

**UNIVERSITY OF GHANA**

**SCHOOL OF PUBLIC HEALTH**

**DEPARTMENT OF BIOSTATISTICS**



**EVALUATION OF PARAMETRIC STATISTICAL METHODS IN PREDICTING  
FACTORS INFLUENCING HEPATITIS B AND HIV AMONG FEMALE SEX  
WORKERS.**

**BY**

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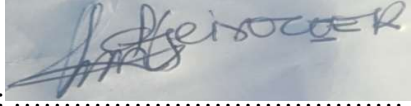
**THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN  
PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF A MSC  
IN BIOSTATISTICS DEGREE.**



## DECLARATION

### Candidate's Declaration

I certify that this thesis is the result of my own research. No part of it has been submitted for another degree at this university or any other institution.



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DATE:.....19-02-2025.....

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### Supervisors' Declaration

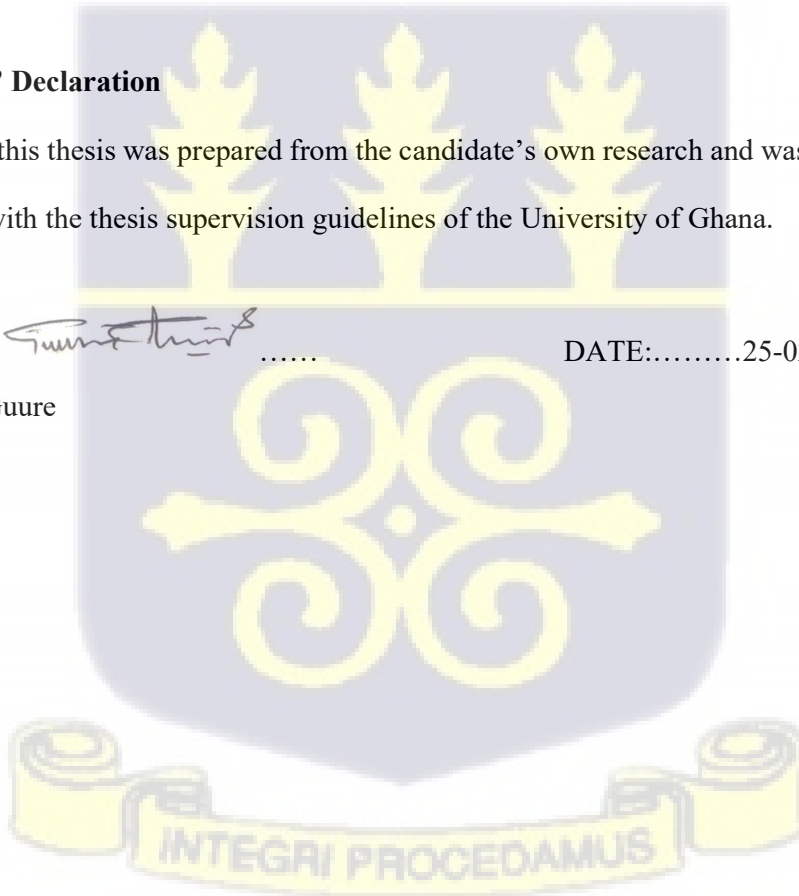
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Prof. Chris Guure



## ABSTRACT

### **Purpose**

This study evaluates parametric statistical methods, including logistic regression, Poisson regression, and Cox proportional hazards models, to determine factors influencing Hepatitis B Virus (HBV) and Human Immunodeficiency Virus (HIV) infections among female sex workers (FSWs) in Ghana. The research focuses on infection prevalence and the effectiveness of the Cox model in identifying significant predictors.

### **Methods**

A cross-sectional survey with biological sampling and structured interviews was conducted among 7,000 participants. Time Location Sampling ensured representativeness. The prevalence of HBV and HIV was calculated, and a Cox proportional hazards model was used to identify significant predictors, with hazard ratios (HR) and p-values evaluated to measure risk associations.

### **Results**

HBV prevalence was 6.53% (95% CI: 6.08–7.01%), and HIV prevalence was 4.53% (95% CI: 3.46–5.92%). Significant predictors for HBV included alcohol use during sex (HR = 1.34,  $p = 0.042$ ) and healthcare avoidance due to stigma (HR = 1.64,  $p = 0.023$ ). For HIV, older age was strongly associated with increased risk, with hazard ratios of 1.60 ( $p = 0.007$ ) for ages 25–35 and 2.20 ( $p = 0.001$ ) for ages above 35. Education was a protective factor for HIV, with secondary education reducing risk by 67% (HR = 0.33,  $p < 0.001$ ) and higher education by 60% (HR = 0.40,  $p = 0.019$ ). The Cox model outperformed logistic and Poisson regression, demonstrating superior discriminatory ability.

## **Conclusions**

The Cox proportional hazards model provided robust identification of risk factors for HBV and HIV. Behavioural and systemic determinants like alcohol use, stigma, age, and education significantly influenced infection risks. These findings underscore the need for targeted public health interventions, particularly addressing alcohol-related behaviours, stigma, and health literacy.

## **Keywords**

Hepatitis B, HIV, female sex workers, Cox regression, prevalence, Ghana.



## ACKNOWLEDGEMENTS

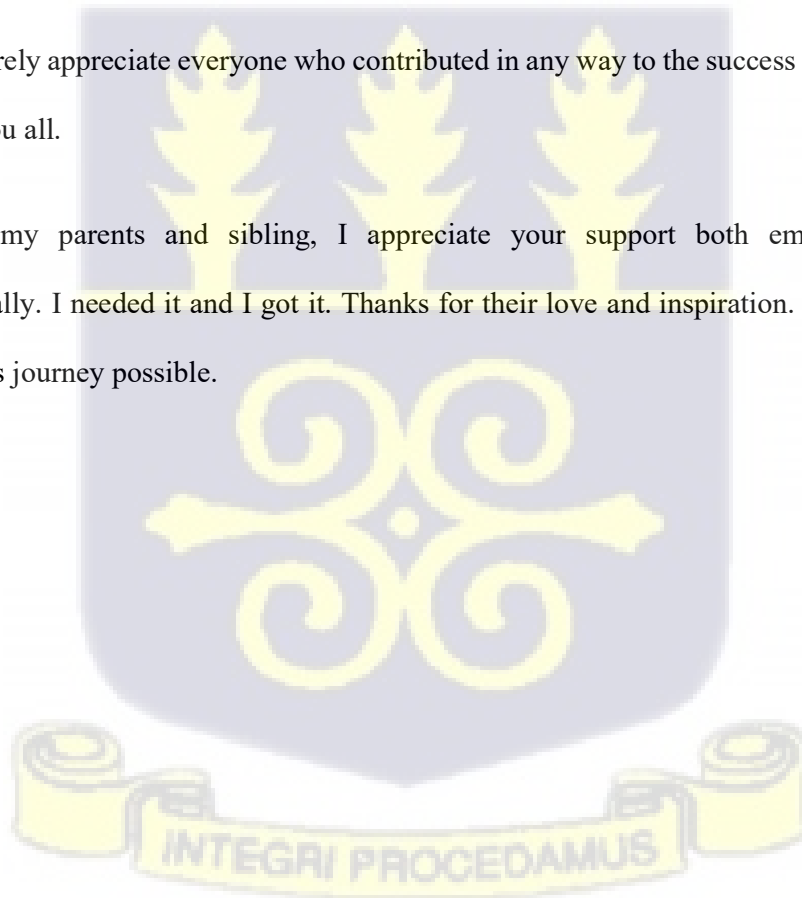
First and foremost, I thank God almighty for his grace and mercies upon my life throughout my academic journey up to this stage. Glory be to your name.

I extend my sincere gratitude to my supervisor, Dr. Chris B. Guure, for his unwavering guidance and support throughout this research. His dedication and encouragement made this work possible. I say thank you

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Also, I sincerely appreciate everyone who contributed in any way to the success of this project. God bless you all.

Finally, to my parents and sibling, I appreciate your support both emotionally and psychologically. I needed it and I got it. Thanks for their love and inspiration. Your belief in me made this journey possible.



**DEDICATION**

To my father, Mr. Roger Kwasi Adje



**TABLE OF CONTENT**

**Contents**

<b>DECLARATION.....</b>	<b>i</b>
<b>ABSTRACT .....</b>	<b>ii</b>
<b>ACKNOWLEDGEMENTS .....</b>	<b>iv</b>
<b>DEDICATION .....</b>	<b>v</b>
<b>TABLE OF CONTENT .....</b>	<b>vi</b>
<b>LIST OF TABLES .....</b>	<b>ix</b>
<b>LIST OF FIGURES .....</b>	<b>x</b>
<b>CHAPTER ONE .....</b>	<b>1</b>
<b>1.0 INTRODUCTION .....</b>	<b>1</b>
1.1 Background of the Study.....	1
1.2 Statement of the Problem.....	5
1.3 Research Questions.....	6
1.4 Research Objectives.....	6
1.5 Significance of the Study.....	7
1.6 Scope and Limitations.....	9
1.7 Limitations .....	10
1.8 Theoretical Framework.....	11
1.9 Organization of the Thesis .....	12
<b>CHAPTER TWO .....</b>	<b>14</b>
<b>2.0 LITERATURE REVIEW.....</b>	<b>14</b>
2.1 Introduction.....	14
2.2 Epidemiology of Hepatitis B.....	14
2.3 Epidemiology of HIV.....	15
2.4 Co-infection of Hepatitis B and HIV .....	15
2.5 Definition and Demographics .....	16

2.6	Global Prevalence of Hepatitis B and HIV among Female Sex Workers.....	16
2.7	Unique Risk Factors for Female Sex Workers.....	17
2.8	Factors Influencing Hepatitis B and HIV Among Female Sex Workers .....	19
2.9	Parametric Statistical Methods in Epidemiology.....	25
2.10	Advantages and Limitations of Parametric Methods.....	27
2.11	Predictive Modelling in HIV and Hepatitis B Research .....	28
2.12	Evaluation Metrics for Predictive Models .....	30
2.13	Conceptual Framework.....	31
2.14	Gaps in the Literature.....	33
2.15	Definition of Terms.....	37
<b>CHAPTER THREE .....</b>		<b>39</b>
<b>3.0 STUDY DESIGN, APPROACH AND DATA .....</b>		<b>39</b>
3.1	Introduction.....	39
3.2	Study Design.....	39
3.3	Study Design and Sampling Methodology .....	40
3.4	Study Variables.....	42
<b>CHAPTER FOUR.....</b>		<b>44</b>
<b>4.0 STATISTICAL CONSIDERATIONS / METHODOLOGY .....</b>		<b>44</b>
4.1	Introduction.....	44
4.2	Theoretical Foundation of Parametric Methods.....	44
4.3	Model Diagnostics .....	54
4.3.1.	Logistic Regression Model Diagnostics.....	54
4.3.2.	Poisson Regression Model Diagnostics .....	54
4.3.3.	Cox Regression Model Diagnostics.....	55
4.4	Model Selection and Comparison .....	55
4.5	Predictive Performance Evaluation.....	57
4.6	Ethical Considerations .....	58
<b>CHAPTER FIVE .....</b>		<b>59</b>
<b>5.0 ANALYSIS AND INTERPRETATION .....</b>		<b>59</b>
5.1	Introduction.....	59
5.2	Data Cleaning Process .....	59
5.3	Analysis of Hepatitis B (HBV) .....	60
5.4	Analysis of HIV .....	73

<b>CHAPTER SIX:</b> .....	<b>87</b>
<b>6.0 DISCUSSION, RECOMMENDATIONS, AND CONCLUSIONS</b> .....	<b>87</b>
6.1 Introduction.....	87
6.2 Discussion.....	87
6.3 Recommendations.....	91
6.4 Conclusions.....	92
<b>REFERENCES</b> .....	<b>93</b>



**LIST OF TABLES**

**Table 1:** Distribution of Socio-demographic Factors, Individual Factors, and Healthcare Access Characteristics Among Female Sex Workers by Hepatitis B Virus (HBV) Status in Ghana ..... 62

**Table 2:** Logistic Regression Analysis of Factors Associated with HBV Among Female Sex Workers ..... 65

**Table 3:** Modified Poisson Regression Analysis of Factors Associated with HBV Among Female Sex Workers ..... 67

**Table 4:** Cox Proportional Hazard Regression Analysis of Factors Associated with HBV Among Female Sex Workers..... 69

**Table 5:** Comparison of Model Performance Metrics for HBV using Logistic Regression, Modified Poisson, and Cox Regression Models Using AIC, BIC, C-Index, ROC, Sensitivity, and Specificity ..... 72

**Table 6:** Distribution of Socio-demographic Factors, Individual Factors, and Healthcare Access Characteristics Among Female Sex Workers by HIV Status in Ghana ..... 75

**Table 7:** Logistic Regression Analysis of Factors Associated with HBV Among Female Sex Workers ..... 78

**Table 8:** Modified Poisson Regression Analysis of Factors Associated with HBV Among Female Sex Workers ..... 80

**Table 9:** Cox Proportional Hazard Regression Analysis of Factors Associated with HBV Among Female Sex Workers..... 83

**Table 10:** Comparison of Model Performance Metrics for HBV using Logistic Regression, Modified Poisson, and Cox Regression Models Using AIC, BIC, C-Index, ROC, Sensitivity, and Specificity ..... 86



**LIST OF FIGURES**

**Figure 1:** Conceptual Framework of the relationship between factors influencing the infection of Female Sex Workers (Source: Authors own construct)..... 33



## CHAPTER ONE

### 1.0 INTRODUCTION

#### 1.1 Background of the Study

Sexual contact—whether vaginal, anal, or oral—can transmit over 30 types of bacteria, parasites, and viruses (World Health Organisation, 2023). Among these, eight pathogens are most prevalent in sexually transmitted infections (STIs). Four of these infections namely syphilis, gonorrhoea, chlamydia, and trichomoniasis can be cured and/or treated using antibiotic medication (Soriano & del Romero, 2018). However, four other sexually transmitted diseases including hepatitis B virus (HBV), herpes simplex virus (HSV), Human Immunodeficiency Virus (HIV), and human papillomavirus (HPV), are incurable.

Globally, STIs represent a major public health concern, with Hepatitis B and HIV standing out as particularly significant. These diseases have been reported by several studies to be predominant among sex workers globally (Vandepitte *et al.*, 2006; Ochako *et al.*, 2018; Johnson *et al.*, 2023).

Sex workers are classified as individuals and/or adults who engage in consensual sexual activities and/or erotic performance for benefits in the form of money or goods regularly or occasionally. Sex workers can be male or female however, the rate of women in sexual activities is rampant as compared to their male counterparts. According to Vandepitte *et al.* (2006), female sex workers are females who exchange sex for money or goods. Female sex workers (FSWs) are a heterogeneous group of women engaged in commercial sex work for various economic and social reasons, often using it as a primary means of income generation. They operate in a range of settings, including but not limited to entertainment venues, street-based locations, and private establishments, highlighting the multifaceted nature of their work environments (Pitpitan *et al.*, 2012; Yi *et al.*, 2010). FSWs are present globally, in both high-

income and low-income countries, including Ghana, with a particularly strong presence in urban centres where the demand for such services tends to be concentrated. The age of entry into sex work varies considerably; some women begin at a young age, often due to socio-economic vulnerabilities, while others may enter later in life, sometimes after experiencing significant economic or social shifts. Additionally, FSWs come from diverse educational backgrounds, with some having limited formal education, whereas others may possess higher educational qualifications. Their socioeconomic statuses also differ widely, reflecting the complex interplay between economic necessity and personal choice in the decision to engage in sex work (Yi *et al.*, 2010). Furthermore, the pathways into sex work can be diverse—ranging from voluntary entry to cases involving coercion, trafficking, or other forms of exploitation (Silverman *et al.*, 2011). The duration of involvement can vary, with some women engaging in sex work for brief periods, while others may remain in the profession for many years, viewing it as a long-term career option or a stable source of livelihood (Kakisingi *et al.*, 2020). This variation underscores the diversity of experiences, motivations, and circumstances among FSWs, making them a uniquely complex and dynamic population group that warrants nuanced understanding in research and policy development.

The nature of female sex work makes sex workers particularly vulnerable to sexually transmitted infections (STIs), including Hepatitis B and Human Immunodeficiency Virus (Qiao *et al.*, 2014). Understanding the prevalence of these infections among this population is essential, especially across Africa, including sub-Saharan and West African regions such as Ghana, where the intersection of sexual health and public health priorities is crucial.

Globally, the burden of HBV and HIV poses a significant public health challenge, especially among vulnerable groups like female sex workers (FSWs). The World Health Organization (2022) estimates that approximately 254 million individuals are living with chronic HBV, while nearly 39 million are affected by HIV worldwide. These infections are associated with

severe health complications, particularly in low- and middle-income countries where healthcare access is often constrained. Since both viruses are predominantly transmitted through sexual contact, targeted interventions for high-risk groups such as FSWs are vital (Diniarti *et al.*, 2024; Kramvis & Lau, 2024).

FSWs face an elevated risk of contracting HBV and HIV due to a range of factors, including limited access to healthcare services, social stigma, and frequent exposure to unprotected sexual encounters (Shaari *et al.*, 2023; Famoni *et al.*, 2024). Many are constrained by inadequate sexual health education and encounter significant barriers in accessing preventive measures such as vaccinations and antiretroviral therapy. This susceptibility is further compounded by social determinants such as poverty, substance use, and exposure to violence, which collectively heighten their vulnerability to infection (Poglia Mileti *et al.*, 2023; Shaari *et al.*, 2023; JVT *et al.*, 2024). Addressing these factors is crucial for reducing infection rates and improving health outcomes in this population.

Identifying the factors contributing to the prevalence of HBV and HIV among FSWs is vital for several reasons. Firstly, it enables the development of targeted public health strategies tailored to their specific needs. Secondly, it facilitates better allocation of resources to reduce infection rates and improve health outcomes (Alege *et al.*, 2023). Lastly, recognizing the combined influence of biological, social, and economic factors allows for a more comprehensive approach to health promotion and disease prevention (Eduku & Senoo-Dogbey, 2024; Famoni *et al.*, 2024).

Parametric statistical methods play a crucial role in epidemiological research, offering valuable tools to analyze data and derive meaningful insights about health trends and risk factors. These methods assume that data follow a specific distribution—often normal—and when this assumption holds true, they enable robust inferences about population characteristics (Sharma

& Jha, 2023). However, different parametric models have distinct sets of assumptions. For instance, logistic regression, commonly used for binary outcomes, assumes linearity between continuous predictors and the log-odds of the outcome, absence of multicollinearity, and independence of observations (Hosmer *et al.*, 2013). Violating these assumptions can lead to biased or misleading results. Similarly, Cox proportional hazards models, widely used in survival analysis, rely on the proportional hazards assumption, which states that the ratio of hazard rates between groups remains constant over time (Kleinbaum & Klein, 2012). If this assumption is not met, the model's ability to provide valid hazard ratio estimates is compromised. Addressing these assumptions through diagnostic checks and appropriate model adjustments is essential to ensure the validity and reliability of findings derived from parametric methods in epidemiological research. Techniques such as t-tests, Analysis of Variance (ANOVA), and ordinary least squares regression are commonly used parametric methods that assume normality of residuals and homoscedasticity. However, other parametric methods, such as logistic regression, Poisson regression, and Cox proportional hazards models, extend the applicability of parametric approaches beyond normality assumptions (Hosmer, Lemeshow, & Sturdivant, 2013; Kleinbaum & Klein, 2012). For instance, logistic regression is used to model binary outcomes and assumes a linear relationship between the log-odds of the outcome and predictor variables, while Poisson regression is suited for count data and assumes that the mean and variance of the count variable are equal (Cameron & Trivedi, 2013). Meanwhile, Cox proportional hazards models, often used in survival analysis, rely on the proportional hazards assumption rather than normality (Kleinbaum & Klein, 2012). In studying the factors influencing HBV and HIV among female sex workers (FSWs), using a combination of these parametric methods leads to the capture of a broad range of data characteristics and derive meaningful insights that can guide effective interventions.

## 1.2 Statement of the Problem

Female sex workers (FSWs) are disproportionately affected by Hepatitis B virus (HBV) and HIV due to a combination of biological, behavioural, and structural risk factors. Despite global efforts to curb these infections, FSWs remain a high-risk population due to limited healthcare access, occupational hazards, and social marginalization (Sitorus *et al.*, 2024). The inability to accurately predict and address the key risk factors contributing to HBV and HIV in this population has significant public health consequences, including increased healthcare costs, loss of productivity, and sustained disease transmission (Holzmeister *et al.*, 2023). Without effective predictive models, interventions remain generalized, often failing to target the most critical determinants of infection. Current challenges in predicting these risk factors include reliance on self-reported data, which may be biased due to underreporting of stigmatized behaviours (Latkin *et al.*, 2017a), as well as inconsistencies in study designs that hinder comparability across different settings (Platt *et al.*, 2018). Furthermore, existing models often fail to account for the dynamic nature of sex work, where legal, economic, and social environments continuously influence risk behaviours (Armstrong *et al.*, 2021). As a result, many public health strategies lack precision, leading to inefficient resource allocation and suboptimal prevention outcomes. This study seeks to address these gaps by evaluating the effectiveness of parametric statistical methods—such as logistic regression, modified Poisson regression, and Cox proportional hazards models—in identifying and predicting individual-level risk factors for HBV and HIV among FSWs. These methods are chosen for their ability to provide interpretable measures of association (e.g., odds ratios, prevalence ratios, and hazard ratios) while controlling for confounding variables (Hosmer, Lemeshow, & Sturdivant, 2013; Kleinbaum & Klein, 2012). By employing cross-sectional data, this study will assess prevalent risk factors at a specific point in time, offering actionable insights for targeted interventions

(Levin, 2006). The findings will contribute to more precise public health strategies, ultimately reducing the economic and societal burden of these infections.

### **1.3 Research Questions**

The primary research question that guides this study is: What is the best fit model in predicting the factors influencing Hepatitis B Virus and Human Immunodeficiency Virus infections among female sex workers?

To address this overarching question, the study explores the following secondary research questions:

1. What are the key individual, social, and structural factors that contribute to the occurrence of HBV and HIV infections among female sex workers?
2. What are the comparative strengths and limitations of different parametric statistical methods, such as modified Poisson regression, logistic regression, and Cox regression, in predicting factors associated with HBV and HIV among FSWs?
3. How can a suitable predictive model be developed by integrating the identified factors and utilizing the most effective parametric statistical methods to provide accurate predictions of HBV and HIV infection occurrence among FSWs?
4. How can the findings from this study inform the design of tailored prevention strategies and resource allocation to mitigate the impact of HBV and HIV among female sex workers?

### **1.4 Research Objectives**

The primary objective of this study is to evaluate the effectiveness of parametric statistical methods in predicting the factors influencing Hepatitis B Virus (HBV) and Human Immunodeficiency Virus (HIV) infections among female sex workers in Ghana.

The specific objectives of the study are as follows:

1. To evaluate the effectiveness of different parametric statistical methods in predicting the factors associated with Hepatitis B and HIV among female sex workers.
2. To identify the key factors that influence the occurrence of Hepatitis B and HIV among female sex workers.
3. To develop a suitable predictive model for forecasting the occurrence of Hepatitis B and HIV among female sex workers.
4. To provide evidence-based recommendations for designing targeted prevention strategies and optimizing resource allocation for mitigating HBV and HIV among female sex workers.

### **1.5 Significance of the Study**

The significance of this research lies in its potential contributions to both theoretical knowledge in epidemiology and statistics, as well as its practical applications in public health.

Findings from the present study would help enhance the theoretical understanding of the relationship between statistical methods and epidemiological research, particularly in the context of vulnerable populations such as female sex workers. It would also help to evaluate the effectiveness of various parametric statistical methods, as well as its contribution to the body of knowledge regarding the appropriateness and limitations of these techniques in predicting health outcomes. It will provide insights into how different modelling approaches can yield varying results, thereby informing researchers about the importance of selecting suitable statistical methods based on the data characteristics and research questions. Furthermore, the identification of key risk factors influencing Hepatitis B Virus (HBV) and Human Immunodeficiency Virus (HIV) infections among FSWs will enrich the existing

literature on epidemiological determinants and contribute to a more nuanced understanding of the health challenges faced by this population.

The development of an improved predictive model for accurately predicting the likelihood of Hepatitis B Virus (HBV) and Human Immunodeficiency Virus (HIV) infection among female sex workers (FSWs) involves integrating multiple parametric statistical techniques, such as logistic regression, modified Poisson regression, and Cox proportional hazards regression. This process requires a systematic evaluation of each model's strengths, assumptions, and suitability for the data, followed by a comparison based on model performance metrics such as the Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), Sensitivity, and Specificity which offer insights into the balance between model fit and complexity, guiding the selection of the optimal model (Burnham & Anderson, 2004). Typically, model development begins with a stepwise approach to variable selection to ensure that only significant predictors are included in the final model, as adding irrelevant variables can lead to overfitting and reduce generalizability (Harrell, 2015). The process also involves diagnostic tests, such as residual analysis and goodness-of-fit statistics, to confirm that assumptions are met (Hosmer, Lemeshow, & Sturdivant, 2013). Once the base models are fitted, their outputs are compared to identify the most effective approach for each outcome variable by examining AIC and BIC for goodness-of-fit for predictive accuracy and generalizability. Combining insights from different models may lead to a hybrid framework that leverages the strengths of each approach (Gelman, Hwang, & Vehtari, 2014). For example, logistic regression might be useful for identifying binary predictors, while Cox regression provides insights into time-dependent covariates, thus enhancing predictive power when integrated. A crucial aspect of this model development is validation through techniques such as k-fold cross-validation, which assess robustness and the ability to predict outcomes on unseen data, thereby preventing overfitting (James, Witten, Hastie, & Tibshirani, 2013). Additionally, using bootstrapping methods helps

estimate the stability of model coefficients, offering a reliable measure of predictive capability (Efron & Tibshirani, 1994).

The implications of this study extend to public health strategies and interventions aimed at reducing the burden of HBV and HIV among FSWs. It will provide evidence-based insights into the factors influencing these infections, the research would guide policymakers and health organizations in the allocation of resources more effectively.

Nonetheless, findings from this study would serve as a source of information for the development of comprehensive health policies that address the social determinants of health affecting FSWs, such as stigma, discrimination, and access to healthcare.

## **1.6 Scope and Limitations**

### **1.6.1 Geographical Area**

This study will focus on a specific geographical area characterized by a high prevalence of Hepatitis B Virus (HBV) and Human Immunodeficiency Virus (HIV) infections among female sex workers (FSWs). The selected region is Ghana, where the intersection of high-risk sexual behaviour and limited access to healthcare services presents significant public health challenges. This geographical focus allows for a detailed examination of the factors influencing HBV and HIV infections in a context where these issues are particularly pronounced.

### **1.6.2 Population Focus**

The population focus of this study will be female sex workers aged 16 years and older. This age range is selected to encompass both young and adult FSWs, allowing for a comprehensive understanding of the risk factors affecting different life stages. Additionally, the study will consider specific subgroups within the FSW population, such as those engaged in street-based versus brothel-based sex work, as well as those who may be part of marginalized communities, including migrants or those with a history of substance abuse. By focusing on these subgroups,

the research aims to identify nuanced factors that may influence the risk of HBV and HIV infections.

### **1.6.3 Methodological Boundaries**

The methodological boundaries of this study will include the use of parametric statistical methods to analyse data collected from surveys, interviews, and existing health records. The study will employ quantitative approaches, primarily focusing on cross-sectional data to assess the prevalence of HBV and HIV among FSWs and to identify associated risk factors. This will involve the application of statistical techniques such, logistic regression, and multilevel modelling to evaluate the relationships between variables. The study will also include qualitative components, such as interviews with key stakeholders and FSWs, to enrich the quantitative findings and provide context to the statistical analyses.

### **1.7 Limitations**

Several limitations may influence the findings of this study. Firstly, the use of self-reported data from FSWs may introduce biases, including social desirability and recall biases, which could affect the accuracy of reported risk behaviours and health status. Moreover, the cross-sectional nature of the study restricts the ability to determine causal relationships between identified risk factors and the prevalence of HBV and HIV infections.

Additionally, the study's geographical focus on a specific region may limit the applicability of the findings to other settings or populations. Socio-cultural and economic factors unique to the study area may not reflect the experiences of FSWs in other regions or countries.

Finally, limitations related to data availability and access to healthcare services for FSWs may affect the completeness of the datasets used in the analysis. This could lead to missing data or an underrepresentation of certain subgroups, potentially influencing the reliability of the predictive model developed.

## 1.8 Theoretical Framework

### 1.8.1 Relevant Epidemiological Theories

This research on Hepatitis B Virus (HBV) and Human Immunodeficiency Virus (HIV) infections among female sex workers (FSWs) is guided by several key epidemiological theories that illuminate the dynamics of disease transmission and the impact of various factors on health outcomes.

**Social Determinants of Health Theory:** This theory asserts that health outcomes are profoundly shaped by social and economic factors such as income, education, and social support networks. For FSWs in Ghana, this theory underscores how socio-economic status, stigma, and discrimination can influence healthcare access and infection risk (Decker *et al.*, 2015). Studies by Baral *et al.* (2012) demonstrate that adverse socio-economic conditions among FSWs contribute to elevated rates of HIV and HBV, highlighting the need for targeted interventions addressing these underlying social determinants (Eduku & Senoo-Dogbey, 2024; O. P *et al.*, 2024).

**Behavioural Epidemiology:** This framework examines how individual behaviours, such as sexual practices and substance use, affect health outcomes. Research indicates that behaviours like inconsistent condom use and having multiple sexual partners are prevalent among FSWs and significantly elevate the risk of HIV and HBV transmission (Dirisu *et al.*, 2022; Kumar *et al.*, 2020; Rashti *et al.*, 2020). This theory is instrumental in guiding the development of behavioural interventions aimed at reducing infection rates among FSWs.

**Epidemiological Transition Theory:** This theory describes the shift in disease patterns as societies evolve, transitioning from a predominance of infectious diseases to a greater burden of chronic diseases. However, in many low- and middle-income countries, including Ghana, FSWs face a dual burden of both infectious diseases like HIV and HBV and chronic conditions. This phenomenon reflects the continued relevance of infectious disease prevention amidst

socio-economic changes (Dery *et al.*, 2024; Guure *et al.*, 2023; Ciccacci *et al.*, 2020). Understanding this transition is crucial for developing effective public health strategies that address both infectious and chronic diseases within this population.

### **1.9 Organization of the Thesis**

The thesis is structured into six chapters, each addressing a specific aspect of the research on the factors influencing Hepatitis B Virus (HBV) and Human Immunodeficiency Virus (HIV) infections among female sex workers (FSWs). Chapter One provides an overview of the research topic, including the background and significance of studying HBV and HIV among FSWs. It also includes the research problem, outline the research questions and the specific objectives of the study. Also, Chapter two is the review of existing literature on HBV and HIV infections, focusing on their prevalence among FSWs. It also explored the socio-demographic, behavioural, and structural factors influencing these infections, as well as the effectiveness of current public health interventions. Additionally, it identifies gaps in the literature that the current study aims to address.

Chapter three provided detailed information on the research design used in the study. It will describe the study population, sampling techniques, data collection methods (including surveys and interviews).

Chapter 4 focuses on the statistical analyses employed. Ethical considerations related to conducting research with FSWs were also explained.

The fifth chapter presents the key findings from the data analysis. It included descriptive statistics, results from logistic regression and multilevel modelling, and any qualitative insights derived from interviews with FSWs and stakeholders. The chapter also highlights key risk factors associated with HBV and HIV infections among the study population.

Chapter Six gives an in-depth discussion of the results through comparison and contrast of the results obtained with already similar existing studies in the subject matter. Also, this chapter discusses the implications of the findings for understanding the factors influencing HBV and HIV infections among FSWs.

The final chapter provides a summary of the main findings of the research and their significance, conclusion and recommendations for implementation and future research.



## CHAPTER TWO

### 2.0 LITERATURE REVIEW

#### 2.1 Introduction

This literature review aims to integrate the available research on the prevalence and influencing factors of Hepatitis B Virus and Human Immunodeficiency Virus infections among female sex workers. It involves exploring infection rates, pinpointing significant risk factors, and assessing the effectiveness of existing measures to curb transmission. Through this analysis, the review lays the groundwork for the research questions of this research, offering direction for investigating how parametric statistical methods could enhance infection prediction within this group.

#### 2.2 Epidemiology of Hepatitis B

Hepatitis B is a viral infection that mainly affects the liver and is caused by the Hepatitis B Virus (HBV). According to the World Health Organization (WHO), an estimated 296 million people globally were living with chronic HBV infection in 2019 (WHO, 2021). The prevalence of HBV shows considerable variation across regions, with the Western Pacific (5.26%, 5.26–5.26) and African regions (8.83%, 8.82–8.83) having the highest rates (Schweitzer *et al.*, 2015).

Numerous studies have examined the epidemiology of HBV among female sex workers (FSWs). For instance, Metaferia *et al.* (2021) reported a pooled HBV prevalence of 13.1% among FSWs. Their review stressed the urgent need for tailored interventions, such as vaccination and screening programmes, to alleviate the HBV burden within this population.

Todd *et al.* (2010) examined the prevalence of HBV among FSWs in Afghan cities and reported a rate of 6.54%. Their analysis identified independent risk factors for HBV infection, including having at least 12 clients per month [adjusted odds ratio (AOR) = 3.15, 95% confidence interval (CI) 1.38–7.17], prior alcohol consumption (AOR = 2.61, 95%CI 1.45–4.69), engagement in

anal sex (AOR = 2.42, 95%CI 1.15–5.08), and having children (AOR = 2.12, 95%CI 1.72–2.63), based on a multivariable analysis that accounted for site-specific factors.

### **2.3 Epidemiology of HIV**

Human Immunodeficiency Virus (HIV) weakens the immune system and can lead to Acquired Immunodeficiency Syndrome (AIDS) if left untreated. According to UNAIDS (2021), an estimated 37.7 million people worldwide were living with HIV in 2020, with sub-Saharan Africa disproportionately affected, accounting for 67% of new infections.

Several studies have examined the prevalence of HIV among female sex workers. Metaferia *et al.* (2021) reported a prevalence of 7.5% among FSWs, stressing the need for comprehensive interventions that address the social and structural factors contributing to their increased vulnerability to HIV. Likewise, a meta-analysis by Eilami *et al.* (2019) estimated an HIV prevalence of 2.17% (95% CI = 1.37–3.14) among FSWs. The analysis identified inconsistent condom use and intravenous drug use as major factors driving HIV transmission in this population. These findings underscore the importance of targeted interventions to mitigate the specific risks faced by FSWs.

In Ghana, Guure *et al.* (2023) reported an HIV prevalence of 4.67% (95% CI: 4.05%–5.40%) among FSWs. However, this rate varied across the country's 16 regions, ranging from 0.00% to 8.40%, with higher infection rates observed among older FSWs.

### **2.4 Co-infection of Hepatitis B and HIV**

Co-infection with Hepatitis B Virus (HBV) and Human Immunodeficiency Virus (HIV) poses a major public health concern, as it is linked to faster liver disease progression in individuals with both infections compared to those with only one (Boyd *et al.*, 2017; Klein *et al.*, 2016; Weber *et al.*, 2013). Studies show that HBV-HIV co-infection prevalence varies widely across populations and regions. Among female sex workers (FSWs), the co-infection rate has been

reported at 1%, highlighting their susceptibility to multiple infections and the urgent need for improved prevention measures (Rashti *et al.*, 2020). This underscores the necessity of targeted interventions to curb the dual transmission of HBV and HIV among FSWs.

A study in Brazil reported a relatively low prevalence of HBV-HIV co-infection among FSWs, estimated at 0.05% (95% CI: 0.01%–0.22%). This low rate suggests the need for further research on sexually transmitted infections and co-infections within this high-risk group, along with the integration of FSWs into comprehensive prevention and treatment programmes (Ferreira-Junior *et al.*, 2018).

## **2.5 Definition and Demographics**

**Female Sex Workers (FSWs):** Female sex workers are commonly defined as adult women who engage in consensual sexual activities, including vaginal, anal, and/or oral sex, in exchange for money or other compensation as their primary means of livelihood (UNAIDS, 2012). Another definition classifies an FSW as any woman aged 16 years or older (the legal age for consensual sex in Ghana) who, within the past six months, has engaged in sexual activities with someone other than her regular partner in return for money or material goods that would not typically be provided by her sexual partners (Guure, Dery, Afagbedzi, Maya, da-Costa Vroom, & Torpey).

## **2.6 Global Prevalence of Hepatitis B and HIV among Female Sex Workers**

The global prevalence of HIV and Hepatitis B Virus among female sex workers has been the focus of numerous studies, highlighting their disproportionate vulnerability to these infections. For instance, research conducted by Rashti *et al.* (2020) revealed an HIV prevalence of 5% and an HBV prevalence of 3% among FSWs. These figures underscore the heightened risk faced by this population, pointing to an urgent need for targeted public health interventions to mitigate the spread of these infections.

Further analysis of global data suggests that the HIV prevalence among FSWs is approximately 5.3% (95% CI: 4.4%–6.2%), with various socio-economic and behavioural factors contributing to the risk of infection. Low educational attainment, involvement in street-based sex work, lower financial remuneration per sexual encounter, longer engagement in sex work, experiences of sexual violence, drug use, and inconsistent condom usage have all been significantly associated with higher rates of HIV infection (Szwarcwald *et al.*, 2018).

In Ethiopia, a study conducted by Daka *et al.* (2022) in Hawassa reported an HBV prevalence of 9.2% (95% CI: 6.3%–12.1%) among FSWs, a rate notably higher than that of the general population. This elevated prevalence was linked to factors such as inconsistent condom use (AOR = 6.38, 95% CI: 2.04–18.51) and experiences of sexual violence (AOR = 2.93, 95% CI: 1.23–9.01), indicating that both behavioural and structural vulnerabilities play a significant role in the heightened risk of HBV infection among FSWs.

## **2.7 Unique Risk Factors for Female Sex Workers**

Female sex workers are subject to a distinct set of risk factors that heighten their vulnerability to Hepatitis B Virus and Human Immunodeficiency Virus infections. These risk factors can be classified across individual, social, and structural dimensions, each contributing to their increased susceptibility.

### **2.7.1 Individual Risk Factors**

At the individual level, behaviours such as inconsistent condom use, substance abuse, and multiple sexual partners are particularly prevalent. For instance, Daka *et al.* (2022) found the prevalence of HBV among FSWs to be 9.2% (95% CI: 6.3%–12.1%). Contributing factors included inconsistent condom use, condom breakage, stimulant use, a history of sexually transmitted infections (STIs), genital ulcers, high numbers of sexual partners, sexual activity during menstruation, experiences of sexual assault, sharing of sharp instruments, and a history

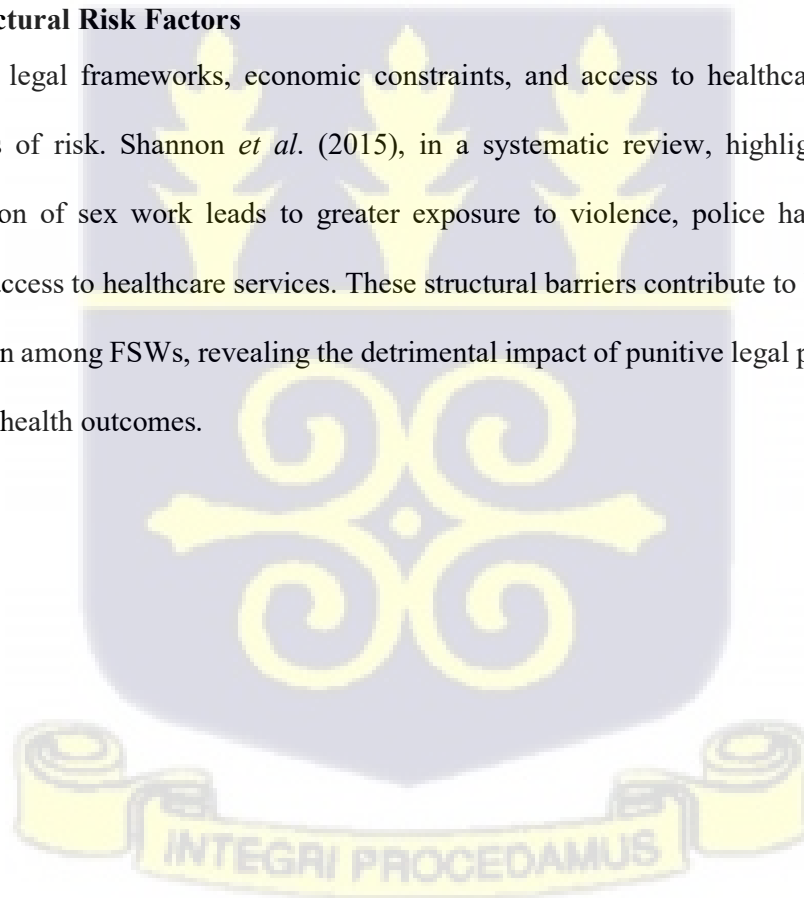
of abortion. These personal behaviours significantly elevate the risk of infection within this population.

### **2.7.2 Social Risk Factors**

Socially, stigma, discrimination, and violence play central roles in exacerbating the vulnerability of FSWs. A qualitative study conducted by Scorgie *et al.* (2013) across four African countries revealed that discrimination from healthcare providers and law enforcement personnel presented significant barriers to healthcare access. Such social exclusion discourages FSWs from seeking essential health services, further increasing their risk of both HBV and HIV infections.

### **2.7.3 Structural Risk Factors**

Structurally, legal frameworks, economic constraints, and access to healthcare are critical determinants of risk. Shannon *et al.* (2015), in a systematic review, highlighted how the criminalisation of sex work leads to greater exposure to violence, police harassment, and diminished access to healthcare services. These structural barriers contribute to higher rates of HIV infection among FSWs, revealing the detrimental impact of punitive legal policies on this population's health outcomes.



## **2.8 Factors Influencing Hepatitis B and HIV Among Female Sex Workers**

### **2.8.1 Behavioural Factors**

Behavioural factors significantly influence the transmission dynamics of Hepatitis B (HBV) and Human Immunodeficiency Virus (HIV) among female sex workers (FSWs). Analysing these behaviours is essential for designing effective intervention strategies.

#### **2.8.1.1 Condom Use**

Condom use is a fundamental preventive measure against sexually transmitted infections (STIs), including HBV and HIV. A study conducted in Ghana highlighted that while 70% (4,781) of FSWs reported consistent condom use with paying clients over the past three months, only 39% maintained this practice consistently. Furthermore, 84% (5,115) of FSWs requested condom use from clients, and 69% utilised condoms primarily for STI and HIV prevention, with 23% also using them to prevent pregnancy. Reasons for non-compliance included client refusal (23%), reliance on regular clients (15%), and higher payment for unprotected sex (16%) (Dery *et al.*, 2024). This disparity reflects a significant gap in protective behaviours, as consistent condom use has been shown to reduce the risk of HIV transmission by 87% (Davis & Weller, 1999). Moreover, inconsistent condom use has been linked to a 1.72 times higher likelihood of HBV and HIV infections in Ethiopia (AOR = 1.72, 95% CI: 1.95–5.07,  $p = 0.03$ ) (Wondmagegn *et al.*, 2022). Enhancing condom negotiation skills and improving access to condoms are essential strategies to mitigate infection rates among FSWs.

#### **2.8.1.2 Needle Sharing**

Needle sharing, though primarily linked to drug use, is also relevant among female sex workers (FSWs) who engage in substance use. While data on needle sharing among FSWs in Ghana are limited, research from other regions highlights its significant role in HIV and HBV transmission. Studies have consistently demonstrated an association between needle sharing and increased risk of HIV and HBV infections (Medhi *et al.*, 2012; Nguyen *et al.*, 2007;

Strathdee *et al.*, 2008). A cohort study in Tanzania reported a strong link between drug use, needle sharing, and higher HIV prevalence (AOR = 3.45 per 100 person-years at risk) (Faini *et al.*, 2022). These findings underscore the urgent need for harm reduction strategies that address both sexual and injection-related risks.

### **2.8.1.3 Sexual Practices**

The sexual behaviours of female sex workers (FSWs), including their number of sexual partners and the types of sexual activities they engage in, play a crucial role in their risk of acquiring Hepatitis B Virus (HBV) and Human Immunodeficiency Virus (HIV). Research in Malawi indicated that having multiple sexual partners heightened the risk of sexually transmitted infections (STIs) among FSWs (Wilson Chialepeh & Sathiyasusuman, 2015). Additionally, engaging in anal sex has been linked to an increased risk of HIV transmission due to the higher likelihood of micro-tears and exposure to bodily fluids (Seshu *et al.*, 2016). These findings highlight the need to consider sexual practices when designing targeted sexual health education and intervention programmes.

## **2.8.2 Socioeconomic Factors**

Socioeconomic factors significantly influence the health outcomes of FSWs, impacting their vulnerability to HBV and HIV.

### **2.8.2.1 Education Level**

Education significantly affects health literacy and access to information about sexually transmitted infections (STIs). Research has shown that higher educational attainment is associated with a lower likelihood of HIV infection. For instance, a study found that individuals with higher education levels had substantially reduced odds of contracting HIV, with adolescents and young adults experiencing reductions of up to 77% (POR = 0.23, CrI: 0.15–0.31) and 81% (POR = 0.19, CrI: 0.13–0.27), respectively, compared to those with no education

(Guure *et al.*, 2023). This underscores the importance of implementing educational interventions to enhance health knowledge and reduce STI risks among FSWs.

### **2.8.2.2 Income**

Income levels are a significant determinant of Hepatitis B virus (HBV) infection risk among female sex workers (FSWs). Research has consistently highlighted the correlation between lower income and increased HBV prevalence. A systematic review by Ding (2020) reported a borderline increased risk (OR = 1.14, 95% CI: 1.00–1.30) of HBV seroprevalence among individuals with lower incomes. The study also found a 28% higher risk of HBsAg seroprevalence in the low-income group compared to their higher-income counterparts (OR = 1.28, 95% CI: 1.16–1.41). Similarly, Zhang *et al.* (2013) found that women with lower family income had a higher prevalence of HBsAg compared to those with higher family incomes ( $p = 0.013$ ).

Income constraints pose significant barriers to accessing healthcare for FSWs. Chakrapani *et al.* (2009) observed that economic pressures force many FSWs in Chennai to engage in sex work to support their families while concealing their profession and HIV status due to fear of stigma and discrimination. This fear of exposure can lead to severe consequences such as family rejection, domestic violence, homelessness, and social exclusion. Consequently, many FSWs delay initiating Antiretroviral Therapy (ART) until their health deteriorates significantly.

In Ghana, economic instability further compounds these issues, leading to reduced access to essential healthcare services such as regular STI screenings and HBV vaccinations (Dery *et al.*, 2024). Lower-income FSWs may prioritise immediate financial needs over health, resulting in riskier behaviours (Decker *et al.*, 2013). Addressing these economic barriers is crucial for enhancing health outcomes among FSWs by improving their access to healthcare services and preventive measures.

### **2.8.2.3 Access to Healthcare**

Research underscores the significant barriers female sex workers (FSWs) face in accessing both sexual and reproductive health (SRH) and general healthcare services. Razu *et al.* (2023) identify social stigma and violence as major obstacles, with various socioeconomic and cultural factors further complicating their access to healthcare. This study highlights the pressing need for heightened awareness and improved access to safe and supportive healthcare services to enhance the overall well-being of FSWs.

Anna Darling *et al.* (2013) similarly reveal that restricted access to healthcare services severely impacts FSWs dealing with sexually transmitted infections (STIs). Their findings indicate that many FSWs encounter challenges such as lack of health insurance, insufficient knowledge about available services, and language barriers. These obstacles prevent timely and appropriate care, leading to untreated STIs, increased health risks, and exacerbated transmission rates. The study emphasises the necessity of better awareness of healthcare resources and improved service provision to overcome these barriers and improve health outcomes for FSWs.

Fauk *et al.* 2021, further elaborate on the critical role of healthcare access. They describe personal barriers, such as lack of knowledge about HIV testing and services, social barriers, including fear of stigma and discrimination, and systemic issues like mistrust of healthcare providers and privacy concerns. These factors contribute to a high prevalence of HIV among FSWs. Improved access to healthcare and efforts to reduce stigma could significantly enhance health outcomes for FSWs, as evidenced by research suggesting that such improvements can lead to better management of STIs and overall health (Decker *et al.*, 2013).

### **2.8.3 Structural Factors**

Structural factors encompass the broader social, legal, and economic contexts that influence the health of FSWs.

### **2.8.3.1 Legal Status of Sex Work**

The legal status of sex work plays a pivotal role in shaping the health outcomes of FSWs. In Ghana, where sex work is criminalised, the resulting stigma and discrimination create significant barriers to healthcare access. Dery *et al.* (2024) highlight that this criminalisation exacerbates the reluctance of FSWs to seek necessary health services. Criminalisation is linked with increased violence and diminished access to healthcare, which in turn heightens the risk of Hepatitis B Virus (HBV) and Human Immunodeficiency Virus (HIV) infections among FSWs (Shannon *et al.*, 2018). This illustrates the profound impact of legal frameworks on the health and well-being of FSWs.

### **2.8.3.2 Violence and Discrimination**

Violence, both physical and sexual, against FSWs is a pervasive issue that significantly worsens their health risks. Research conducted in Ghana indicates that violence from clients and law enforcement can discourage FSWs from using condoms, thereby increasing their risk of sexually transmitted infections (Dery *et al.*, 2024). Addressing violence against FSWs is critical for improving their health outcomes and reducing STI incidence. Decker *et al.* (2015) underscore the importance of tackling violence to better protect the health of FSWs and mitigate their vulnerability to infections.

### **2.8.3.3 Healthcare Policies**

The development and implementation of healthcare policies tailored to the needs of FSWs are crucial for enhancing their health outcomes. The Ghana Adolescent Health Service Policy, for example, has faced significant implementation challenges, with only 17% of the policy fully executed (Agblevor *et al.*, 2023). This highlights a broader issue of inadequate attention to specific populations, including FSWs, within health strategies. Research indicates that inclusive healthcare policies are essential for improving access to STI prevention and treatment services for FSWs, which can significantly reduce the burden of HBV and HIV (Shannon *et*

*al.*, 2018). This underscores the need for targeted policy interventions to address the unique health needs of FSWs.

#### **2.8.4 Biological Factors**

Biological factors also play a significant role in the susceptibility of FSWs to HBV and HIV.

##### **2.8.4.1 Age**

Age is a crucial biological factor affecting the susceptibility of FSWs to HBV and HIV. Research indicates that younger FSWs, particularly those aged 18-24, experience higher rates of HIV infection. This increased risk is attributed to various factors, including reduced power in negotiating safe sex practices (Faini *et al.*, 2022). This finding underscores the need for age-targeted interventions that address the specific vulnerabilities faced by younger FSWs, aiming to empower them with the skills and resources to protect themselves more effectively.

##### **2.8.4.2 Pre-existing Health Conditions**

Underlying health issues, including untreated sexually transmitted infections (STIs), may heighten susceptibility to HIV and HBV infections. Research from Ethiopia demonstrates that female sex workers (FSWs) with prior STI diagnoses face significantly elevated HIV acquisition risks (Wondmagegn *et al.*, 2022). These findings underscore the importance of implementing regular STI screenings and timely therapeutic interventions for this population to lower co-infection probabilities. Consistent health monitoring and proactive infection control measures remain vital for diminishing general vulnerability to both HIV and HBV

##### **2.8.4.3 Sexually Transmitted Infections**

The presence of other STIs can significantly increase the likelihood of HIV and HBV transmission. Decker *et al.* (2015) demonstrate that FSWs with concurrent STIs are more susceptible to HIV due to factors such as mucosal inflammation and elevated viral loads. Addressing the high prevalence of STIs among FSWs is thus vital for reducing the transmission

rates of HIV and HBV. By focusing on comprehensive STI management, health interventions can more effectively curtail the spread of these infections among FSWs.

## **2.9 Parametric Statistical Methods in Epidemiology**

### **2.9.1 Overview of Parametric Methods**

Parametric statistical methods are fundamental in epidemiological research, relying on assumptions about the data's underlying distribution. Typically, these methods assume a normal distribution, employing mathematical relationships between design variables and a limited number of parameters to model structural variability and explore relationships between variables (Sharma & Jha, 2023). According to Pérez-Guerrero *et al.* (2024), common parametric methods include the two-sample t-test, paired t-test, Welch test, ANOVA, simple linear regression, and Pearson correlation. These techniques are extensively used to examine variable relationships and infer population parameters.

When the underlying assumptions of parametric methods are satisfied, they generally offer greater power compared to non-parametric methods. This increased power results in more accurate estimates of effect sizes and p-values. The key advantage of parametric methods lies in their ability to provide precise statistical inferences, given that the data meets the necessary assumptions. However, if these assumptions are violated, the results may be misleading, underscoring the importance of verifying the distributional assumptions before relying on parametric analyses.

### **2.9.2 Common Parametric Methods Used in HIV/Hepatitis B Research**

Several parametric methods are commonly used in research on HIV and Hepatitis B among female sex workers (FSWs). These methods include logistic regression, and Poisson regression.

### **2.9.3 Logistic Regression**

Logistic regression models the relationship between a binary dependent variable and one or more independent variables. It is particularly useful in HIV and Hepatitis B research for estimating the probability of infection and identifying risk factors (Hosmer & Lemeshow, 2000).

For instance, Wondmagegn *et al.* (2022) used logistic regression to examine factors contributing to HBV and HIV co-infection among FSWs in Ethiopia. This method allows researchers to pinpoint key predictors and better understand what drives the spread of these infections.

### **2.9.4 Poisson Regression with robust standard error**

Poisson regression models the relationship between a count-dependent variable and one or more independent variables. It is particularly effective in studying infection incidence rates or exploring the link between risk factors and the number of sexual partners (Zou, 2004).

For example, Faini *et al.* (2022) used Poisson regression to estimate HIV incidence rates among FSWs in Tanzania and identify factors influencing these rates. Using robust standard errors in Poisson regression addresses overdispersion, providing more reliable estimates, which makes it an ideal tool for count data analysis in epidemiological research.

### **2.9.5 Cox regression**

Cox's proportional hazards model was initially designed to estimate instantaneous conditional hazard ratios using complete or censored longitudinal data with varying follow-up times. Breslow (1974) later showed that by assuming constant follow-up time, the model could also estimate rate ratios.

Puplampu *et al.* (2021) employed weighted adjusted Cox regression to examine disparities in high-risk sexual behaviour across ten sub-Saharan African countries. Their study explored the

relationship between sexual behaviour and factors such as sociodemographic, socioeconomic, knowledge, and mass media influences.

## 2.10 Advantages and Limitations of Parametric Methods

Parametric methods provide several advantages in epidemiological research:

1. **Inference Capabilities:** Parametric methods enable researchers to make inferences about population parameters by estimating effect sizes and p-values, facilitating the understanding of relationships between variables (Sharma & Jha, 2023).
2. **Flexibility:** These methods can be adapted to model complex relationships, including interactions and non-linear effects, which enhances their applicability in diverse research contexts (Hosmer & Lemeshow, 2000).
3. **Computational Efficiency:** Parametric methods are generally efficient computationally and can be readily implemented using statistical software, making them accessible for a wide range of analyses (Zou, 2004).

Despite these advantages, parametric methods have notable limitations:

1. **Distribution Assumptions:** They rely on assumptions about the data's underlying distribution, which may not always be accurate, potentially affecting the validity of the results (Sharma & Jha, 2023).
2. **Sensitivity to Outliers:** Parametric methods can be highly sensitive to outliers and influential data points, which may skew the estimates of effect sizes and p-values (Hosmer & Lemeshow, 2000).
3. **Handling Missing Data:** These methods may struggle with missing data, a common challenge in epidemiological studies, which can limit their effectiveness and reliability (Zou, 2004).

## **2.11 Predictive Modelling in HIV and Hepatitis B Research**

### **2.11.1 Current Approaches to Predictive Modelling**

Predictive modelling plays a crucial role in epidemiological research by forecasting disease outcomes based on various predictor variables. In HIV and Hepatitis B research among female sex workers (FSWs), diverse predictive models are employed to understand and predict infection dynamics.

#### **Logistic Regression**

Logistic regression is frequently used to model the probability of infection based on risk factors. This method helps in identifying predictors such as inconsistent condom use, multiple sexual partners, and limited access to healthcare. For example, Wondmagegn *et al.* (2022) utilised logistic regression to create a predictive model for HBV and HIV co-infection in Ethiopia, identifying history of sexually transmitted infections and lower educational attainment as significant predictors.

#### **Survival Analysis**

Survival analysis techniques, such as Cox proportional hazards models, are employed to predict the time to infection. These models account for various risk factors and estimate the impact of each on the time to event. Faini *et al.* (2022) applied Cox proportional hazards models to predict HIV incidence among FSWs in Tanzania, incorporating variables like age, drug use, and number of sexual partners.

#### **Poisson Regression with Robust Standard Errors**

Poisson regression is another valuable tool for predicting the incidence rate of infections, especially when dealing with count data. Zou (2004) highlights its utility in examining the association between risk factors and the number of sexual partners. Faini *et al.* (2022) used

Poisson regression to estimate HIV incidence rates among FSWs in Tanzania, identifying significant risk factors.

### **2.11.2 Challenges in Developing Predictive Models for High-Risk Populations**

Developing predictive models for high-risk populations, such as female sex workers (FSWs), involves addressing several significant challenges:

#### **Heterogeneity**

FSWs represent a highly diverse population with varying risk profiles influenced by factors such as work settings, socioeconomic conditions, and cultural backgrounds. Capturing this diversity in predictive models is complex, as Baral *et al.* (2012) highlight. The variability in risk factors and experiences necessitates nuanced models that can accommodate the heterogeneous nature of this population.

#### **Data Quality**

Obtaining accurate data on risk behaviours and health outcomes among FSWs is fraught with difficulties due to stigma, mistrust, and social desirability bias. Decker *et al.* (2015) note that these challenges are compounded by widespread human rights abuses, including violence and discrimination, which undermine data accuracy and hinder effective intervention efforts. These issues result in biased estimates and compromised model validity.

#### **Missing Data**

Missing data is a prevalent issue in research involving FSWs, often arising from participants being lost to follow-up or incomplete study procedures. Zou (2004) emphasises that such missing data can significantly impact the accuracy and generalisability of predictive models, making it essential to employ robust methods for handling and imputing missing values.

## **Dynamic Nature of Risk**

The risk factors associated with HIV and Hepatitis B among FSWs can evolve over time due to shifts in work environments, legal conditions, and the availability of preventive services. As Shannon *et al.* (2018) point out, predictive models must be regularly updated to reflect these changes and maintain their relevance and accuracy.

### **2.12 Evaluation Metrics for Predictive Models**

Assessing the performance of predictive models is essential for ensuring their accuracy and reliability. Several key metrics are commonly used in the evaluation of predictive models in HIV and Hepatitis B research:

#### **Discrimination**

Discrimination measures a model's ability to differentiate between individuals who experience the outcome and those who do not. This can be quantified using metrics such as the area under the receiver operating characteristic (ROC) curve (AUC) and the C-statistic. Both are widely used to assess a model's overall predictive discrimination (Begg *et al.*, 2000; Gönen & Heller, 2005; Harrell *et al.*, 1982; Heagerty & Zheng, 2005; Schmid & Potapov, 2012; Uno *et al.*, 2011).

#### **Calibration**

Calibration examines how closely probabilities match observed outcomes predicted. This can be evaluated using goodness-of-fit tests, which compare predicted probabilities with actual outcomes (Hosmer & Lemeshow, 2000). Effective calibration indicates that the model's predictions align well with real-world data.

#### **Validity**

Validity is evaluated through sensitivity and specificity, which assess the model's accuracy in predicting outcomes. Sensitivity measures the model's ability to correctly identify positive cases, while specificity gauges its ability to correctly identify negative cases (Parikh *et al.*, 2008). These metrics are crucial in determining how well a model distinguishes between the presence and absence of the outcome, ensuring its reliability in real-world applications.

### **Predictive Accuracy**

Predictive accuracy evaluates how well the model's predictions align with actual outcomes. Key measures include sensitivity, specificity, and predictive values, which provide insight into the model's performance in real-world scenarios (Steyerberg *et al.*, 2010). Additionally, Cox proportional hazards models are valuable for survival analysis, allowing for the evaluation of time-to-event data and calculation of hazard ratios (HRs) to understand treatment effects over time (McLernon *et al.*, 2023).

### **Measures of Association**

Measures of association, such as odds ratios (ORs) and hazard ratios (HRs), assess the strength and significance of the relationship between predictors and outcomes. These metrics help determine the clinical relevance of the predictive model by highlighting how changes in predictors are associated with variations in outcomes (Harrell *et al.*, 1982; Hosmer & Lemeshow, 2000).

### **2.13 Conceptual Framework**

Below is a conceptual framework illustrating the relationships among various variables relevant to the study of Hepatitis B Virus (HBV) and Human Immunodeficiency Virus (HIV) infections among female sex workers (FSWs):

The conceptual framework outlines the intricate relationships between various factors influencing HBV and HIV infections among female sex workers (FSWs). This framework serves as a guide for understanding how different elements interrelate and impact the risk of infection.

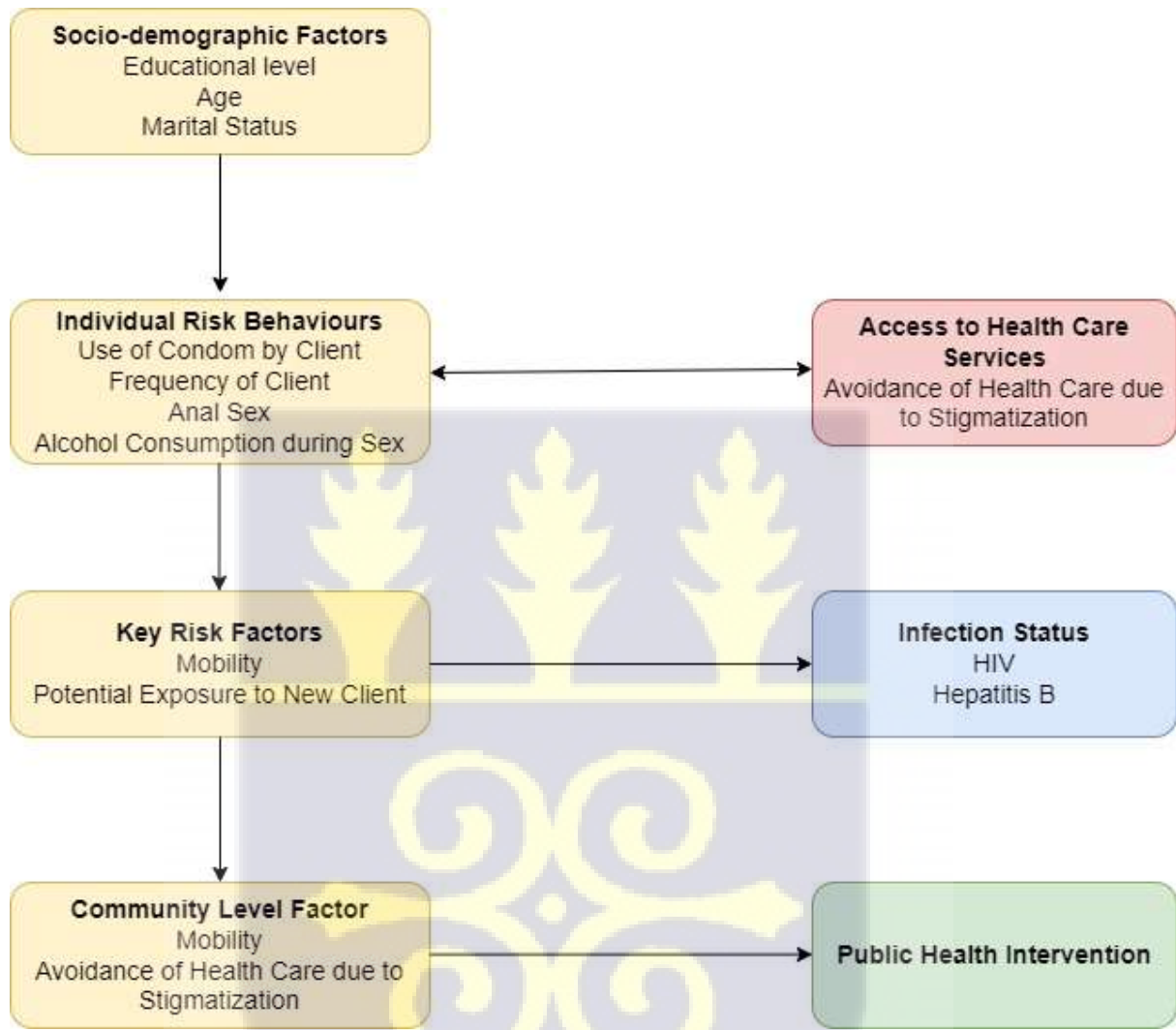
Socio-demographic factors such as age, education, and income level are pivotal in shaping both individual risk behaviours and access to healthcare services. For example, disparities in healthcare access and utilisation linked to these factors have been observed in various populations, including U.S. adults (Qi *et al.*, 2023). Younger FSWs, for instance, may have distinct risk profiles compared to older individuals, which can influence their engagement in high-risk behaviours (Sinha *et al.*, 2022).

Individual risk behaviours, including inconsistent condom use, substance abuse, and multiple sexual partners, are crucial determinants of HBV and HIV risk. These behaviours are not only shaped by socio-demographic factors but also significantly affect an individual's infection status (Kumar *et al.*, 2020; Rashti *et al.*, 2020).

Access to healthcare services plays a critical role in determining health outcomes. Barriers such as stigma, discrimination, and resource shortages can hinder FSWs from receiving essential preventive services like HBV vaccinations or HIV antiretroviral therapy. The framework suggests that improved access to healthcare can reduce the risk of infection (Vedio *et al.*, 2017).

Key risk factors arise from the cumulative impact of socio-demographic factors, individual risk behaviours, and access to healthcare. Identifying these factors is essential for designing targeted interventions. The infection status of FSWs, which is the focal outcome of this study, is influenced by the complex interplay of these elements.

Community-level factors, such as stigma, also significantly affect access to healthcare. Stigma not only obstructs access to necessary resources but also perpetuates health inequalities among socially disadvantaged groups like FSWs (Hatzenbuehler *et al.*, 2013).



**Figure 1:** Conceptual Framework of the relationship between factors influencing the infection of Female Sex Workers (Source: Authors own construct).

## 2.14 Gaps in the Literature

### 2.14.1 Limitations of Current Research

Research on Hepatitis B (HBV) and Human Immunodeficiency Virus (HIV) among female sex workers (FSWs) faces several notable limitations that impede a thorough understanding of the epidemiological dynamics within this population.

A primary limitation is the heterogeneity of study populations. Many studies concentrate on specific subgroups of FSWs, such as those involved in brothel-based or street-based sex work. This focus can result in findings that are not broadly applicable to the entire FSW population, limiting the generalisability of the results (Nakiggala *et al.*, n.d.; Nhurod *et al.*, 2010).

Additionally, human rights abuses against sex workers, including unlawful detention and coerced HIV testing, are well-documented (Decker *et al.*, 2015). Nonetheless, the data quality from FSWs is often compromised by stigma and reporting biases. This leads to the underreporting of high-risk behaviours and undermines the effectiveness of HIV interventions. Stigma and fear of discrimination can result in participants concealing or minimising risky behaviours, which affects the reliability of the data and hampers the development of effective public health strategies (Decker *et al.*, 2015).

Another notable issue is the dependence on self-reported data concerning sexual behaviours and healthcare access. This data is often influenced by social desirability bias and stigma, resulting in underreporting of high-risk behaviours and skewing the findings. Such biases hinder the effectiveness of interventions targeting these behaviours and challenge the accuracy of research conclusions (King, 2022).

For example, research conducted in Ghana has predominantly focused on street-based sex workers, potentially neglecting the distinct vulnerabilities and risk factors encountered by those in alternative contexts, such as escort services or informal settings (Ayamah *et al.*, 2023; Dery *et al.*, 2024; Guure *et al.*, 2023). This lack of inclusivity may result in incomplete data on the overall prevalence and risk factors for HBV and HIV among female sex workers.

Moreover, recent epidemiological analyses have highlighted disparities in mortality rates associated with chronic viral hepatitis and hepatocellular carcinoma, with socially vulnerable populations being disproportionately affected. These findings underscore the need for targeted strategies to reduce HCC-related mortality and to address gaps in research that fail to capture the evolving risks and behaviours contributing to viral infections among vulnerable groups such as FSWs (Ozturk *et al.*, 2024).

#### **2.14.2 Areas Requiring Further Investigation**

In light of the aforementioned limitations, several critical areas warrant further exploration to enhance understanding of Hepatitis B (HBV) and Human Immunodeficiency Virus (HIV) among female sex workers (FSWs), particularly in Ghana:

1. **Comprehensive Studies Across Subgroups:** Future research should encompass diverse subgroups of FSWs, including those working in street-based, brothel-based, and escort settings. This broader approach will help identify the full range of risk factors and health outcomes associated with different types of sex work. By capturing the unique vulnerabilities of each subgroup, researchers can develop targeted interventions tailored to the specific needs of each group (Baral *et al.*, 2012).
2. **Qualitative Research:** Integrating qualitative methodologies is crucial for gaining a deeper understanding of the lived experiences of FSWs. Qualitative research can shed light on barriers to healthcare access, the social determinants influencing risk behaviours, and the overall impact of stigma. These insights can complement quantitative findings and provide a more nuanced view of the challenges faced by FSWs, leading to more effective interventions (Decker *et al.*, 2015).

3. Interventions and Policy Evaluation: There is a need for research focused on evaluating the effectiveness of current interventions and policies designed to reduce HBV and HIV prevalence among FSWs. This includes assessing harm reduction strategies, healthcare access initiatives, and legal reforms. Understanding the impact of these measures on health outcomes will be essential for refining existing policies and developing new strategies (Shannon *et al.*, 2018).

4. Addressing Stigma and Discrimination: Further investigation into how stigma and discrimination affect healthcare access for FSWs is necessary. Building on existing evidence of the impact of stigma on health and the need for culturally sensitive interventions (Kyei *et al.*, 2024), research should explore effective strategies for mitigating stigma and improving access to healthcare for FSWs.

### **2.14.3 Statistical Modelling Theories**

In addition to epidemiological theories, statistical modelling theories are vital for analysing the factors influencing HBV and HIV infections among female sex workers (FSWs). These theories guide the selection of appropriate statistical methods and their evaluation.

1. Parametric Statistical Modelling: This approach is based on the assumption that data follow a specific distribution, often a normal distribution, and employs methods such as linear and logistic regression. Logistic regression, for example, is commonly used to estimate the probability of infection based on various risk factors (Hosmer & Lemeshow, 2000). Szwarcwald *et al.* (2011) utilised logistic regression to pinpoint significant predictors of HIV infection among FSWs, showcasing the effectiveness of this modelling technique in elucidating disease dynamics.

2. Multilevel Modelling: Given the hierarchical nature of epidemiological data, multilevel modelling is suited for analysing data structured at various levels, such as individuals within communities. This approach is particularly relevant for FSWs, as individual risk factors can be

influenced by community-level factors, such as local healthcare availability and social stigma (Goldstein, 1999). For instance, Ang and Morisky (2012) employed multilevel modelling in the Philippines to assess the impact of community-level factors on HIV prevalence among FSWs. Their findings highlighted significant effects of community and establishment-level factors on condom use, underscoring the importance of incorporating multiple levels of influence in HIV/AIDS intervention strategies.

3. Survival Analysis: This method is designed for analysing time-to-event data, such as the time until infection occurs. Techniques like Cox proportional hazards models are used to identify risk factors associated with the timing of HIV and HBV infections among FSWs (Cox & Oakes, 1984). Understanding the timing of infections can help in developing targeted interventions and prevention strategies, as demonstrated by various studies that use survival analysis to provide insights into the dynamics of disease progression and risk factor effects.

## **2.15 Definition of Terms**

### **2.15.1 Key Epidemiological Terms**

Hepatitis B Virus (HBV) is a viral infection that targets the liver, potentially causing chronic disease, liver cirrhosis, and hepatocellular carcinoma. It is transmitted through contact with infectious body fluids like blood, semen, and vaginal secretions (World Health Organization, 2021). Human Immunodeficiency Virus (HIV), on the other hand, weakens the immune system by attacking CD4 cells (T cells), and if untreated, progresses to acquired immunodeficiency syndrome (AIDS). HIV is primarily transmitted through unprotected sexual contact, needle sharing, and from mother to child during childbirth or breastfeeding (Centers for Disease Control and Prevention, 2022).

Co-infection occurs when an individual is infected with both HBV and HIV simultaneously. Due to shared transmission routes, co-infection is common. It results in accelerated liver

disease progression, increasing the risks of liver-related conditions such as hepatocellular carcinoma and elevated all-cause mortality (Corcorran & Kim, 2023). Prevalence refers to the total number of cases of a disease in a given population at a specific time, often expressed as a percentage or per 1,000 or 100,000 individuals (Keller, 2014).

### **2.15.2 Relevant Statistical Concepts and Methods**

Parametric statistical methods are techniques that assume the data follows a specific distribution, often a normal distribution. These methods, including linear regression, logistic regression, and analysis of variance (ANOVA), allow researchers to make inferences about population parameters from sample data (Sharma & Jha, 2023). In the study of factors influencing Hepatitis B (HBV) and HIV among Female Sex Workers (FSWs), multivariable regression analysis is particularly useful. It models the relationships between multiple outcome variables (such as HBV and HIV status) and predictor variables, including socio-demographic factors, individual risk behaviours, and access to healthcare services (Multivariate Regression Analysis | Stata Data Analysis Examples, n.d.).

### **2.15.3 Population-Specific Terminology Related to Female Sex Workers**

Female sex workers (FSWs) are adult women who engage in consensual sex for money or other forms of payment, making it their primary livelihood (UNAIDS, 2012). FSWs face significant vulnerability due to a combination of inherent factors, such as gender and age, and acquired risk factors, like health behaviors and environmental conditions (Havrilla, 2017). This vulnerability is further exacerbated by stigma, which results in exclusion, abuse, and mistreatment from both the community and clients. They are often labeled negatively, which leads to police harassment and worsens their access to essential healthcare services, including those for HIV and HBV prevention and treatment (Wong *et al.*, 2011).

## CHAPTER THREE

### 3.0 STUDY DESIGN, APPROACH AND DATA

#### 3.1 Introduction

This chapter presents the study design, methodological approaches, and data collection strategies utilized to evaluate parametric statistical methods in predicting factors influencing Hepatitis B (HBV) and HIV among female sex workers (FSWs). A cross-sectional design was adopted to capture a snapshot of the demographic, behavioural, and socioeconomic predictors associated with HBV and HIV infections within this vulnerable population.

The Time Location Sampling (TLS) technique was employed to ensure a representative sample, enabling researchers to identify and engage with venues where FSWs congregate. Prior to the main study, thorough pre-survey assessments were conducted to verify venue accessibility and gather insights from stakeholders, which enhanced the reliability of the data collected. This chapter outlines the sampling frame, data collection methods, and analytical strategies, providing a comprehensive overview that sets the stage for the analysis and discussion of the findings.

#### 3.2 Study Design

In this study, a cross-sectional design was used to evaluate parametric statistical methods in predicting factors influencing Hepatitis B and HIV among female sex workers (FSWs). A pre-survey assessment was conducted to ensure the data's relevance and quality. This phase included consultations with national and regional stakeholders, such as civil society organizations (CSOs) and representatives from the Ghana Police Service, to gather insights on FSW venues and identify potential data collection challenges.

During the pre-survey, trained field staff verified venues where FSWs operate, using data from the 2011 and 2015 Behavioural Surveillance Surveys (BBS) as a baseline. CSOs, gatekeepers,

and the Police Service contributed by compiling a list of active venues, enhancing the verification process.

To support effective data collection, 207 research assistants and 44 field supervisors were deployed across the country. This team spent three weeks confirming existing venues and identifying new ones, ensuring a comprehensive understanding of FSW activity. The venues were mapped using Geographic Information System (GIS) techniques, with GPS technology and tablets to capture precise coordinates. This mapping effort revealed a total of 2,482 active FSW venues nationwide.

This groundwork provided a robust foundation for the main study, ensuring that the collected data accurately reflects HBV and HIV risk factors among FSWs in Ghana. The cross-sectional design, stakeholder input, and use of advanced tools aimed to generate meaningful results to inform future public health strategies for this vulnerable population.

### **3.3 Study Design and Sampling Methodology**

#### **3.3.1 Study Design**

This study employed a cross-sectional design, which is appropriate for assessing the prevalence and predictors of Hepatitis B Virus (HBV) and Human Immunodeficiency Virus (HIV) among female sex workers (FSWs) in Ghana. Cross-sectional studies are well-suited for public health research involving key populations, as they allow for the simultaneous examination of multiple risk factors and infections at a specific point in time (Levin, 2006). The design aligns with the study's objective of identifying associations between sociodemographic, behavioural, and structural factors and HBV/HIV infections, providing a foundation for targeted interventions.

To enhance the study's validity, a pre-survey assessment was conducted, involving consultations with national and regional stakeholders, including civil society organizations (CSOs) and the Ghana Police Service. This preparatory phase ensured the accurate

identification of FSW hotspots and addressed potential logistical or security challenges during data collection. Additionally, venue mapping and verification were performed using Geographic Information System (GIS) techniques, updating the sampling frame with newly identified active venues (n=2,482). These steps reinforced the methodological rigor and contextual relevance of the study.

### 3.3.2 Sampling Techniques and Justification

The study utilized Time Location Sampling (TLS), a probability-based method designed to enrol hard-to-reach populations such as FSWs (Muhib *et al.*, 2001; WHO *et al.*, 2017). TLS, also referred to as Venue-Day-Time (VDT) sampling, accounts for temporal and spatial variability in FSW attendance at congregating venues. This approach was selected for three key reasons:

1. Representativeness: TLS minimizes selection bias by randomly sampling venues, days, and time slots, ensuring coverage of diverse FSW subgroups (e.g., "seaters" at fixed venues and "roamers" with no fixed location).
2. Adaptability: The method accommodates dynamic changes in sex work environments, such as venue closures or shifts in operational hours, through real-time updates to the sampling frame.
3. Precision: By recording the total number of FSWs present at each sampled VDT and tracking eligibility/refusal rates, TLS enables the calculation of sampling weights, improving the accuracy of population-level estimates (Guure *et al.*, 2021).

The sampling process occurred in three stages:

- Stage 1: Simple random selection of unique venues, stratified by region, without replacement.

- Stage 2: Random selection of one VDT (4-hour interval) per venue. Conflicts were resolved by substituting alternative VDTs via the same randomization process.
- Stage 3: Enumeration of all FSWs present at the VDT, followed by systematic screening, consent, and enrolment. Sampling weights were applied to adjust for regional disparities in venue selection probabilities.

### **3.3.3 Data Collection and Quality Assurance**

Trained research assistants administered electronic questionnaires via REDCap, ensuring real-time data synchronization. Biological samples (blood/urine) were collected for HIV, HBV, and STI testing, following national protocols and quality control measures (e.g., duplicate testing for 10% of samples).

## **3.4 Study Variables**

### **3.4.1 Outcome variables**

This study focuses on two main outcome variables: HIV infection and hepatitis B infection among female sex workers. HIV infection is categorized as a binary outcome, classifying the sex workers into either HIV-positive or HIV-negative groups. Similarly, hepatitis B infection is also a binary outcome, dividing the sex workers into those who are reactive and those who are non-reactive.

### **3.4.2 Independent variables**

The independent variables for this study were selected based on a comprehensive review of previous literature on the predictors of Hepatitis B and HIV among Female Sex Workers (FSWs). The selection of variables was guided by a conceptual framework that categorized the predictors into socio-demographic factors, individual risk behaviours, access to healthcare services, key risk factors, infection status, and community level factors/public health interventions.

Socio-demographic factors, such as educational level, age category, region, and country of nationality, were included as they have been shown to influence HIV and Hepatitis B infection rates among FSWs. Individual risk behaviours, including condom use, marital status, client volume, alcohol consumption during sex, and anal sex, were also selected based on their significance in predicting infection rates. Access to healthcare services, including mobility and access to healthcare, as well as avoidance of healthcare services due to stigma, were included to examine their impact on infection rates.



## CHAPTER FOUR

### 4.0 STATISTICAL CONSIDERATIONS / METHODOLOGY

#### 4.1 Introduction

This chapter describes the statistical methods used to evaluate factors influencing Hepatitis B (HBV) and HIV among female sex workers (FSWs). Logistic regression was chosen to model binary outcomes like HBV and HIV status, providing odds ratios to understand predictor relationships. Poisson regression was used to analyse count data, such as risky behaviours, while Cox regression addressed time-to-event data, examining the progression to liver disease or HIV complications. These methods were selected for their ability to handle the diverse factors affecting HBV and HIV risk in this population.

#### 4.2 Theoretical Foundation of Parametric Methods

##### 4.2.1 Logistic Regression

##### 4.2.1.1 Theoretical Background

Logistic regression is used when the dependent variable is categorical, particularly in binary cases like HBV or HIV infection. Binary logistic regression models the probability of one of two outcomes. For situations with more than two categories, multinomial logistic regression is applied. This method uses predictor variables to estimate the probability of each outcome, ensuring predicted probabilities remain between 0 and 1 through the logistic function (Hosmer & Lemeshow, 2000).

The logistic regression model is formulated as follows:

$$P(Y = 1|X) = \frac{1}{1 + e^{-(\beta_0 + \beta_1 X_1 + \dots + \beta_k X_k)}} \quad (4.1)$$

Here,  $P(Y = 1|X)$  represents the probability of infection given the predictor variables  $X_1, X_2, \dots, X_k$ . The logit transformation allows for this relationship to be expressed in a linear form:

$$\log\left(\frac{P(Y = 1|X)}{1 - P(Y = 1|X)}\right) = \beta_0 + \beta_1 X_1 + \dots + \beta_k X_k \quad (4.2)$$

where  $\beta_0$  is the intercept and  $\beta_1, \beta_2, \dots, \beta_k$  are the coefficients of the explanatory variables.

#### 4.2.1.2 Assumptions

Logistic regression requires several assumptions:

**Independence of Observations:** Each observation should be independent of the others, a requirement that is often challenged in studies involving social networks, where behaviours may be influenced by connected individuals (Matthews *et al.*, 2024).

**Linearity in the Logit:** The relationship between the independent variables and the log odds of the dependent variable should be linear. This can be assessed using the Box-Tidwell test or by examining interaction terms (Box & Tidwell, 1962).

**Absence of Multicollinearity:** Absence of multicollinearity is essential, as independent variables should not be highly correlated with each other. Multicollinearity, which can distort regression analysis, can be assessed using several methods, including Variance Inflation Factors (VIF), with values above 10 indicating potential issues (Upendra *et al.*, 2023).

**Model Specification:** Model specification in logistic regression involves selecting appropriate independent variables that influence the likelihood of infection. For example, factors such as age, education, and risk behaviours should be included based on prior research.

#### 4.2.1.3 Parameter Estimation

Parameter estimation in logistic regression is typically performed using maximum likelihood estimation (MLE), which finds the parameter values that maximize the likelihood of observing the given data (Hosmer & Lemeshow, 2000).

The likelihood function for the observed data is given by:

$$L(\beta) = \prod_{i=1}^n P(Y_i|X_i)^{Y_i} [1 - P(Y_i|X_i)]^{1-Y_i} \quad (4.3)$$

Maximizing the log-likelihood function provides the estimates for the coefficients  $\beta_0, \beta_1, \beta_2, \dots, \beta_k$  in logistic regression. These coefficients represent the change in the log odds of the outcome for a one-unit increase in the corresponding continuous explanatory variable. For categorical variables, the coefficients indicate the change in log odds relative to a reference category, providing a comparative assessment of the impact of different categories on the outcome.

#### 4.2.1.4 Interpretation of Coefficients

The coefficients in logistic regression have a meaningful interpretation in terms of odds ratios:

The intercept  $\beta_0$  represents the log odds of the outcome when all explanatory variables are zero.

Each coefficient  $\beta_j$  represents the change in the log odds of the outcome for a one-unit increase in the explanatory variable  $X_j$  when  $X_j$  is a continuous variable. For categorical variables, the interpretation of the coefficients is relative to a reference category, meaning that each coefficient indicates the change in log odds for being in a particular category compared to the reference category. The odds ratio for  $X_j$  is given by  $e^{\beta_j}$ , which indicates how the odds of the outcome change with a one-unit increase in  $X_j$  for continuous variables, or how the odds

change when moving from the reference category to the category represented by  $X_j$  for categorical variables.

## **4.2.2 Method 3: Poisson Regression**

### **4.2.2.1 Theoretical Background**

Poisson regression is a generalized linear model (GLM) designed for modelling count data, where the outcome represents the number of events that occur within a fixed time period or space. It is particularly useful in predicting the incidence of infections like Hepatitis B (HBV) and HIV among Female Sex Workers (FSWs) by modelling the rate of infections over a defined period. In this context, Poisson regression accounts for the count nature of the outcome and allows for a log-linear relationship between the incidence rate and the predictor variables.

While Poisson regression is primarily used for count outcomes, it can also be adapted for binary outcomes using quasi-likelihood models, especially in cases of overdispersion. Robust standard errors can enhance the reliability of the model's inference (McCullagh & Nelder, 1989; Green, 1984; Agresti, 2015; McCullagh, 1983; Wedderburn, 1974).

### **4.2.2.2 Assumptions**

Poisson regression is based on several key assumptions:

**Independence of Observations:** Similar to other regression methods, observations should be independent. This is crucial to avoid bias in estimating the incidence rates

**Equality of Mean and Variance:** In Poisson regression, the mean of the response variable is assumed to be equal to its variance. If this assumption is violated, alternative methods, such as negative binomial regression, may be more appropriate.

### **4.2.2.3 Model Specification**

Model specification involves selecting the appropriate independent variables that influence the count of infections. Relevant predictors may include risk behaviours, socio-economic factors, and access to healthcare services.

#### 4.2.2.4 Parameter Estimation

Parameter estimation in Poisson regression is typically conducted using MLE, similar to logistic regression. The estimated coefficients represent the expected change in the log count of the outcome variable for a one-unit change in the predictor variable.

The Poisson regression model assumes that the expected count  $\lambda$  is related to the predictor variables via a log-link function:

$$\log(\lambda_i) = \beta_0 + \beta_1 X_{i1} + \dots + \beta_k X_{ik} \quad (4.4)$$

where  $\lambda_i$  represents the expected count for individual  $i$ , and  $X_{i1}, X_{i2}, \dots, X_{ik}$ , are the explanatory variables. Maximum Likelihood Estimation (MLE) is used to estimate the regression coefficients ( $\beta_0, \beta_1, \beta_2, \dots, \beta_k$ ) by maximizing the likelihood function:

$$L(\beta) = \prod_{i=1}^n \frac{e^{-\lambda_i} \lambda_i^{y_i}}{y_i!}$$

The log-likelihood function simplifies the estimation process:

$$\log L(\beta) = \sum_{i=1}^n [y_i(\beta_0 + \beta_1 X_{i1} + \dots + \beta_k X_{ik}) - e^{\beta_0 + \beta_1 X_{i1} + \dots + \beta_k X_{ik}} - \log(y_i!)]$$

The log-likelihood is maximized with respect to the coefficients to obtain their estimates, allowing inference about the relationship between the explanatory variables and the infection rates. The estimated coefficients represent the expected change in the log count of the outcome variable for a one-unit change in the predictor variable.

#### 4.2.2.5 Quasi-Likelihood Estimation

When the strict assumptions of Poisson regression (such as equidispersion) are violated, quasi-likelihood estimation provides a flexible alternative. Quasi-likelihood does not assume that the data follows a fully specified probability distribution; rather, it focuses on the relationship between the mean  $\mu$  and the variance  $V(\mu)$ . This method is particularly useful in the presence of overdispersion, where the variance exceeds the mean.

The quasi-likelihood function is given by:

$$Q(y, \mu) = \int \frac{y - \mu}{V(\mu)} \partial \mu \quad (4.5)$$

where  $y$  is the observed outcome,  $\mu$  is the expected mean, and  $V(\mu)$  represents the variance as a function of the mean. In quasi-likelihood estimation, the quasi-score function is used to estimate the parameters by solving:

$$\sum_{i=1}^n \frac{y_i - \mu_i}{V(\mu_i)} \cdot \frac{\partial \mu_i}{\partial \beta} = 0 \quad (4.6)$$

This approach allows for robust estimation of parameters even when the exact distributional assumptions of the Poisson model are not satisfied. This flexibility makes quasi-likelihood particularly suitable for modelling count data with overdispersion in studies of Hepatitis B and HIV among FSWs, where the data may not adhere strictly to Poisson assumptions.

#### 4.2.2.6 Robust Standard Errors

When model assumptions like equidispersion are violated, robust standard errors provide more reliable inferences. The sandwich estimator adjusts the standard errors to account for misspecification or overdispersion:

$$\hat{V}_R = (X^T W X)^{-1} X^T W \hat{D} W X (X^T W X)^{-1} \quad (4.7)$$

where  $X$  is the matrix of explanatory variables,  $W$  is a diagonal matrix of weights, and  $\hat{D}$  contains the squared residuals divided by the predicted values. This method improves the

estimation of standard errors and ensures valid inference even when the variance structure deviates from the Poisson assumptions (Cameron & Trivedi, 2013).

#### **4.2.2.7 Interpretation of Coefficients**

The coefficients in Poisson regression are interpreted as follows:

The intercept  $\beta_0$  represents the log of the expected count when all predictors are at their reference levels (typically zero).

Each coefficient  $\beta_j$  the change in the log of the expected count for a one-unit increase in the corresponding predictor variable  $X_j$ . The exponentiated coefficients  $e^{\beta_j}$  indicate the multiplicative change in the expected count for a one-unit change in  $X_j$ .

#### **4.2.3 Cox regression model**

##### **4.2.3.1 Theoretical Background**

The Cox proportional hazards model is traditionally a semiparametric model used for survival analysis, examining the relationship between time to an event (e.g., infection, death) and explanatory variables. In this study on predicting Hepatitis B and HIV among female sex workers (FSWs), this model can be adapted for binary outcomes by treating infection status (e.g., infected or not infected) as the event of interest. Here, the time component becomes constant, and we focus on the risk factors influencing the likelihood of infection.

##### **4.2.3.2 Model Formulation**

The Cox proportional hazards model evaluates the relationship between the event occurrence (in this case, infection by Hepatitis B or HIV) and the covariates. The hazard function  $h(t | X)$  describes the instantaneous risk of infection occurring at time  $t$ , given a set of covariates  $X$ .

For binary outcomes, the event either occurs (infected) or does not occur (not infected). The model can still be formulated as:

$$h(t | X) = h_0(t) \exp(\beta_1 X_1 + \beta_2 X_2 + \dots + \beta_k X_k) \quad (4.8)$$

where:

- $h(t | X)$  is the hazard function, or the risk of infection at time  $t$  given the covariates  $X$ .
- $h_0(t)$  is the baseline hazard function.
- $X_1, X_2, \dots, X_k$ , are the covariates influencing the risk of infection (e.g., age, condom use, number of sexual partners).
- $\beta_1, \beta_2, \dots, \beta_k$  are the coefficients representing the effect of each covariate on the hazard rate.

Even with fixed covariates (as in binary outcomes), the model's framework remains useful for evaluating the relative hazard, i.e., the risk of infection across different levels of predictors.

#### 4.2.3.3 Hazard Ratio

The hazard ratio (HR) in the Cox model compares the relative risk of the event (infection) between two individuals or groups with different covariates. If we have two different sets of covariates  $X$  and  $X'$ , the hazard ratio is:

$$\frac{h(t|X)}{h(t|X')} = \exp(\beta_1(X_1 - X'_1) + \beta_2(X_2 - X'_2) + \dots + \beta_k(X_k - X'_k)) \quad (4.9)$$

A Hazard ratio greater than 1 suggests an increased risk of infection for the individual with covariates  $X$ .

- A hazard ratio less than 1 suggests a decreased risk of infection.
- A hazard ratio equal to 1 indicates no difference in risk.

#### 4.2.3.4 Partial Likelihood Estimation

The parameters  $\beta$  in the Cox model are estimated using partial likelihood, which does not require specifying the baseline hazard function  $h_0(t)$ . This makes the Cox model semiparametric. The partial likelihood function for  $n$  individuals is:

$$L(\beta) = \prod_{i=1}^n \frac{\exp(\beta^T X_i)}{\sum_{j \in R(t_i)} \exp(\beta^T X_j)} \quad (4.10)$$

where:

- $R(t_i)$  is the risk set, consisting of all individuals who are at risk just before time  $t_i$
- The numerator is the exponential function of the covariates for the individual  $i$ , while the denominator sums the exponential functions of the covariates for all individuals at risk at time  $t_i$

The log-partial likelihood is then:

$$\log L(\beta) = \sum_{i=1}^n [\beta^T X_i - \log(\sum_{j \in R(t_i)} \exp(\beta^T X_j))] \quad (4.11)$$

Maximizing this log-partial likelihood provides estimates of the regression coefficients  $\beta$ , which describe the influence of each predictor (e.g., age, educational level, risky sexual behaviour) on the risk of infection with Hepatitis B or HIV.

#### Robust Variance Estimator

To account for potential violations of the proportional hazards assumption and to provide more reliable estimates of the variance of the coefficients, the robust variance estimator (also known as the sandwich estimator) is employed. This method adjusts the standard errors of the coefficient estimates to be more resilient against certain types of model misspecifications,

particularly when there are correlated events or when the proportional hazards assumption is not fully met.

The robust variance estimator is computed as follows:

$$\text{Var}(\hat{\beta}) = (X'WX)^{-1}X'WHWX(X'WX)^{-1} \quad (4.12)$$

where:

- $X$  is the design matrix of covariates.
- $W$  is a diagonal matrix of the weights, typically derived from the Cox model's estimated baseline hazard.
- $H$  is the matrix of derivatives of the log-likelihood function with respect to the estimated coefficients.

#### 4.2.3.5 Interpretation of Coefficients

The coefficients  $\beta$  from the Cox model are interpreted as log hazard ratios. For a one-unit increase in the covariate  $X_j$  the hazard ratio is:

$$\text{Hazard Ratio} = \exp(\beta_j) \quad (4.13)$$

#### 4.2.3.6 Assumptions

Several assumptions must be met for the Cox regression model to be valid:

- **Proportional Hazards:** The hazard ratios are constant over time.
- **Independence:** Observations are independent of each other.
- **No Multicollinearity:** Covariates should not be highly correlated.
- **Linearity:** The effect of covariates is linear on the log hazard scale.

For your analysis, these assumptions should be carefully examined to ensure the reliability of the model when predicting the likelihood of infection in FSWs.

#### **4.2.3.7 Application to Binary Outcomes**

Though the Cox model is traditionally used for time-to-event data, it can be adapted to binary outcomes by fixing the time element and focusing on risk factors for infection. The event (infection) either occurs or does not, making the Cox model appropriate for examining how various risk factors (such as lack of age, condom use, number of sexual partners) influence the likelihood of infection among FSWs. The coefficients from this model can be used to estimate hazard ratios, providing insights into the relative risks of infection.

### **4.3 Model Diagnostics**

#### **4.3.1. Logistic Regression Model Diagnostics**

Model diagnostics for logistic regression involve several key assessments to ensure the model's reliability and validity. The Hosmer-Lemeshow test is employed to evaluate the goodness-of-fit, comparing observed frequencies with expected frequencies in subgroups. The Receiver Operating Characteristic (ROC) curve is examined to assess the model's discrimination ability, where a higher area under the ROC curve indicates better performance. Additionally, the Akaike Information Criterion (AIC) is utilized, with lower values suggesting a better model fit, thus facilitating comparisons across different models. Lastly, the pseudo  $R^2$  provides insight into the proportion of variance explained by the model, serving a similar purpose to  $R^2$  in linear regression.

#### **4.3.2. Poisson Regression Model Diagnostics**

In assessing the fit of a Poisson regression model, various diagnostic tools are applied. Deviance statistics are utilized as a goodness-of-fit measure, where lower deviance values

indicate a better fit to the data. The Pearson Chi-Square statistic is another important goodness-of-fit metric that compares observed and predicted counts. The Akaike Information Criterion (AIC) is also employed, where lower values signify better-fitting models. Additionally, residual analysis is conducted to identify potential violations of model assumptions, such as overdispersion or influential outliers, providing further validation of the model's appropriateness.

### **4.3.3. Cox Regression Model Diagnostics**

Evaluating the fit of the Cox regression model involves several techniques. The log-likelihood value is considered, where a higher value indicates a better fit for the model. The Wald test assesses the significance of individual coefficients, while the Score (Log-rank) test evaluates the overall significance of the model. The Likelihood Ratio Test is employed to compare nested models, determining whether adding or removing covariates improves model fit. These assessments are crucial for binary outcomes, as they help gauge how effectively the model predicts the likelihood of infection among female sex workers (FSWs).

## **4.4 Model Selection and Comparison**

### **4.4.1 Criteria for Model Selection**

Model selection is a critical aspect of statistical analysis, particularly when developing predictive models for health outcomes such as Hepatitis B Virus (HBV) and Human Immunodeficiency Virus (HIV) among female sex workers (FSWs) in Ghana. Two widely used criteria for model selection are the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC).

#### **4.4.1.1 Akaike Information Criterion (AIC)**

The AIC is a measure used to compare different statistical models, balancing model fit and complexity. It is calculated as:

$$AIC = 2k - 2 \ln(L) \quad (4.14)$$

where  $k$  is the number of parameters in the model and  $L$  is the likelihood of the model (Burnham & Anderson, 2002). A lower AIC value indicates a better-fitting model. The AIC is particularly useful in situations where multiple models are being compared, as it penalizes models with more parameters, thus discouraging overfitting (Burnham & Anderson, 2002).

#### 4.4.1.2 Bayesian Information Criterion (BIC)

Similar to AIC, the BIC is another criterion for model selection, but it places a heavier penalty on model complexity. It is calculated as:

$$BIC = \ln(n) k - 2 \ln(L) \quad (4.15)$$

where  $n$  is the sample size (Schwarz, 1978). Like AIC, a lower BIC value indicates a better model fit. The BIC is particularly useful when the sample size is large, as it tends to favour simpler models compared to AIC (Schwarz, 1978).

#### 4.4.2 Comparative Analysis of Models

In the context of this study, comparative analysis of models was carried out to determine the most appropriate predictive models for evaluating factors influencing Hepatitis B and HIV infections among female sex workers (FSWs). The logistic regression, modified Poisson regression, and Cox proportional hazards regression models were each assessed using the AIC and BIC to establish their relative performance.

The final model was selected based on its ability to balance goodness-of-fit with predictive accuracy, while minimizing overfitting. This approach ensures that the chosen model can be generalized to other settings and is robust in predicting infection risk among this high-risk population. Through this comparative analysis, insights were gained into the strengths and

limitations of each model, contributing to the development of a more accurate and reliable predictive framework for guiding interventions and policy decisions.

#### **4.5 Predictive Performance Evaluation**

Evaluating the predictive performance of statistical models is crucial for ensuring that they accurately reflect the relationships within the data and provide reliable predictions. Several metrics are commonly used to assess model performance, particularly in the context of predicting Hepatitis B Virus and Human Immunodeficiency Virus infections among female sex workers in Ghana.

##### **4.5.1 Area Under the Receiver Operating Characteristic Curve (AUC-ROC)**

The AUC-ROC measures a classification model's performance across different thresholds, assessing its ability to distinguish between positive and negative cases. An AUC of 0.5 means no discrimination (equivalent to random guessing), while an AUC of 1.0 represents perfect discrimination.

###### **4.5.1.1 Sensitivity and Specificity**

Sensitivity measures the proportion of actual positives correctly identified by the model, while specificity evaluates the proportion of actual negatives correctly identified. Both metrics are essential for assessing the accuracy of binary classification models, like logistic regression, in predicting health outcomes.

###### **4.5.1.2 Positive and Negative Predictive Values**

Positive predictive value (PPV) is the proportion of positive results that are true positives, while negative predictive value (NPV) measures the proportion of negative results that are true negatives. These metrics are crucial in clinical settings, as they show the likelihood that a positive or negative test result accurately reflects the actual condition.

#### 4.6 Ethical Considerations

This study received ethical approval from the University of Ghana Noguchi Memorial Institute for Medical Research Institutional Review Board (CPN 083/18–19), the Ghana Health Service Ethics Review Committee (GHS-ERC 002/05/19), and the Population Council Institutional Review Board (Protocol 891) in New York, USA.



## CHAPTER FIVE

### 5.0 ANALYSIS AND INTERPRETATION

#### 5.1 Introduction

This chapter discusses the findings from the study evaluating parametric statistical methods in predicting factors influencing Hepatitis B (HBV) and HIV among female sex workers (FSWs) in Ghana. A comprehensive approach was used, starting with a descriptive analysis of the socio-demographic and behavioural characteristics of the participants. Pearson's Chi-Square test was applied to explore associations between categorical variables and infection outcomes, using a significance threshold of  $\leq 0.2$  to identify key factors for further analysis.

Multiple logistic regression estimated adjusted odds ratios, while modified Poisson regression and Cox proportional hazards regression were used to assess relative risks and prevalence ratios. Model fit and predictive performance were evaluated using metrics like the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC). This methodology ensured a robust and generalizable model through cross-validation.

The chapter presents a detailed analysis of factors associated with HBV and HIV among FSWs in Ghana, incorporating data cleaning, descriptive statistics, bivariate analysis, and comparisons among parametric methods. The findings highlight the prevalence of these infections and the impact of socio-demographic and behavioural factors, offering valuable insights for developing intervention strategies to reduce risks within this population.

#### 5.2 Data Cleaning Process

The data cleaning process was an essential initial step in preparing the dataset for reliable analysis. Data were exported into STATA 17, where variables were selected based on a review of existing literature to ensure relevance to the study's objectives. Out of the 7,000 FSWs who

participated in the biobehavioural survey, 6,773 engaged in the behavioural survey, and 6,217 provided biological samples. In total, 5,990 participants completed both components of the survey, while 783 participated only in the behavioural survey, and 227 provided only biological samples. To maintain data integrity, responses marked as “Don’t know,” “No Response,” or “Missing” were excluded, leaving a dataset optimized for complete-case analysis. This careful data preparation process was critical for minimizing biases and enhancing the accuracy of subsequent statistical tests.

### **5.3 Analysis of Hepatitis B (HBV)**

#### **5.3.1 Prevalence of HBV and Chi-square Analysis of Socio-Demographic Factors**

The prevalence of Hepatitis B (HBV) among female sex workers (FSWs) in Ghana was found to be 6.53% (95% CI: [6.08%, 7.01%]), with 330 out of 5,052 participants testing positive for HBV. This finding highlights the relatively low but significant burden of HBV within this high-risk population. Chi-square analyses revealed a statistically significant association between age group and HBV status ( $\chi^2 = 12.214$ ,  $p = 0.047$ ). Participants aged 25–35 years exhibited the highest proportion of HBV-positive cases at 55.07%, followed by those aged 16–24 years at 36.56%, and those over 35 years at 8.37%. This trend indicates a concentration of HBV infections among individuals in the mid-adult age category, possibly reflecting increased exposure risk during this period.

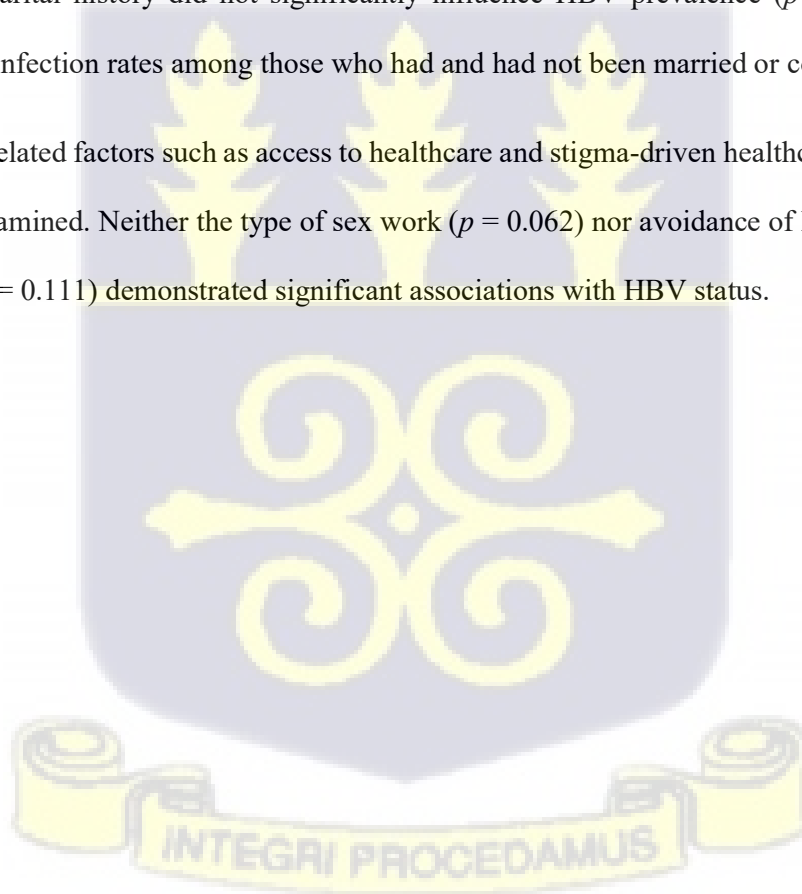
In contrast, other socio-demographic factors such as educational level, nationality, region of residence, religious affiliation, and weekly income showed no statistically significant associations with HBV status. For instance, while the majority of participants across all levels of education tested negative for HBV, the prevalence remained consistent, with no discernible pattern linked to educational attainment ( $p = 0.834$ ). Similarly, HBV prevalence did not vary

significantly by nationality ( $p = 0.101$ ) or region ( $p = 0.253$ ), suggesting that geographic and cultural variations had minimal influence on infection rates within this population.

### 5.3.2 Individual Factors

Individual behavioural factors were also analysed for their potential association with HBV status. The results indicated no significant relationships between HBV status and condom use frequency, marital history, weekly client volume, alcohol use during sex, or participation in anal sex. For instance, the proportion of HBV-positive participants who reported consistent condom use was comparable to those who reported inconsistent use ( $p = 0.405$ ), suggesting that condom use alone may not adequately explain HBV transmission dynamics in this group. Similarly, marital history did not significantly influence HBV prevalence ( $p = 0.67$ ), with comparable infection rates among those who had and had not been married or cohabited.

Healthcare-related factors such as access to healthcare and stigma-driven healthcare avoidance were also examined. Neither the type of sex work ( $p = 0.062$ ) nor avoidance of healthcare due to stigma ( $p = 0.111$ ) demonstrated significant associations with HBV status.



**Table 1: Distribution of Socio-demographic Factors, Individual Factors, and Healthcare Access Characteristics Among Female Sex Workers by Hepatitis B Virus (HBV) Status in Ghana**

Variables	Negative	Positive	Total (%)	Chi <sup>2</sup> (P-Value)
	n = 4722 (93.47%)	n = 330 (6.53%)	N (5,052)	
<b>Socio-demographic factors</b>				
<b>Age Group</b>				<b>12.214(0.0474)</b>
16-24 years	2,054 (43.49)	121 (36.56)	2,175 (43.04)	
25-35 year	2,243 (47.51)	182 (55.07)	2,425 (48.00)	
>35 years	425 (9.00)	28 (8.37)	453 (8.96)	
<b>Educational Level</b>				<b>0.0733(0.8341)</b>
None	374 (7.92)	24 (7.42)	398 (7.89)	
Primary	795 (16.85)	59 (17.75)	854 (16.90)	
Middle/JSS/JHS	1,800 (38.13)	123 (37.34)	1,924 (38.08)	
Secondary	1,493 (31.63)	106 (31.97)	1,599 (31.65)	
Higher	259 (5.48)	18 (5.52)	277 (5.48)	
<b>Country/Nationality</b>				<b>4.955(0.101)</b>
Ghana	3,911 (82.83)	292 (88.62)	4,203 (83.20)	
Nigeria	688 (14.58)	32 (9.61)	720 (14.25)	
Others	123 (2.60)	6 (1.77)	129 (2.54)	
<b>Region</b>				<b>2.3665(0.2533)</b>
Ahafo	101 (2.14)	7 (2.11)	108 (2.14)	
Ashanti	900 (19.06)	75 (22.72)	975 (19.30)	
Bono	262 (5.54)	17 (5.26)	279 (5.52)	
Bono East	102 (2.16)	5 (1.63)	107 (2.13)	
Central	256 (5.43)	30 (9.23)	287 (5.68)	
Eastern	546 (11.57)	14 (4.32)	561 (11.10)	
Greater	1,324 (28.05)	112 (34.02)	1,437 (28.44)	
North East	19 (0.41)	3 (0.86)	22 (0.43)	
Northern	117 (2.47)	6 (1.69)	122 (2.42)	
Oti	112 (2.37)	12 (3.60)	124 (2.45)	
Savannah	25 (0.54)	1 (0.35)	27 (0.53)	

<b>Variables</b>	<b>Negative</b>	<b>Positive</b>	<b>Total (%)</b>	<b>Chi<sup>2</sup> (P-Value)</b>
Upper East	106 (2.24)	9 (2.76)	115 (2.27)	
Upper West	48 (1.02)	4 (1.20)	52 (1.03)	
Volta	118 (2.50)	1 (0.23)	119 (2.35)	
Western	653 (13.82)	30 (9.17)	683 (13.52)	
Western North	32 (0.69)	3 (0.85)	35 (0.70)	
<b>Religion</b>				<b>0.793(0.4791)</b>
Christian	3,893 (82.44)	278 (84.23)	4,171 (82.56)	
Moslem	616 (13.04)	38 (11.66)	654 (12.95)	
Traditionalist	34 (0.72)	1 (0.44)	36 (0.70)	
No-religion	179 (3.80)	12 (3.67)	191 (3.79)	
<b>Earn per week</b>				<b>0.5488(0.536)</b>
GHC0-GHC1000	4,515 (95.63)	312 (94.65)	4,828 (95.56)	
>GHC1000	206 (4.37)	18 (5.35)	224 (4.44)	
<b>Individual risk factors</b>				
<b>Paying client use condom</b>				<b>1.0941(0.4054)</b>
Not Always	453 (9.59)	25 (7.52)	478 (9.45)	
Always	4,269 (90.41)	305 (92.48)	4,574 (90.55)	
<b>Ever Married/Cohabited</b>				<b>0.2441(0.6702)</b>
Yes	1,980 (41.93)	145 (43.84)	2,124 (42.05)	
No	2,742 (58.07)	185 (56.16)	2,928 (57.95)	
<b>Client per week</b>				<b>0.4836(0.5675)</b>
<10	3,516 (74.46)	253 (76.77)	3,769 (74.61)	
11 to 20	772 (16.35)	52 (15.81)	824 (16.32)	
>20	434 (9.18)	24 (7.42)	458 (9.07)	
<b>Alcohol during sex</b>				<b>5.7561(0.1385)</b>
No	1,904 (40.32)	107 (32.28)	2,011 (39.80)	
Yes	2,818 (59.68)	223 (67.72)	3,041 (60.20)	
<b>Anal sex</b>				<b>1.8628(0.3056)</b>
Yes	462 (9.79)	26 (7.76)	488 (9.66)	
No	4,260 (90.21)	304 (92.24)	4,564 (90.34)	
<b>Access to healthcare</b>				
<b>Sex Work Type</b>				<b>14.5343(0.0624)</b>

Variables	Negative	Positive	Total (%)	Chi <sup>2</sup> (P-Value)
Roamer	3,965 (83.97)	282 (85.48)	4,247 (84.07)	
Seater	757 (16.03)	48 (14.52)	805 (15.93)	
Avoid Health care due to Stigma				7.531(0.111)
No	4,429 (93.80)	295 (89.49)	4,725 (93.52)	
Yes	293 (6.20)	35 (10.51)	327 (6.48)	

### 5.3.3 Logistic Regression Analysis for HBV

Among the variables examined, three factors emerged as significant in predicting HBV status among FSWs. Female sex workers from Nigeria demonstrated a reduced likelihood of HBV infection compared to those from Ghana, with an adjusted odds ratio (AOR) of 0.61 (95% CI [0.39, 0.94];  $p = 0.026$ ). Alcohol use during sex also showed a significant association, with individuals who consumed alcohol being 1.35 times more likely to have HBV compared to those who did not (95% CI [1.01, 1.81];  $p = 0.041$ ). Additionally, healthcare avoidance due to stigma was linked to higher odds of HBV infection, with an AOR of 1.69 (95% CI [1.07, 2.66];  $p = 0.023$ ). These findings underscore the importance of addressing stigma-related barriers to healthcare access and risky behaviours associated with alcohol use.

Conversely, other socio-demographic and behavioural factors, including age group, educational attainment, condom use frequency, weekly client volume, and time spent on sex work, were not significantly associated with HBV infection in this analysis. Nationality categorized as "Others" also showed no significant effect.



**Table 2: Logistic Regression Analysis of Factors Associated with HBV Among Female Sex Workers**

<b>Variables</b>	<b>HBV AOR [95% CI]</b>	<b>p-value</b>
<b>Age Group</b>		
16-24 years	ref	
25-35 years	1.34 [0.99, 1.83]	0.061
>35 years	1.16 [0.71, 1.89]	0.553
<b>Education</b>		
None	ref	
Primary	1.15 [0.68, 1.95]	0.605
Middle/JSS/JHS	1.05 [0.65, 1.69]	0.843
Secondary/SSS/SHS	1.19 [0.74, 1.93]	0.478
Higher	1.16 [0.57, 2.36]	0.682
<b>Country</b>		
Ghana	ref	
Nigeria	0.61 [0.39, 0.94]*	0.026
Others	0.65 [0.21, 2.00]	0.448
<b>Condom Use</b>		
No	ref	
Yes	1.39 [0.88, 2.19]	0.156
<b>Clients per Week</b>		
<10	ref	
11 to 20	0.90 [0.62, 1.30]	0.575
>20	0.84 [0.50, 1.39]	0.487
<b>Alcohol Use</b>		

Variables	HBV AOR [95% CI]	p-value
No	ref	
Yes	1.35 [1.01, 1.81]*	0.041
<b>Time Spent on Sex Work</b>		
Roamer	ref	
Seater	0.90 [0.61, 1.32]	0.579
<b>Avoidance of Services</b>		
No	ref	
Yes	1.69 [1.07, 2.66]*	0.023

#### 5.3.4 Modified Poisson Regression Analysis for HBV

The analysis identified three significant predictors of HBV prevalence among FSWs. Female sex workers from Nigeria exhibited a lower prevalence of HBV compared to their Ghanaian counterparts, with a prevalence ratio (PR) of 0.63 (95% CI [0.41, 0.95];  $p = 0.027$ ). Alcohol use was associated with an increased HBV prevalence, as those who consumed alcohol during sex were 1.33 times more likely to have HBV compared to those who did not (95% CI [1.01, 1.74];  $p = 0.041$ ). Furthermore, avoidance of healthcare services due to stigma significantly increased the HBV prevalence, with a PR of 1.61 (95% CI [1.08, 2.42];  $p = 0.021$ ). These findings underscore the importance of addressing stigma and alcohol use through targeted interventions in this population.

Other variables, including age, educational attainment, condom use, number of weekly clients, and type of sex work (roamer versus seater), did not show statistically significant associations with HBV prevalence.

**Table 3: Modified Poisson Regression Analysis of Factors Associated with HBV Among Female Sex Workers**

<b>Variables</b>	<b>HBV PR [95% CI]</b>	<b>p-value</b>
<b>Age Group</b>		
16-24 years	ref	
25-35 years	1.31 [0.99, 1.75]	0.062
>35 years	1.15 [0.73, 1.81]	0.555
<b>Education</b>		
None	ref	
Primary	1.14 [0.70, 1.86]	0.605
Middle/JSS/JHS	1.05 [0.67, 1.63]	0.843
Secondary/SSS/SHS	1.18 [0.75, 1.84]	0.479
Higher	1.15 [0.59, 2.22]	0.681
<b>Country</b>		
Ghana	ref	
Nigeria	0.63 [0.41, 0.95]*	0.027
Others	0.66 [0.23, 1.94]	0.453
<b>Condom Use</b>		
No	ref	
Yes	1.36 [0.89, 2.09]	0.159
<b>Clients per Week</b>		
<10	ref	
11 to 20	0.91 [0.64, 1.28]	0.572
>20	0.85 [0.52, 1.36]	0.489
<b>Alcohol Use</b>		
No	ref	
Yes	1.33 [1.01, 1.74]*	0.041

Variables	HBV PR [95% CI]	p-value
<b>Time Spent on Sex Work</b>		
Roamer	ref	
Seater	0.90 [0.63, 1.30]	0.582
<b>Avoidance of Services</b>		
No	ref	
Yes	1.61 [1.08, 2.42]*	0.021

### 5.3.5 Cox Proportional Hazards Analysis for HBV

The Cox proportional hazards model revealed significant risk factors for HBV among female sex workers (FSWs). Nationality was an important determinant, with Nigerian FSWs having a 38% lower risk of HBV compared to Ghanaian FSWs (HR: 0.62, 95% CI [0.40, 0.95],  $p = 0.027$ ). Alcohol use was associated with increased risk, as FSWs who consumed alcohol during sexual encounters experienced a 34% higher risk of HBV compared to non-drinkers (HR: 1.34, 95% CI [1.01, 1.77],  $p = 0.042$ ). Similarly, FSWs who avoided healthcare services due to stigma had a 64% higher risk of HBV compared to those who did not avoid care (HR: 1.64, 95% CI [1.10, 2.42],  $p = 0.023$ ). These findings highlight the significant influence of structural and behavioural factors on HBV risk in this population, particularly stigma and alcohol consumption.

Other factors, including age, education, condom use, number of clients per week, and time spent in sex work, were not significantly associated with HBV risk in this model.

**Table 4: Cox Proportional Hazard Regression Analysis of Factors Associated with HBV Among Female Sex Workers**

<b>Variables</b>	<b>HBV HR [95% CI]</b>	<b>p-value</b>
<b>Age Group</b>		
16-24 years	ref	
25-35 years	1.33 [0.98, 1.79]	0.064
>35 years	1.15 [0.72, 1.84]	0.556
<b>Education</b>		
None (ref)	ref	
Primary	1.15 [0.69, 1.94]	0.583
Middle/JSS/JHS	1.05 [0.66, 1.67]	0.822
Secondary/SSS/SHS	1.19 [0.75, 1.93]	0.463
Higher	1.16 [0.61, 2.19]	0.671
<b>Country</b>		
Ghana (ref)	ref	
Nigeria	0.62 [0.40, 0.95]**	0.027
Others	0.65 [0.23, 1.84]	0.443
<b>Condom Use</b>		
No (ref)	ref	
Yes	1.37 [0.90, 2.10]	0.163
<b>Clients per Week</b>		
<10 (ref)	ref	
11 to 20	0.90 [0.62, 1.31]	0.566
>20	0.84 [0.52, 1.36]	0.5
<b>Alcohol Use</b>		

Variables	HBV HR [95% CI]	p-value
No (ref)	ref	
Yes	1.34 [1.01, 1.77]**	0.042
<b>Time Spent on Sex Work</b>		
Roamer (ref)	ref	
Seater	0.90 [0.63, 1.30]	0.586
<b>Avoidance of Services</b>		
No (ref)	ref	
Yes	1.64 [1.10, 2.42]**	0.023

### 5.3.6 Model Evaluation for HBV

The Cox regression model demonstrated the best fit for assessing the risk of HBV among female sex workers, outperforming both logistic regression and modified Poisson models in terms of model performance. With the lowest AIC (5923.345) and BIC (5831.959), the Cox model exhibited superior model parsimony and predictive accuracy, suggesting it provides the most robust explanation of the data among the evaluated approaches. Additionally, the C-index for the Cox model was 0.5993, indicating moderate discriminatory ability for predicting HBV risk based on the covariates included in the model.

In terms of classification performance, the Cox model yielded a sensitivity of 0.973, meaning it effectively identified nearly all individuals at risk for HBV. However, specificity was notably lower at 0.085, reflecting limited accuracy in identifying those not at risk. This trade-off suggests that the Cox model prioritizes capturing true positives, which is critical in public health contexts aiming to mitigate risks among vulnerable populations.

By comparison, the logistic regression and modified Poisson models were less optimal, with higher AIC and BIC values, lower specificity, and no computation of the C-index, making the Cox regression model the most suitable for evaluating risk factors influencing HBV among this population. The threshold of 0.1 further supports the model's focus on maximizing sensitivity for identifying individuals at risk.



**Table 5: Comparison of Model Performance Metrics for HBV using Logistic Regression, Modified Poisson, and Cox Regression Models Using AIC, BIC, C-Index, ROC, Sensitivity, and Specificity**

<b>Model</b>	<b>AIC</b>	<b>BIC</b>	<b>C-Index (Cox)</b>	<b>AUC-ROC</b>	<b>Sensitivity</b>	<b>Specificity</b>
Logistic Regression	22123.4	22221.31	NA	0.59	0.9667	0.0571
Modified Poisson	22347.08	22444.99	NA	0.59	0.9773	0.033
Cox Regression	5923.345	5831.959	0.5993	0.58979	0.972973	0.084976
Threshold					0.1	



## 5.4 Analysis of HIV

### 5.4.1 Prevalence of HIV and Chi-square Analysis of Socio-Demographic Factors

The prevalence of HIV among female sex workers (FSWs) in this study was 4.53% (95% CI: [3.46%, 5.92%]), with 246 cases testing positive out of the total sample of 5,426. The prevalence underscores the public health significance of addressing HIV transmission in this vulnerable population.

Chi-square analysis revealed significant associations between HIV status and certain socio-demographic factors, specifically age group ( $\chi^2 = 28.1584$ ,  $p = 0.0147$ ) and educational level ( $\chi^2 = 13.2083$ ,  $p = 0.0468$ ). Within the age groups, FSWs aged 25–35 years exhibited the highest prevalence of HIV (54.54%), followed by those over 35 years (16.27%). This trend indicates that older age groups may be at greater chance of HIV infection compared to younger individuals (29.18% in the 16–24 years group). Similarly, educational attainment revealed disparities, with FSWs having no education (14.21%) or only primary education (29.95%) demonstrating higher HIV prevalence compared to those with secondary (17.99%) or higher education (3.76%).

In contrast, no significant associations were found between HIV status and other socio-demographic factors, including nationality ( $p = 0.2803$ ), region of residence ( $p = 0.2276$ ), religion ( $p = 0.4248$ ), or weekly earnings ( $p = 0.6915$ ). These results suggest that these variables do not independently influence HIV status in this population.

### 5.4.2 Individual Factors

Among individual behavioural factors, only condom use frequency demonstrated a significant association with HIV status, with a notable p-value of less than 0.05. While the overall prevalence of HIV among FSWs who reported always using condoms was lower (91.21%) than those who reported inconsistent use (8.79%), this protective behaviour still did not entirely eliminate the chance of HIV transmission.

The analysis did not identify significant associations between HIV status and other individual factors such as marital history ( $p = 0.1156$ ), weekly client volume ( $p = 0.0586$ ), alcohol use during sex ( $p = 0.824$ ), participation in anal sex ( $p = 0.8317$ ), or sex work type ( $p = 0.756$ ). Similarly, healthcare avoidance due to stigma ( $p = 0.5263$ ) and comprehensive knowledge of HIV ( $p = 0.3687$ ) were not significantly linked to HIV status.



**Table 6: Distribution of Socio-demographic Factors, Individual Factors, and Healthcare Access Characteristics Among Female Sex Workers by HIV Status in Ghana**

Variables	Negative	Positive	Total n (%)	Chi <sup>2</sup> (P-value)
	n = 5180 (95.47)	n = 246 (4.53)	N (5426)	
<b>Socio-demographic factors</b>				
<b>Age Group</b>				<b>28.1584(0.0147)</b>
16-24 years	2,251 (43.45%)	72 (29.18%)	2,323 (42.81%)	
25-35 year	2,494 (48.15%)	134 (54.54%)	2,628 (48.44%)	
>35 years	435 (8.40%)	40 (16.27%)	475 (8.76%)	
<b>Educational Level</b>				<b>13.6803(0.0468)</b>
None	380 (7.34%)	35 (14.21%)	415 (7.65%)	
Primary	816 (15.75%)	74 (29.95%)	890 (16.40%)	
Middle/JSS/JHS	2,042 (39.43%)	84 (34.09%)	2,126 (39.19%)	
Secondary	1,666 (32.16%)	44 (17.99%)	1,710 (31.52%)	
Higher	276 (5.32%)	9 (3.76%)	285 (5.25%)	
<b>Country/Nationality</b>				<b>2.1262(0.2803)</b>
Ghana	4,357 (84.11%)	206 (83.86%)	4,563 (84.10%)	
Nigeria	700 (13.52%)	31 (12.73%)	732 (13.49%)	
Others	123 (2.37%)	8 (3.41%)	131 (2.42%)	
<b>Region</b>				<b>2.7202(0.2276)</b>
Ahafo	106 (2.04%)	3 (1.26%)	109 (2.01%)	
Ashanti	946 (18.26%)	39 (15.75%)	984 (18.14%)	
Bono	324 (6.25%)	13 (5.19%)	337 (6.21%)	
Bono East	100 (1.94%)	8 (3.26%)	108 (2.00%)	
Central	546 (10.54%)	14 (5.66%)	560 (10.32%)	
Eastern	557 (10.76%)	23 (9.46%)	581 (10.70%)	
Greater	1,350 (26.05%)	77 (31.24%)	1,426 (26.29%)	
North East	22 (0.43%)	0 (0.00%)	22 (0.41%)	
Northern	120 (2.32%)	3 (1.34%)	123 (2.27%)	
Oti	125 (2.41%)	1 (0.49%)	126 (2.32%)	
Savannah	26 (0.49%)	1 (0.49%)	27 (0.49%)	
Upper East	106 (2.04%)	10 (4.06%)	116 (2.13%)	
Upper West	48 (0.92%)	5 (2.02%)	53 (0.97%)	
Volta	114 (2.19%)	6 (2.54%)	120 (2.21%)	
Western	658 (12.70%)	40 (16.33%)	698 (12.86%)	

<b>Variables</b>	<b>Negative</b>	<b>Positive</b>	<b>Total n (%)</b>	<b>Chi<sup>2</sup> (P-value)</b>
Western North	33 (0.64%)	2 (0.91%)	36 (0.66%)	
<b>Religion</b>				<b>0.998(0.4248)</b>
Christian	4,310 (83.21%)	190 (77.23%)	4,500 (82.94%)	
Moslem	640 (12.35%)	42 (17.12%)	682 (12.57%)	
Traditionalist	34 (0.65%)	2 (0.86%)	36 (0.66%)	
No-religion	197 (3.79%)	12 (4.78%)	208 (3.84%)	
<b>Earn per week</b>				<b>0.2534(0.6915)</b>
GHC0-GHC1000	4,958 (95.72%)	234 (95.26%)	5,193 (95.70%)	
>GHC1000	222 (4.28%)	12 (4.74%)	233 (4.3%)	
<b>Individual risk factors</b>				
<b>Paying client use condom</b>				<b>0.2196(0.6855)</b>
Not Always	519 (10.02%)	22 (8.79%)	541 (9.97%)	
Always	4,661 (89.98%)	224 (91.21%)	4,885 (90.03%)	
<b>Ever Married/Cohabited</b>				<b>7.1789(0.1156)</b>
Yes	2,204 (42.54%)	120 (48.59%)	2,323 (42.81%)	
No	2,976 (57.46%)	126 (51.41%)	3,103 (57.19%)	
<b>Client per week</b>				<b>13.7853(0.0586)</b>
<10	3,901 (75.30%)	183 (74.37%)	4,084 (75.26%)	
11 to 20	837 (16.15%)	30 (12.02%)	866 (15.96%)	
>20	443 (8.54%)	34 (13.61%)	476 (8.77%)	
<b>Alcohol during sex</b>				<b>0.064(0.824)</b>
No	2,046 (39.49%)	95 (38.50%)	2,140 (39.45%)	
Yes	3,134 (60.51%)	151 (61.50%)	3,286 (60.55%)	
<b>Anal sex</b>				<b>0.0583(0.8317)</b>
Yes	523 (10.10%)	23 (9.16%)	546 (10.05%)	
No	4,657 (89.90%)	223 (90.84%)	4,880 (89.95%)	
<b>Access to healthcare</b>				
<b>Sex Work Type</b>				<b>0.1266(0.756)</b>
Roamer	4,385 (84.65%)	210 (85.40%)	4,595 (84.69%)	
Seater	795 (15.35%)	36 (14.60%)	831 (15.31%)	
<b>Avoid Health care due to Stigma</b>				<b>0.5788(0.5263)</b>

Variables	Negative	Positive	Total n (%)	Chi <sup>2</sup> (P-value)
No	4,850 (93.63%)	232 (94.33%)	5,082 (93.66%)	<b>1.3254(0.3687)</b>
Yes	330 (6.37%)	14 (5.67%)	344 (6.34%)	
<b>Comprehensive Knowledge of HIV &amp; AIDS</b>				
Yes	1,763 (34.03%)	79 (31.98%)	1,841 (33.93%)	
No	3,417 (65.97%)	167 (68.02%)	3,585 (66.07%)	

#### 5.4.3 Logistic Regression Analysis for HIV

The analysis of HIV status identified several significant predictors. Age was a strong factor, with individuals aged 25-35 years having 1.63 times higher odds of being HIV-positive compared to those aged 16-24 years (95% CI [1.15, 2.30];  $p = 0.006$ ). Individuals older than 35 years had even higher odds (2.29, 95% CI [1.41, 3.71];  $p = 0.001$ ). Education level also played a significant role: those with middle or junior secondary education (JHS) had 50% lower odds of being HIV-positive compared to those with no formal education (95% CI [0.31, 0.79];  $p = 0.003$ ). Higher education levels further decreased the odds, with odds ratios of 0.33 (95% CI [0.19, 0.55];  $p < 0.0001$ ) for secondary education and 0.39 (95% CI [0.18, 0.85];  $p = 0.018$ ) for higher education. These findings suggest that older age and higher education are protective factors against HIV among FSWs.

In contrast, factors such as condom use (OR = 1.16, 95% CI [0.66, 2.03];  $p = 0.606$ ), marital status (OR = 0.99, 95% CI [0.73, 1.35];  $p = 0.956$ ), alcohol use (OR = 1.06, 95% CI [0.77, 1.44];  $p = 0.722$ ), avoidance of healthcare services due to stigma (OR = 0.94, 95% CI [0.50, 1.77];  $p = 0.84$ ), and comprehensive HIV knowledge (OR = 0.99, 95% CI [0.71, 1.37];  $p = 0.942$ ) were not significantly associated with HIV status. These factors do not appear to have a direct impact on HIV prevalence among FSWs in this study.

**Table 7: Logistic Regression Analysis of Factors Associated with HBV Among Female Sex Workers**

<b>Variables</b>	<b>HIV Odds Ratio [95% CI]</b>	<b>p-value</b>
<b>Age Category</b>		
16-24 years	ref	-
25-35 years	1.63 [1.15, 2.30]	0.006*
>35 years	2.29 [1.41, 3.71]	0.001*
<b>Education</b>		
None	ref	-
Primary	1.08 [0.66, 1.77]	0.77
Middle/JSS/JHS	0.50 [0.31, 0.79]	0.003*
Secondary/SSS/SHS	0.33 [0.19, 0.55]	0.000*
Higher	0.39 [0.18, 0.85]	0.018*
<b>Condom Use</b>		
No	ref	-
Yes	1.16 [0.66, 2.03]	0.606
<b>Ever Married</b>		
YES	ref	-
NO	0.99 [0.73, 1.35]	0.956
<b>Client Week</b>		
<10	ref	-
11 to 20	0.73 [0.47, 1.14]	0.169
>20	1.64 [0.97, 2.77]	0.066
<b>Alcohol Use</b>		
No	ref	-

Variables	HIV Odds Ratio [95% CI]	p-value
Yes	1.06 [0.77, 1.44]	0.722
<b>Avoid Service Stigma</b>		
No	ref	-
Yes	0.94 [0.50, 1.77]	0.84
<b>Comprehensive Knowledge</b>		
Yes	ref	-
Not yes	0.99 [0.71, 1.37]	0.942

#### 5.4.4 Modified Poisson Regression Analysis for HIV

The prevalence ratio (PR) analysis of HIV status revealed several significant factors. Age was a notable determinant, with individuals aged 25-35 years having a 1.59 times higher prevalence of HIV compared to those aged 16-24 years (95% CI [1.14, 2.21];  $p = 0.006$ ). Those over 35 years exhibited an even higher prevalence, with a PR of 2.17 (95% CI [1.38, 3.40];  $p = 0.001$ ), indicating a strong association between older age and increased HIV prevalence. Education level also played a significant role in HIV prevalence, with individuals having middle or junior secondary education (JHS) showing a 48% lower prevalence (95% CI [0.34, 0.80];  $p = 0.003$ ). Those with secondary or higher education had even lower HIV prevalence, with PRs of 0.35 (95% CI [0.21, 0.56];  $p < 0.001$ ) and 0.41 (95% CI [0.20, 0.87];  $p = 0.020$ ), respectively. These findings highlight older age and higher education as factors associated with lower HIV prevalence among female sex workers.

On the other hand, factors such as condom use (PR = 1.15, 95% CI [0.68, 1.95];  $p = 0.607$ ), marital status (PR = 0.99, 95% CI [0.74, 1.33];  $p = 0.955$ ), alcohol use (PR = 1.05, 95% CI [0.79, 1.41];  $p = 0.722$ ), avoidance of healthcare services due to stigma (PR = 0.94, 95% CI [0.52, 1.71];  $p = 0.839$ ), and comprehensive HIV knowledge (PR = 0.99, 95% CI [0.73, 1.34];

p = 0.938) were not significantly associated with HIV status. These results suggest that these factors do not directly influence HIV prevalence in this population.

**Table 8: Modified Poisson Regression Analysis of Factors Associated with HBV Among Female Sex Workers**

<b>Variables</b>	<b>HIV PR [95% CI]</b>	<b>p-value</b>
<b>Age Category</b>		
16-24 years	ref	-
25-35 years	1.59 [1.14, 2.21]	0.006*
>35 years	2.17 [1.38, 3.40]	0.001*
<b>Education</b>		
None	ref	-
Primary	1.07 [0.68, 1.68]	0.764
Middle/JSS/JHS	0.52 [0.34, 0.80]	0.003*
Secondary/SSS/SHS	0.35 [0.21, 0.56]	0.000*
Higher	0.41 [0.20, 0.87]	0.020*
<b>Condom Use</b>		
No	ref	-
Yes	1.15 [0.68, 1.95]	0.607
<b>Ever Married</b>		
Yes	ref	-
No	0.99 [0.74, 1.33]	0.955
<b>Client Week</b>		
<10	ref	-
11 to 20	0.74 [0.49, 1.13]	0.17
>20	1.58 [0.98, 2.54]	0.061

**Alcohol Use**

No	ref	-	
Yes	1.05 [0.79, 1.41]		0.722

**Avoid Service Stigma**

NO	ref	-	
YES	0.94 [0.52, 1.71]		0.839

**Comprehensive Knowledge**

Yes	ref	-	
Not yes	0.99 [0.73, 1.34]		0.938

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**5.4.5 Cox Proportional Hazards Analysis for HBV**

The Cox regression analysis of HIV status identified several significant predictors of HIV incidence. Age was a strong risk factor, with individuals aged 25-35 years exhibiting a 1.60 times higher risk of developing HIV compared to those aged 16-24 years (95% CI [1.27, 2.02];  $p = 0.007$ ). The risk was even higher among individuals over 35 years, with a hazard ratio of 2.20 (95% CI [1.55, 3.14];  $p = 0.001$ ), suggesting that older age is associated with an increased likelihood of HIV onset in female sex workers.

Education level was another significant factor, with individuals having middle, junior secondary, or high school education showing a 49% reduced risk of HIV (HR = 0.51, 95% CI [0.35, 0.73];  $p = 0.003$ ). Those with secondary education had a hazard ratio of 0.33 (95% CI [0.19, 0.53];  $p < 0.001$ ), and individuals with higher education exhibited an even lower risk (HR = 0.40, 95% CI [0.19, 0.85];  $p = 0.019$ ). These findings highlight that higher education levels provide a protective effect against HIV infection among this population.

On the other hand, variables such as condom use (HR = 1.16, 95% CI [0.68, 1.97];  $p = 0.593$ ), marital status (HR = 0.99, 95% CI [0.73, 1.34];  $p = 0.937$ ), alcohol use (HR = 1.06, 95% CI

[0.78, 1.41];  $p = 0.712$ ), avoidance of service stigma (HR = 0.94, 95% CI [0.53, 1.68];  $p = 0.844$ ), and comprehensive HIV knowledge (HR = 0.98, 95% CI [0.73, 1.34];  $p = 0.923$ ) did not show statistically significant associations with HIV risk. These results suggest that these factors do not directly affect HIV incidence in this population.



**Table 9: Cox Proportional Hazard Regression Analysis of Factors Associated with HBV Among Female Sex Workers**

Variables	HIV HR [95% CI]	p-value
<b>Age Category</b>		
16-24 years	ref	-
25-35 years	1.60 [1.27, 2.02]	0.007*
>35 years	2.20 [1.55, 3.14]	0.001*
<b>Education</b>		
None	ref	-
Primary	1.07 [0.66, 1.70]	0.79
Middle/JSS/JHS	0.51 [0.35, 0.73]	0.003*
Secondary/SSS/SHS	0.33 [0.19, 0.53]	<0.001*
Higher	0.40 [0.19, 0.85]	0.019*
<b>Condom Use</b>		
No	ref	-
Yes	1.16 [0.68, 1.97]	0.593
<b>Ever Married</b>		
Yes	ref	-
No	0.99 [0.73, 1.34]	0.937
<b>Client Week</b>		
<10	ref	-
11 to 20	0.74 [0.47, 1.16]	0.167
>20	1.61 [0.98, 2.66]	0.065
<b>Alcohol Use</b>		
No	ref	-

Variables	HIV HR [95% CI]	p-value
Yes	1.06 [0.78, 1.41]	0.712
<b>Avoid Service Stigma</b>		
No	ref	-
Yes	0.94 [0.53, 1.68]	0.844
<b>Comprehensive Knowledge</b>		
Yes	ref	-
Not Yes	0.98 [0.73, 1.34]	0.923

#### 5.4.6 Model Evaluation for HIV

The results of the model comparison underscore the superiority of the Cox regression model in predicting HIV risk among female sex workers. While both logistic regression and modified Poisson models showed relatively poor performance in terms of classification accuracy, with AUC-ROC values of 0.6483 and 0.6484 respectively, the Cox regression model demonstrated a substantial improvement. It achieved a higher C-Index of 0.6699, indicating a better ability to rank individuals by their risk of HIV infection. Additionally, the AUC-ROC for the Cox model was 0.6476, which, although lower than desired, was still notably superior compared to the other two models.

Furthermore, the Cox model exhibited a balance between sensitivity and specificity, with a sensitivity of 0.4702 and a specificity of 0.7415. This performance indicates that the Cox regression model was able to correctly identify those at higher risk of HIV while maintaining a reasonably good classification of those not at risk. In contrast, logistic regression and modified Poisson models showed much lower specificity (0.1298 and 0.1228, respectively), meaning they were less effective at identifying true negatives, while their sensitivities remained high, suggesting a potential for high false positive rates.

Overall, the Cox regression model outperforms the other two models, demonstrating its suitability for predicting HIV risk, especially in terms of distinguishing between high- and low-risk individuals within this population.



**Table 10: Comparison of Model Performance Metrics for HBV using Logistic Regression, Modified Poisson, and Cox Regression Models Using AIC, BIC, C-Index, ROC, Sensitivity, and Specificity**

<b>Model</b>	<b>AIC</b>	<b>BIC</b>	<b>C-Index (Cox)</b>	<b>AUC-ROC</b>	<b>Sensitivity</b>	<b>Specificity</b>
Logistic Regression	17479.74	17572.12	NA	0.6483	0.9555	0.1298
Modified Poisson	17624.35	17716.74	NA	0.6484	0.9592	0.1228
Cox Regression	2323.845	2409.631	0.6699	0.6476	0.4702	0.7415
Threshold					0.1	



## CHAPTER SIX:

### 6.0 DISCUSSION, RECOMMENDATIONS, AND CONCLUSIONS

#### 6.1 Introduction

This chapter summarizes findings on the prevalence and risk factors of Hepatitis B (HBV) and HIV among female sex workers (FSWs) in Ghana. The Cox proportional hazards model identified age and education as significant factors, with older age and lower education associated with higher HIV risk. Condom use, alcohol consumption, and healthcare avoidance due to stigma were not significantly linked to infection status. The findings highlight the need for public health interventions targeting education and healthcare access. Limitations include the cross-sectional design and potential self-report biases. Future research should focus on longitudinal studies to better understand these associations.

#### 6.2 Discussion

##### 6.2.1 Hepatitis B (HBV) Infection

###### 6.2.1.1 Prevalence and Socio-Demographic Influences

The prevalence of HBV among FSWs in Ghana was 6.53%, highlighting a significant public health concern in this population. This finding aligns with prior studies indicating that high-risk populations, including FSWs, experience a disproportionate burden of HBV due to systemic and behavioural vulnerabilities (Metaferia *et al.*, 2021; WHO, 2020). The relatively lower prevalence compared to regional estimates may reflect improvements in vaccination coverage, but gaps remain, particularly among mid-adult FSWs.

Age emerged as a significant socio-demographic factor, with individuals aged 25–35 years showing the highest HBV prevalence. This pattern is consistent with findings from Daka *et al.* (2022) and Todd *et al.* (2010), which suggest that mid-adulthood represents a peak period of exposure to risk factors, including increased sexual activity and prolonged occupational

hazards. However, the absence of significant associations with variables such as education, nationality, and region suggests that structural barriers, such as inadequate vaccination campaigns and limited healthcare access, may be more influential than individual-level socio-demographic characteristics.

### **6.2.1.2 Behavioural Factors and HBV Status**

The Cox regression model identified alcohol use during sex and stigma-driven healthcare avoidance as significant behavioural predictors of HBV status. Alcohol use increased HBV risk by 34% (HR = 1.34,  $p = 0.042$ ), consistent with evidence highlighting alcohol's role in reducing self-control and increasing engagement in unsafe sexual practices (Dery *et al.*, 2024; Scorgie *et al.*, 2013). This association underscores the need for integrating substance-use reduction programs into broader HBV prevention strategies.

Healthcare avoidance due to stigma was associated with a 64% increased risk of HBV (HR = 1.64,  $p = 0.023$ ). Fear of discrimination often prevents FSWs from accessing vaccinations and routine healthcare, exacerbating their vulnerability to preventable infections (Scorgie *et al.*, 2013; Todd *et al.*, 2010). Addressing stigma through community-based interventions and training healthcare providers to deliver non-discriminatory services is essential for reducing HBV transmission in this population.

Interestingly, the study found no significant association between HBV and condom use, marital status, or healthcare access. This suggests that sexual transmission, while important, may not be the dominant pathway for HBV in this context. Non-sexual transmission routes, such as unsafe medical practices or shared tools in occupational settings, warrant further exploration (WHO, 2020).

## 6.2.2 HIV Infection

### 6.2.2.1 Prevalence and Socio-Demographic Influences

The HIV prevalence of 4.53% among FSWs underscores the persistent vulnerability of this population to the virus. While lower than estimates from other sub-Saharan African settings, this prevalence reflects systemic inequities, including limited access to prevention resources and healthcare services (Guure *et al.*, 2023; UNAIDS, 2021). Age and education emerged as critical socio-demographic predictors, offering valuable insights into HIV transmission dynamics.

Older FSWs faced significantly higher HIV risks, with those aged 25–35 years having a 1.60 times greater risk (HR = 1.60,  $p = 0.007$ ) and those over 35 years exhibiting a 2.20 times higher risk (HR = 2.20,  $p = 0.001$ ). These findings are consistent with UNAIDS (2021), which highlights the cumulative effect of prolonged exposure to high-risk behaviours and potential gaps in access to early prevention measures for older individuals. Targeting older FSWs with age-specific interventions, such as PrEP and regular screenings, is critical to mitigating this risk.

Education served as a protective factor, with secondary education reducing HIV risk by 67% (HR = 0.33,  $p < 0.001$ ) and higher education showing similar effects (HR = 0.40,  $p = 0.019$ ). Educated FSWs are more likely to access HIV prevention tools, negotiate safer sexual practices, and engage in health-seeking behaviours, aligning with findings by Dery *et al.* (2024) and Scorgie *et al.* (2013).

### 6.2.2.2 Behavioural Factors and HIV Risk

Unlike socio-demographic factors, behavioural predictors such as condom use, alcohol consumption, and healthcare avoidance were not significantly associated with HIV risk. The lack of association with condom use may reflect inconsistent usage or barriers to effective

negotiation, which have been documented as challenges within this population (Daka *et al.*, 2022; Todd *et al.*, 2010). Similarly, the absence of significant effects for alcohol use and stigma-related healthcare avoidance highlights the complex interplay of structural and behavioural determinants, suggesting that broader systemic factors may mediate these associations.

## **6.2.3 Model Evaluation**

### **6.2.3.1 Rationale for Selecting the Cox Proportional Hazards Model**

The Cox proportional hazards model emerged as the most suitable analytical framework for predicting HBV and HIV risks, outperforming logistic regression and modified Poisson models in multiple dimensions. For both infections, the Cox model achieved the lowest AIC and BIC values, indicating superior parsimony and model fit. Its C-index values (HBV: 0.5993; HIV: 0.6699) demonstrated better discriminatory ability compared to the AUC-ROC values of the logistic (HBV: 0.6483; HIV: 0.6484) and Poisson models.

In addition to its statistical advantages, the Cox model's ability to incorporate time-to-event data provided nuanced insights into the progression of infection risks. This feature was particularly valuable for identifying the cumulative impacts of age and education, as well as behavioural factors like alcohol use and stigma-related healthcare avoidance (Guure *et al.*, 2023; Todd *et al.*, 2010). By balancing sensitivity and specificity (HIV: 0.4702 and 0.7415, respectively), the Cox model offered a robust framework for distinguishing high-risk individuals while minimizing false positives.

## 6.3 Recommendations

### 6.3.1 Practical Recommendations for Policy and Intervention

#### 1. Hepatitis B (HBV):

- **Expand vaccination programs:** Prioritize mid-adult FSWs aged 25–35 years, addressing a critical gap in preventative care.
- **Address alcohol-related risks:** Develop targeted harm-reduction programs that address the link between alcohol use and unsafe behaviours.
- **Reduce stigma in healthcare:** Implement anti-stigma campaigns and train healthcare providers to offer non-discriminatory services.

#### 2. Human Immunodeficiency Virus (HIV):

- **Develop age-specific interventions:** Focus on older FSWs with tailored prevention programs, including PrEP, education, and routine screenings.
- **Enhance education-based strategies:** Expand literacy programs and health education to empower less-educated FSWs with knowledge and skills for HIV prevention.
- **Strengthen healthcare access:** Address systemic barriers to healthcare, ensuring equitable access to prevention and treatment services.

### 6.3.2 Recommendations for Future Research

1. Investigate non-sexual HBV transmission pathways, such as unsafe medical practices and occupational exposures.
2. Conduct longitudinal studies to refine predictive models and assess intervention impacts over time.
3. Explore the interplay of structural determinants, such as stigma and socio-economic inequities, on infection risks among FSWs.

## **6.4 Conclusions**

### **6.4.1 Summary of Key Findings and Contributions**

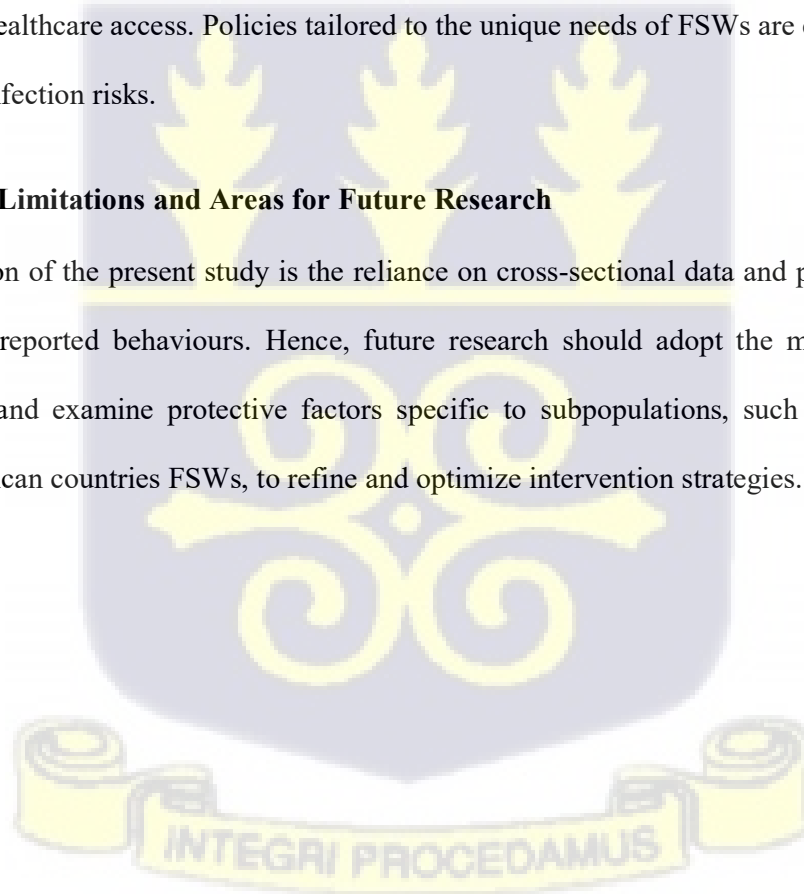
This study identified age, education, alcohol use, and healthcare avoidance as significant predictors of HBV and HIV risks among FSWs. The Cox proportional hazards model proved to be the most effective tool for analyzing these risks, providing a robust framework for targeted interventions.

### **6.4.2 Implications for Public Health and Policy**

Findings emphasize the importance of integrating behavioural and structural interventions into public health strategies, focusing on reducing stigma, enhancing education, and improving healthcare access. Policies tailored to the unique needs of FSWs are essential for mitigating infection risks.

### **6.4.3 Study Limitations and Areas for Future Research**

The limitation of the present study is the reliance on cross-sectional data and potential recall bias in self-reported behaviours. Hence, future research should adopt the mixed methods approaches and examine protective factors specific to subpopulations, such as other sub-Saharan African countries FSWs, to refine and optimize intervention strategies.



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