AUGUST 2025

MISSING AT BIRTH:

AN ANALYSIS OF HEPATITIS B BIRTH DOSE COVERAGE IN THE PHILIPPINES

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A thesis submitted in partial fulfilment of the requirement for the degree of

Master of Science in Public Health and Health Equity

by

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Declaration:

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Master of Science in Public Health and Health Equity

09 September 2024 – 29 August 2025

KIT Institute/Vrije Universiteit Amsterdam

Amsterdam, The Netherlands

August 2025

Organised by:

KIT Institute

Amsterdam, The Netherlands

In cooperation with:

Vrije Universiteit Amsterdam (VU)

Amsterdam, The Netherlands

Abstract

Introduction:
Timely coverage of the available and effective hepatitis B birth dose (HepB-BD) vaccine remains suboptimal in the Philippines. This study investigates national and regional uptake of HepB-BD and key factors influencing vaccination. It seeks to generate evidence to inform immunisation strategies.

Methodology:
This study utilised the 2022 Philippine National Demographic and Health Survey, which includes vaccination data of children under five. Logistic regression models were used to identify predictors of vaccine uptake, and a predictive model was developed to estimate vaccination probabilities under different maternal and contextual scenarios. Spatial autocorrelation and clustering were assessed.

Results:
Key determinants of HepB-BD uptake included place of delivery, antenatal care attendance, internet usage, religion, and region. Births at government hospitals (aOR 8.00; p-value <0.001), more ANC visits (aOR 1.11; p-value 0.001) and recent internet use (aOR 1.56; p-value 0.002) were associated with higher odds of vaccination, while Muslim children were associated with lower odds (aOR 0.48; p-value <0.028). Regional disparities were prominent, and spatial analysis showed clusters of under-prediction in underserved regions, suggesting the presence of unmeasured barriers. Substantial missing data was significantly correlated with non-vaccination, particularly for ANC and place of delivery.

Discussion:
Improving facility birth rates, strengthening ANC services, expanding internet access, and engaging Muslim communities through culturally sensitive strategies are key priorities. Predictive modelling and spatial analysis proved useful in identifying at-risk populations. Future surveys must address data completeness to better guide policy. These findings support strengthened and equitable immunisation strategies.

Keywords: Philippines; Hepatitis B; Hepatitis B Vaccines; Social Determinants of Health; Maternal and Child Health

Word Count: 11998 (excluding pre-textual elements, illustrative tables/figures/graphs/text boxes and their title/captions, the reference list, appendices)

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Abbreviations

AIC – Akaike Information Criterion

ANC – Antenatal care

ASEAN – Association of Southeast Asian Nations

AUC – Area under the ROC curve

BARMM – Bangsamoro Autonomous Region in Muslim Mindanao

CAR - Cordillera Administrative Region

CHB – Chronic Hepatitis B

DoH – Department of Health

GDP – Gross Domestic Product

GVIF – Generalised Variance Inflation factors

HbsAg – Hepatitis B surface antigen

HBV – Hepatitis B Virus

HepB-BD – Hepatitis B birth dose

LISA – Local Indicators of Spatial Association

LMIC – Low-middle income country

MAR – Missing At Random

MCAR – Missing Completely At Random

MNAR – Missing Not At Random

MTCT – Mother-to-child transmission

NCR – National Capital Region

NDHS – National Demographic and Health Survey

PSA – Philippine Statistics Authority

PSU – Primary sampling unit

ROC – Receiver Operating Characteristic

WHO - World Health Organisation

WPR – Western Pacific Region

Introduction

I am a specialist General Practitioner based in Australia with extensive clinical experience across diverse healthcare settings in multiple countries. Throughout my work, I have witnessed how deeply social and structural factors influence health outcomes; an understanding that has been further reinforced during my Master's in Public Health and Health Equity. This academic experience has strengthened my interest in health systems and deepened my commitment to addressing health inequities through evidence-informed policy and practice.

During the course, I was particularly drawn to the epidemiology and statistics specialisation streams. I developed a strong interest in how large-scale population data can be used to understand health disparities and guide public health decision-making. This interest led me to select a thesis topic using the Philippine National Demographic and Health Survey, one of the most robust household datasets in the region. The focus of my research is on hepatitis B birth dose vaccination, a critical public health intervention in the Philippines, where hepatitis B remains a significant burden.

As a primary care physician, I have a longstanding interest in preventive medicine. I believe that vaccination is one of the most impactful advances in modern medicine, and improving access to timely immunisation is fundamental to advancing health equity. Through this thesis, I aim to identify the key individual, household, and system-level factors influencing hepatitis B vaccination uptake, and to offer insights that can support equitable policy and program responses.

Chapter 1: Background

1.1 Study Setting

The Philippines is an archipelagic nation in Southeast Asia consisting of over 7,500 islands covering 300,000 square kilometres of low-lying coastal regions and mountainous areas. This geography has created diverse demographics, language and culture, and makes it a challenging environment for healthcare logistics and access [1]. There are three main island groups: Luzon, Visayas and Mindanao. The capital city of Manila lies on the largest island of Luzon. The Philippines falls under the Western Pacific Region (WPR) in the World Health Organisation (WHO) classification.

The Philippines has multiple levels of government, each of which plays a role in healthcare provision. In total, there are 5 main levels of government - the federal government, provinces, cities, municipalities and barangays. Provinces are the main political and administrative divisions of the Philippines, of which there are 82. Each administrative level has its own elected officials and responsibilities. There is one autonomous region in the country, the Bangsamoro Autonomous Region in Muslim Mindanao (BARMM), consisting of five predominantly Muslim provinces.

The Philippines is an emerging market economy. The Gross Domestic Product (GDP) is US$437 billion [2], with a per capita GDP of $3,804 [3], making it the 4th largest economy among Association of Southeast Asian Nations (ASEAN) countries and a low-middle income country (LMIC). There is heterogeneity in the GDP per capita, with some regions having much lower figures compared to Manila, which has the highest. The National Capital Region (NCR) makes up 255% of the national GDP per capita average, compared to BARMM which makes up just 31% [4].

The Philippines has a long history of occupation by global powers. It became a Spanish colony in the 16th century and has also been occupied by the United States of America and Japan. The country gained its independence as the Republic of the Philippines in 1946 [1]. Colonialism has deeply shaped the Philippines' political, social, and health systems, leaving legacies of centralised governance, regional inequality, and structural dependence that continue to influence development and service delivery today.

1.2 Demographic Profile

According to the 2020 census, the population of the Philippines was 109,033,245 [5]. As of 2025 the population is estimated at 119 million with a population doubling time of 47, in part due to the young population and the fertility rate remaining above replacement at 2.7 children per woman [6]. It has the fastest growing population in Southeast Asia, and is expected to become the second most populous country in the region after Indonesia by 2050 [7]. Figure 1 shows the regions and population density of the Philippines based on WorldPop estimates.

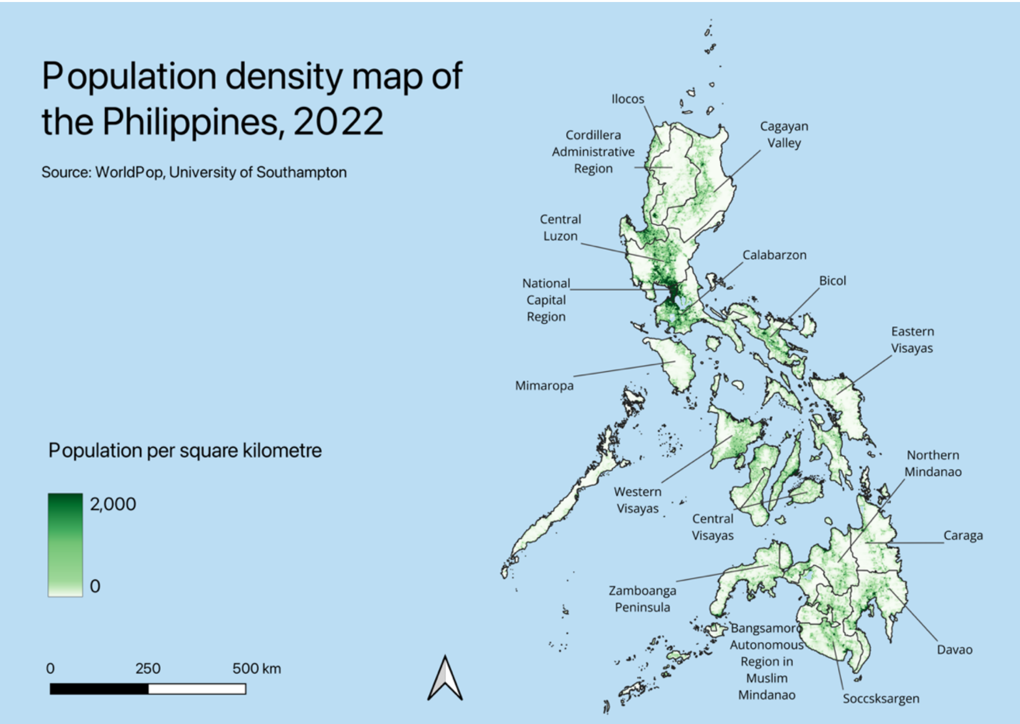


Figure 1: Population density and regions in the Philippines

The Philippines is one of the most diverse countries in the region, with over 100 ethnic groups and around 170 languages spoken. The largest ethnic group is Tagalog, which makes up over a quarter of the population while the Tagalog language forms the basis for the official language of Filipino. English is the second official language and is widely used in government and business. The population is majority Roman Catholic at 78%, with Islam making up the next largest religious group at 6.4% [1].

1.3 Key Health Indicators

The Philippines currently faces a dual burden of disease. While progress has been made in reducing child and maternal deaths, preventable diseases such as tuberculosis, dengue, and vaccine-preventable illnesses remain public health challenges. The average life expectancy of Filipinos lags behind neighbouring countries at 66.4 [8]. Health outcomes and access to services in the Philippines are also highly uneven across regions. The island of Luzon and especially urban centres such as Manila tend to have better health indicators, greater availability of health professionals, and more advanced medical infrastructure [9]. In contrast, many rural provinces especially in Mindanao, the Visayas, and remote island regions, face persistent shortages in healthcare personnel, limited facility capacity, and weaker health system integration [9, 10]. These disparities are linked to broader socioeconomic inequalities, challenging terrain, and historical underinvestment in regional development.

Table 1 shows how the Philippines fares in common indicators compared to the average across the WPR. It is important to note that the WPR contains some of the highest performing health systems in the world including Australia and Japan.

Table 1: Health and demography summary table [5, 8, 11]

	Philippines	**Western Pacific Region**
Demographics		
Total population	119.1 million	1.9 billion
Total fertility rate (per woman)	2.7	1.8
Health Indicators		
Average life expectancy	66.4	77.4
Maternal mortality rate (per 100000 live births)	83.8	35.4
Neonatal mortality (per 1000 live births)	12.28	5.58
Under-5 child mortality (per 1000 live births)	25.74	11.57
Health expenditure (% of GDP)	5.87	8.19

1.4 Health System Overview

The Filipino health system is a dual delivery system made up of public and private sectors. This public system is largely financed through taxation, and the private sector is mostly funded through user fees or private insurance. As of 2018, there are 1,224 hospitals, 2,587 health centres and 20,216 barangay health stations in the country [10]. The variation of health infrastructure across the country is significant. In the NCR, there are 23 hospital beds and 12.6 nurses per 10,000 people, while on the island of Mindanao there are only 8.3 beds and 4.2 nurses per 10,000 [10]. The Philippines has also become a major exporter of healthcare professionals, with almost 85% of Filipino-trained nurses working overseas [12].

The 2019 Universal Health Care Act ensures that all Filipinos have access to a wide range of health services without financial hardship [13]. All Filipinos are automatically signed up to the national insurance program called PhilHealth, which covers inpatient, maternal and neonatal, and primary care services at either no cost or small co-payment. While PhilHealth has existed for decades, the Act has significantly increased coverage and has prioritised primary care in an attempted shift to focus on preventive health strategies. However, significant implementation challenges have arisen, including a lack of medical staff and mismanagement of funds [14].

1.5 National Demographic and Health Survey

The National Demographic and Health Survey (NDHS) is a large-scale and nationally representative cluster survey that has been conducted in some format every 5 years since 1968. It collects comprehensive data on population, health and nutrition and is run by the Philippines Statistics Authority (PSA) with assistance from USAID. The most recent NDHS was completed in 2022 and surveyed over 30,000 households. The structured questionnaires are delivered using computer-assisted personal interviewing, and the survey design ensures that data is representative at all levels of the country [15]. The ongoing viability of the NDHS has recently been brought into question due to recent changes by the United States government.

1.6 Overview of Hepatitis B

Hepatitis B is a potentially severe cause of liver disease and is caused by the Hepatitis B virus (HBV) [16]. It is spread through exposure to infected blood or other bodily fluids. The leading route is through vertical transmission from an infected mother to a neonate during pregnancy, delivery or breastfeeding, otherwise known as mother-to-child transmission (MTCT). Other routes include poorly sterilised medical equipment, infected blood products, and through unsafe sexual practices and intravenous drug use [17]. HBV can cause a range of serious medical conditions, including acute hepatitis B, chronic hepatitis B, cirrhosis and hepatocellular carcinoma (HCC). High-risk populations include sex workers, men who have sex with men, transgender and gender diverse individuals, people who inject drugs, people living with HIV, incarcerated people and healthcare workers who perform blood-borne procedures [18].

Hepatitis B diagnosis can be complex, and is made using clinical, biochemical and serological findings (see Appendix 1).

1.6.1 Acute Hepatitis B

Patients with acute hepatitis B infection may experience different levels of severity and symptomatology. Around two-thirds of infections are asymptomatic, with the other third experiencing non-specific hepatitis symptoms such as fatigue, nausea, abdominal pain and jaundice. A small proportion (1%) experience acute liver failure with brain dysfunction and clotting disorders [19].

The average incubation period is 90 days (range 1 – 6 months) but can occasionally be detected 1 week following infection. If the body can clear the virus, the infection can last up to 6 months [16]. Over 95% of adults who become infected with hepatitis B will be able to clear the virus completely after an acute infection. This contrasts with children aged 1-5 where 30% progress to a chronic infection. For infants less than 1 year, this grows dramatically to 90% [20, 21].

1.6.2 Chronic Hepatitis B

Chronic hepatitis B (CHB) is an ongoing detection of certain viral markers after 6 months. Most individuals chronically infected with HBV are asymptomatic but may experience malaise, poor appetite and other non-specific symptoms. Chronic infection with HBV can lead to fibrosis, cirrhosis and end-stage liver disease. Symptoms of end-stage liver disease can cause ascites, encephalopathy, gastrointestinal bleeding and death. Patients with CHB are also at high risk for HCC [16]. This paper will focus on CHB rather than the acute form due to the long-term health sequelae.

1.6.3 Global Burden of Hepatitis B

Globally it is estimated that around 300 million people are living with CHB [22], accounting for around 4% of the adult population [23], with Africa and Asia disproportionately affected. Figure 2 shows the distribution of CHB by WHO region, showing that the WPR is the most impacted [24]. There are an estimated 1.2 million new infections globally each year with over 1 million deaths, mostly due to cirrhosis and HCC [25]. Despite a 31% decrease in chronic hepatitis B prevalence between 1990 and 2019, deaths have continued to increase given the chronicity and slow progression of the disease [23].

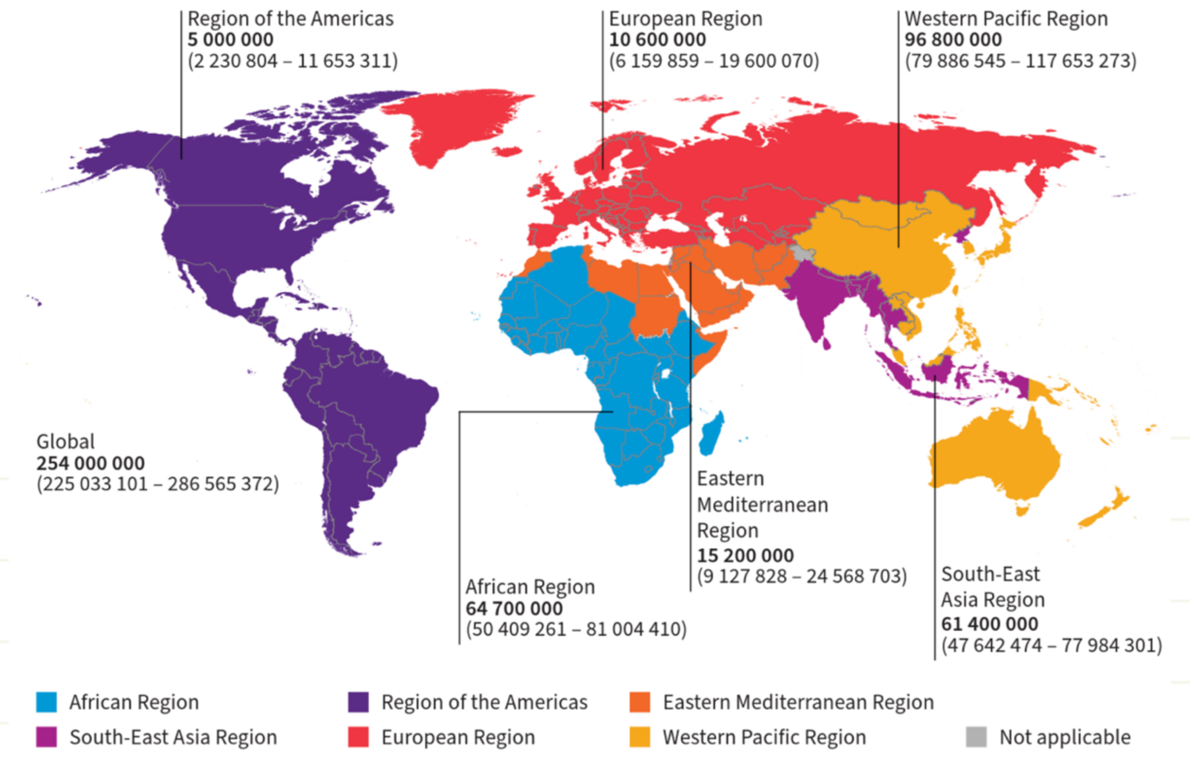


Figure 2: Geographic distribution of chronic hepatitis B prevalence by WHO region, 2022 [24]

The costs of treatment increase significantly with more advanced disease. A recent multi-country study found that, on average, CHB with no liver disease may cost US$2,748 per person, and up to $93,228 for hepatocellular carcinoma [26]. If current intervention levels remain unchanged and hepatitis B cases continue on their present trajectory, the global economic burden is projected to reach US$780 billion in lost productivity and healthcare costs between 2022 and 2050.[27].

1.6.4 Treatment

There is currently no complete cure for CHB. Treatment relies on viral suppression with antiviral medications or immunotherapy. This reduces the risk of progression to chronic liver disease [28]. Babies born to positive mothers require hepatitis B immunoglobulin and vaccination within 12 hours to further reduce the risk of transmission [29]. Specific treatments for end-stage liver disease and HCC are available but will not be discussed in this paper.

1.6.5 Prevention and Vaccination

The most effective strategy to prevent transmission of HBV is intramuscular vaccination. The WHO has long recommended childhood vaccination as the cornerstone of MTCT reduction. The current guidelines recommend a hepatitis B birth dose (HepB-BD within the first 24 hours of life, followed by 2 childhood doses to complete the primary course [30]. The birth dose may be given up to 7 days after birth, however the efficacy in preventing MTCT decreases significantly outside of the recommended 24-hour window [31]. Globally, 83% of infants have successfully completed a 3-dose regimen, compared to only 29% in 2000. However coverage for the birth dose is much lower at 45% [32], with the WHO recommending a 90% HepB-BD coverage to prevent MTCT [33].

Other important prevention strategies include screening of blood products, effective sterilisation of medical equipment, promotion of safe sex practices, vaccination of high-risk adults and harm reduction strategies for intravenous drug users[18].

1.7 Determinants Affecting Childhood Vaccination Uptake Globally

1.7.1 Individual or Household Level Determinants

Parental characteristics play a critical role in childhood vaccination. Low levels of maternal education and low socioeconomic families have been consistently associated with lower vaccination rates, likely due to reduced access to health information and limited understanding of vaccine importance [34-36]. Families with young mothers, high numbers of children or higher maternal parity also face greater challenges in ensuring vaccination [35, 37].

Religious affiliation can influence parental attitudes toward vaccination. A large-scale study of 66 LMICs showed that children from a country's majority religion were more likely to be vaccinated than the rest of the population. It also showed that children from Muslim families had a much higher likelihood of not being vaccinated [38], potentially due to cultural beliefs and mistrust in government services.

Unmarried and divorced mothers have been shown to have a higher risk of childhood under-vaccination [39, 40]. This may be due to single-parent households facing greater time and financial constraints. The sex of infant has also been shown to play a role in vaccination, with female children less likely to complete vaccinations than their male counterparts [41]. In some cultures, male children may be viewed as higher status or more valuable to the family, which may lead to prioritisation of health services for boys.

Access to and usage of the internet is emerging as an influential factor, with potentially both positive and negative effects. In some LMIC settings it is associated with increased childhood vaccine coverage [42]. Studies in higher income countries like the United States found that higher internet usage has negative effects on vaccination uptake due to misinformation via social media [43].

1.7.2 Health System and Service Delivery Determinants

Health system factors are key determinants of childhood vaccination coverage. Antenatal care (ANC) visits provide an important opportunity for mothers to receive information about the benefits of vaccination. Studies have shown that mothers who attend ANC visits are significantly more likely to vaccinate their children [44, 45]. The quality of ANC also has an impact, with high quality ANC improving health-seeking behaviours [46]. Trust in healthcare staff is extremely important in vaccination uptake as they are often the main source of information [35]. Sufficient healthcare worker staffing, vaccine training along with caregiver education are effective at improving vaccination uptake [47].

Distance to health facilities is a commonly cited barrier to vaccination [35]. Families in rural or remote areas may face long travel times, poor road infrastructure or a lack of public transport that limit access to health services, especially when multiple visits are required throughout infancy for full coverage. Health insurance coverage can also influence vaccination access by encouraging the use of formal health services. Families who have health insurance have also been shown to have higher rates of childhood vaccination in similar settings [48].

1.7.3 Contextual and Structural Determinants

Geographic disparities are consistently reported across LMICs. Regions that are remote, underserved or conflict affected often have lower vaccination coverage due to limited healthcare access, weaker local health systems and logistical issues [49]. This may lead to vaccine stockouts and limited health workforce, contributing to poor vaccination performance. Urban-rural inequalities also persist in many countries. Urban slums often have higher proximity to health services than rural areas yet suffer from overcrowded and under-resourced facilities along with competing economic demands [50], whereas rural areas often face greater distances to health facilities and fewer health services generally [41].

Ethnicity and minority status are also associated with vaccination disparities. A multi-country analysis found significant associations between minority ethnic groups and low vaccination rates, even after adjusting for individual factors [51]. This may be due to language barriers, a lack of culturally appropriate services or marginalisation of these communities.

National-level policies and programs also have significant impacts. Countries with strong immunisation programs, including clear vaccine schedules, robust supply and cold chain systems and well-trained staff tend to achieve higher vaccination coverage [52].

1.7.2 Additional Barriers to Timely Hepatitis B Birth Dose Vaccination

While many factors affecting childhood vaccination also influence HepB-BD coverage, the birth dose presents unique challenges due to its required timing and administration context.

As the vaccine is recommended to be given within the first 24 hours of life, the birth location is important. It is generally easier for health facilities to manage birth dose vaccination due to availability of healthcare staff and a higher likelihood of cold chain storage. Infants born at home are less likely to receive the vaccine, likely due to a lack of trained personnel and availability of the vaccine [53]. In addition, issues with vaccine storage and wastage have played a role in poor vaccination outcomes, particularly when multi-dose vials are used [54].

Disconnected or paper-based data systems prevent real-time monitoring of vaccine coverage and hinder coordination between facilities and programs [55]. Without effective coordination between the facility and local health workers, newborns may miss the narrow window for HepB-BD vaccination. In addition, birth registration rates remain low in many LMICs. This means the infant may not be entered into health information systems, hampering the ability of programs to track vaccination status or plan effective outreach [55].

Chapter 2: Problem Statement & Justification

2.1 Problem Statement

2.1.1 Burden of Hepatitis B in the Philippines

The Philippines is one of the countries most impacted in the WPR by CHB, with the estimated adult prevalence of CHB as high as 16.7%, (over 7 million Filipinos) [56]. CHB is a major cause of end-stage liver disease in the Philippines, and HCC is the leading cause of cancer deaths [56]. As of 2017, viral hepatitis (all forms) caused more deaths than HIV, tuberculosis and malaria combined [31]. As mentioned previously, MTCT is the most common form of transmission and chronic hepatitis B infection occurs in 90% of perinatal infections [21]. The prevalence of CHB in pregnant women in the Philippines remains high at 9.6% despite advances in screening and treatment [57]. Without vaccination, between 40,000 – 80,000 Filipino newborns are at risk of contracting CHB each year [21]. The WHO recommends a Hepatitis B surface antigen (HbsAg) seroprevalence of less than 1% among children under 5 to successfully eliminate MTCT. Studies in the Philippines have estimated that the seroprevalence of HBsAg among children under 5 is between 0.86 and 2.5% [58, 59].

2.1.2 Hepatitis B Vaccination Landscape in the Philippines

Hepatitis B vaccination was commenced in the Philippines in 1990 but did not include a birth dose, and thus did not impact MTCT. The HepB-BD was initiated in 2007 to align with the WHO schedule [60]. It is mandated as part of the national immunisation schedule and provided at no cost. The Philippines has a current childhood 3-dose coverage of 76% which shows significant strides to combat CHB. However timely HepB-BD coverage lags behind at 54%, compared to 79% in the WPR [32]. There is a National Viral Hepatitis Taskforce that is tasked with developing and maintaining a national strategy to eliminate Hepatitis B and C in the Philippines, however the national policy framework is fragmented and uncoordinated [61].

2.1.3 Determinants of Childhood Vaccination in the Philippine Context

Studies in the Philippines have echoed many globally recognised barriers to childhood vaccination, including socioeconomic status, family size, maternal education, maternal age and location of residence [62, 63]. However additional research specific to the Philippines provides a more local context. A large survey showed that Muslim ethnic groups experience much lower rates of vaccination [51]. The Philippines has seen a rise in vaccine hesitancy, following the Dengvaxia vaccine controversy in 2017 which eroded Filipino trust in vaccination. Ongoing vaccine hesitancy following this has led to outbreaks of infectious diseases such as measles [64]. The COVID-19 pandemic has also impacted childhood vaccine uptake and infectious outbreaks, perpetuating mistrust in vaccines [65].

2.1.3 Additional Determinants of HepB-BD Vaccination in the Philippine Context

There are still high proportions of home births, up to 23% in rural areas, which impacts the timely delivery of a HepB-BD dose [66]. Even among facility-based births, disparities in vaccination occur. A study showed that neonates born in private facilities were less likely to be vaccinated at birth compared to at other facilities, due to multiple factors including lack of staff training. The study also found that neonates who were born prematurely or of low birth weight were less likely to be vaccinated due to providers believing administration of the vaccination was unsafe [60]. A 2011 study showed large disparities in HepB-BD coverage between islands in the Philippines, with the Visayas vaccinating 65% of infants within 24 hours, compared to 0% in Mindanao. All HepB-BD vaccinations given in Mindanao during this study did not have timing of administration documented, suggesting a lack of training or poor data management [67].

2.1.4 Gaps in Research

Despite ongoing efforts to understand childhood vaccination in the Philippines, significant knowledge gaps remain around the specific determinants of timely HepB-BD coverage. The existing research is limited and outdated, with no studies completed within the last 10 years. However, the birth dose of hepatitis B has unique requirements that introduce distinct challenges related to maternal health service access, delivery location, and health system readiness, and there is limited evidence that integrates these factors with wider determinants. In addition, no studies have applied predictive modelling to estimate how different maternal and contextual profiles affect the probability of HepB-BD uptake. Spatial dimensions of coverage also remain under-explored, with little research investigating regional disparities or clusters of low coverage using spatial autocorrelation techniques. As a result, policy efforts often rely on broad national indicators rather than sub-national insights, limiting the precision of targeted interventions.

2.2 Justification

2.2.1 Rationale for Study Focus

CHB remains a significant public health issue in the Philippines. While the HepB-BD is a highly effective prevention measure, coverage for the vaccine remains well below the WHO recommendation. Despite being part of the national immunisation schedule, many newborns do not receive the birth dose due to a range of barriers as previously discussed. The existing literature focusing on the determinants of HepB-BD coverage in the Philippines is limited and outdated, focusing mainly on health system factors including place of delivery, and do not look at wider sociodemographic factors or access to health information. As a nationally representative survey including maternal, child and health system indicators, the NDHS provides a robust source for analysing HepB-BD coverage and its determinants in the Philippines.

2.2.2 Advancing Public Health and Research

This study addresses the gaps in the literature by creating both an explanatory model and a predictive model. The explanatory model investigates specific variables that may influence vaccination and examines their relationships. These findings can strengthen the existing evidence base and inform future research, policies and programmes. The predictive model complements this by simulating specific scenarios, highlighting how coverage probabilities change based on certain characteristics. This makes the findings more actionable and able to be targeted to at-risk groups.

2.2.3 Relevance to Policy and Elimination Goals

The Philippines has committed to WHO's goal of Hepatitis B elimination by 2030, which includes achieving >90% timely HepB-BD vaccination. Although there are national strategies to reduce HBV prevalence in place, these remain disparate and uncoordinated. This study, combining the dual-modelling approach, will help provide key evidence and recommendations for policy makers to create localised and effective plans to tackle the significant burden in the Philippines.

Chapter 3: Research Objectives

3.1 Objectives

3.1.1 Main Objective

To assess the coverage, determinants, and probabilities of HepB-BD vaccination among children in the Philippines using data from the 2022 NDHS.

3.1.2 Specific Objectives

1. To estimate the national and regional coverage of the HepB-BD among children under five years of age in the Philippines.
2. To examine the individual, household and health system factors associated with HepB-BD uptake.
3. To develop a predictive model for HepB-BD uptake and apply it to specific scenarios.
4. To provide evidence-based recommendations to improve equitable access to neonatal vaccination services in the country.

Chapter 4: Methods

4.1 Study Design

This cross-sectional study is a secondary data analysis of nationally representative data from the 2022 Philippine NDHS. It aims to investigate HepB-BD vaccination among children under 5 and its determinants across the country. R was used for data management and statistical analysis.

4.2 Data Source and Sampling

The 2022 NDHS used a two-stage stratified sample design based on the listings of households in the 2010 and 2015 Censuses of Population and Housing. The country was divided into its 17 administrative regions and further stratified into urban and rural areas.

The primary target population of the NDHS was women aged 15-49, however information was also collected related to all children born in the 5 years preceding the survey to an interviewed woman. All usual household members were also interviewed for other demographic data. For this cross-sectional study, children under 5 were the primary target population, with their mothers as the secondary target population.

The primary stage involved a systematic selection of 1,247 primary sampling units (PSUs) based on probability proportional to size and distributed by province or highly urbanised cities. A PSU can be a barangay, a portion of a large barangay or two or more adjacent small barangays, for sampling efficiency and logistical practicalities. The secondary stage involved taking either 22 or 29 sample housing units from each sampled PSU using systematic random sampling. A total of 30,372 households were successfully interviewed. All women aged 15-49 who were usual residents of the households were eligible to be interviewed, and 27,821 women were successfully interviewed.

4.3 Conceptual Framework

Andersen's Behavioural Health Model of Health Services Use (Figure 3) was initially developed in 1968. It was created to identify factors that are associated with the use of a health service. Multiple studies have adapted this model to identify and categorise factors associated with childhood vaccination coverage, and it has even been used to examine HepB-BD uptake [68]. It has four levels of factors that may influence the provision of childhood vaccinations:

1. External environment
2. Predisposing characteristics
3. Need factors
4. Enabling factors

The evaluated need for HepB-BD vaccination is uniform across the population, as all infants are eligible and recommended to receive the vaccine. The perceived need for vaccination is based on beliefs and motivation and is more difficult to define. There are no specific variables in the NDHS dataset specifically evaluating this, although it may be partially answered by proxies such as maternal exposure to media. For this reason, the need factors have not been included in the framework but are acknowledged as important.

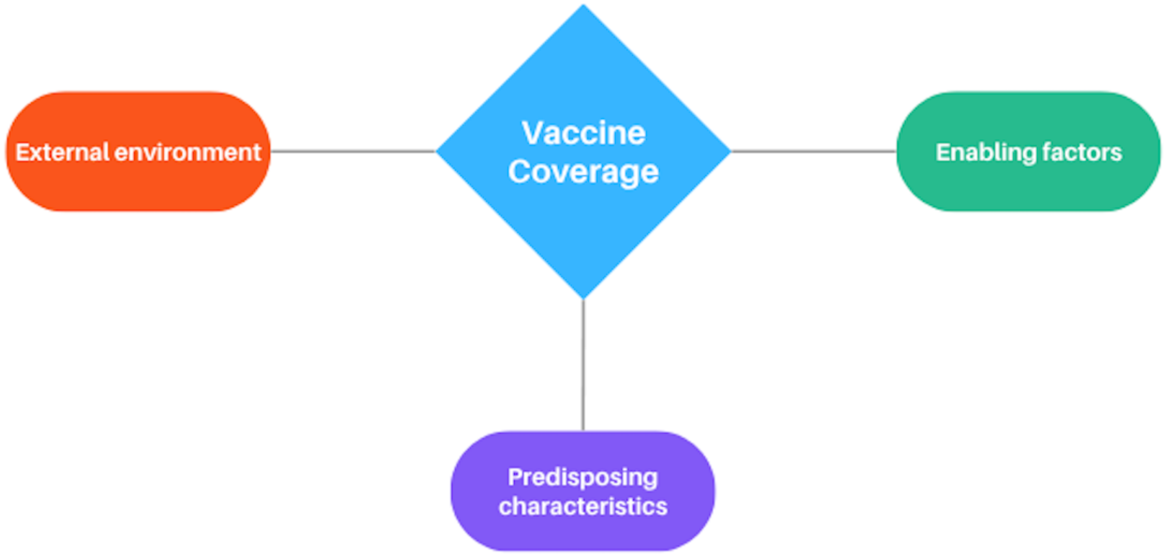


Figure 3: Modified Andersen model

This conceptual framework is used in this study to help guide the selection and interpretation of variables related to HepB-BD vaccination uptake. It provides a structured lens through which to understand the determinants of vaccine coverage. This helps ensure that policy recommendations emerging from this study are grounded in an understanding of the broader drivers of vaccination behaviour.

4.4 Data Management

NDHS data contains individual and household level variables and is publicly available from the Philippine Statistical Authority [69].

The following recode files were used in the analysis:

- Children's dataset (**KR**) contains one record per child under 5 and includes immunisation history and mother's background.
- Household dataset (**HR**) contains asset information and dwelling characteristics.

Datasets were merged using constant identifier variables (line number (b16), household number (v002) and cluster number (v001)) to ensure that individual-level records were linked with household data. The target population of this analysis is children under the age of 5 with available HepB-BD vaccination data. Missing values were not included in the regression analysis but will be discussed further below.

4.5 Outcome Variable

The main outcome variable is whether a child received the HepB-BD. In the original KR dataset this was a categorical variable (h50) with 5 response options "No", "Vaccination date on card", "Reported by mother", "Vaccination marked on card" and "Don't know". Responses were recoded as a binary variable: "Yes" if any positive vaccination information was recorded on the vaccination card or reported by the mother, and "No" if lack of vaccination was confirmed. The "Don't know" and "Missing" values were recoded as missing values (N/A). This variable does not distinguish whether the HepB-BD was given within the recommended 24-hour window. There is an additional binary variable (h68) which relates to whether the HepB-BD was given within 24 hours however this was not included in this analysis as 88% of the observations were missing.

4.6 Covariates

Covariates were chosen for the explanatory model based on theory-based selection using the modified Andersen framework and the preceding literature review. This helps ensure that the model is conceptually grounded, avoids including irrelevant variables and improves interpretability. Guided by the theoretical framework illustrated in Figure 3, explanatory variables were selected for their hypothesised association with the outcome variable. These covariates were then sorted into the main blocks of the framework, as can be seen in Figure 4. Multicollinearity was assessed using Generalised Variance Inflation factors (GVIF).

External Environment:

- Urban/rural
- Region
- Ethnicity
- Religion

Predisposing Characteristics

- Mother's education level
- Religion
- Ethnicity
- Age of mother at first birth
- Birth order number
- Sex of child
- Marital status of mother

Enabling Factors:

- Number of ANC visits during pregnancy
- Place of delivery
- Internet usage
- Internet use frequency
- Wealth quintile index
- Health insurance
- Minutes to nearest healthcare facility

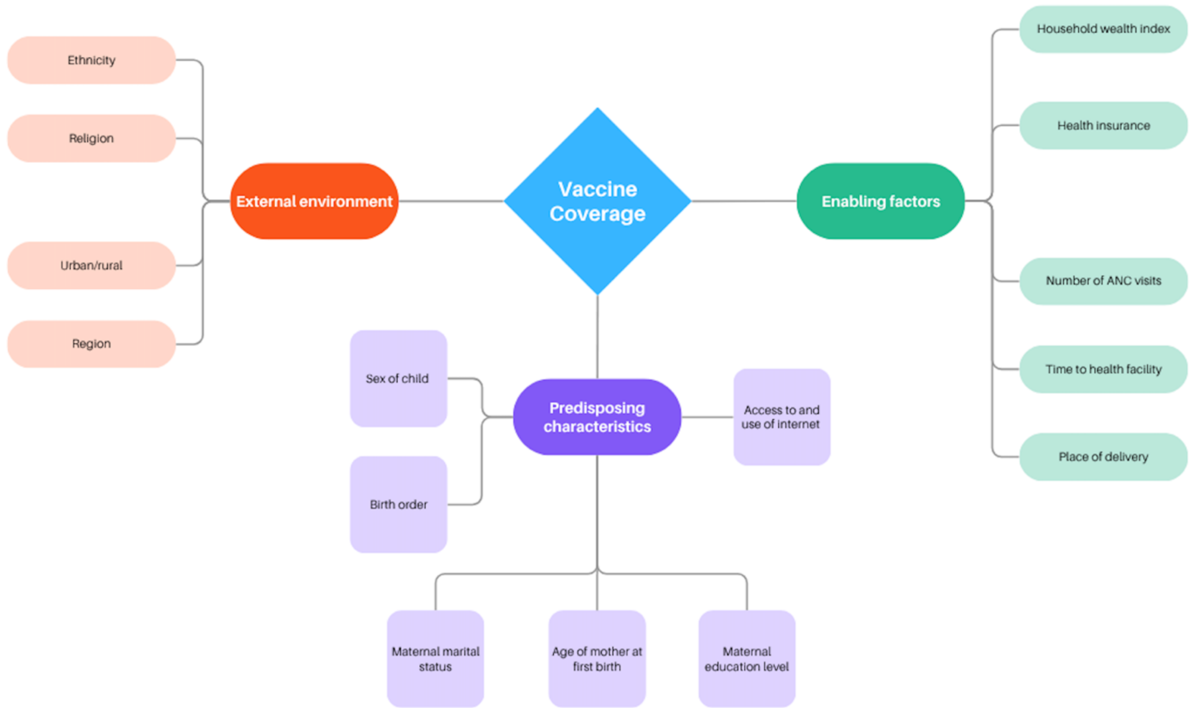


Figure 4: Categorised variables in modified Andersen model

All explanatory variables were recoded to treat “Don’t Know’ or “Missing” responses as missing (N/A). The ethnicity and place of delivery variables were further recoded to address small sample sizes in some categories, which can cause unstable regression estimates and convergence issues. There were initially 42 ethnicities: the largest eight ethnicities remained separate, while smaller groups were combined based on ethnolinguistic similarities to preserve analytic power. Specifically, the Igorot, Moro and Lumad were each grouped according to their indigenous or ethnolinguistic identities, with remaining smaller indigenous groups categorised together as Other Indigenous. The Other Visayan/Chavacano includes the remaining Christian groups of the Lowlands along with the Zambageño-Chavacano who have strong Spanish colonial influences.

For place of delivery, the categories were collapsed to show home deliveries, Barangay health station, health centre, government hospital, private hospital/clinic, and the remaining categories were grouped together as “other” due to the very small sample sizes.

See Appendix 2 for full recoding table.

4.7 Statistical Analysis

Descriptive statistics were used to estimate the national prevalence of HepB-BD vaccination among children under 5 and to describe the distribution of the explanatory variables. Categorical variables were summarised using counts and proportions, and continuous variables using means or medians.

Univariable and multivariable logistic regression models were used to assess unadjusted and adjusted associations between the variables and HepB-BD vaccination. Results were reported as unadjusted and adjusted odds-ratios with 95% confidence intervals and p-values. Values with missing outcomes were excluded from the regression models. P-values of <0.05 were considered significant.

All variables were initially tested in a univariate model. The multivariate model was then run with variables chosen using backward stepwise selection [70], using a p-value threshold of 0.10 for variable removal. Variables with the highest non-significant p-value were iteratively removed until all remaining variables met the inclusion criteria. This approach balances statistical relevance with parsimony while accounting for the complex survey design.

In developing the predictive model, the theory-informed variables were reduced using backward selection based on the Akaike Information Criterion (AIC) [71], following the principle of maximum parsimony. Variables that contributed least to model fit were systematically and sequentially removed to minimise redundancy and reduce the risk of overfitting. AIC was chosen as the selection criterion because it balances model complexity with goodness of fit by penalising unnecessary parameters. Backward AIC was used on a training set of data which was 80% of the total dataset. Predictive performance was then evaluated on test data, which was the remaining 20% of the total dataset. Model performance was assessed using measures of both predictive accuracy and goodness of fit. The area under the ROC (Receiver Operating Characteristic) curve (AUC) evaluated the model’s discrimination. Calibration was assessed using the Hosmer-Lemeshow goodness-of-fit test. To improve calibration, logistic recalibration was performed by regressing the observed outcome on the model’s predicted log-odds.

Tests for missingness were performed to evaluate whether missingness in HepB-BD data may be systematic rather than random. Logistic regression models were fitted with missingness in HepB-BD as the outcome, and each covariate as a predictor. Chi-squared tests were conducted between the missing outcome and missingness in key exposures of interest.

R version 4.5.0 was used for data management and statistical analysis.

4.8 Survey Design Specifications

To account for the complex survey design, sample weights, PSUs and stratification variables were incorporated into the regression models using the survey design framework in R. The PSU (v021) corresponds to the cluster selected in the first stage of sampling. The stratification variable (v022) represents the 17 administrative regions by urban and rural residence. The sampling weights (v005) are scaled as 6-digits integers and were divided by 1,000,000 for analysis.

4.9 Geospatial Analysis

GPS data was unable to be accessed for this survey due to the issues with USAID. QGIS 3.40.4-Bratislava and GeoDa 1.22.0.14 have been used to create maps using the survey data for limited spatial analysis at a regional level and visualisation purposes.

4.10 Ethical Considerations

This study used publicly available and deidentified data from the 2022 NDHS found on the Philippine Statistical Authority website [69]. The data is anonymised, and the individuals have given consent for the data to be used for research purposes at the time of collection. As per the KIT Institute research ethics committee terms of reference, no ethical clearance or waiver is required for this secondary data analysis [72].

Chapter 5: Results

5.1 Descriptive Statistics

5.1.1 Study Population

The total number of children under 5 included in the survey was 8112. For the outcome variable of receiving HepB-BD, 3429 were coded was "Don't know" or "Missing". These were recoded as missing values. With these excluded, 3593 received the vaccination and 1090 did not receive it, corresponding to 76.7% and 23.3% respectively. If the missing values are not included, the national coverage is estimated at 76.7%. If the missing values are included and treated as the child not having the vaccination, the coverage is 44.3%.

For regression modelling, children with missing HepB-BD and exposure data were excluded, and so the regression modelling uses the data from 3968 observations (see Figure 5).

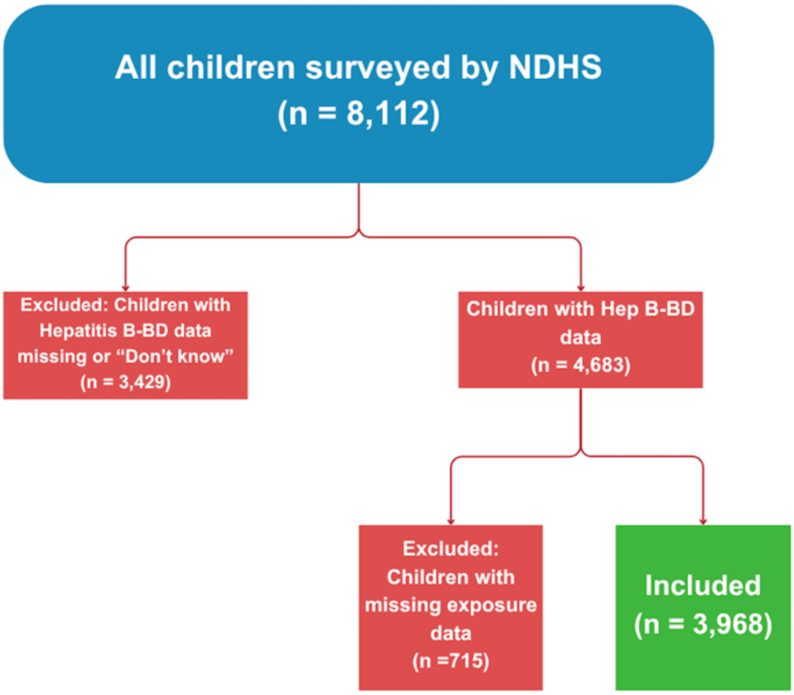


Figure 5: Exclusion criteria

5.1.2 External Environment

Almost two thirds of those surveyed lived in rural areas (63%). The distribution between regions was similar (between 3 and 7% of the total), however a much higher proportion (11%) were in the Bangsamoro Autonomous Region in Muslim Mindanao (BARRM).

Almost all regions fell between 40-54% HepB-BD coverage when recoding missing values as not vaccinated, and between 70-91% when excluding missing values. Four regions reached the 90% coverage recommended by WHO (when excluding N/As): Cagayan Valley, Calabarzon, Cordillera Administrative Region (CAR) and Ilocos. One region fell significantly behind the others. BARMM has estimated HepB-BD coverage of between 20 and 35%, at around half of the coverage of the next worse region. See Table 2 and Figure 6 below.

Table 2: Vaccination coverage by region

	HepB-BD vaccination						
Region	**No**	**Yes**	**N/A**	**Total**	**Total excl. N/As**	**Total vaccinated (%)**	**Total vaccinated excl. N/As (%)**
National Capital Region	39	263	260	562	302	47%	87%
BARMM	337	182	407	926	519	20%	35%
Bicol	32	218	193	443	250	49%	87%
Cagayan Valley	17	155	114	286	172	54%	90%
Calabarzon	21	226	195	442	247	51%	91%
Caraga	79	199	197	475	278	42%	72%
Central Luzon	40	302	262	604	342	50%	88%
Central Visayas	51	177	181	409	228	43%	78%
Cordillera Administrative Region	26	257	192	475	283	54%	91%
Davao	36	184	178	398	220	46%	84%
Eastern Visayas	61	257	193	511	318	50%	81%
Ilocos	16	146	118	280	162	52%	90%
Mimaropa	75	182	169	426	257	43%	71%
Northern Mindanao	91	225	230	546	316	41%	71%
Soccsksargen	79	187	183	449	266	42%	70%
Western Visayas	32	254	197	483	286	53%	89%
Zamboanga Peninsula	58	179	160	397	237	45%	76%

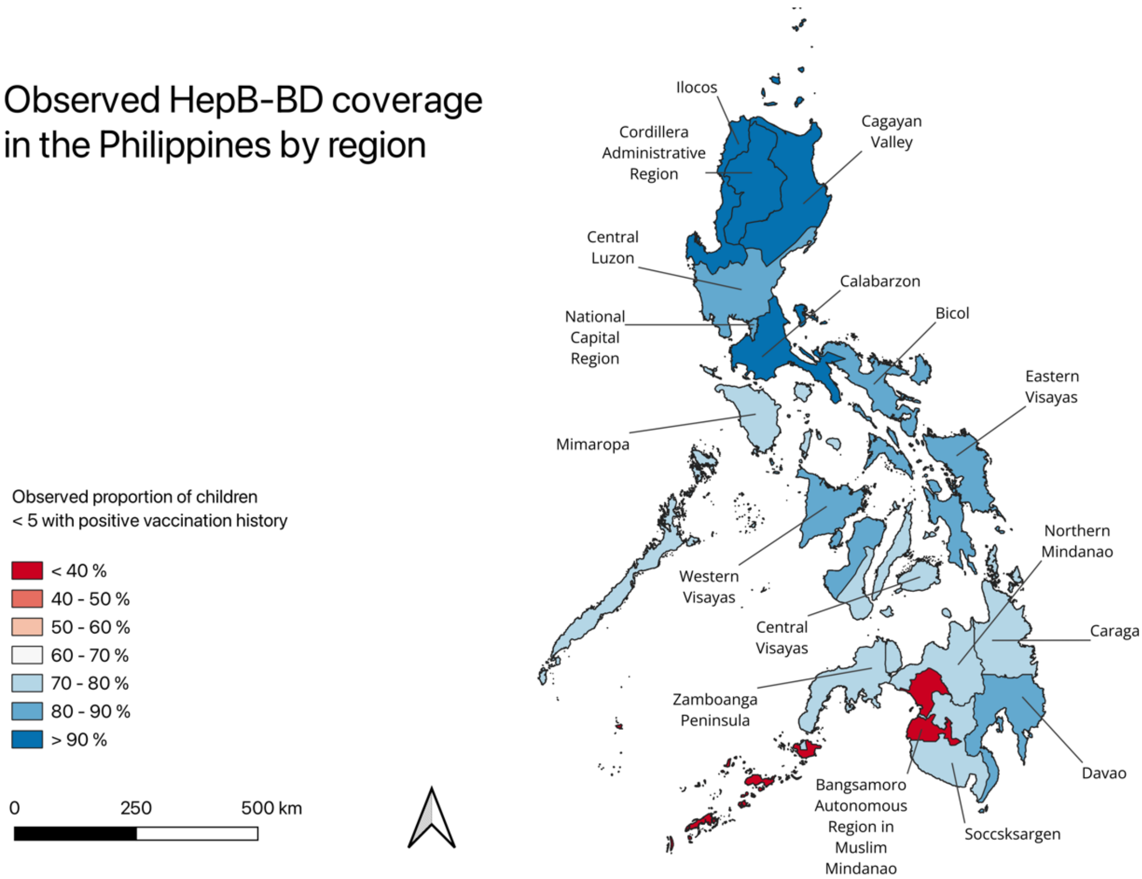


Figure 6: Observed HepB-BD coverage by region

The largest proportion of mothers identify as Cebuano (22%) or Tagalog (15%). Bikolano (6%), Ilokano (9%), Hiligaynon/Illonggo (7%) and Waray (6%) are the other most reported ethnicities. As discussed above, the less common ethnicities were divided into groups based on ethnolinguistic similarities. 281 observations were missing data on the ethnicity of the mother.

The majority religion among participants was Roman Catholicism constituting almost two-thirds (65%), followed by Islam (16%) and Protestantism (11%). Other religions made up 4% and 0% (only 7 participants) recorded as “No religion”. 259 of those surveyed had no observation recorded.

5.1.3 Predisposing Characteristics

Out of the full sample of children included in the analysis 47.7% were female and 52.3% male (Figure 7). The mean age in months was 30.4 with a median of 31.0 (range 0.0 – 59.0).

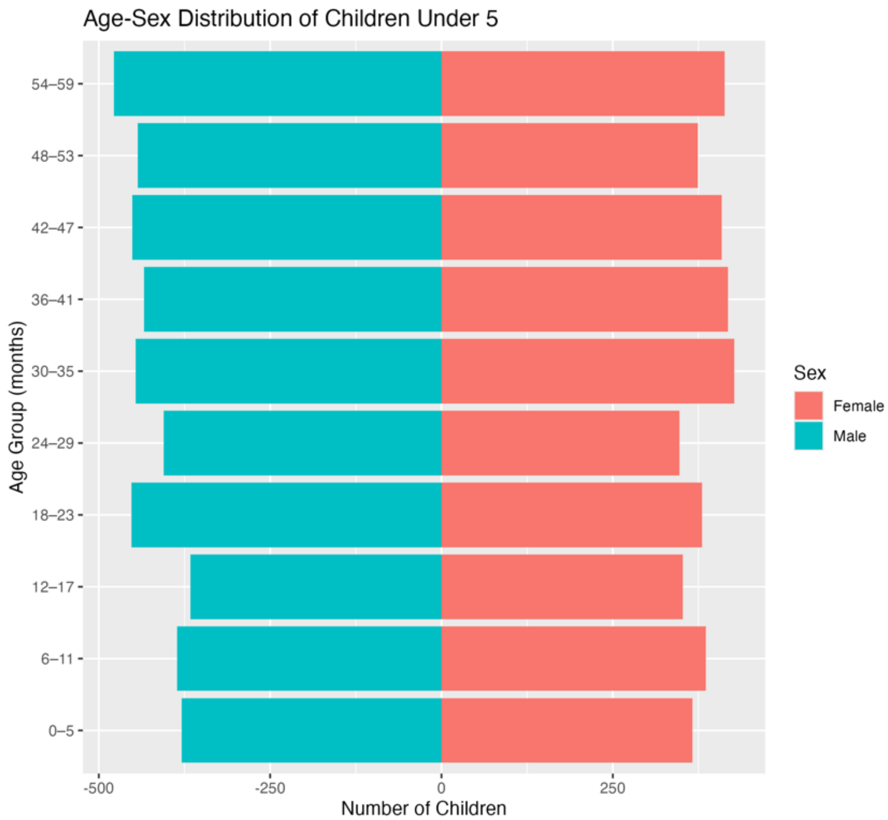


Figure 7: Age-sex distribution of the sample

Birth order ranged from 1 to 16, with a mean of 2.783 and a median of 2.000. The age of mother at first birth ranged from 12 to 45, with a mean of 21.8 and a median of 21, suggesting a symmetrical distribution. There were 587 women who became mothers at age 16, constituting 7% of those surveyed. Most women had their first child between the ages of 18 and 25.

49% of mothers had at least secondary school education, and 35% had attended higher education. Only 1% reported never attending school. Over half of mothers (56%) were married, with another 37% living with their partners. Only a small proportion (7%) were widowed, separated or had never been in a partnership.

29% of those surveyed had never used the internet before. A vast majority at 70% had used the internet in the last 12 months, and 1% had used the internet but not in the last 12 months. In terms of frequency of usage, almost half (46%) of respondents used the internet almost every day, and 31% stated they never used it.

5.1.4 Enabling Factors

The wealth quintile data shows the survey participants are more likely to belong to poorer households, with 59% falling in to the "Poor" or "Poorest" categories. Only 25% of households belong to the "Rich" or "Richest" categories. 79% of respondents did not have health insurance, with only 23 missing values for this question.

Only 9% of women birthed at home. Most women delivered in a health facility; government hospital was the most common (26%), followed by private hospital or clinic (14%), health centre (8%) and barangay health station (2%). 3420 of those surveyed did not report a place of delivery.

On average, women had 6.02 antenatal visits during the pregnancy. The median is also consistent with the mean at 6.00 suggesting a symmetrical distribution. The range is between 0 and 20 visits. However, there are a significant number of missing values for this variable, with 3836 not reporting any ANC visits.

The mean time to the nearest health facility is 15.8 minutes with a high standard deviation suggesting large variability between those surveyed. The median is 10 minutes which is lower than the mean, indicating a right-skewed distribution.

Tables 3 and 4 contain descriptive statistics for all included covariates.

Table 3: Descriptive table of continuous variables

Variables	Mean	SD	Median	Min	Max	IQR	Missing values
ANC visits	6.02	3.08	6.00	0	20	4	3836
Time to nearest facility	15.78	21.75	10.00	0	600+	10	0
Maternal age at first birth	21.80	4.58	21.00	12	45	5	0
Birth order of child	2.78	1.89	2.00	1	16	3	0

Table 4: Descriptive table of categorical/binary variables

Variables	Characteristics	Count	Proportion	Variables	Characteristics	Count	Proportion
			n = 8112				
Sex of child	Male	4240	52%	**Ethnicity**	Lumad	334	4%
	Female	3872	48%		Igorot	324	4%
Maternal education level	None	118	1%		Kapampangan	151	2%
	Primary	1235	15%		Pangasinan/Paggalato	67	1%
	Secondary	3952	49%		Other Indigenous	57	1%
	Higher	2807	35%		Missing	281	3%
Wealth quintile index	Poorest	2881	36%	**Religion**	Roman Catholic	5302	65%
	Poor	1842	23%		Protestant	879	11%
	Middle	1368	17%		Islam	1311	16%
	Rich	1069	13%		Aligpay	0	0%
	Richest	952	12%		Iglesia ni Cristo	167	2%
Place of residence	Urban	2991	37%		Other Christian	187	2%
	Rural	5121	63%		No Religion	7	0%
Region	Ilocos	280	3%		Missing	259	3%
	Cagayan Valley	286	4%	**Health insurance**	Yes	1718	21%
	Central Luzon	604	7%		No	6371	79%
	Calabarzon	442	5%		Missing	23	0%
	Bicol	443	5%	**Place of delivery**	Home	725	9%
	Western Visayas	483	6%		Government Hospital	2078	26%
	Central Visayas	409	5%		Health Centre	632	8%
	Eastern Visayas	511	6%		Barangay Health Station	125	2%
	Zamboanga Peninsula	397	5%		Private Hospital/Clinic	1109	14%
	Nothern Mindanao	546	7%		Other	23	0%
	Davao	398	5%		Missing	3420	42%
	Soccskargen	449	6%	**Maternal marital status**	Never in union	323	4%
	National Capital Region	562	7%		Married	4568	56%
	CAR	475	6%		Living with partner	3012	37%
	BARMM	926	11%		Widowed	48	1%
	Caraga	475	6%		Separated	161	2%
	Mimaropa	426	5%	**Internet usage**	Never	2345	29%
Ethnicity	Cebuano	1787	22%		Yes, in last 12 months	5701	70%
	Moro	1279	16%		Yes, before last 12 months	66	1%
	Tagalog	1246	15%		Yes, can't establish when	0	0%
	Ilokano	693	9%	**Internet frequency**	Not at all	2495	31%
	Hiligaynon/Ilonggo	557	7%		Less than once a week	386	5%
	Bikolano	478	6%		At least once a week	1475	18%
	Waray	452	6%		Almost every day	3756	46%
	Other Visayan/Chavacano	406	5%				

5.2 Missingness

The outcome variable of HepB-BD vaccination had many missing values (3429), corresponding to 42% of the data. Along with the outcome variable, both place of delivery and number of ANC visits show high missingness. The missingness between HepB-BD data and these two covariates was significantly associated, as confirmed by chi-squared tests (ANC: $\chi^2 = 6566.3$, df = 1, $p < 0.001$; Place of delivery: $\chi^2 = 8071.1$, df = 1, $p < 0.001$). The descriptive table of HepB-BD missing data by variable can be found in Appendix 3.

Logistic regression analysis of missingness showed that several variables were significantly associated with the odds of HepB-BD data being missing. These included religion, health insurance, place of delivery, region, birth order number, marital status, and ethnicity (see Table 5 below for univariate regression table).

Table 5: Univariate regression model of HepB-BD missingness

Missingness Univariate Model							
	OR	SE	p-value		OR	SE	p-value
ANC visits				**Region**			
intercept (0)	0.01	0.01	0.005	intercept (NCR)	0.92	0.12	0.528
Number of ANC visits	0.75	0.25	0.384	BARMM	0.84	0.14	0.301
Marital status				Bicol	0.84	0.14	0.305
intercept (Never in union)	0.65	0.12	0.02	Cagayn Valley	0.58	0.14	0.020
Married	1.27	0.24	0.209	Calabarzon	0.86	0.15	0.407
Living with partner	0.98	0.18	0.922	Caraga	0.82	0.13	0.214
Widowed	2.47	0.82	0.006	Central Luzon	0.83	0.14	0.285
No longer living with partner/separated	1.75	0.46	0.032	Central Visayas	0.81	0.14	0.225
Sex of child				CAR	0.66	0.11	0.013
intercept (Female)	0.71	0.03	<0.001	Davao	0.92	0.16	0.623
Male	1.08	0.07	0.226	Eastern Visayas	0.68	0.12	0.035
Age of mother at first birth				Ilocos	0.84	0.17	0.375
intercept (12)	0.83	0.12	0.206	MIMAROPA	0.72	0.13	0.077
Mother's age at first birth	0.99	0.01	0.432	Northern Mindanao	0.78	0.13	0.136
Maternal education level				SOCCSKSARGEN	0.67	0.12	0.019
intercept (None)	0.87	0.20	0.540	Western Visayas	0.70	0.13	0.057
Primary	1.09	0.27	0.725	Zamboanga Peninsula	0.71	0.12	0.038
Secondary	0.79	0.18	0.310	**Wealth index quintile**			
Higher	0.87	0.20	0.566	intercept (Poorest)	0.74	0.03	<0.001
Religion				Poor	1.04	0.08	0.617
intercept (Roman Catholic)	0.76	0.03	<0.001	Middle	0.92	0.09	0.379
Islam	0.99	0.08	0.905	Rich	1.04	0.09	0.688
Protestant	0.93	0.10	0.504	Richest	1.00	0.11	0.981
Other Christian	0.82	0.16	0.304	**Birth order number**			
Iglesia ni Cristo	1.07	0.19	0.705	intercept (1)	0.66	0.03	<0.001
No religion	0.06	0.07	0.015	Birth order number	1.05	0.02	0.002
Health insurance				**Internet frequency**			
intercept (No)	0.70	0.02	<0.001	intercept (Never)	0.78	0.04	<0.001
Yes	1.24	0.09	0.006	Less than once a week	0.83	0.13	0.242
Place of delivery				At least once a week	0.90	0.08	0.208
intercept (Home)	0.01	0.01	<0.001	Almost every day	0.95	0.07	0.459
Barangay Health Station	0.00	0.00	<0.001	**Ethnicity**			
Health Centre	0.08	0.10	0.057	Intercept (Tagalog)	0.83	0.06	0.016
Government Hospital	0.19	0.20	0.111	Bikolano	0.96	0.12	0.709
Private hospital/clinic	0.05	0.06	0.023	Cebuano	0.81	0.08	0.034
Other	0.00	0.00	<0.001	Hiligaynon/Ilonggo	0.86	0.11	0.230
Urban/rural location				Igorot	0.74	0.13	0.086
intercept (Rural)	0.70	0.03	<0.001	Ilokano	0.89	0.12	0.386
Urban	1.12	0.07	0.076	Kapampangan	1.17	0.20	0.350
Minutes to nearest health facility				Lumad	0.89	0.10	0.447
intercept (0)	0.73	0.03	<0.001	Moro	0.89	0.10	0.277
Minutes	1.00	0.00	0.451	Other Indigenous	0.55	0.38	0.387
Internet usage				Other Visayan/Chavacano	0.90	0.12	0.410
intercept (Never)	0.76	0.04	<0.001	Pangasinan/Paggalato	0.99	0.30	0.962
Yes, before last 12 months	1.61	0.51	0.136	Waray	0.88	0.15	0.460
Yes, last 12 months	0.97	0.06	0.620				

Women with no reported religion had lower odds of missing HepB-BD data. Having health insurance was associated with increased odds of missingness. Place of delivery had a strong relationship with missingness: Barangay Health Stations and "Other" birth locations had 0% missingness; private hospitals had only 0.1% missingness and were significantly associated with lower odds of missing HepB-BD data. Regional variation in missingness ranged from 37.8% to 46.3%, with significantly lower odds of missingness observed in Cagayan Valley, CAR, Eastern Visayas, SOCCSKSARGEN, and Zamboanga Peninsula. Higher birth order was positively associated with increased HepB-BD data missingness. Widowed and separated mothers had much higher odds of missing data, although small subgroup sizes may contribute to this effect. Cebuano ethnicity was also significantly associated with missingness.

For the remaining covariates, missingness was minimal or relatively evenly distributed across categories.

5.3 Univariate Regression Modelling

5.3.1 Multicollinearity

All variables had an adjusted GVIF of less than 3 signifying no strong evidence of problematic multicollinearity in the model (see Appendix 5 for log). Therefore, all variables were carried forward to the regression models.

5.3.2 External Environment

An urban location (OR 1.55; 95% CI: 1.16 – 2.09; p-value 0.003) had a significant positive association with receipt of the vaccine.

Certain administrative regions were significantly associated with lower coverage of Hep B-BD vaccination compared to the National Capital Region in the univariate model. The affected regions were BARMM, Caraga, Central Visayas, Eastern Visayas, MIMAROPA, Northern Mindanao, SOCCSKSARGEN and the Zamboanga Peninsula.

In addition, particular ethnicities or ethnic groups had significant negative associations with vaccine uptake compared to Tagalog as the largest ethnic group in the country. The Moro/Muslim-majority groups had the strongest association (OR 0.10; 95% CI: 0.07 – 0.16; p-value <0.001), followed by the Lumad indigenous groups, the Waray and the Cebuano.

Certain religions were shown to have a significant negative association with the birth dose, namely Protestantism (OR 0.65; 95% CI: 0.43 – 0.98; p-value 0.041) and Islam (OR 0.13; 95% CI: 0.09 – 0.18; p-value <0.001), compared to Roman Catholicism.

5.3.3 Predisposing Characteristics

Maternal education level had a strong and significant unadjusted association with Hep B-BD vaccination, that increased with each level of education compared to no education (higher education = OR 9.55; 95% CI: 3.38 – 26.98; p-value <0.001).

Mothers who had used the internet within the last 12 months were much more likely to have their children vaccinated against Hepatitis B (OR 3.09; 95% CI: 2.39 – 3.99; p-value <0.001) compared to those who had never used the internet. The frequency of internet use was also positively associated with vaccine uptake. Those who use the internet almost every day (OR 3.47; 95% CI: 2.58 – 4.69; p-value <0.001), those who use it at least once a week (OR 2.06; 95% CI: 1.51 – 2.80; p-value <0.001), and those who use it less than once a week (OR 2.36; 95% CI: 1.44 – 3.87; p-value <0.001) were all more likely to vaccinate their child compared to those who do not use the internet at all.

Older age of the mother at her first birth (OR 1.05; 95% CI: 1.02 – 1.08; p-value <0.001) was positively associated with vaccination.

Higher birth order number had a significant and negative association with the birth dose uptake (OR 0.81; 95% CI: 0.76 – 0.0.86; p-value <0.001).

Sex of the child and mother's marital status were not significantly associated with Hep B-BD uptake in the univariate model.

5.3.4 Enabling Factors

Higher number of ANC visits (OR 1.28; 95% CI: 1.21 – 1.35; p-value <0.001) showed a significant unadjusted positive association.

The place of delivery had the largest positive associations in the unadjusted model and were highly significant, compared to birth at home. Specifically, birth in a government hospital had the largest association (OR 15.7; 95% CI: 11.1 – 22.0; p-value <0.001).

Health insurance (OR 2.33; 95% CI: 1.62 – 3.35; p-value <0.001) had significant positive unadjusted associations with receipt of the vaccine.

Wealth index quintile also has a significant positive association with the vaccination in the univariate model. Odds ratios increased with each higher quintile level, with the richest category having the strongest association (OR 4.64; 95% CI: 2.67 – 8.03; p-value <0.001) compared to the poorest category.

There was a slight but significant negative unadjusted association between the Hep B-BD vaccine and minutes to the nearest health facility (OR 0.99; 95% CI: 0.98 – 0.99; p-value <0.001).

See Table 6 for univariate analysis table.

Table 6: Univariate regression analysis

	Univariate Analysis								
	OR	SE	CI	p-value		OR	SE	CI	p-value
ANC visits					**Region**				
intercept (0)	1.075	0.166	0.795 - 1.454	0.639	intercept (NCR)	9.292	2.375	5.627 – 15.346	<0.001
Number of ANC visits	1.277	0.037	1.207 - 1.351	<0.001	BARMM	0.056	0.017	0.031 – 0.102	<0.001
Marital status					Bicol	0.834	0.313	0.400 – 1.741	0.629
intercept (Never in union)	5.303	1.571	2.965 – 9.485	<0.001	Cagayan Valley	0.935	0.437	0.374 – 2.339	0.885
Married	0.736	0.229	0.400 – 1.354	0.323	Calabarzon	1.061	0.436	0.474 – 2.375	0.886
Living with partner	0.995	0.299	0.552 – 1.796	0.987	Caraga	0.324	0.102	0.174 – 0.603	<0.001
Widowed	0.188	0.179	0.029 – 1.222	0.080	Central Luzon	0.767	0.280	0.375 – 1.569	0.467
No longer living with partner	0.884	0.487	0.300 – 2.606	0.822	Central Visayas	0.306	0.108	0.153 – 0.613	0.001
Sex of child					CAR	1.217	0.488	0.555 – 2.672	0.624
intercept (Female)	4.142	0.353	3.504 – 4.897	<0.001	Davao	0.538	0.172	0.287 – 1.008	0.053
Male	1.167	0.128	0.942 – 1.447	0.158	Eastern Visayas	0.493	0.158	0.263 – 0.926	0.028
Age of mother at first birth					Ilocos	1.266	0.565	0.528 – 3.037	0.596
intercept (12)	1.561	0.499	0.834 – 2.921	0.164	MIMAROPA	0.217	0.072	0.114 – 0.415	<0.001
Mother's age at first birth	1.050	0.015	1.020 – 1.080	0.001	Northern Mindanao	0.326	0.116	0.163 – 0.654	0.002
Maternal education level					SOCCSKSARGEN	0.281	0.110	0.131 – 0.604	0.001
intercept (None)	0.698	0.364	0.250 – 1.944	0.491	Western Visayas	0.809	0.288	0.403 – 1.627	0.552
Primary	2.824	1.425	1.049 – 7.601	0.040	Zamboanga Peninsula	0.525	0.168	0.281 – 0.984	0.044
Secondary	6.531	3.472	2.301 – 18.534	<0.001	**Wealth index quintile**				
Higher	9.551	5.055	3.381 – 26.983	<0.001	intercept (Poorest)	1.924	0.200	1.569 – 2.360	<0.001
Religion					Poor	2.658	0.432	1.933 – 3.655	<0.001
intercept (Roman Catholic)	6.306	0.506	5.388 – 7.381	<0.001	Middle	3.440	0.644	2.382 – 4.968	<0.001
Islam	0.126	0.022	0.090 – 0.177	<0.001	Rich	3.936	0.875	2.545 – 6.087	<0.001
Protestant	0.649	0.137	0.428 – 0.983	0.041	Richest	4.635	1.299	2.675 – 8.033	<0.001
Other Christian	1.112	0.372	0.577 – 2.144	0.752	**Internet usage**				
Iglesia ni Cristo	0.737	0.374	0.272 – 1.994	0.547	intercept (Never)	1.985	0.224	1.591 – 2.477	<0.001
No religion	0.466	0.560	0.044 – 4.923	0.525	Yes, before last 12 months	2.355	1.617	0.612 – 9.059	0.212
Health insurance					Yes, last 12 months	3.091	0.403	2.393 – 3.991	<0.001
intercept (No)	3.712	0.263	3.231 – 4.265	<0.001	**Internet frequency**				
Yes	2.330	0.432	1.619 – 3.352	<0.001	intercept (Never)	2.058	0.223	1.664 – 2.547	<0.001
Place of delivery					Less than once a week	2.363	0.593	1.445 – 3.865	0.001
intercept (Home)	0.499	0.073	0.374 – 0.665	<0.001	At least once a week	2.059	0.323	1.514 – 2.801	<0.001
Barangay Health Station	4.928	1.725	2.480 – 9.793	<0.001	Almost every day	3.474	0.530	2.575 – 4.686	<0.001
Health Centre	9.399	2.217	5.917 – 14.931	<0.001	**Ethnicity**				
Government Hospital	15.655	2.724	11.127 – 22.027	<0.001	Intercept (Tagalog)	7.634	1.251	5.535 – 10.529	<0.001
Private hospital/clinic	14.808	3.198	9.692 – 22.623	<0.001	Bikolano	0.930	0.296	0.498 – 1.736	0.819
Other	2.997	1.778	0.935 – 9.602	0.065	Cebuano	0.571	0.113	0.387 – 0.842	0.005
Urban/rural location					Hiligaynon/Ilonggo	0.957	0.254	0.568 – 1.611	0.868
intercept (Rural)	3.606	0.339	2.999 – 4.335	<0.001	Igorot	1.471	0.613	0.650 – 3.331	0.354
Urban	1.556	0.233	1.160 – 2.087	0.003	Ilokano	1.550	0.441	0.886 – 2.709	0.124
Minutes to nearest health facility					Kapampangan	1.251	0.607	0.483 – 3.243	0.645
intercept (0)	5.582	0.509	4.668 – 6.675	<0.001	Lumad	0.250	0.083	0.131 – 0.478	<0.001
Minutes	0.985	0.004	0.977 – 0.993	<0.001	Moro	0.103	0.023	0.066 – 0.160	<0.001
Birth order number					Other Indigenous	0.657	0.312	0.259 – 1.669	0.377
intercept (1)	8.132	0.941	6.481 – 10.203	<0.001	Other Visayan/Chavacano	0.825	0.247	0.459 – 1.484	0.521
Birth order number	0.807	0.027	0.755 – 0.863	<0.001	Pangasinan/Paggalato	1.184	0.779	0.326 – 4.305	0.797
					Waray	0.541	0.143	0.323 – 0.908	0.020

5.4 Multivariate Regression Modelling

Many of the variables that were significant in the univariate model became non-significant after backward stepwise selection (see Appendix 5 for log). Only ANC, sex of child, religion, place of birth, region and internet usage remained significant (see Table 7 below).

The number of ANC visits remains significantly associated with HepB-BD vaccination however the adjusted odds ratio is reduced compared to the unadjusted model (aOR 1.11; 95% CI: 1.05 – 1.17; p-value 0.001).

The place of delivery is still strongly associated with Hep B-BD vaccination even after adjustment, but again the odds ratios have decreased. Government hospitals (aOR 8.00; 95%

CI: 5.35 – 11.9; p-value <0.001), private hospitals/clinics (aOR 6.73; 95% CI: 4.07 – 11.1; p-value <0.001), health centres (aOR 5.20; 95% CI: 3.15 – 8.59; p-value <0.001) and barangay health stations (aOR 3.02; 95% CI: 1.38 – 6.61; p-value 0.006) all have significant and positive associations with vaccination. The Other category became non-significant in the multivariate model.

The regions of Caraga (OR 0.43; 95% CI: 0.22 – 0.84; p-value 0.013), Central Visayas (OR 0.30; 95% CI: 0.15 – 0.62; p-value 0.001) and MIMAROPA (OR 0.33; 95% CI: 0.16 – 0.66; p-value 0.002) remained significantly associated in the multivariate model. The other regions that were significant in the univariate model became non-significant when adjusted for the other variables.

Internet usage, namely usage in the last 12 months (aOR 1.56; 95% CI: 1.17 – 2.07; p-value 0.002) had a significantly positive association with receipt of the vaccine.

The Islam category in the religion variable has a significantly negative association with vaccination (aOR 0.48; 95% CI: 0.25 – 0.93; p-value <0.028). No other religions were significant.

Table 7: Multivariate regression model

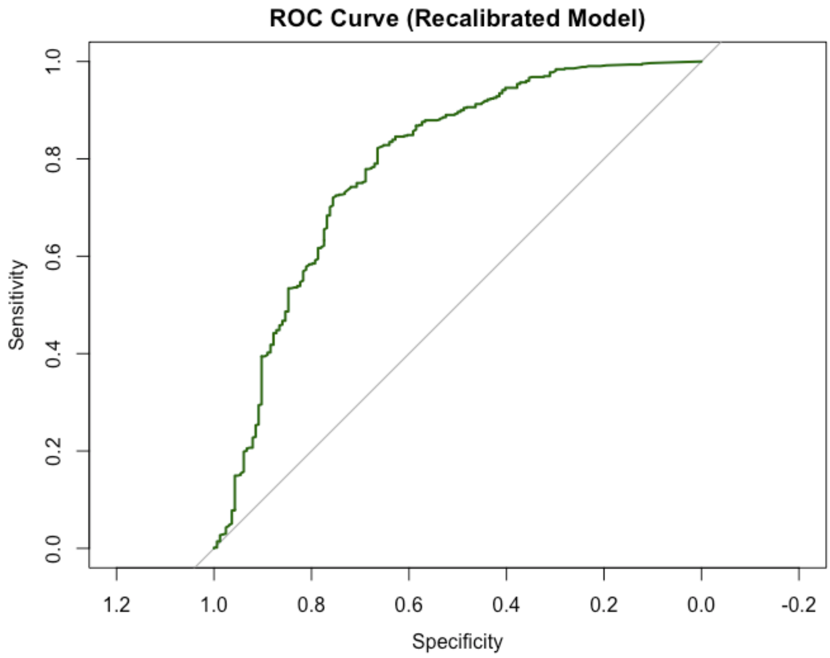
	Univariate					Multivariate			
	OR	SE	CI	p-value		OR	SE	CI	p-value
					intercept	0.562	0.192	0.288 – 1.098	0.092
ANC visits									
intercept (0)	1.075	0.166	0.795 - 1.454	0.639					
Number of ANC visits	1.277	0.037	1.207 - 1.351	<0.001		1.108	0.033	1.046 – 1.174	0.001
Religion									
intercept (Roman Catholic)	6.306	0.506	5.388 – 7.381	<0.001					
Islam	0.126	0.022	0.089 – 0.177	<0.001		0.482	0.160	0.251 – 0.926	0.028
Protestant	0.649	0.137	0.428 – 0.983	0.041		0.681	0.168	0.420 – 1.103	0.118
Other Christian	1.112	0.372	0.577 – 2.144	0.752		1.138	0.383	0.588 – 2.202	0.701
Iglesia ni Cristo	0.737	0.374	0.272 – 1.994	0.547		0.551	0.306	0.186 – 1.636	0.283
No religion	0.466	0.560	0.044 – 4.923	0.525		0.179	0.191	0.022 – 1.448	0.107
Place of delivery									
intercept (Home)	0.499	0.073	0.374 – 0.665	<0.001					
Barangay Health Station	4.928	1.725	2.480 – 9.793	<0.001		3.016	1.205	1.377 – 6.606	0.006
Health Centre	9.399	2.217	5.917 – 14.930	<0.001		5.199	1.329	3.148 – 8.587	<0.001
Government Hospital	15.655	2.724	11.127 – 22.027	<0.001		7.996	1.635	5.353 – 11.943	<0.001
Private hospital/clinic	14.808	3.198	9.692 – 22.623	<0.001		6.729	1.720	4.074 – 11.112	<0.001
Other	2.997	1.778	0.935 – 9.602	0.065		2.778	1.612	0.889 – 8.675	0.079
Region									
intercept (NCR)	9.292	2.375	5.627 – 15.346	<0.001					
BARMM	0.056	0.017	0.031 – 0.102	<0.001		0.497	0.215	0.213 – 1.160	0.106
Bicol	0.834	0.313	0.400 – 1.741	0.629		1.160	0.457	0.535 – 2.513	0.707
Cagayan Valley	0.935	0.437	0.374 – 2.339	0.885		1.111	0.497	0.462 – 2.672	0.815
Calabarzon	1.061	0.436	0.474 – 2.375	0.886		1.046	0.426	0.470 – 2.328	0.912
Caraga	0.324	0.102	0.174 – 0.603	<0.001		0.434	0.146	0.224 – 0.838	0.013
Central Luzon	0.767	0.280	0.375 – 1.569	0.467		0.704	0.270	0.332 – 1.493	0.359
Central Visayas	0.306	0.108	0.153 – 0.613	0.001		0.301	0.112	0.145 – 0.623	0.001
CAR	1.217	0.488	0.555 – 2.672	0.624		1.544	0.726	0.614 – 3.886	0.356
Davao	0.538	0.172	0.287 – 1.008	0.053		0.806	0.283	0.405 – 1.607	0.540
Eastern Visayas	0.493	0.158	0.263 – 0.926	0.028		0.615	0.209	0.316 – 1.199	0.154
Ilocos	1.266	0.565	0.528 – 3.037	0.596		1.080	0.491	0.443 – 2.634	0.865
MIMAROPA	0.217	0.072	0.114 – 0.415	<0.001		0.329	0.117	0.164 – 0.659	0.002
Northern Mindanao	0.326	0.116	0.163 – 0.654	0.002		0.493	0.182	0.239 – 1.019	0.056
SOCCSKSARGEN	0.281	0.110	0.131 – 0.604	0.001		0.701	0.241	0.356 – 1.378	0.302
Western Visayas	0.809	0.288	0.403 – 1.627	0.552		1.053	0.388	0.511 – 2.171	0.889
Zamboanga Peninsula	0.525	0.168	0.281 – 0.984	0.044		1.361	0.470	0.692 – 2.678	0.372
Internet usage									
intercept (Never)	1.985	0.224	1.591 – 2.477	<0.001					
Yes, before last 12 months	2.355	1.617	0.612 – 9.059	0.212		1.588	1.527	0.241 – 10.485	0.631
Yes, last 12 months	3.091	0.403	2.393 – 3.991	<0.001		1.557	0.224	1.174 – 2.066	0.002

5.5 Predictive Modelling

The predictive model showed that the number of ANC visits, place of delivery, mother's marital status, religion, sex of child, region and internet use were predictive of Hep B-BD outcomes.

The final model achieved an AUC of 0.78, indicating good ability to distinguish between vaccinated and unvaccinated children (see figure 8). Calibration was assessed using the Hosmer-Lemeshow goodness-of-fit test. The final recalibrated model had a non-significant p-value of 0.20, indicating that the predicted probabilities from the model adequately match the observed outcomes.

Figure 8: Area Under the ROC Curve



Predicted probabilities are based on scenario simulations in which one factor is varied at a time, with all other variables held at their reference categories. The baseline probability for HepB-BD coverage is 80.4%, reflecting the average across the test dataset. The full set of predicted probabilities for the test dataset is presented in Table 9.

Male children showed marginally higher predicted coverage than female children (+1.1% from baseline). Marital status also influenced predictions. The lowest values were associated with widowed mothers (-27%), while scenarios involving those married, cohabiting, or no longer living with a partner produced relatively higher coverage estimates.

Internet use was associated with a gradient in predicted probabilities. Situations where the mother had never used the internet resulted in lower coverage predictions (-5.1%) compared to those who had used it recently (+1.6%). Antenatal care attendance had a similar pattern.

Scenarios with no ANC visits produced notably lower predicted coverage (-6%), while those with eight or more visits resulted in higher values (+2.2%).

Place of delivery showed the most pronounced differences. Home birth scenarios produced the lowest predicted probabilities of HepB-BD vaccination (-31.9%). In contrast, predicted coverage increased in scenarios involving facility births, particularly in government hospitals (+6.0%) and private clinics (+4.6%).

Variation was also observed across religious affiliation. Scenarios involving Muslim mothers yielded the lowest predicted vaccination probabilities (-7.4%), followed by Protestant mothers (-4.9%), while those identifying with other Christian denominations (+3.8%) or reporting no religious affiliation (+19.5%) were associated with higher estimates.

Regional variation was substantial. Central Visayas, MIMAROPA, and BARMM were associated with lower predicted coverage, while other regions such as Cagayan Valley, CAR and Zamboanga Peninsula yielded higher values (see Figure 9).

Table 8: Predictive probabilities in the test dataset

Factor	Predictive probability (%)	Change from baseline (%)	Factor	Predictive probability (%)	Change from baseline (%)
Baseline	80.4		**Region**		
Sex of child			BARMM	74.4	-6.1
Male	81.5	+1.1	Bicol	85.9	+5.5
Female	79.5	-1.0	Cagayan Valley	89.4	+9.0
Marital status			Calabarzon	85.5	+5.1
Never in union	80.6	+0.2	Caraga	74.8	-5.7
Married	81.7	+1.2	Central Luzon	81.4	+0.9
Living with partner	78.7	-1.7	Central Visayas	68.6	-11.8
Widowed	53.5	-27.0	CAR	89.2	+8.8
Divorced	N/A	N/A	Davao	81.2	+0.7
Separated	86.3	+5.8	Eastern Visayas	79.6	-0.8
Internet usage			Ilocos	86.6	+6.1
Never	75.4	-5.1	MIMAROPA	69.7	-10.8
Yes, before 12 months	85.3	+4.8	NCR	84.9	+4.4
Yes, last 12 months	82	+1.6	Northern Mindanao	74	-6.4
Place of delivery			SOCCSKSARGEN	78.6	-1.8
Home	48.5	-31.9	Western Visayas	85	+4.6
Barangay Health Station	75.4	-5.0	Zamboanga Peninsula	86.9	+6.5
Health Centre	81.7	+1.2	**Religion**		
Government Hospital	86.4	+6.0	Islam	73	-7.5
Private Hospital/Clinic	85.1	+4.6	Roman Catholic	82.6	+2.2
Number of ANC visits			Protestant	75.6	-4.9
0	74.5	-6.0	Other Christian	84.3	+3.8
4	78.7	-1.8	Iglesia ni Cristo	77	-3.4
8+	82.6	+2.2	No religion	100	+19.5

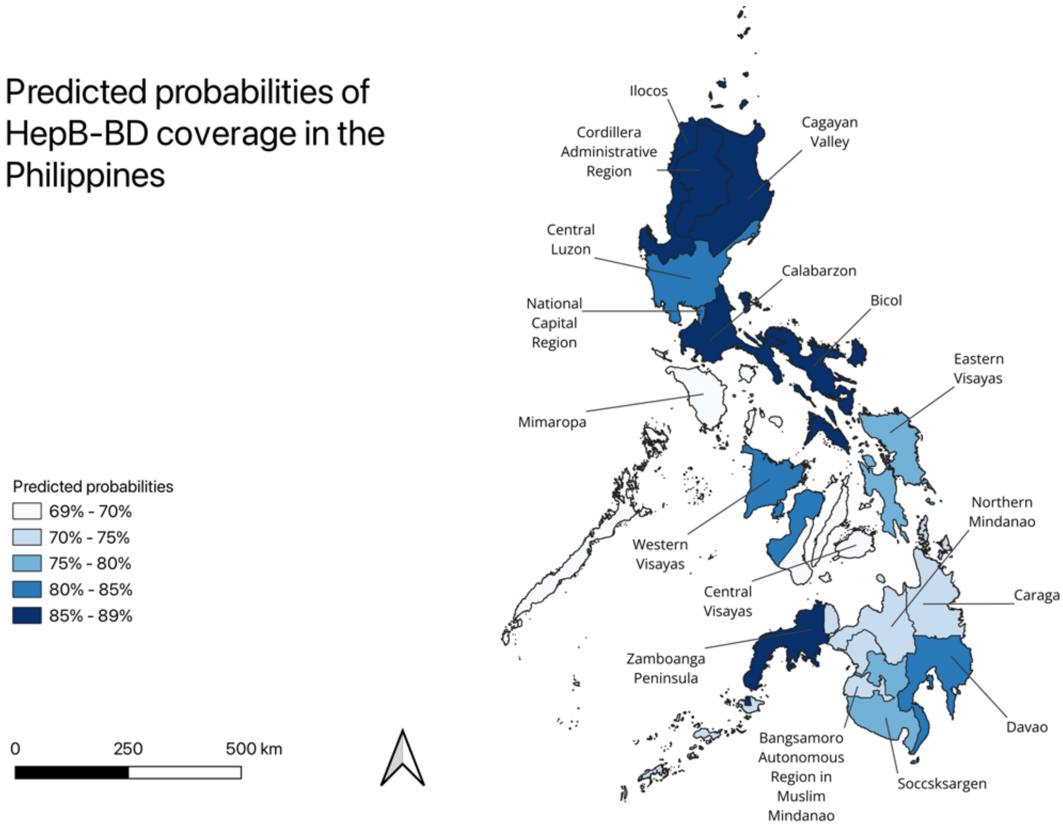


Figure 9: Predicted probabilities of HepB-BD coverage in test dataset

Figure 10 presents the geographic distribution of differences between observed and predicted HepB-BD coverage across regions in the Philippines. The model correctly predicted lower vaccination probabilities in MIMAROPA and Caraga, where predicted probabilities closely matched observed values. However, the model overpredicted coverage in Central Luzon and Central Visayas, where there was higher observed coverage than predicted. Conversely, the model underpredicted coverage in regions in the south of the country such as BARMM, Zamboanga Peninsula and SOCCSKSARGEN, indicating that the observed coverage was considerably lower than the model predicted.

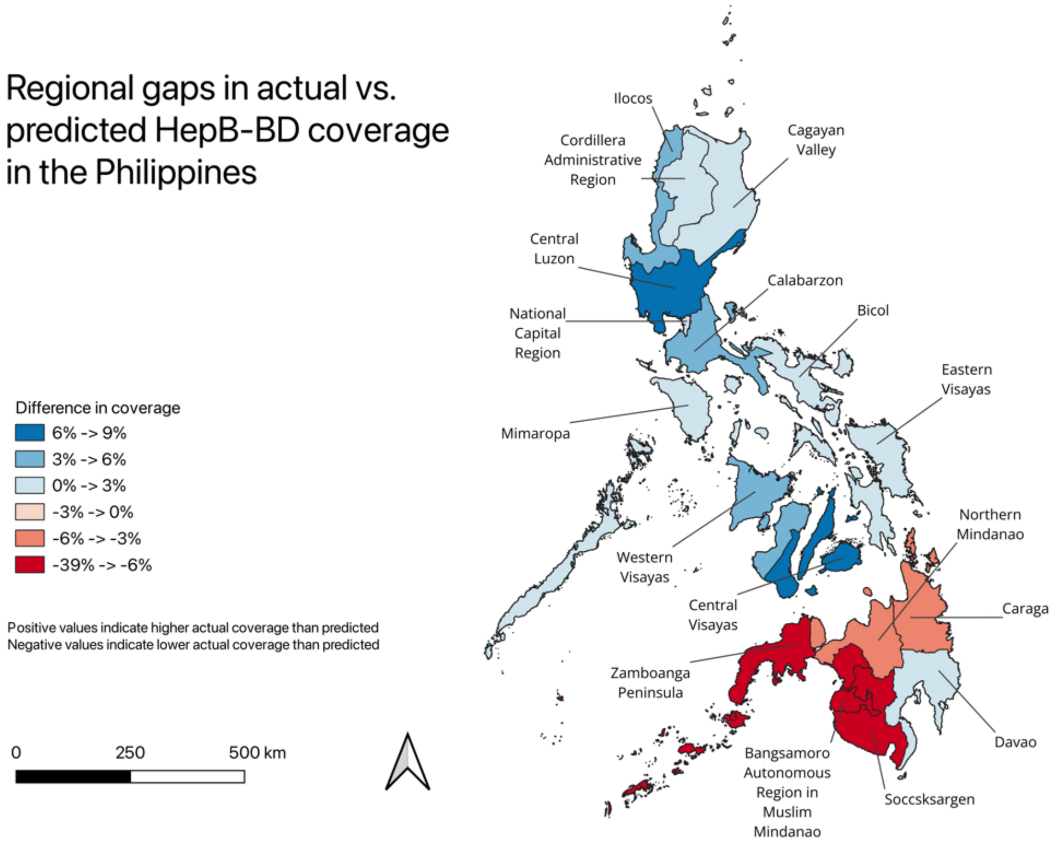


Figure 10: Residuals in HepB-BD coverage based on test dataset

Figure 11 shows the Local Indicators of Spatial Association (LISA) clusters for residuals in vaccination coverage. National Capital Region is the only High-High cluster, where a region with high positive residual is surrounded by regions with similarly high residuals. BARMM, Zamboanga Peninsula, SOCCSKSARGEN and Northern Mindanao form a Low-Low cluster. They have negative residuals and are also surrounded by regions also with low residuals. Davao is the only High-Low cluster, where a region with high positive residuals is surrounded by low residual areas. There are no Low-High clusters. All other regions show no significant clustering of residuals.

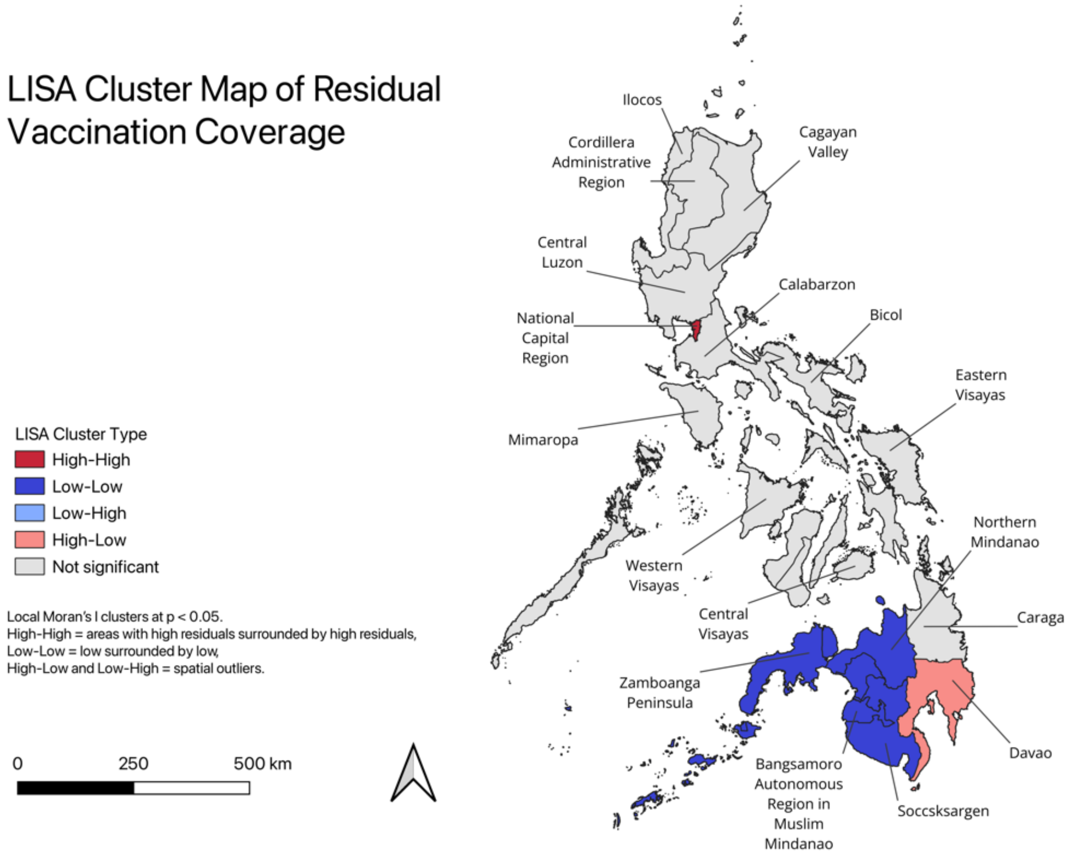


Figure 11: LISA cluster map of residuals based on test dataset

Chapter 6: Discussion

6.1 National and Regional Coverage

Due to the high number of missing outcomes, the accuracy of HepB-BD coverage is difficult to estimate. In this analysis, missing data for the vaccination outcome were treated as N/A; however, missingness in vaccination data may often be due to the child truly not being vaccinated. The national coverage is estimated between 44.3 and 76.7%, depending on if the missing values are included and treated as the child not having the vaccination. If missing vaccination data implies non-receipt produces more conservative estimates which may be closer to the true coverage rates. These estimates are in-keeping with the WHO estimates at 54%, but far below the recommendations of 90% coverage [32]. The regional differences in coverage were reasonably small, between 14 and 21% depending on how missing values were coded.

6.2 External Environment

6.2.1 Region

The distribution of survey participants between regions was reasonably well balanced, except for BARMM where a much higher proportion was represented compared to its population. This is likely due to this region being generally underserved by health infrastructure, with generally worse health outcomes [9].

Region remained a significant factor in the univariate and multivariate models. Specifically, Caraga, Central Visayas and MIMAROPA had significant negative associations with HepB-BD vaccination compared to the NCR, suggesting that children from these regions are less likely to receive the vaccine. No region was significantly associated with higher odds of vaccination in both the adjusted and unadjusted models, compared to the NCR. In the predictive model, Cagayan Valley and CAR had the highest predictive probabilities of vaccination, whereas MIMAROPA and Central Visayas had the lowest probabilities. However, the model overpredicted vaccination in regions on Mindanao, including BARMM and Zamboanga Peninsula. The LISA cluster analysis confirmed spatial autocorrelation in Mindanao, with Low-Low clusters encompassing BARMM, Zamboanga Peninsula, SOCCSKSARGEN and Northern Mindanao. This indicates that the model systematically over-predicted vaccination coverage in these regions, and this underperformance is spatially concentrated; suggesting shared regional factors that may not be fully captured by the predictive model.

Interestingly, Davao emerged as a High-Low cluster, suggesting that it outperformed model predictions despite being surrounded by areas with low residuals. Conversely, the NCR emerged as a High-High cluster, indicating a significant cluster of under-prediction where actual coverage exceeded model expectations. Missingness of HepB-BD data varied across regions, potentially reflecting differences in health infrastructure or reporting. Five regions were significantly associated with lower odds of HepB-BD missingness compared to the NCR: CAR, Cagayan Valley, Eastern Visayas, SOCCSKSARGEN and Zamboanga Peninsula. These regions had varied coverage of vaccination.

Region of residence and urbanicity have been consistently reported as determinants in childhood vaccination across LMICs [41, 49, 50]. Mindanao, specifically BARMM, has the worst childhood vaccination rates in the Philippines [73, 74]. Timely HepB-BD vaccination in the country has already been shown to follow a similar pattern, with Mindanao performing significantly worse than Luzon and Visayas [62, 67]. For decades, Mindanao has experienced conflict rooted in historical injustices and ethnoreligious tensions. The struggle for autonomy by Moro Muslim groups has led to repeated confrontations with the Philippine government, contributing to high levels of poverty, population displacement and limited access to health and social services [75]. Despite the creation of BARMM (formerly the Autonomous Region in Muslim Mindanao), post conflict tensions remain high with ongoing challenges in governance and service delivery, particularly in rural and remote communities [76]. The spatial clustering in Mindanao suggests shared issues not fully captured by the model's included variables. These may include fragile health infrastructure, understaffing and cold chain limitations. Conversely, Davao emerging as a High-Low outlier offers insights into how governance and improved infrastructure can reduce structural barriers and support higher vaccination rates. It is the most populous region in Mindanao and is an area of relatively greater political stability and investment [75].

Beyond Mindanao, MIMAROPA and Central Visayas demonstrated significantly lower HepB-BD coverage. These regions have diverse geography, including island provinces and mountainous regions. This affects health facility density and service delivery, and transport to services for patients [77, 78]. Additionally, healthcare infrastructure development has primarily been focused on Luzon, especially the NCR [79], which may further exacerbate regional inequities.

The regional differences in data missingness may reflect stronger reporting systems or survey engagement rather than differences in vaccination itself. Notably, BARMM and MIMAROPA, which had low predicted coverage and spatial clusters of overprediction, did not show significantly higher missingness, suggesting that model underperformance in those areas is more likely due to structural barriers not captured by the model, rather than data loss. This highlights the importance of improving health information systems alongside service delivery.

In low coverage areas such as those on Mindanao, targeted efforts are required to overcome persistent structural and contextual barriers. This may include investing in regional health infrastructure, addressing transport and logistical issues, improving local health governance and supporting community-based outreach programmes.

6.2.2 Religion

The distribution of religious affiliation among survey participants was broadly in-keeping with population estimates, but Islam was over-represented [1].

Islam was also associated with a significantly lower odds of HepB-BD vaccination compared to the majority religion in the explanatory models. Although, the odds ratio was attenuated from 0.126 to 0.482 after adjusting for other predictors, suggesting that part of the low coverage is explained by other factors affecting Muslim communities. Islam was also associated with the lowest predictive probabilities of all the religions. No other religions were significant in the multivariate model. The three majority religions had balanced HepB-BD missingness, and only No religion was significantly associated with lower odds of vaccine missingness compared to the intercept. This is likely due to the very small sample size in this category.

Religious disparities in vaccination coverage affecting Muslim populations have already been seen in the Philippines [51], and specifically with HepB-BD in other contexts such as India and West Africa [80, 81]. The potential explanations for this are complex. Muslim communities are often marginalised and face systemic barriers to healthcare access. As mentioned in the previous section, regions with high Muslim populations such as BARMM have faced long-standing challenges related to conflict, displacement and underinvestment [75]. There has been historic mistrust in government health programs, where misinformation or religious concerns about vaccine contents exacerbate vaccine hesitancy [82]. Other studies have shown lower health-seeking behaviours among women in conservative settings, which may limit access to antenatal care and facility-based births [83, 84].

These findings suggest that religious affiliation influences HepB-BD uptake, particularly among Muslim populations. While religion may not be the direct cause of lower coverage, and cannot be modified, it coexists with geographic, socioeconomic and gender-related vulnerabilities that may compound access challenges. This highlights the importance of culturally sensitive and community-engaged approaches in Muslim-majority areas.

6.2.3 Other External Environment Factors

Although showing some significance in the univariate model, ethnicity showed no significant associations when adjusted for other variables. despite previous studies suggesting that there are ethnic disparities in childhood vaccination in the Philippines and in other LMICs [51]. This may reflect overlapping effects with region or religion. While there was variation in missing HepB-BD data across ethnic groups, only one ethnicity was significant. Cebuano children had lower odds of missing outcome data, potentially reflecting differences in reporting or health service utilisation across ethnic groups. Urbanicity was also non-significant in the multivariate model despite global evidence [50], perhaps due to being mediated by more specific factors such as region or household wealth.

6.3 Predisposing Characteristics

6.3.1 Internet Use

Recent internet use was reported by 70% of the surveyed population, with almost 30% having never used it before. According to the 2020 Census of Population and Housing, 56% of households in the country have access to the internet, with substantial regional variation; 74.6% in the NCR compared to just 28.5% in Zamboanga Peninsula [5].

Internet usage within the last 12 months was associated with significantly higher odds of HepB-BD vaccination, even when adjusting for other variables. It was also included in the predictive model, where lack of internet usage decreased the predictive probability of vaccination.

These findings align with existing literature from LMICs where internet access and usage have been shown to promote and advance vaccination coverage through improved awareness and health information dissemination [42]. It can also act as a proxy indicator of broader structural and social advantage. Households with internet access often have higher income, higher education levels, and are in more urban settings [85]. This introduces a risk of digital inequities where those without internet are excluded from key health information.

Expanding access to reliable internet infrastructure and providing subsidised or no-cost internet access to vulnerable populations, can support digital delivery of health information, facilitate outreach programs and counter vaccine misinformation.

6.3.2 Other Predisposing Characteristics

Numerous studies suggest associations between childhood vaccination and maternal education [34-36]. A very high proportion of mothers had at least secondary school education in the surveyed population. Although this variable was strongly associated with HepB-BD uptake in the univariate model, the effect diminished and became non-significant in the multivariate model, suggesting that its influence may operate indirectly through increased service utilisation or other socioeconomic factors.

Birth order and mother's age at first birth have been linked with incomplete vaccination in other countries [35, 37] but were also non-significant in the multivariate model, which may suggest that structural or facility-based factors play a larger role in influencing HepB-BD coverage. Higher birth order was associated with missing HepB-BD data, possibly due to health becoming less prioritised in later-born children.

Although internet usage has been shown to be an important variable in this analysis, internet use frequency did not show a significant association. This suggests that basic access to the internet serves as a proxy for the wider socioeconomic status of an individual rather than having an effect through repeated exposure to digital health.

Most surveyed mothers were either married or cohabiting with their partner. Marital status was not a significant factor in both the unadjusted and adjusted models, despite evidence of its role in other settings [39, 40]. However, it remained part of the predictive model as it improved prediction when combined with the other variables. In this model, widowed mothers had a much lower predictive probability of vaccination. In addition, widowed and separated mothers had higher odds of HepB-BD missing data compared to those who had never been in a union. However, this is likely due to the very small sample size for these categories. It is possible that the effects of marital status were mediated by other socioeconomic factors captured by the other covariates.

The gender distribution of the surveyed children was skewed towards male (52.3%), which is in-keeping with the PSA-reported distribution [5]. Sex of child has been shown to be an important determinant of vaccination in some countries [41], however this has not been seen in the Philippines [63]. Similarly, sex of child was not a significant variable in this univariate or multivariate analysis. However, along with marital status, it remained in the predictive model to provide accuracy. In this model, males had slightly higher predictive probabilities of HepB-BD vaccination. It is possible that patterns of strong son preference found in other countries are less pronounced in the Philippines.

6.4 Enabling Factors

6.4.1 Place of Delivery

Facility-based deliveries had significant positive associations with receipt of the HepB-BD vaccination in both the univariate and multivariate models compared to home births, with government hospitals reporting the highest odds. The associations were all attenuated when adjusting for the other predictors. Place of delivery was also highly predictive of HepB-BD in the predictive model, with home births showing much lower predictive probability of vaccination. Most surveyed mothers delivered in a health facility, with only 9% reporting a home birth. However, a substantial proportion of responses (42%) lacked information on place of delivery. This missingness strongly overlapped with missing data on HepB-BD vaccination; specifically, every individual with an unreported place of delivery also lacked vaccination data, while HepB-BD missingness was minimal among those with a recorded birth location.

Place of delivery has been cited as a main determinant of HepB-BD coverage in the literature, both globally and in the Philippines, with children born at home much less likely to be vaccinated [53, 66]. The Maldives have achieved very high facility-based deliveries (93%) and persistent HepB-BD coverage over 96% [86]. Additionally, a study in the Philippines compared government and private hospitals, and found that private hospitals were less likely to provide the birth dose [60]. This fits with the findings of this analysis, however the difference in odds between the two facility types is minimal. There are many potential reasons why babies born in a health facility are more likely to be vaccinated. Facilities have skilled healthcare providers that can provide appropriate counselling and administer vaccinations [87], and they are likely to have direct access to cold-chain maintained vaccines [88]. Facilities also typically follow standard clinical guidelines and national immunisation schedules.

The proportion of home births is significantly lower than found in other research [66]. This may reflect an ongoing change in birth preference in the country. However, the missing data may confound this interpretation. The missing data on place of delivery likely biases the observed results towards underestimating the true gap in coverage between home and facility-based births. If the missing data was reported correctly, it is plausible that a higher proportion of the unreported deliveries would be home births. Given what is known about vaccination coverage for home births, it is also likely that many of these infants did not receive the vaccine. This would likely result in a stronger association between place of delivery and vaccination.

These findings highlight the importance of focusing on newborns delivered outside of facilities. In China, studies have shown significant increases in HepB-BD coverage when village health workers visited homes to provide the vaccination, or provided them at local primary care centres [89]. The monovalent vaccine has been shown to be stable at room temperature for up to 28 days which reduces the requirement for cold-chain storage [90]. Barangay health workers could provide administration at barangay health stations or at home, and mobile health units could be created to reach remote communities. Accurate documentation and reporting of delivery location through digital immunisation records should also be prioritised, as these data gaps hinder monitoring and effectiveness of targeted interventions.

6.4.2 Antenatal Care

The number of ANC visits among surveyed women ranged from 0 to 20, with an average of 6 visits per pregnancy, falling below the 8 visits recommended by the WHO [91]. It was a significant determinant in the regression analysis even after adjusting for other variables. The odds of vaccination increase with each additional ANC visit compared to no ANC visits, assuming a linear effect. The predictive model showed a similar result, with scenarios involving no ANC visits associated with the lowest predicted probabilities of vaccination. However, almost half of responses (47%) had missing ANC data, and this missingness significantly correlated with missing HepB-BD data; 89% of those with missing ANC data also lacked HepB-BD data.

The findings of this analysis are backed up by research globally, where antenatal care has been reported as a key determinant in childhood vaccination [44, 45]. The quality of the services is also an important factor [46] but has not been evaluated by this study. The WHO underscores ANC as a key method of improving coverage [91]. ANC offer critical opportunities for health education, counselling and linkage to health services. During visits, healthcare providers can inform expectant mothers about the importance of vaccinations, including the timely administration of the birth dose. Mothers who attend more ANC visits are also more likely to deliver in health facilities, where HepB-BD is more readily available immediately after birth [92]. Additionally, regular ANC attendance is an indicator of greater health-seeking behaviour and trust in the healthcare system, contributing to better adherence to immunisation schedules [46].

Similarly to place of delivery, it is likely that if the missing data was reported correctly then more women would be recorded as not having received ANC. Based on the correlation between no ANC and lack of vaccination, it is also likely that many of these infants did not receive the vaccine. Therefore, the missing data likely leads to underestimation of the association between ANC and HepB-BD.

Evidence from Nigeria has shown that integrating vaccine education into ANC visits improved both maternal awareness and staff knowledge and motivation [93]. Financial incentives have shown effectiveness in increasing ANC attendance in countries such as Nepal and India through conditional cash payments [94, 95]. These incentives help offset direct and indirect costs for patients which are common barriers to ANC attendance. Strengthening community outreach is essential to reach remote or underserved communities. A randomised control trial in Mali showed that home visits by community health workers can increase ANC engagement and even increase facility-based delivery [96]. Similarly, group antenatal care has also been shown to be effective in improving ANC attendance and promoting health literacy [97].

6.4.3 Other Enabling Factors

The reported wealth quintiles were unequally distributed across categories, with more children observed in the lowest quintile. This may be due to wealth being calculated based on household rather than child or mother. In the univariate analysis, wealth appears to be strongly associated with vaccination with a positive dose-response relationship; wealthier households are increasingly more likely to vaccinate their children. This is in line with global research [34-36, 62, 63]. However, each category substantially attenuates and becomes non-significant once adjusting for the other factors. It is likely that the effect of wealth on HepB-BD vaccination is mediated through other variables. Wealthier households may be more likely to give birth in facilities, attend more ANC visits, and have access to the internet. In addition, given maternal and child healthcare is covered under PhilHealth [13], the effect of wealth may be less pronounced.

Over three quarters of surveyed mothers reported having no health insurance, which is surprising given all Filipinos are eligible for PhilHealth [13]. Health insurance was positively associated with HepB-BD coverage in the univariate model but became non-significant after adjusting for other variables. Having health insurance was associated with higher odds of missing HepB-BD data, which is somewhat counterintuitive, as it could be expected that individuals with insurance would be more engaged with the health system, and therefore more likely to receive and report vaccinations. Although other studies report higher rates of childhood vaccination in families with health insurance [48], the non-significance in this analysis signals that insurance coverage alone is not a primary facilitator of HepB-BD uptake. Possessing insurance does not necessarily guarantee access to health services, especially in underserved areas.

The average minutes to the nearest health facility is between 10 and 15 minutes, with a right-skewed distribution. This suggests that although most respondents live within 10 minutes of a facility, a smaller proportion live much further away. Again, this variable had a significant association in the univariate analysis, but lost significance in the multivariate model. Research has shown an association between travel time and vaccination coverage [35], but the effects may be mediated by other health system factors. However, this variable may not accurately reflect true access to vaccination services. It does not distinguish between modes of transport, and it may refer to facilities that do not offer HepB-BD vaccination. In addition, even if a facility is nearby, patients may choose not to use it due to trust issues, cultural preferences or perceived poor quality of services.

6.5 Strengths and Limitations

6.5.1 Strengths

The 2022 NDHS used for this analysis collected nationally representative data which was designed for comparability. This allows for generalisability of findings to the broader paediatric population in the Philippines. Sampling weights, clustering and stratification were incorporated to adjust for the complex survey design, ensuring that the results are representative of the national population. The sample size of several thousand is large even with the high proportion of missing values, which allows for model stability.

The predictive model was recalibrated and validated which indicates good model performance; useful in identifying high-risk subgroups for targeted intervention.

The multiple modelling approaches used in this study yielded broadly consistent findings, with key health service-related factors such as place of delivery, ANC attendance and region emerging as important predictors across all models. The similarity in results across models strengthens the validity of the analysis.

6.5.2 Limitations

The main limitation in this analysis relates to missing data, particularly for the HepB-BD vaccination outcome, number of ANC visits and place of delivery variables. Missing values were treated as N/A and excluded from the primary regression analyses rather than being assumed to represent non-vaccination. This conservative approach aimed to avoid introducing bias from incorrect assumptions, however it significantly reduced the sample size and may have impacted statistical power and the generalisability of the findings.

This data is likely not Missing Completely At Random (MCAR), but likely Missing at Random (MAR). Under MAR, the probability of missingness is dependent on the observed variables, but not on unobserved variables. There is also a risk that data is Missing Not At Random (MNAR), where underreporting or incomplete documentation is systematically related to unobserved factors such as mistrust in vaccination programs.

Assumptions about missingness influence the validity of the statistical inferences. Given the dataset is likely under a MAR mechanism, removal of missing data may introduce bias if the variables associated with missingness are not adequately adjusted for. As outlined above, the analysis likely underestimates the effect of ANC and place of delivery on HepB-BD, and the true association is possibly stronger than estimated. However, for the other covariates the effect is less certain. Improving the completeness of data should be of paramount importance in future surveys.

There are other limitations to this analysis. The NDHS dataset used in this analysis is from 2022, may not capture current conditions, and does not fully capture important factors, such as cultural beliefs or quality of care. The data is cross sectional, and although associations and predictive relationships have been modelled, causality is unable to be established. Although the predictive model has been internally validated using a test set, no external validation was performed, limiting generalisability to those children in the Philippines without complete data, and to other contexts.

Chapter 7: Recommendations

The following recommendations are directed towards intersectoral national and regional stakeholders, including policymakers in health, technology and social development, as well as academic and research institutes.

1. Strengthen **community-based vaccine delivery** to reach those born outside of facilities, through home visits or mobile clinics.

2. Promote **alternative ANC delivery models** such as home visits or in group settings.

3. Fully **integrate vaccine counselling and education** into ANC visits to improve the quality of services.

4. Explore **financial incentives** to promote ANC attendance and facility-based delivery.

5. Improve **internet infrastructure** for rural or underserved areas through subsidies or community access to improve health information dissemination.

6. Expand digital health infrastructure including **electronic immunisation records** to provide accurate documentation and reporting structures.

7. Ensure **complete data collection** in future NDHS surveys to allow for more complete data analysis.

8. Design and implement **culturally sensitive programs** tailored to Muslim communities, involving community and religious leaders, targeting vaccine safety and misinformation.

9. Develop **regionally tailored vaccination strategies**, particularly for Mindanao and other areas with low vaccination rates.

10. Conduct **qualitative research** to fully explore barriers to vaccination, from a health professional and individual perspective.

11. Conduct **childhood HbsAg seroprevalence survey** to provide contemporary information about the current burden in the Philippines.

Chapter 8: Conclusions

This study investigated factors associated with HepB-BD vaccination among children under 5 in the Philippines using nationally representative data and a combination of explanatory and predictive modelling. HepB-BD coverage remains suboptimal, with marked variation across regions, especially in Mindanao.

Key determinants associated with increased vaccination uptake included facility-based delivery, ANC attendance and recent internet use. Children from Muslim households had lower odds of vaccination compared to the dominant religion, consistent with findings from national and international contexts. This disparity likely reflects structural, geographic and historical barriers rather than religious belief alone.

These findings highlight the interconnected roles of the health system, digital connectivity and the sociocultural context in shaping vaccination outcomes. However, the health system factor variables consistently emerged as the most influential across models, suggesting that improving access to and quality of maternal health services may be the most effective route for increasing vaccination.

Spatial analysis suggests that some unmeasured structural or systemic barriers persist between regions. Mindanao has significant geographic clustering of low HepB-BD coverage, reinforcing the need for targeted strategies.

Unfortunately, the analysis was constrained by high levels of missing data in the outcome and some of the covariates. The missingness may have impacted the strength of the associations and reduced the precision of predictions, highlighting the importance of improving data completeness in future surveys.

Ultimately, ensuring timely HepB-BD vaccination is not only a technical challenge but a broader health systems and equity issue. Sustained political will, investment in frontline services, and inclusive public health programming will be essential to achieve the Philippines' goals of HBV elimination.

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Appendices

Appendix 1: Serological and Virological Markers of Hepatitis B [16]

Markers	Interpretation
HbsAg (Hepatitis B surface antigen)	HBV infection (acute and chronic)
HBeAg (Hepatitis B e-antigen)	High-level HBV replication and infectivity; marker for treatment response
HBV DNA (Hepatitis B Virus DNA)	Level of HBV replication; primary virologic marker for treatment response
Anti-HBc (IgM) (Hepatitis B core antibody – immunoglobulin M)	Acute HBV infection; could be seen in flare of chronic hepatitis B
Anti-HBc (IgG) (Hepatitis B core antibody – immunoglobulin G)	Recovered or chronic HBV infection
Anti-HBs (Hepatitis B surface antibody)	Recovered HBV infection or marker of HBV vaccination or immunity (titre can assess vaccine efficacy)
Anti-HBe (Hepatitis B e-antibody)	Low-level HBV replication and infectivity; marker for treatment response
Anti-HBc (IgG) and anti-HBs	Past HBV infection; could lose anti-HBs
Anti-HBc (IgG) and HBsAg	Chronic HBV infection
Anti-HBc (IgG) and/or anti-HBs and HBV DNA (PCR)	Latent or occult HBV infection

Appendix 2: Variable Recoding Table

Variable	Recoded label	Original label	Type	Original coding	Recoding	Source
HepB-BD	HB	h50	Binary	0 = No 1 = Vaccination date on card 2 = Reported by mother 3 = Vaccination marked on card 8 = Don't know 9 = Missing	0 = No 1, 2, 3 = Yes 8, 9 = N/A	KR
Mother's education level	edu	v106	Categorical	0 = None 1 = Primary 2 = Secondary 3 = Higher 9 = Missing	0 = None 1 = Primary 2 = Secondary 3 = Higher 9 = N/A	KR
Religion	religion	v130	Categorical	1 = Roman Catholic 2 = Protestant 3 = Iglesia ni Cristo 4 = Aligpay 5 = Islam 6 = Other Christian 95 = No Religion 96 = Other	1 = Roman Catholic 2 = Protestant 3 = Iglesia ni Cristo 4 = Aligpay 5 = Islam 6 = Other Christian 95 = No Religion 96 = N/A	KR
Ethnicity	ethnicity	v131	Categorical	1 = Tagalog 2 = Cebuano 3 = Ilokano 4 = Hiligaynon/ Ilonggo 5 = Bikolano 6 = Kapampangan 7 = Maranao 8 = Tausog 9 = Waray 10 = Aeta 11 = Badjao 23 = Akeanon 26 = Ayangan 27 = Blaan 33 = Bantoanon 35 = Boholano 43 = Cuyonon/ Cuyone 48 = Higaonon 49 = Ibaloi/Ibaloy 50 = Ibanag 52 = Ifugao 53 = Iranon/Iranun/ Iraynon 55 = Isneg/Isnag/ Apayao 58 = Ivatan 62 = Kalibugan/ Kolibugan 63 = Kalinga 64 = Kankanaey 67 = Manobo 68 = Subanen/ Subanon 69 = Surigaonon 71 = Maguindanao 73 = Mandaya 77 = Masbateño/ Masbatenon 80 = Pangasinan/ Paggalato 82 = Sama/Bangingi/ Badajo/Laut/Samal 84 = Tagakaulo 85 = Tuwali 86 = Yakan 87 = Zambageño - Chavacano 88 = Other Nationality 96 = Other	1 = Tagalog 2 = Cebuano 3 = Ilokano 4 = Hiligaynon/ Ilonggo 5 = Bikolano 6 = Kapampangan 7, 8, 11, 53, 62, 71, 82, 86 = Moro 9 = Waray 10, 50, 58 = Other Indigenous 23, 33, 35, 43, 69, 77, 87 = Other Visayan/ Chavacano 26, 49, 52, 55, 63, 64, 85 = Igorot 27, 48, 67, 68, 73, 84 = Lumad 80 = Pangasinan/ Paggalato 88, 96 = N/A	KR
Region	region	v024	Categorical	1 = Region I - Ilocos 2 = Region II - Cagayan Valley 3 = Region III - Central Luzon 4 = Region IVA - Calabarzon 5 = Region V - Bicol 6 = Region VI - Western Visayas 7 = Region VII - Central Visayas 8 = Region VIII - Eastern Visayas 9 = Region IX - Zamboanga Peninsula 10 = Region X - Northern Mindanao 11 = Region XI - Davao 12 = Region XII - SOCCSKSARGEN 13 = National Capital Region 14 = CAR - Cordillera 15 = BARMM - Bangsamoro Autonomous Region in Muslim Mindanao 16 = Caraga 17 = MIMAROPA	No recoding	KR

Urban or rural residence	urban	v025	Binary	1 = Urban 2 = Rural	No recoding	KR
Wealth quintile index	wealth	v190	Ordinal	1 = Poorest 2 = Poor 3 = Middle 4 = Rich 5 = Richest	No recoding	KR
Minutes from health facility	HF_dist	v483a	Continuous	0 – 599 600+ 999 = Missing	No recoding	KR
Internet usage	internet_use	v171a	Categorical	0 = Never 1 = Yes, last 12 months 2 = Yes, before last 12 months 3 = Yes, can't establish when 9 = Missing	0 = Never 1 = Yes, last 12 months 2 = Yes, before last 12 months 3 = Yes, can't establish when 9 = N/A	KR
Internet use frequency	internet_freq	v171b	Categorical	0 = Not at all 1 = Less than once a week 2 = At least once a week 3 = Almost every day 9 = Missing	0 = Not at all 1 = Less than once a week 2 = At least once a week 3 = Almost every day 9 = N/A	KR
Number of ANC visits	ANC	m14	Continuous	0 = No antenatal visits 1 – 40 98 = Don't know 99 = Missing	0 -40 98, 99 = N/A	KR
Place of delivery	birth_loc	m15	Categorical	11 = Respondent's home 12 = Other home 21 = Government hospital 22 = Rural health center (RHC) / Urban health center (UHC) / lying in 23 = Barangay health station 24 = Barangay supply / service point officer / BHW 26 = Other public sector 31 = Private hospital / clinic / lying in clinic 32 = Industry-based clinic 36 = Other private medical sector 96 = Other 99 = Missing	11, 12 = Home 21 = Government Hospital 22 = Health Centre 23 = Barangay Health Station 31 = Private Hospital/Clinic 24, 26, 32, 36, 96 = Other 99 = N/A	KR
Age of mother at first birth	mum_age	v212	Continuous	10 - 49	No recoding	KR
Health insurance	insurance	sh20b	Binary	0 = No 1 = Yes 8 = Don't know	0 = No 1 = Yes 8 = N/A	HR
Birth order	bord	bord	Continuous	1 - 20	No recoding	KR
Marital status	marital	v501	Categorical	0 = Never in union 1 = Married 2 = Living with partner 3 = Widowed 4 = Divorced 5 = Separated 9 = Missing	0 = Never in union 1 = Married 2 = Living with partner 3 = Widowed 4 = Divorced 5 = Separated 9 = NA	KR
Sex of child	sex	b4	Binary	1 = Male 2 = Female	No recoding	KR

Appendix 3: Descriptive Table of HepB-BD Missingness by Variable

Hepatitis B Missingness							
	Observed	Missing	% Missing		Observed	Missing	% Missing
Number of ANC visits				**Mother's age at first birth**			
0	246	1	0.4%	12–14	43	28	39.4%
1-5	1468	1	0.1%	15–19	1646	1161	41.4%
6-10	2321	4	0.2%	20–24	1927	1469	43.3%
11-15	196	1	0.5%	25–29	623	429	40.8%
16-20	38	0	0.0%	30–34	282	189	40.1%
NA	414	3422	89.2%	35–39	94	68	42.0%
Place of delivery				40+	9	8	47.1%
Home	723	2	0.3%	NA	0	0	0.0%
Barangay Health Station	125	0	0.0%	**Birth order**			
Health Centre	631	1	0.2%	1	1423	953	40.1%
Government Hospital	2073	5	0.2%	2	1177	895	43.2%
Private Hospital/Clinic	1108	1	0.1%	3	870	628	41.9%
Other	23	0	0.0%	4–5	798	633	44.2%
NA	0	3420	100.0%	6–7	285	210	42.4%
Region				8–9	97	82	45.8%
National Capital Region	302	260	46.3%	10+	33	29	46.8%
BARMM	519	407	44.0%	**Minutes to nearest health facility**			
Bicol	250	193	43.6%	0–9 min	639	376	37.0%
Cagayan Valley	172	114	39.9%	10–29 min	3008	2265	43.0%
Calabarzon	247	195	44.1%	30–59 min	625	471	43.0%
Caraga	278	197	41.5%	60–119 min	144	119	45.2%
Central Luzon	342	262	43.4%	120+ min	40	29	42.0%
Central Visayas	228	181	44.3%	NA	0	0	0.0%
CAR	283	192	40.4%	**Insurance**			
Davao	220	178	44.7%	No	3741	2630	41.3%
Eastern Visayas	318	193	37.8%	Yes	927	791	46.0%
Ilocos	162	118	42.1%	NA	15	8	34.8%
Mimaropa	257	169	39.7%	**Internet use**			
Northern Mindanao	316	230	42.1%	Never	1305	1040	44.3%
Soccsksargen	266	183	40.8%	Yes, before last 12 months	32	34	51.5%
Western Visayas	286	197	40.8%	Yes, last 12 months	3346	2355	41.3%
Zamboanga Peninsula	237	160	40.3%	NA	0	0	0.0%
NA	0	0	0.0%	**Internet frequency**			
Sex of child				Not at all	1387	1108	44.4%
Female	2255	1617	41.8%	Less than once a week	240	146	37.8%
Male	2428	1812	42.7%	At least once a week	849	626	42.4%
NA	0	0	0.0%	Almost every day	2207	1549	41.2%
Ethnicity				NA	0	0	0.0%
Tagalog	695	551	44.2%	**Maternal education**			
Bikolano	258	220	46.0%	None	58	60	50.8%
Cebuano	1040	747	41.8%	Primary	641	594	48.1%
Hiligaynon/Ilonggo	328	229	41.1%	Secondary	2360	1592	40.3%
Igorot	190	134	41.4%	Higher	1624	1183	42.1%
Ilokano	409	284	41.0%	NA	0	0	0.0%
Kapampangan	75	76	50.3%	**Wealth quintile index**			
Lumad	194	140	41.9%	Poorest	1634	1247	43.3%
Moro	729	550	43.0%	Poor	1067	775	42.1%
Other Indigenous	35	22	38.6%	Middle	820	548	40.1%
Other Visayan/Chavacano	234	172	42.4%	Rich	612	457	42.8%
Pangasinan/Paggalato	38	29	43.3%	Richest	550	402	42.2%
Waray	283	169	37.4%	NA	0	0	0.0%
NA	175	106	37.7%	**Religion**			
Marital status				Roman Catholic	3053	2249	42.4%
Never in union	205	118	36.5%	Islam	746	565	43.1%
Married	2504	2064	45.2%	Protestant	509	370	42.1%
Living with partner	1877	1135	37.7%	Other Christian	117	70	37.4%
Widowed	19	29	60.4%	Aligpay	0	0	0.0%
No longer living with partner	78	83	51.6%	Iglesia ni Cristo	99	68	40.7%
NA	0	0	0.0%	No Religion	6	1	14.3%
Urban/rural				NA	153	106	40.9%
Rural	2973	2148	41.9%				
Urban	1710	1281	42.8%				
NA	0	0	0.0%				

Appendix 4: GVIF Table of Multicollinearity

Variable	Generalised variance inflation factors (GVIF)	Degrees of freedom (Df)	Adjusted GVIF (GVIF^(1/(2*Df)))
Internet use	25.84	2	2.25
Region	593.17	16	1.22
Religion	23.87	5	1.37
Ethnicity	2347.53	12	1.38
Sex of child	1.02	1	1.01
Mother's marital status	1.61	4	1.06
Number of ANC visits	1.33	1	1.15
Place of delivery	1.77	5	1.06
Birth order of child	1.43	1	1.19
Wealth quintile index	2.36	4	1.11
Maternal education	2.00	3	1.12
Internet frequency	31.53	3	1.78
Urban/rural	1.36	1	1.17
Age of mother at first birth	1.31	1	1.15
Insurance	1.31	1	1.14
Travel time to nearest facility	1.09	1	1.05

Appendix 5: Backward Selection Log

Step	Removed	P_value
1	wealth	0.9785
2	urban	0.9796
3	insurance	0.9049
4	bord	0.8202
5	mum_age	0.7491
6	internet_freq	0.7013
7	edu	0.419
8	HF_dist	0.3582
9	marital	0.299
10	ethnicity	0.2263
11	sex	0.2051
Final Model	HB ~ internet_use + region + birth_loc + religion + sex + ANC	

Appendix 6: AI Declaration

KIT Institute (Masters or Short course) Participants
Declaration for Use of Generative AI (GenAI)

Check the box that applies to your completion of this assignment:

☐ I confirm that **<u>I have not used</u>** any generative AI tools to complete this assignment.

☒ I confirm that **<u>I have used</u>** generative AI tool(s) in accordance with the ***"Guidelines for the use of Generative AI for KIT Institute Master's and Short course participants".*** Below, I have listed the GenAI tools used and for what specific purpose:

Generative AI tool used	Purpose of use
1. ChatGPT	Debugging R code Brainstorming and planning assistance
2. Perplexity AI	Assistance with literature search
...	