this study
3. Tuberculosis patients who were critically ill and so were unable to participate

3.6 Data Collection

A special form was designed to collect data from TB patients for this study. The data that were collected includes background characteristics of patients, HIV status, distance to the nearest health facility and spatial data (coordinates) of the place of residence of patients and health facilities using global positioning system device (GPS). Research assistants were trained to collect data on coordinates (points) for the place of residence and distance in kilometers to the nearest health facilities only since the other relevant data was available at the health facilities as well as the district health directorate. The names of the patients were not collected for this study.

3.7 Data Analysis

The pre-coded data was entered into excel, clean and later exported to STATA version 16 software for statistical analysis. Frequency distribution was used to compute the proportions for age, education level, sex, religion, marital status, occupation and HIV status. The mean age and mean distance in kilometers to health facilities and their respective standard deviations were also computed. The spatial data (coordinates) for place of residence and the health facilities were organized in excel and later migrated to geographical information system (ArcGIS) version 10.7.1 software for spatial analysis. Clustering analysis of 1000 metres was performed to determine whether tuberculosis cases were preponderance or concentrated in a particular area in the district. Kernel density analysis was also performed to determine the density of tuberculosis cases in the district. A buffer analysis of 5km, 3km and 2km was performed around health facilities in the form of points within the district to determine the geographical access to health care for tuberculosis patients within the district. This was done by first converting the Birim South district, health facilities and tuberculosis cases shape files from geographic coordinates system to projected coordinate system.

3.8 Ethical Consideration

Ethical approval was sought from Ghana Health Service Ethics Review Committee for this study (GHS-ERC 022/09/20). Permission was also sought from the district in which the study was conducted. Approval was also sought from the sub-districts as well as health facilities where the study took place. Also, approval was sought from each patient before the spatial data (coordinates) for their place of residence was taken for the study. Assurance was given to patients that the information they provided will be used for the purposes of academic only and not for any other reason. The participants were also assured of maximum confidentiality and privacy during and after data collection process.

3.9 Limitations of the study

The study may be limited by the study design as the study was dependent on the number of patients who were put on TB treatment from 2019 as well as those who were diagnosed as having tuberculosis in the cause of the study. This was a cross-sectional study and thus time was of great essence. The study focused mainly on patients who were put on TB treatment from 2019 and those who were identified as having tuberculosis in the cause of the study and did not include those who were on treatment before the year 2019. Therefore, the situation at the moment might not be a true reflection of what might have occurred in the previous years.

CHAPTER FOUR

4.0 RESULTS

4.1 Introduction

The results section of this study has been presented in five sections. Section one presents a descriptive statistics of the socio-demographic characteristics of participants. Section two provides findings of the HIV status of participants. Section three presents the findings of the spatial distribution of TB cases in the district. The last section presents findings on distance to the nearest health facilities.

4.2 Demographic characteristics

The results in Table 1 shows the socio-demographic characteristics of the respondents. The mean age of the respondents was 45 years with a standard deviation (± 16.3 SD). Most of the respondents (31) were within the age group of 36-45 years representing 29.0% of the total respondents followed by those above 55 years with 26 cases representing 24.3% with the least being recorded in those below 25 years with 14 cases representing 13.1% of the respondents. Majority of the respondents were male constituting 68.2% of the total respondents. Christians constituted majority (90.7%) of the respondents. Most of the respondents (72.0%) had some form of formal education compared with 28.0% of the respondents who had no formal education. Majority of the respondents (67.3%) were married followed by 23.4% of the respondents being single with the least representing 0.9% of the respondents being separated. Most of the respondents (66.4%) were engaged in some form of economic activities with only 17.7% of the respondents being unemployed.

Table 1: Socio-demographic characteristics of participants (n=107)

Variable	Frequency	Percentage (%)
Age in years (M ± SD)	**45 ± 16.3**	
Age Group		
<25	14	13.1
26-35	15	14.0
36-45	31	29.0
46-55	21	19.6
55+	26	24.3
Sex		
Male	73	68.2
Female	34	31.8
Education Level		
None	30	28.0
Primary School	12	11.2
Middle/JHS	44	41.1
SHS	19	17.8
Tertiary	2	1.9
Religion		
Christian	97	90.7
Muslim	8	7.4
Others	2	1.9
Marital Status		

Married	72	67.3
Single	25	23.4
Divorced	5	4.7
Separated	1	0.9
Widow	4	3.7
Occupation		
Public Sector	2	1.9
Private Sector	11	10.3
Self-Employed	71	66.4
Student/Apprentice	4	3.7
Unemployed	19	17.7

Source: Field data, 2020

4.3 HIV status

Presented in Figure 2 is a pie chart showing the distribution of HIV status of respondents. The figure shows that 93 representing 86.9 of the respondents were negative for HIV whiles 9 respondents were HIV positive representing 8.4% of the respondents with 5 respondents representing 4.7 % whose HIV test had not been done and therefore their HIV status was unknown.

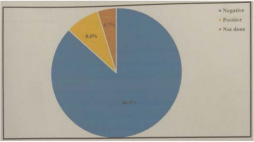

Figure 2: HIV status of respondents

Source: Field data, 2020

4.4 Spatial distribution of TB cases

Spatial analysis for TB cases was carried to determine the spatial distribution of TB in the district in which the district was divided in sub-districts for easy description of the disease distribution (Figure 3). The spatial analysis shows that TB cases in the district was randomly distributed and that no community in the district was found to be recording more cases than others. The findings from the study further reveal that TB case detection rate in the district ranged from 7 to 35 cases per 100,000 populations at risk based on the 2019 population. A total of 107 TB cases were recorded from January 2019 to July 2020 in which 87 cases representing 81.3% of the cases were pulmonary positive (PP) cases. Findings reveal that Achiase, Akim Swedru and Aperade sub-districts recorded 97.6%, 88.0% and 63.2% respectively of case detection rate for tuberculosis as compared to the target for 2019. Therefore, these sub-districts can be described as a high risk areas or areas with preponderance of tuberculosis cases in the district.

Figure 3: Spatial distribution of tuberculosis

Source: Field data, 2020

4.6 Density of tuberculosis case

Figure 4 shows the density of tuberculosis cases recorded in the district. Findings from the density surface reveal that high density of tuberculosis cases were recorded in Achiase and Swedru communities. The findings further show that few cases of tuberculosis were recorded in other communities. Generally, it was observed that communities at the peripheries with low population density recorded fewer cases of tuberculosis per square kilometer. Figure 4 shows that the highest density of tuberculosis cases of more than 10 per square kilometer was recorded in Achiase which is located within the Achiase sub-district.

Figure 4: Density of tuberculosis cases

Source: Field data, 2020

4.7 Clustering of tuberculosis cases

The Global Moran's I statistic was used to determine clustering of tuberculosis cases in the district. Figure 5 shows that tuberculosis cases within the district occurred at random with no preponderance or concentration of cases within a particular area. Within an estimated two (2) kilometers neighborhood of communities, using the Euclidean distance and the inverse distance weighting, there was no evidence of clustering of tuberculosis cases in the district (Moran's I= 0.015425, Expected Index= 0.009804, Variance= 0.041504, Z-score=0.123840, p-value=0.901442). The random distribution of tuberculosis as shown by the statistics above implies that there was no justification to investigate further using hotspot/coldspot analysis, cluster-outlier analysis or spatial autocorrelation to know where the clustering of cases had occurred. This means that the distribution of tuberculosis cases in the district especially the high risk communities was randomly or uniformly distributed with no specific area being classified as area with high concentration of tuberculosis cases.

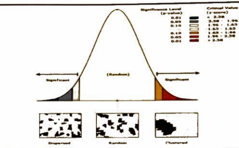

Figure 5: Clustering of tuberculosis cases

Source: Field data, 2020

4.8 Geographical access to health care

Figure 6 shows the number of health facilities in the district where TB patients can access health care when needed. The figure also shows the distribution of TB cases against health facilities where health care or treatment for tuberculosis is provided. The figure shows that 106 cases representing 99.1% of TB cases recorded for this study were located within a radius of 5 kilometers coverage by health facilities with the exception one case representing 0.9% recorded outside the Euclidean distance of 5 kilometer radius. The figure also shows that a total of 104 cases representing 97.2%

cases were recoded within a Euclidean distance of 3km radius with only 3 cases representing 2.8% recorded outside a Euclidean distance of 3km radius. The figure further shows that a total of 99 cases representing 92.5% cases were recoded within a Euclidean distance of 2km with only 8 cases representing 7.5% recorded outside a Euclidean distance of 2km radius. The study shows a mean distance of the respondents to the nearest health facility to be 2.1km with a standard deviation (±1.2km) which implies that the places of residence of the participants were not far from health facilities in the district. Therefore, it can be concluded that geographical accessibility particularly proximity or closeness to health facilities where healthcare is provided can be described as appropriate. This is consistent with the concept of CHPS which states that distance to health facilities should not be more than 5 kilometers.

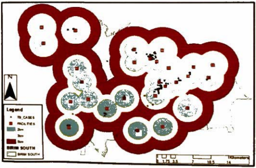

Figure 6: Geographical Access to health facilities

Source: Field data, 2020

CHAPTER FIVE

5.0 DISCUSSION

5.1 HIV and tuberculosis

HIV and tuberculosis have long been described as twins as there seems to be a strong relationship between the two as HIV infection is believe to weaken the immune system of an infected person and thus making it possible for tuberculosis which is considered an opportunistic infection to take advantage to cause disease (Pawlowski et al., 2012). Therefore, it was expected that many of the tuberculosis cases would be HIV positive. However, findings from the study show that majority of respondents 93 representing 86.9 of the respondents were negative for HIV with only 9 respondents representing 8.4% of the respondents were HIV positive. The findings imply that the district may have a unique situation and that the general assertion where HIV and TB are considered as twins may not be applicable in the district as only few of the TB patients recorded for this study were HIV positive.

This findings however contradict a study by Narasimhan et al., (2013) which reported that HIV infection significantly increases the reactivation of dormant tuberculosis and therefore escalates the rapid progression of tuberculosis after exposure and therefore in countries where there is high prevalence of HIV, the spatial and temporal disparity in tuberculosis incidence is significantly associated with HIV infection prevalence. The findings of the study also contradict a study in Portugal where it was reported that the geographical distribution of tuberculosis cases was not different from HIV/AIDS infection distribution (Couceiro et al., 2011).

The findings of the study again contradict another study which reported that in an advanced HIV infection, there could be a widespread absence of any immunological protection to tuberculosis and as a result most of the HIV patients may suffer from tuberculosis (Bell et al., 2016). The findings show that other risk factors such as poor nutrition and others rather than HIV infection may be contributing to the increase incidence of tuberculosis in the district as tuberculosis is believed to mostly affect poor or the vulnerable who are known to be associated with poor nutrition.

5.2 Spatial distribution of TB cases

The spatial analysis shows that tuberculosis cases in the district was randomly distributed as no community in the district was found to have recorded more cases than others spatially. This implies that communities in this district such as Achiase and Swedru with high population density did not record more cases than other communities with low population density. This outcome contradicts a study conducted in Iran which reported that majority of the cases were more concentrated in the outskirts of the urban areas with high population density and therefore concluded that the tuberculosis cases were not randomly distributed (Kolifarhood et al., 2015). The findings of the study also contrast a study by Wang et al., (2012) in China which reported that spatial dispersion of tuberculosis cases were not randomly distributed.

The findings of the study also contradict a study carried out in Mexico which reported that tuberculosis cases were not distributed randomly and that places which were near Mexico City with high population density recorded higher concentration of tuberculosis cases and therefore concluded that tuberculosis cases occur mostly in urban communities as compared to rural communities (Zaragoza Bastida et al., 2012). The findings of the study also contrast a study in Gambia which reported that communities with high population density recorded more cases when purely spatial analysis was conducted (Touray et al., 2010). The findings of the study again contrast a study which was carried out in Brazil where it was reported that majority of the cases were recorded in areas with high population density especially in areas where there was overcrowding and therefore concluded that densely population was a significant factor that may be related with an increase incidence of tuberculosis cases (De Abreu E Silva et al., 2016).

The findings of this study also contradict a study in Portugal which reported that places like Porto and Lisbon Metropolitan which are associated with high population density recorded high number of tuberculosis cases (Couceiro et al., 2011). The findings of the study again contradict a study in Cameroun which found more tuberculosis cases in the city of Douala and added that most of the cases were recorded in areas with high population density particularly the area in the city where the main market is located (Nana-Yakam et al., 2014). The findings of the study also contrast another study in Ghana by (Abdul, Ankamah, Iddrisu, & Danso, 2020) which reported that more tuberculosis cases were recorded in areas with higher population density and thus concluded that tuberculosis cases seems to be higher in the most populated regions of the country.

5.3 Clustering of tuberculosis cases

The study reveals that tuberculosis cases within the district occurred at random with no preponderance or clustering of cases within a particular area. This outcome is quite different from the general perception that tuberculosis is associated with high population density as it was expected that clustering of tuberculosis would be found within some communities which have high population in the district. This could be due to passive case search being used to search for cases in the densely populated communities as well as inadequate contact tracing as case search in the district mainly focuses on suspected cases who visit health facilities for treatment. The findings of the study however contrast a study in Gambia which found several significant clusters of tuberculosis cases in the capital Banjul which is associated with high population density (Touray et al., 2010). The findings of this study also contradict a study which reported that a significant number of clusters were identified in Porto and Lisbon Metropolitan areas which are associated with high population density (Couceiro et al., 2011). The findings of the study further contradict a study in Cameroun which detected three (3) important clusters with varying number of cases in the city of Douala which is associated with high population (Nana-Yakam et al., 2014).

The outcome of the study contradicts a study conducted in Iran which found three (3) significant clusters of tuberculosis in which majority of the cases were more concentrated in the outskirts of the urban areas with high population density and therefore concluded that the tuberculosis cases distribution could be associated with population density (Kolifarhood et al., 2015). The findings of the study also contradict a study by Wang et al., (2012) in China which reported that five (5) important clusters were identified in Linyi City when only space distribution was used and that spatial dispersion of tuberculosis cases were not randomly distributed.

5.4 Geographical access to health facilities

Buffer analysis was performed to determine the geographical access of the participants to the health facilities. The study found that 106 cases representing 99.1% of TB cases recorded for this study were located within a radius of 5 kilometers coverage by health facilities with the exception one case representing 0.9% which was found outside the 5 kilometer radius. The study further shows that a total of 104 cases representing 97.2% cases were recoded within a Euclidean distance of 3km radius with only 3 cases representing 2.8% recorded outside a Euclidean distance of 3km radius This implies that health facilities where healthcare or services are provided are not far from the places of residence of the respondents and this is consistent with the concept of CHPS. This is similar to a study conducted in Iran which reported that tuberculosis patients who defaulted or interrupted in their treatment were not residing far away from treatment centers (Kolifarhood et al., 2015).

However, this contradicts a study in Atwima Mponua district in Ghana where it was reported that a significant number of communities members did not have access to health facilities within a radius of 8km and that a greater percentage of the population in the district had to travel long distances of about 6 kilometers or more in their efforts to seek health care (Asaah & Ussiph, 2017). The findings also contradict a study in Zambia which reported that the distance between the places of residence of the respondents to the treatment centers were far and that people had to travel more than 5 km to go for their drugs on routine basis (Ibrahim et al., 2014). The findings again contradict another study conducted in the Eastern region of Ghana which reported that respondents had to travel long distances from their places of residence (homes) to the treatment sites and that was responsible for their inability to comply with tuberculosis treatment (Boateng et al., 2010).

5.4 Summary of the chapter

The findings reveal that the distribution of tuberculosis cases in the district was random distributed. The study also shows that there was no clustering of tuberculosis cases in the district. The distance that tuberculosis clients (cases) had travel to the health facilities in the district were found to be appropriate which is in line with the concept of CHPS which stipulates that the distance should not be more than 5 kilometers.

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 Summary

The study shows that the distribution of tuberculosis cases in the district was randomly distributed and therefore was no evidence of clustering of tuberculosis cases. The study also reveals that there was a substantial surge in the number of tuberculosis cases from 2017 to 2019. The study again shows that the geographical access to health care by tuberculosis patients was not a challenge as most 99.1%, 97.2% and 92.5% of the study participants were found within 5km, 3km and 2km radius respectively.

6.2 Conclusion

This study describes the spatial distribution of tuberculosis cases in Birim South district using the geographical information system. The utilization of the geographical information system to display the spread of TB and other diseases of public health importance and physical access to healthcare in the country is quiet new and therefore not being employed as expected. The benefits of using the geographic information system for investigations are enormous as it assists investigators to know where things are happening and why things happen. The application allows individuals responsible for policy formulation to have a clear visualization of problems with respective to available health and social services to make inform decision.

Additionally, geographic information system is capable of performing spatial analysis and provide some level of understanding that cannot be provided by many other information system and that makes it the best application as far as displaying health conditions is concern. Therefore, it is expected that the use of this application would be encouraged in other activities associated with public health so that certain problems which are geographically related such as hotspots of road accident or disease outbreak can be identified easily and appropriate measures put in place to address them.

6.3 Recommendations

Based on the findings of this study, the following recommendations were made:

- The district health directorate should conduct intensive health education on tuberculosis with emphasis on prevention in the district to decrease the spread of tuberculosis in the district
- The district health directorate should conduct active case search in communities to detect or identify all possible cases in the communities for treatment
- The health workers in the district should be trained on the use of global positioning system (GPS) and geographic information system (GIS) as it has shown to improve case management and public health activities in general

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APPENDICES

Appendix I: CONSENT FORM

STUDY TITLE: **Geospatial distribution of TB cases and access to healthcare in Birim South District**

PARTICIPANTS' STATEMENT

I acknowledge that read and have had the contents and purpose of participants' information sheet read and explained to me satisfactorily in a language I understand (Twi). I fully understand the contents and any potential consequences as well as my right to change my mind (i.e. withdraw from the research) even after I have signed this form.

I voluntarily agree to be part of this research.

Name or Initials of Participant.................................. ID Code ....

Participants' Signature ....OR Thumb Print..................................

Date...

INTERPRETERS' STATEMENT

I interpreted the purpose and contents of the participants' information sheet to the aforenamed participant to the best of my ability in the (Twi) language to his /her proper understanding.

All questions, appropriate clarifications sort by the participant and answers were also duly interpreted to his/her satisfaction.

Name of Interpreter.................................

Signature of Interpreter.............................. Date.............................

Contact Details.......................................

WITNESS STATEMENT

I was present when the purpose and contents of the participants' information sheet was read and I satisfactorily explained to the participant in the language he/she understood (Twi) language.

I confirm that he/she was given the opportunity to ask questions/seek clarifications and same were duly answered to his/her satisfaction before voluntarily agreeing to be part of the research.

Name:..............................

Signature................ OR Thumb Print ....

Date:.................................

INVESTIGATOR STATEMENT AND SIGNATURE

Brief statement or declaration that investigator has given enough information to participants to make an informed decisions.

I certify that the participant has been given ample time to read and learn about the study. All questions and clarifications raised by the participant have been addressed.

Researcher's name..

Signature ....

Date...

Appendix II: DATA COLLECTION TOOL

No	Age	Sex	Educ. Level	Occupation	Marital Status	Religion	HIV Status	Type of TB	Address	Sub-district	Latitude	Longitude	Distance to health facility	phor
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														

Appendix III: ETHICAL CLERANCE

GHANA HEALTH SERVICE ETHICS REVIEW COMMITTEE

In case of reply the number and date of this Letter should be quoted.

My Ref. GHS/RL ... 9/9/20/3??
Your Ref. No

Owusu Kingsley
University of Ghana
School of Public Health

The Ghana Health Service Ethics Review Committee has reviewed and given approval for the implementation of your Study Protocol.

GHS-ERC Number	GHS-ERC 022/09/20
Project Title	Geospatial Distribution of TB Cases and Access to Healthcare in Birim South District
Approval Date	5th October, 2020
Expiry Date	4th October, 2021
GHS-ERC Decision	Approved

This approval requires the following from the Principal Investigator

- Submission of yearly progress report of the study to the Ethics Review Committee (ERC)
- Renewal of ethical approval if the study lasts for more than 12 months.
- Reporting of all serious adverse events related to this study to the ERC within three days verbally and seven days in writing.
- Submission of a final report after completion of the study
- Informing ERC if study cannot be implemented or is discontinued and reasons why
- Informing the ERC and your sponsor (where applicable) before any publication of the research findings.
- Please note that any modification of the study without ERC approval of the amendment is invalid

The ERC may observe or cause to be observed procedures and records of the study during and after implementation.

Kindly quote the protocol identification number in all future correspondence in relation to this approved protocol

SIGNED.
Dr. James Akazili
(Head, Ethics & Research Management Department)

Cc: The Director, Research & Development Division, Ghana Health Service, Accra