Factors affecting Oral Polio Vaccination at birth among children under 5 years in Ahafo Region, Ghana: A Retrospective Analysis (2019-2023)

Joseph Kwasi Nkrumah[1], Sabina Ampon-Wireko[2], Emmanuel Ayaakawana[3]

[1] School of Public Health and Allied Sciences, Catholic University of Ghana, Sunyani-Fiapre
[2] School of Public Health and Allied Sciences, Catholic University of Ghana, Sunyani-Fiapre; ORCID ID: 0000-0001-6456-3660
[3] School of Public Health and Allied Sciences, Catholic University of Ghana, Sunyani-Fiapre
[*]Corresponding author's email: nkrumahj7@gmail.com

Open Access

Cite this article as:

Nkrumah, K. J., Ampon-Wireko, S. & Emmanuel Ayaakawana, E. (2025). Factors affecting oral polio vaccination at birth among children under 5 years in Ahafo Region, Ghana: A Retrospective Analysis (2019-2023). Ghana Journal of Nursing and Midwifery (GJNMID), 2025(2), 47 – 71.

https://doi.org/10.69600/GJNMID/2025.i2.v2.47-71

Received: 9th August 2024

Revision Received: 14th April 2025

Accepted for Publication: 20th July 2025

Paper DOI: *https://doi.org/10.69600/GJNMID/2025.i2.v2.47-71*

Journal URL: https://gjnmid.com

Journal DOI: https://doi.org/10.69600

ISSN (Online): 3057-3602

Abstract

Background: Globally, the World Health Organization (WHO) has proposed three vaccines to be administered to newborns immediately after birth. These are; zero dose of Oral Polio Vaccine (OPV0), Bacillus Calmette-Guérin (BCG) and birth dose of hepatitis B vaccine (HepB-BD). Despite these recommendations, there are still significant differences in coverage especially with regards to OPV0 coverage across nations and among regions. In Ghana, ensuring access to newborn vaccine of OPV0 is an important indicator for immunization success and achieving sustainable development goal 3 as well as universal health coverage; but full immunization coverage still remains a challenge in some regions despite significant efforts.

General Aim: The study sought to analyze the factors affecting vaccination coverage against polio at birth among children under 5 years in Ahafo Region of Ghana. In view of this, three specific objectives were formulated; the first was to determine the association between improving vaccine accessibility on birth dose of oral polio vaccine. Second objective was to identify newborn related factors affecting birth dose of oral polio vaccine coverage and lastly, to forecast the trend of oral polio vaccine coverage at birth by the year 2030.

Methodology: The research was a quantitative study which employed a retrospective study design. Secondary data from DHIMS 2 and regional AFP surveillance case-based database from 2019-2023 were reviewed. A total of 109,070 vaccination records of children under 5 years from 2019-2023 were analyzed. Correlation, trend and projection analysis were used for data analysis. Statistical significance was set at p-value < 0.05.

Results: The results revealed that both accessibility and newborn related factors increased oral polio vaccination coverage at birth. The study showed a strong positive linear relationship (r = 0.759) between child's birth weight < 2.5kg and OPV0 coverage but with a moderate positive linear relationship (r = 0.382) between the number vaccination centers and OPV0 coverage. However, despite the apparent correlations, the relationships were not statistically significant (P-value > 0.05). It was also estimated that OPV0 coverage in the Ahafo Region will decline by 2.6% resulting in 84.1% coverage by the year 2030 if the current trend is maintained.

Conclusion/Recommendation: The current study revealed that OPV0 coverage will remain below the national target of 95% by the year 2030 making Ghana's certification as a polio free country problematic if nothing is done about the current situation. Hence it is recommended for robust studies to be conducted into the influence of both accessibility and newborn factors on OPV0 coverage and AFP status using larger data sets or primary data to clarify the relationships for informed decision making. Health facilities should also abolish the practice of scheduling newborns for birth dose vaccines only on some specific days within the week. The current practice leads to increase in the number of defaulters since most parents will refuse to report within the recommended 2 weeks but may only show up for 40 days postnatal by which time OPV0 would have elapsed.

Keywords: Birth dose, Children, Ghana, OPV0, Polio, Under 5 years, Vaccination

INTRODUCTION

Globally, children are required to receive all essential services including vaccination after delivery and

throughout infancy (Alhassan et al., 2020). As at 2019, 19.7 million children globally were either under-vaccinated or did not receive some important childhood vaccines, with 48% of those cases occurring in Africa (Bobo et al., 2022). The foundation of immunization protection for children starts immediately after birth where all live birth babies are given newborn vaccines such as BCG, OPV0 and HepB-BD (Alhassan et al., 2020). Within the period of 1990 to 2019, there has been a significant universal decline in child deaths (from 12.5 million to 5.3 million), with childhood vaccination being a major contributory factor for the decline (Bobo et al., 2022). Evidence further shows that childhood vaccination is the most effective means of preventing communicable diseases among newborns (Baguune et al., 2017). Since the introduction of the Expanded Program on Immunization (EPI), Vaccines have been proven to be one of the most cost effective public health interventions by which most childhood diseases have been either prevented or eradicated (Baguune et al., 2017).

The introduction of vaccines to newborns has led to the eradication of small pox and polio in America and some African Countries with a drastic decrease in the number of vaccine preventable deaths worldwide (Bobo et al., 2022). As proposed by the World Health Assembly (WHA), the World Health Organization launched the Expanded Programme of Immunization (EPI) in 1974 (Sally & Kenu, 2017). This was done to assist member states in creating vaccination programs and surveillance systems against tetanus, poliomyelitis, TB, diphtheria, and pertussis (Sally & Kenu, 2017). The vaccine-preventable diseases namely; pertussis, pediatric TB, tetanus, polio, measles, and diphtheria have seen a high vaccination coverage due to the introduction of EPI at Kwahu Afram Plains in Ghana (Sally & Kenu, 2017). Levels and trends of vaccination coverage are used to track the effectiveness of immunization programs on a local, national, and worldwide scale and to inform plans for the eradication, control, and elimination of illnesses that can be prevented by vaccination (Sally & Kenu, 2017).

Depending on a country's epidemiological situation, the World Health Organization (WHO) has proposed three vaccines to be administered to newborns immediately after birth (Bassoum et al., 2020). These newborn vaccines are; zero dose of Oral Polio Vaccine (OPV0), Bacillus Calmette-Guérin (BCG) and birth dose of hepatitis B vaccine (HepB-BD) (Bassoum et al., 2020). The goal of administering these vaccines as soon as possible after delivery is to lower the mortality rate from pediatric tuberculosis in the case of BCG, raise the levels of neutralizing antibodies against poliovirus and sero-conversion rates with the completion of subsequent doses for OPV or Inactivated Polio Vaccine (IPV), and halt the human-to-human transmission of hepatitis B virus (HBV) at an early stage for HepB-BD as well as perinatal mother-to-child transmission (Bassoum et al., 2020). The OPV0, BCG, and HepB-BD coverage rates among infants in the WHO African area were estimated by WHO and UNICEF to be 80%, 74%, and 4%, respectively in 2019 (Bassoum et al., 2020).

Additionally, since the rate of newborn mortality among fully vaccinated babies is significantly low as

compared to non-vaccinated babies (Budu et al., 2020), it suggests that newborn vaccination is vital in attaining the Sustainable Development Goal (SDG) 3 which seeks to reduce global neonatal mortality to at least 12 per 1000 live births (Bobo et al., 2022). As launched in 2021, the Immunization Agenda 2030 aims to increase vaccine equity and improve vaccine accessibility worldwide (Dimitrova et al., 2023). The agenda's primary goals are to cut the percentage of children who are completely unvaccinated by 50% and to get at least 90% coverage of necessary childhood immunizations across all nations (Dimitrova et al., 2023). Reaching these objectives has necessitated a thorough comprehension of the children that have been neglected and the obstacles preventing them from obtaining life-saving vaccinations at birth (Dimitrova et al., 2023). Historically, the percentage of children who received all newborn antigens at birth has been a significant indicator of vaccination coverage. If a child has received the BCG vaccine, full doses of the polio vaccine, one dose of the DTP-containing vaccine, and one dose of the measles vaccine, they are deemed completely immunized against all basic antigens (GSS GHS and ICF, 2023).

Although vaccination services have improved in sub-Saharan Africa over the past few decades, many nations still have low rates of basic childhood immunization coverage (Bobo et al., 2022). Most of these nations are either having difficulty reaching the most disadvantaged part of their populations or are failing to achieve the required coverage altogether (Bobo et al., 2022). Meanwhile, one of the main objectives of the Sustainable Development Goals (SDGs) is to guarantee that every child has fair access to immunization services (Bobo et al., 2022).

In Ghana, the EPI schedule recommends that vaccinations against polio is given at birth (OPV0), 6 weeks (OPV1), 10 weeks (OPV2) and 14 weeks (OPV3), whereas the BCG vaccine is preferably administered at birth or on any initial visit to the clinic before the age of twelve months (Baguune et al., 2017; GSS GHS & ICF, 2023). This indicates that the OPV0 vaccine is given only up to two weeks of child's life whilst BCG vaccine is given up to one year of age (Baguune et al., 2017). The Hepatitis B vaccine is not routinely given to all newborns in Ghana unless exposed babies (Baguune et al., 2017). OPV coverage is determined by the number of children who have finished the third dose (Bassoum et al., 2022).

According to the 2022 Ghana Demographic and health Survey report, the percentage of children age 12–23 months who have been fully vaccinated against all basic antigens increased from 19% in 1988, peaked at 79% in 2008, declined slightly to 77% in 2014, and to 73% in 2022 (GSS GHS and ICF, 2023). This suggests that Ghana's vaccination program may still be facing some challenges despite significant improvement (GSS GHS & ICF, 2023). Ensuring access to newborn vaccine of OPV0 is therefore an important indicator for immunization success in Ghana and achieving sustainable development goal 3 as well as universal health coverage; but full immunization coverage is still a challenge (GSS GHS and ICF, 2023). It is known that majority of research on immunization conducted in Ghana have mainly focused on questions that correlated a specific vaccination type with acceptance rate or were carried out in specific Ghanaian

locations rather than the Ahafo Region (Budu et al., 2020). Meanwhile, findings from the 2022 demographic and health survey report showed that the Ahafo Region recorded OPV0 coverage of 68.2% being among the low performing regions in Ghana (GSS GHS and ICF, 2023). Additionally, report from the District Health Information Management System (DHIMS 2) further revealed that there has consistently been significant inequalities between the BCG and OPV0 coverage in the Ahafo region; although both vaccines are being administered routinely at birth as per EPI schedule (DHIMS2, 2024). It has been found that; the OPV0 coverage has mostly been lower than the national target of 95% as compared to BCG (DHIMS2, 2024). This means that significant proportion of newborns are missing out on oral polio vaccine at birth in the Ahafo Region and this could put the children at risk of contracting poliomyelitis.

In order to close this gap and specifically add to the conversation on oral polio birth dose vaccination, the current study sought to analyze the factors affecting vaccination coverage against polio at birth among children under 5 years in Ahafo Region of Ghana using secondary data from 2019 – 2023. The results of a regional study of this kind could strengthen current systems to increase newborn immunization rates in Ghana in order to lower and eradicate vaccine preventable diseases specifically poliomyelitis and its associated mortalities.

Practical Significance

The findings from this study serve as a form of health system evaluation with regards to oral polio vaccination at birth in the Ahafo region of Ghana. It provides practical information to help inform the Ministry of Health, Regional and District Directors of Health Services about the specific factors affecting OPV0 coverage to help them in their planning, monitoring and allocation of resources such as targeted neonatal intensive care unit follow-ups to improve immunization for babies who were admitted as well as allocating resources to establish mobile vaccination clinics. Furthermore, the study will help reveal the proportion of newborns missing out on oral polio vaccine to help provide an insight into the success of newborn vaccine implementation and suggest early signals about issues regarding herd immunity with an ultimate goal of improving oral polio vaccine coverage among newborns.

Scientific/Policy Contributions

This study suggests the need for policy makers and stakeholders to strengthen the community based health planning and services (CHPs) concept to improve oral polio vaccine coverage at birth towards achieving Universal Health Coverage and the Sustainable Development Goals by the year 2030.

Additionally, as the world is striving to end poliomyelitis, findings from this study will help suggest Ghana's status towards achieving certification as a polio free country since certification depends mainly on high OPV0 coverage of > 90%, absence of wild poliovirus for at least 3 consecutive years as certified by WHO with active AFP surveillance and adequate testing.

The data will also reveal a trend analysis of oral polio vaccine coverage and the associated factors affecting the coverage which will help inform policy and serve as relevant source of information for future studies in the academic industry.

METHODS

Data used for the study was solely from all the six districts in the Ahafo Region of Ghana considering data from both rural and urban settlements. The Ahafo Region is one of the six (6) new regions established in 2018 after being carved from the old Brong Ahafo Region (Ahafo Regional Coordinating Council, 2021). The region is located in Ghana's southwestern part and forms boundaries with the Bono Region to the north and western part, the Ashanti Region to the north and eastern part, and the Western North Region to the south (Ahafo Regional Coordinating Council, 2021). The region's total land area is 5,193 km2 (2,005 sq. miles) with six (6) administrative districts in the Region comprising of Tano North, Tano South, Asunafo North, Asunafo South, Asutifi North, and Asutifi South (Ahafo Regional Coordinating Council, 2021). Report from the Ghana Statistical Service indicate that there were 564,668 people living in the Ahafo Region as of the 2021 Population and Housing Census, which was about 2% of Ghana's total population with an estimated 77,598 children under five years (Iverson & Dervan, 2021). The administrative pinnacle in the provision of health services in the region is represented by the Regional Health Directorate (RHD) (Ghana Health Service, 2023). The RHD is responsible for coordinating, planning and implementation of health policies and programmes in the region as well as policy dissemination, supportive supervision and capacity-building for district health directorates and health facilities (Ghana Health Service, 2023). Similar to other regions in Ghana, health services in the region are decentralized to the district and sub-district levels allowing for more localized decision making. Vaccination activities in the region are delivered through the Expanded Program on Immunization (EPI) and utilises the cold chain system to maintain vaccine potency through refrigeration and transportation (Ghana Health Service, 2023). Community and Public health nurses in the region support vaccination efforts and deliver vaccines to hard-to-reach areas. In relation to immunization activities, the region operates under six District Health Directorates and 27 Sub-districts with a total of 96 health facilities comprising 13 Hospitals (6 Government, 2 CHAG, 4 private and 1 Islamic), 7 private Maternity Homes, 22 Health Centres, 18 Clinics, 160 demarcated CHPS zones, 143 functional CHPS zones and 45 CHPS compounds (Ghana Health Service, 2023).

A descriptive retrospective cross-sectional study design was employed by the researcher for this study using secondary data from Ghana Health Service (GHS) District Health Information Management System 2 (DHIMS 2) and regional AFP surveillance case-based database for the period of 2019-2023. The period of 2019 – 2023 was considered appropriate for this study since 2019 was the year the region was carved from the old Brong Ahafo Region and solely responsible for managing their administrative issues hence accurate data was available for the study to cover the stipulated period, reducing the impact of missing or incomplete

data. Additionally, the period coincided with the implementation of targeted policies such as Maternal, Child health and Nutrition Program (MCHNP) which were geared towards improving CHPs activities in the country and therefore the chosen period will indirectly help to assess their effectiveness. Therefore, only quantitative research approach was used for the study. Both descriptive and correlational research design were used since the numerical data were described accurately and systematically using frequencies and trends to obtain better understanding about the situation. McCombes (2023) mentioned that when the research aims to identify characteristics, frequencies and trends, then a descriptive approach is an appropriate choice. A retrospective approach was also appropriate since the intent was to look back in time to study DHIMS 2 data from 2019 - 2023.

The study population comprised of 109,070 vaccination records of all children under five (5) years of age in the Ahafo Region of Ghana. Secondary data from DHIMS 2 and regional AFP surveillance case-based database from 2019-2023 were reviewed to determine the OPV0 coverage and AFP reporting rate among children under 5 years in the Ahafo Region of Ghana.

The sampling technique for this study was the census approach. Khalifa (2020) mentioned that sampling is the method of choosing a representative subset of the population to be studied with each participant having equal chance of being selected into the study. She added that with small populations or situations where the entire population will be studied, there is no need for calculating a sample (Khalifa, 2020). The census strategy was therefore applicable in this study since the researcher aimed to obtain information from all healthcare facilities in Ahafo Region that reported in DHIMS 2 from 2019-2023 to best describe the regional performance in relation to the study variables. The District Health Information Management System 2 (DHIMS-2) is the database for capturing, storing and analyzing healthcare data in Ghana (Gbenga et al., 2014).

Data for the study was extracted from the Ghana Health Service (GHS)-EPI data capturing form in DHIMS 2 and the AFP surveillance case-based form. Therefore, 109,070 immunization records from DHIMS 2 and regional AFP surveillance case-based database from 2019-2023 were analysed for this study (DHIMS2, 2024). The assistance of a health information officer at the Ahafo Regional Health Directorate was employed in extracting the data based on the specific objectives of the study such as determining the influence of improving vaccine accessibility on OPV0 coverage, identifying newborn related factors affecting OPV0 coverage as well as OPV0 dosing coverage from 2019-2023.

DATA ANALYSIS

Since the main dependent variable (OPV0 coverage) and the other independent variables were quantitative in nature, data was processed and analyzed using correlation, trend and projection analysis. The correlation analysis was used to evaluate the strength and direction of the linear relationship between the variables. This analysis helps in understanding whether, and to what extent, variables are related. The result of a

correlation analysis is usually represented by a correlation coefficient, (r) which ranges from -1 to +1. Correlation coefficient reported in this analysis was Pearson's correlation coefficient. The trend and projection analysis on the other hand was used to identify the pattern of the data over time and forecast future values based on historical data. The trend and projection analysis are essential techniques in statistical and data analysis used to identify patterns over time and forecast future values based on historical data (Profillidis & Botzoris, George, 2019). Therefore, after obtaining the raw data, it was organized into spreadsheet format and exported into STATA 17 windows version statistical software for analysis.

Data was cleaned by checking for and handling any missing values or outliers, as these can distort the results. Since the missing values and outliers were few, they were handled by means of Listwise deletion where any cases that contained the missing values or outliers were removed and only complete dataset were analysed but this did not have any significant effect on the number of records being analysed. Scatter plots were generated to visually inspect the relationship between the main outcome and related variables. The data visualization helped to assess the potential linearity and direction of the relationship. The associated p-values were reported to indicate statistical significance at $p < 0.05$. However, it is crucial to remember the limitations of this analytic approach (Correlation does not imply causation. It only indicates the strength and direction of a relationship) and its use for broader analytical decisions. To do the trend analysis, the collected data was organized chronologically in a spreadsheet and checked for any missing values, outliers, or inconsistencies that could skew the analysis which were handled by means of Listwise deletion.

Time series plot was created to visualize the data and identify for any obvious trends or patterns. The x-axis represented time, and the y-axis represented the OPV0 coverage and AFP reporting status. Based on the outcome variable and to provide a clear interpretable estimate of the vaccination trend, linear trend model was selected as suitable. The fitted model was used to forecast the OPV0 coverage and AFP status for the next six (6) years i.e 2030 with the assumption that trend in the data will remain constant over time. The key limitation of trend analysis is the fact that it is based on historical data and may not account for future changes or unexpected events; and projections are therefore inherently uncertain and should be interpreted with caution.

There was no conflict of interest in this study as the researcher did not intend to derive personal benefits from this study except using it for academic purposes. Also, no institution or organization sponsored the research work for gains. The principal investigators were the sole source of funding for the study.

The study was carried out following ethical principles involved in research. Ethical consideration involves carrying out the study to protect the rights and freedoms of study participants, data collected as well as contributing to positive research outcomes (Bhandari, 2023). To ensure that these principles were upheld, the following considerations were adopted: Ethical approval for the study was obtained from the Ghana

Health Service Ethics Review Committee (GHS-ERC) following an introductory letter from the Catholic University of Ghana. Also, permission was sought from the Ahafo Regional Health Directorate before data collection began. The researchers ensured that the research was conducted in accordance with accepted principles of ethics in research practice. However, since the study was solely focused on secondary data and no human subject was involved, participant's informed consent was not applicable. Bhandari (2023) mentioned that participant's informed consent is used in studies that involve engagement with human subjects. The ethical approval number is GHS-ERC: 075/05/24.

Due to the retrospective nature of the study, the researchers had limited control over data quality since information from secondary data source was utilized for the study. However, data was extracted from a reliable data source (DHIMS 2 and AFP surveillance case-based form) hence the outcome of this study was valid and can be a reliable source of information for decision making.

RESULTS

The results indicate findings from all the six districts in the Ahafo Region of Ghana and presented based on the key specific objectives of the study:

Number of babies receiving OPV0 at birth from 2019-2023

Table 1 and chart 1 below illustrate the number of babies receiving the Oral Polio Vaccine zero dose (OPV0) at birth across the study districts in the Ahafo Region from 2019 to 2023. There was a general declining trend in the number of babies receiving OPV0 from 2019 to 2020 across most districts (i.e. Asunafo North, Asutifi South, and Tano North districts) likely due to the impact of covid-19 pandemic. However, the period of 2021 onwards began to experience a slight increase in coverage. Over the years, Asunafo North had its highest OPV0 coverage (113.8%) in 2019 with the least coverage of 55.7% in 2022. Among the six districts in the Ahafo Region, Asutifi South recorded the highest dose coverage throughout the period of 2019- 2023 covering a percentage of 153.8 in 2021. The vast highest coverage for Asutifi South was likely due to the underestimation of the population denominator that was given for the year as well as unique district specific interventions, and that equally explains why some districts were recording more than 100% coverages. The district with the lowest coverage throughout the period was Tano South district; recording 44.2% in 2020. The regional highest performance in coverage was in 2021 with 101.6% coverage and the least performance of 76.6% in 2020 possibly due to the impact of the covid-19 pandemic. Overall, the number of babies receiving OPV0 at birth in the Ahafo Region saw a declining trend from 2020- 2023 as compared to 2019.

Table 1: Number of babies receiving OPV0 at birth from 2019 – 2023

District	Year 2019		Year 2020		Year 2021		Year 2022		Year 2023	
	Freq.	**Cov (%)**	**Freq**	**Cov (%)**	**Freq**	**Cov (%)**	**Freq**	**Cov (%)**	**Freq**	**Cov (%)**
Asunafo North	7022	113.8	5309	84.1	4605	76.6	3414	55.7	5071	**90.0**
Asunafo South	4564	97.4	4694	98.0	4855	132.4	4289	114.5	3987	**104.3**
Asutifi North	1689	64.2	1744	64.9	2066	70.2	2228	74.2	2308	**75.3**
Asutifi South	4272	118.2	4025	94.5	4210	153.8	3423	122.6	2796	**98.0**
Tano North	3645	91.1	3327	81.3	3854	102.9	3490	91.3	3597	**92.2**
Tano South	3139	60.9	2929	44.2	3362	96.4	2504	70.3	2652	**72.9**
Total (Ahafo)	**24331**	**92.7**	**22028**	**76.6**	**22952**	**101.6**	**19348**	**83.9**	**20411**	**86.7**

Source: Ahafo Regional Health Directorate DHIMS 2 Report, 2024

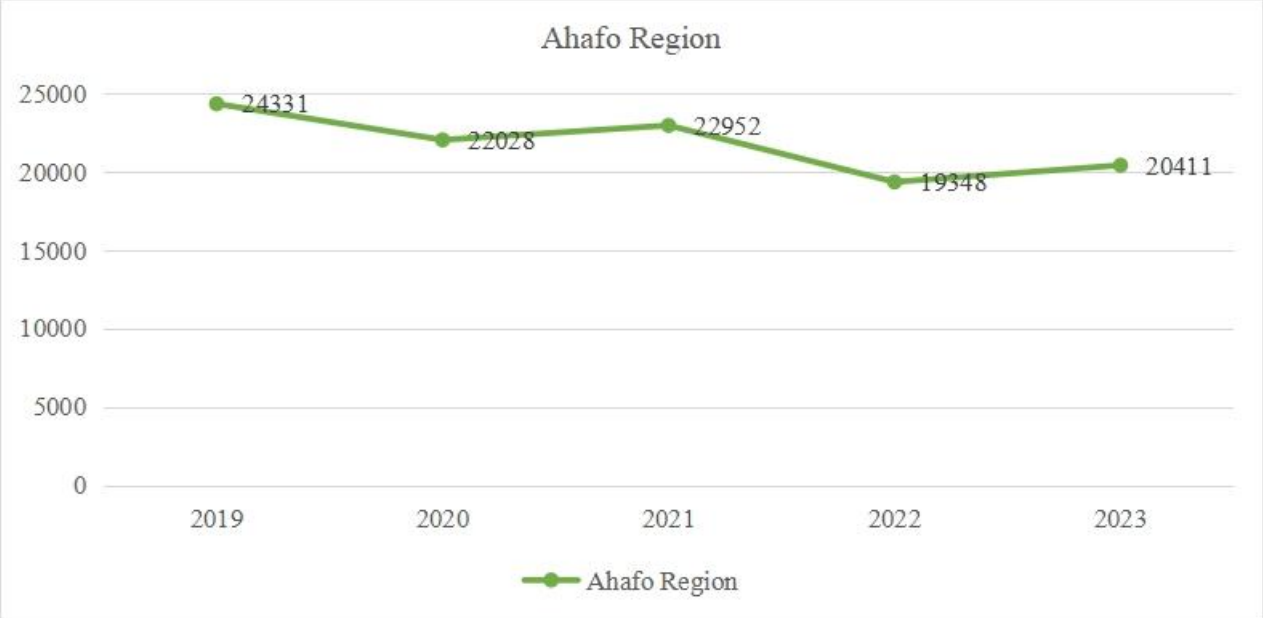

Figure 1: Ahafo Regional Trend of number of babies receiving OPV0 at birth from 2019 – 2023

REGIONAL TREND OF OPV0 COVERAGE

Accessibility factors associated with OPV0 coverage

The data in table 2 below captures correlation coefficients for various health facility variables in the Ahafo Region related to OPV0 coverage. Variables (i.e. Number of hospitals in the Region) whose values remained constant over the years had no impact on the outcome variable and were therefore excluded from the analysis. This means that such variables had no significant effect on the outcome variable. An increase in the number of vaccination posts indicates a moderate positive linear relationship, (r = 0.382) between the number of vaccination posts and the outcome variable. The association was however not statistically significant (p = 0.525). Number of cold chain facilities had a weak negative correlation coefficient (r = -0.121) and a high p-value (p = 0.846) indicating a weak association between the variables and poses the assumption that the observed correlation is likely due to chance. Facilities in rural areas showed a weak positive linear relationship, (r = 0.297) with OPV0 coverage. Similar results were observed in those located in urban settings.

Facilities owned by Government indicate a weak positive linear relationship, (r = 0.258) which was not statistically significant, (p = 0.675). Facilities that are privately owned showed similar associations with no statistical significance (r = 0.448, p = 0.449). Facility-level association with OPV0 coverage was also assessed. Increase in the number of CHPs compound indicates a moderate positive linear relationship, (r = 0.373) but not statistically significant (p = 0.537). Increase in the number of clinics also indicated a very weak positive linear relationship with no statistical significance, (r = 0.131, p = 0.834).

Table 2: OPV0 accessibility factors

Variable	Correlation Coefficient, (r)	p-value
Vaccine related		
Number of vaccination posts	0.382	0.525
Number of cold chain facilities	-0.121	0.846
Location of facility		
Rural	0.297	0.627
Urban	0.324	0.595
Number of Facility ownership		
Government	0.258	0.675
Private	0.448	0.449
Facility level		
CHPs Compound	0.373	0.537

Clinics	0.131	0.834

Source: Ahafo Regional Health Directorate DHIMS 2 Report, 2024

Newborn-related factors associated with OPV0 Coverage

Table 3 contains child-related information and its level of association with birth dose of Oral Polio Vaccine Coverage. The study showed a strong positive linear relationship (r = 0.759) between child's birth weight < 2.5 kg and OPV0 Coverage even though the correlation was not statistically significant (p = 0.137). Children with birth weight ≥ 2.5 kg showed a very weak negative linear relationship (r = -0.128) which was also not statistically significant, (p = 0.837). There is no evidence to suggest a meaningful relationship between birth weight ≥ 2.5 kg and the OPV0 dose. With regards to newborn admissions, data was segregated into those insured and those not insured. For females that were not insured, there was a very weak positive linear relationship **(**r = 0.161) between child admissions and the OPV0 coverage with no statistical significance, **(**p = 0.966). The relationship between boys' admission and OPV0 coverage was an almost negligible positive linear relationship (r = 0.026). For girls who were insured, a moderate positive linear relationship (r = 0.587) was observed between admissions and the OPV0 coverage which was not statistically significant. Similar relationship was observed for boys who were insured, (r =0.683) despite the lack of statistical significance (p = 0.204).

Table 3: Newborn-related data associated with OPV0 coverage

Variable	Correlation coefficient, (r)	p-value
Birth weight		
< 2.5kg	0.759	0.137
≥ 2.5	-0.128	0.837
Admissions		
Female Non insured	0.161	0.796
Male Noninsured	0.026	0.966
Female insured	0.587	0.297
Male insured	0.566	0.319
Total	0.683	0.204

Source: Ahafo Regional Health Directorate DHIMS 2 Report, 2024

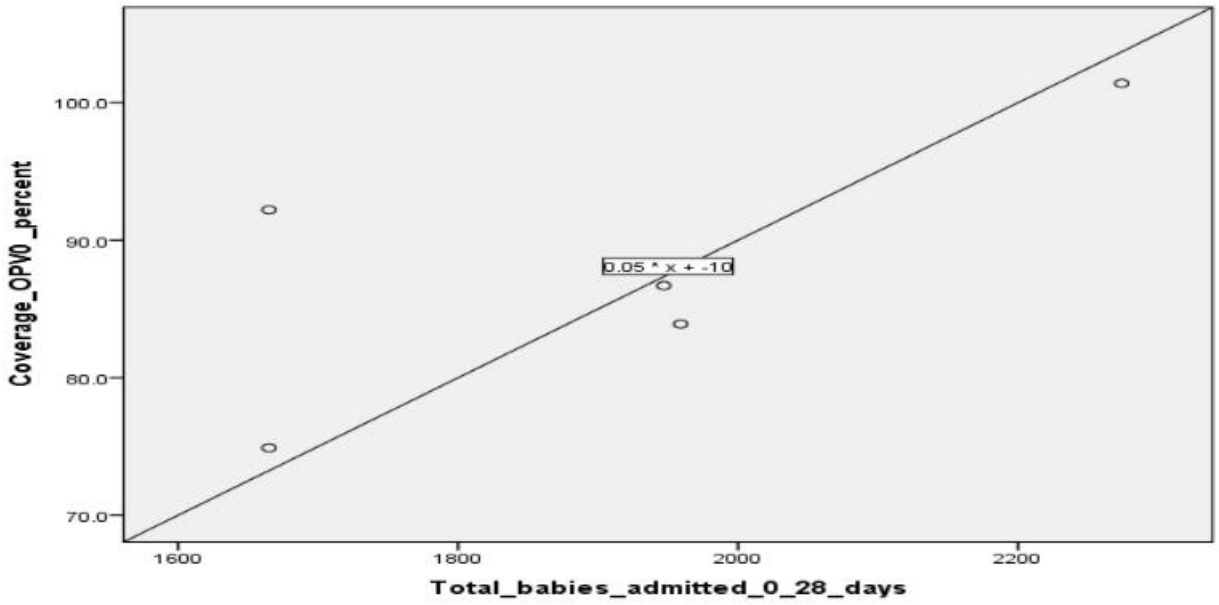

Figure 2: Scatter diagram showing relationship between total newborn admissions and OPV0 coverage

Newborn related factors: Association between Newborn's Order of birth and OPV0 coverage from 2019-2023

The data presented in Table 4 includes the correlation analysis of OPV0 coverage with birth order. First born children showed a correlation coefficient very close to 0, (-0.025) indicating a very weak negative linear relationship between first born babies and OPV0 dose. The p-value of (0.969) is very high, indicating that the correlation is not statistically significant. There is no evidence to suggest a meaningful relationship between first borns and OPV0 dose. Second and third borns also indicate a strong negative linear relationship (r = -0.776) which is not statistically significant, (p = 0.125) There was a weak negative linear relationship between 4 or more birth orders and OPV0 dose and was not statistically significant (p = 0.745). All the birth orders show p-values greater than 0.05, indicating that none of the observed correlations are statistically significant. Therefore, there is no strong evidence to suggest that birth order of the newborn has a significant linear relationship with OPV0 coverage. The results is shown in the table below:

Table 4: Birth order and OPV0 coverage

Variable	Correlation coefficient, (r)	p-value
Birth Order		
First	-0.025	0.969
Second and Third	-0.776	0.125
Fourth or more	-0.201	0.745

Source: Ahafo Regional Health Directorate DHIMS 2 Report, 2024

Forecasting the trend in birth dose of Oral Polio Coverage and rate of Acute Flaccid Paralysis among children under 5 years

The data presented in table 5 below includes the percentage coverage of the Oral Polio Vaccine zero dose (OPV0) and the total number of Acute Flaccid Paralysis (AFP) cases reported each year from 2019 to 2023 in the Ahafo Region of Ghana. In the year 2019, the coverage of OPV0 was 92.2%, indicating a high level of OPV0 administration but there was a significant drop in coverage to 74.9% in 2020. The year 2021 saw the highest coverage of 101.4%, suggesting a catch-up effect where more children were vaccinated. Coverage decreased slightly to 83.9%in 2022, still higher than 2020 but not as high as 2019.

With regards to cases of AFP, there were 16 AFP cases reported in 2019. The number of AFP cases slightly increased to 17 in 2020, despite the drop in OPV0 coverage in the same year. The cases then rose to 21, correlating with the increased vaccination coverage of 101.4% in 2021. The cases again decreased to 19, in the year 2022 which aligns with improved but not optimal OPV0 coverage. In the year 2023, AFP cases increased to 21, despite a higher OPV0 coverage as compared to 2022. The Ahafo Region also recorded one (1) positive poliomyelitis case in 2019. However, the number of positive cases remained zero (0) during the period of 2020- 2023.

Table 5: OPV0 coverage and the total number of Acute Flaccid Paralysis (AFP) in the Ahafo Region

Year	OPV0 coverage (%)	Total AFP cases	Total Positive
2019	92.2	16	1
2020	74.9	17	0
2021	101.4	21	0
2022	83.9	19	0
2023	86.7	21	0

Source: Ahafo Regional Health Directorate AFP case based Reporting form & DHIMS II, 2024

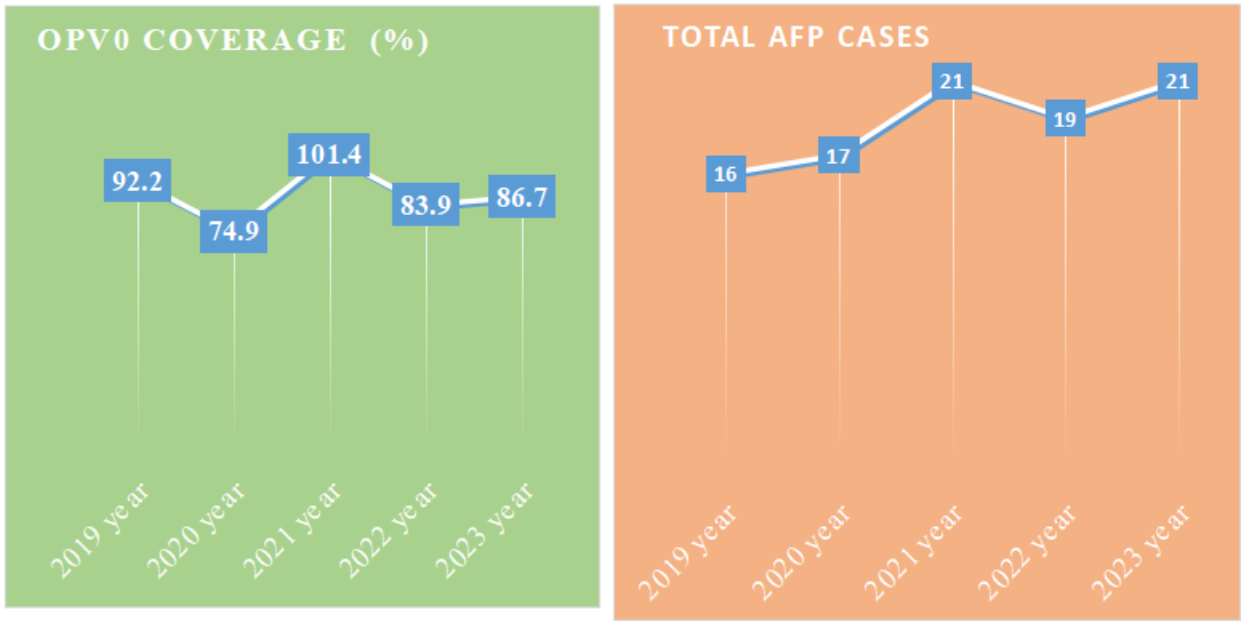

Figure 3: Ahafo Regional Trends in OPV0 coverage and AFP reporting rate among children under 5 years

Projecting the OPV0 coverage and AFP status in the region by the year 2030

Figure 4 below illustrates the projection of OPV0 coverage and AFP reporting status by the year 2030. It is estimated that OPV0 coverage will be about 84.1% if nothing is changed in the current dosage rate. This indicates a 2.6% drop from the 2023 coverage of 86.7%. On the other hand, the total Acute Flaccid Paralysis (AFP) case count will also increase from the current 21 cases to 30 by the year 2030 if the current rate is maintained. This trend is shown in the figure below:

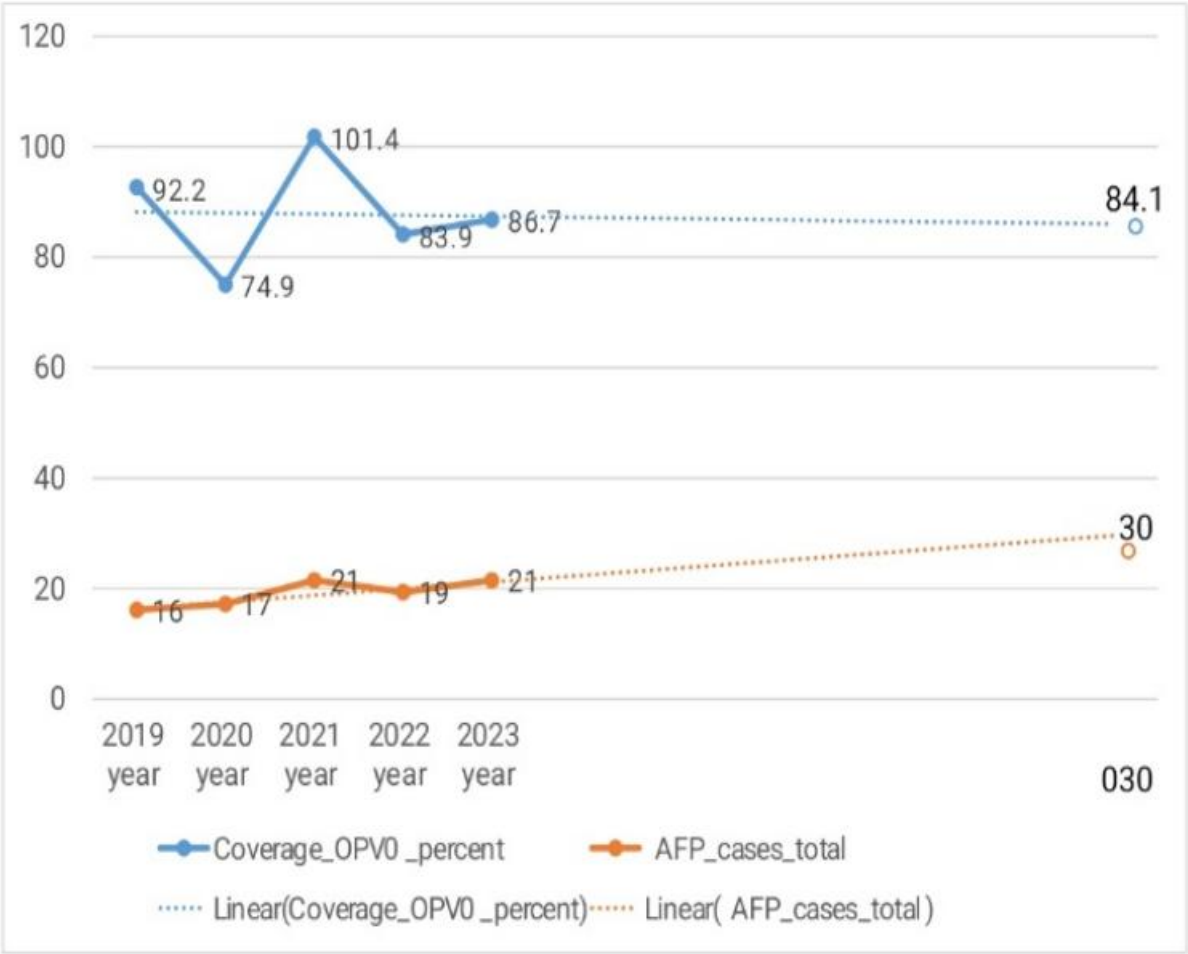

Figure 4: Projection of OPV0 coverage and AFP cases from the current figures up to the year 2030

DISCUSSION

Association between improving vaccine accessibility on birth dose of oral polio vaccine coverage

The analysis of this study found weak to moderate positive correlations between various health facility variables and birth dose of oral polio vaccine coverage, but none were statistically significant. All the p-values for the accessibility variables were greater than 0.05, indicating that none of the observed correlations were statistically significant. This suggests there was no strong evidence to suggest meaningful associations between these accessibility variables (such as number of vaccination posts, number of cold chain facilities, location of facility, ownership and prescription level of facility) and the OPV0 coverage. These findings do not support the argument of Bobo and his colleagues who found that in Sub-Saharan Africa, low vaccination coverage was associated with rural location of communities (Bobo et al., 2022).

Similarly, the findings from the present study deviate from the situation in Democratic Republic of Congo

where timely uptake of neonatal immunizations was positively correlated with visits to private, non-religious institutions as opposed to religious facilities (Boisson-Walsh et al., 2023). It is significant to note that correlation does not imply causation and therefore other factors such as maternal knowledge on newborn immunization and socioeconomic status may be driving both accessibility and OPV0 coverage, masking the true relationship despite being statistically insignificant. For instance, in Ghana, timely uptake of OPV0 is within 14 days after birth. After this period, the birth dose is not given to the newborn. Therefore, low socio-economic status of the mother may make it difficult to report within the scheduled period to receive the vaccine especially if the mother does not understand the benefits of the vaccine. Additionally, the scheduling of newborns to receive birth dose vaccines on only some specific days in the week as done in most health institutions may negatively affect vaccination coverage despite an increase in vaccine accessibility.

Most caretakers may not be able to satisfy the required appointment date because of several unforeseen factors and may only show up after 2 weeks of delivery; by which time the duration of administering the birth dose of Oral Polio Vaccine might have elapsed. Despite the aforementioned disparities with literature, this study is in tandem with the situation in Afghanistan; where it was found that increase in the number of health institutions offering immunization service did not have any significant association on vaccination coverage (Aalemi et al., 2020). This suggests that other factors or interventions must be considered when putting in measures to improve oral polio vaccine coverage at birth.

Additionally, although some variables, such as number of private facilities and number of vaccination posts showed moderate correlation coefficients, the lack of statistical significance implies these results should be analyzed with vigilance. The moderate and null-significant correlations suggest a need for more comprehensive studies with larger sample sizes or more refined data collection methods to determine if these relationships actually exist. Investigating potential confounding variables and employing different statistical methods could also yield more insightful results.

Also, in reality, the increase in number of cold chain facilities in the region should have caused a direct positive relationship with OPV0 coverage, but the negative correlation coefficient ($r = -0.021$) as found in this study indicates that further research with larger datasets or more sophisticated methodologies may help to clarify these relationships. The current situation can be attributed to situational factors such as improper, rude, or violent treatment of mothers by medical professionals as well as long waiting times at child welfare clinics resulting in a decrease in the number of people receiving vaccinations despite an attempt to increase the number of cold chain facilities.

According to current structural reviews of the literature, women who forgot to bring their kid's immunization cards, missed an appointment, or had a dirty or improperly dressed child were reprimanded

by health professionals (Bobo et al., 2022). Therefore, mothers who may feel humiliated as a result of this provider abuse may be discouraged from vaccinating their children irrespective of increasing number of cold chain facilities. On the other hand, the Carol Weiss theory of change model stipulates that, if something is done for or about a program or event, then something should change or happen (Bolton, 2022).

This proposes how activities towards improving vaccination coverage such as increasing accessibility to oral polio vaccines at birth will contribute to increasing OPV0 coverage. Therefore, the lack of strong evidence to suggest meaningful associations between these accessibility variables and OPV0 coverage may be as a result of the fact that there has not been significant input in these accessibility indicators to necessitate an association within the study period. Moreover, this study found a weak positive relationship between number of CHPS compounds and immunization coverage and with an associated non-significant relationship. The Community-Based Health planning and Services (CHPS) concept is a community-based approach to healthcare delivery.

Evidence shows that the Ghana's health system has been built on the fundamental healthcare model where the Community level (CHPS) is set up to provide services in close proximity to the community's residents (Yeboah et al., 2019). This means that the CHPS concept seeks to provide close-to-client health services, which include house-to-house visits for preventative and promotional services such as vaccinations, and clinical care for minor illnesses (Yeboah et al., 2019).

Therefore, despite the non-significance in its relationship with vaccination coverage as shown in this study, the CHPS concept is still considered important in improving immunization coverage. Over the years, the CHPS concept has helped to bring healthcare services closer to communities, reducing barriers to access and improving vaccination rates. The concept has also promoted community involvement in healthcare which has increased some form of awareness and demand for immunization services. Additionally, it is a fact that CHPS has fostered trust between healthcare providers and communities leading to stronger partnerships and improved health outcomes by tailoring interventions to address specific community needs and challenges. This suggests that while the study findings may not demonstrate any statistically significant correlation, the CHPS concepts remains valuable in enhancing immunization coverage through community-centeredness and context-specific strategies.

Newborn related factors affecting birth dose of oral polio vaccine coverage.

In analyzing the newborn related factors that may affect birth dose of oral polio vaccine coverage in the Ahafo region of Ghana, all the variables such as baby's birth weight ($p = 0.137$), admission to a newborn care unit ($p = 0.204$) and birth order of the baby showed p-values greater than 0.05, signifying that none of

the detected correlations were statistically vital. The findings from this study therefore disagree with the situation in an Indian community where having newborns admitted to a sick neonatal care unit showed significant statistical association (p-value <0.05) for not getting birth dose vaccinations (Verma & Kadyan, 2022).

Also, there was no evidence to suggest that birth order has a significant linear relationship or association with OPV0 coverage since the current study found negative correlation coefficient and p value > 0.05 in relation to these variables. The study corroborates with a similar study conducted in Hong Kong where there was a negative linear correlation between the order of birth and completion of newborn vaccination (Huang et al., 2023). The negative correlation means that, as birth order increases (i.e higher sibling number), the outcome (OPV0 coverage) tends to decrease. This explains that parents may be less likely to prioritize vaccinations for later-born children as resource or attention may decrease with each additional sibling. Therefore, the impression created by Huang and colleagues in their study that third-born children had considerably lower vaccination rates than first-born children (Huang et al., 2023), somehow supports the findings from this study. However, further research with more robust data may help to clarify these relationships.

Furthermore, the study found no relationship between baby's birth weight and OPV0 coverage. This means that baby's with birth weight either greater or less than 2.5Kg had no significant impact on OPV0 coverage. This is in contrast to the study by Verrier et al (2023) who found that in Senegal, Madagascar and Cambodia, low birth weight (< 2500g) was positively linked to not receiving birth dose vaccinations accounting for lower coverage in newborn vaccine coverage as compared to World Health Organization recommendations.

Also, whilst it is expected that stable babies with birth weight greater than 2.5Kg receive their birth dose vaccines to protect them from vaccine preventable diseases, the findings from this study however suggests a weak negative correlation (- 0.128) between high birth weight and vaccination coverage. This means that there is a slight tendency for stable babies with birth weights more than 2.5kg to have lower vaccination coverage, but such relationship is very weak. The observed correlation may arise from limited knowledge about the importance of birth dose vaccines or raised concerns about vaccine safety in newborns since this may cause healthcare providers and caregivers to delay or decline vaccination. Additionally, the high p-value (0.837) may indicate that the observed correlation is likely as a result of other factors instead of a genuine relationship between birth weight and vaccination coverage. Base on the current study findings, it may therefore be argued that newborn- related factors may not be the basic drivers of birth dose of OPV coverage.

However, other factors, such as health system factors or socioeconomic factors and maternal characteristics,

may truly play a more significant role in influencing coverage. For instance, the Andersen's behavioural model for health service utilization specified that, vaccination coverage may be influenced by Predisposing factors, Enabling factors and Need factors (Goldstein et al., 2015). The predisposing factors are those aspects of the newborn's socio-cultural makeup and characteristics of the parents or significant others such as education, occupation, ethnicity, social networks, interpersonal relationships, and culture make up the parents or caretakers which may affect how the newborn will receive vaccinations (Goldstein et al., 2015).

Also Andersen hypothesized that, the practical aspects of the newborn being vaccinated is termed as the enabling factors which are inspired by family factors such as the quality and caliber of social relationships, financial status, uphold systems and the ability to obtain immunization services (Goldstein et al., 2015). Community factors such as waiting times at vaccination centers, amenities and medical staff that are available for the immunization exercise are all enabling factors to assessing immunization services (Goldstein et al., 2015). The need factors on the other hand give rise to the need for immunization services for newborns; ranging from people's perceptions of their own general health and functional state, as well as how they perceive symptoms of illness, pain and whether or not they believe that their babies are susceptible to vaccine preventable diseases (Goldstein et al., 2015). This suggests that the study is also in line with the findings from Ethiopia where a group of researchers identified that issues such as low income level, unease with immunization service, and fear of adverse result limit polio vaccination in addition to limited access to health services (Gebremedhin et al., 2023).

Although some variables, such as birth weight < 2.5 kg and total babies admitted, showed stronger correlation coefficients, the lack of statistical significance means these relationships should be interpreted with caution. For instance, the study found moderate positive relationship between newborn admissions and vaccination coverage indicating that, the increase in newborn admissions tend to increase vaccination coverage. However, the p-value (0.204) indicates that this relationship is not statistically significant. Despite this non-significance, the relationship suggests increase in newborn admissions may indicate increased healthcare utilization, which can lead to increased opportunities for vaccination since mothers may like to protect their babies against future diseases.

This study highlights the need for additional studies with larger sample sizes or more comprehensive data collection methods to determine if there are indeed significant relationships between these variables and the OPV0 coverage. It might also be beneficial to explore non-linear relationships or other potential confounding variables that could influence these results. This emphasize the importance of exploring multiple factors beyond newborn related characteristics when it comes to improving OPV0 coverage.

Forecasting the trend of oral polio vaccine coverage at birth and status of Acute Flaccid Paralysis (AFP) among children under 5 years by the year 2030.

Evidence suggests that early protection of children against poliomyelitis is ensured by the administration of Oral Polio Vaccine (OPV) at birth since a protective immune response is elicited when OPV is administered to babies (Tesfaye et al., 2020). The data from this study further suggests that high OPV0 coverage is essential for controlling acute flaccid paralysis (AFP) cases. The study found that a reduction in OPV0 coverage in 2020 (74.9%) increased the number of accumulated AFP cases by 6.25 percent in the Ahafo region of Ghana within a period of one year. This means that in a particular year where there was low Oral Polio Vaccine coverage, the next calendar year saw an increase in the number of reported AFP cases putting babies at risk of poliomyelitis. This may also imply that an enhanced AFP surveillance system is necessary for tracking polio eradication efforts since it could suggest the need for an improved OPV coverage.

Nevertheless, the high number (n = 21) of AFP cases in 2021 and 2023 despite an increase in OPV0 coverage of 101.4 percent and 86.7 percent within the same periods respectively, indicate a successful catch-up strategies that were carried out during these periods coupled with an improved surveillance and reporting mechanisms. This is crucial for early detection and response to potential polio outbreaks. The number of AFP cases in 2021 and 2023, remaining high despite higher vaccination coverage may also suggest that factors other than OPV0 coverage might influence AFP incidence and broader studies are crucial to establish these relationships. The situation in this study may also suggest that suboptimal AFP surveillance system raises the possibility of missed chances and puts the region at danger of polio transmission.

Interestingly, despite the trend in OPV0 coverage and number of AFP cases during the period, there has not been increase relationship on the number of positive AFP cases in the Ahafo region since only one positive case was recorded in 2019 with the number of positive cases remaining zero throughout the remaining years. This may suggest the effectiveness of oral polio vaccine in preventing polio among children. This study found that since a significant proportion of the target population are being immunized against polio, it has helped to halt the spread of the virus by reducing the number of positive cases. However, the positive case reported in 2019 suggests that robust measures are required to completely eradicate poliomyelitis in Ghana.

On the other hand, AFP surveillance may detect cases that are not actually polio, but rather other causes of paralysis, leading to a significant number of reported AFP cases that are non-polio. This somehow agrees with the situation in Kenya where it was determined that despite a high number of AFP cases, none of the reported cases in Kenya showed positive test result for poliomyelitis (Tesfaye et al., 2020).

The decrease in OPV0 coverage in 2020 likely reflects the effect of the COVID-19 pandemic on routine

immunization services. Although recovery efforts in subsequent years showed positive trends in coverage, it indicates the need for well-structured health systems, comprehensive surveillance and timely immunization schedules. Outcomes from the recovery strategies post Covid-19 pandemic in 2021 suggests that strengthening routine immunization services and ensuring that all eligible children receive OPV0 on time are essential to maintain high coverage and prevent AFP positive cases.

Additionally, continued public health education and targeted campaigns are necessary to address gaps in immunization coverage and improve community acceptance and participation in vaccination programs. This is crucial because, in forecasting the OPV0 coverage and AFP status in the Ahafo region of Ghana by the year 2030, the current study found that OPV0 coverage will drop from 86.7 percent in 2023 to about 84.1 percent by the year 2030. On the other hand, AFP case report will rather increase from 21 in 2023 to an estimated thirty (30) cases by the year 2030 if the current dosage trend and reporting rate remain constant. The observed trend of drop in OPV0 coverage having a correlated increase in AFP cases coupled with the positive case reported in 2019 pose significant public health implications including the potential for polio outbreaks and the need for additional vaccination efforts. These reports align with the findings from a similar study conducted in Cameroon where an AFP post-response assessment revealed that the country was at a residual risk of increasing the number of AFP cases in the long term (Nkontchou et al., 2024).

The projected OPV0 coverage of 84.1% by the year 2030 is still below the national target of >95% for an established herd immunity for poliomyelitis. This means that the current performance with regards to OPV0 coverage in the Ahafo Region is projected to reduce further by 2.6% in 2030 if the current trend is maintained putting children at high risk of poliomyelitis. This is in tandem with similar exploration carried out by Gebremedhin and colleagues in Ethiopia where they revealed that children are still susceptible to contracting polio as long as poor vaccination rates exist in at-risk areas (Gebremedhin et al., 2023).

The data on OPV0 coverage across the districts suggest a need for targeted healthcare interventions, particularly in Asutifi North and Tano South districts to improve their coverage and reduce the number of babies missing out on oral polio vaccines at birth. This means that continuous monitoring and strategic planning activities are essential to sustain and enhance vaccine coverage. This is crucial because the study has revealed that some districts need to be assisted to address peculiar obstacles that may hinder equal access to vaccination services for marginalized or hard-to-reach groups within their specific districts.

The analysis of OPV0 coverage and the AFP situation in the Ahafo region of Ghana from 2019 to 2023; and the linear forecast reveals important trends and implications for public health strategies. While high vaccination coverage correlates with better control of AFP cases, the observed disparities in association highlight the need for robust studies using larger data sets to help understand the relationships and improve

AFP surveillance towards sustaining progress in polio eradication and preventing outbreaks.

CONCLUSION

The study investigated the factors affecting vaccination coverage against polio at birth among children under 5 years in Ahafo Region of Ghana from 2019 – 2023. The results displayed a positive linear correlation between the various variables, indicating that both accessibility and newborn related factors increased oral polio vaccination at birth. The study showed a strong positive linear relationship ($r = 0.759$) between child's birth weight < 2.5kg and OPV0 coverage but with a moderate positive linear relationship ($r = 0.382$) between the number vaccination centers and OPV0 coverage. However, despite the apparent correlations, the relationship were not statistically significant (P-value > 0.05). The lack of statistical significance may indicate that confounding variables, such as gender, health system factors or socioeconomic factors and maternal characteristics, may all play a more significant role in influencing birth dose of OPV coverage rather than accessibility or newborn related factors only. Furthermore, a projected decrease of 84.1% in oral polio vaccine coverage by the year 2030 means that the coverage will remain below the national target of 95% by the year 2030 making herd immunity unlikely if nothing is done about the current situation.

RECOMMENDATIONS

1. The World Health Organization and UNICEF should support the procurement of potent vaccines and ensure the availability of vaccines throughout the year. The Regional and District Health Directorates must also collaborate with local authorities to develop targeted vaccination programs and mop-up exercises to reach out to defaulters. By organizing mop-up exercises, it will help to reach out to missed-babies to close immunity gaps and reduce the risk of outbreaks.
2. The Ministry of Health and the Ghana Health Service should also rely on the existing CHPS concept to ensure successful immunization services to improve the situation of OPV0 coverage to prevent the projected reduction in coverage by 2030 in the quest of achieving Universal Health Coverage.
3. Health facilities should also abolish the practice of scheduling newborns for birth dose vaccines only on some specific days within the week. The current practice leads to increase in the number of defaulters since most parents will refuse to report within the recommended 2 weeks but may only show up for 40 days postnatal by which time OPV0 would have elapsed.
4. Furthermore, the current study focused mainly on secondary data and therefore considering the statistical insignificance of the p-values among the study variables, it is highly recommended that academic and research institutions should conduct further studies to explore the relationship between the accessibility factors, newborn factors and OPV0 coverage using primary data.
5. The study revealed that children with birth weight > 2.5kg has no strong relationship for receiving

OPV0 but in contrast, children with birth weight less than 2.5kg has a strong correlation for receiving OPV0. Therefore, further studies should also consider investigating into the contrasting relationship between birth weight and OPV0 coverage.

ACKNOWLEDGEMENT

The authors would like to acknowledge the efforts of the Regional Health Information Officer of the Ahafo Regional Health Directorate for his assistance in the retrieval of the secondary data for the study.

FUNDING

This research did not receive any specific funding.

REFERENCES

Aalemi, A. K., Shahpar, K., & Mubarak, M. Y. (2020). Factors influencing vaccination coverage among children age 12-23 months in Afghanistan: Analysis of the 2015 Demographic and Health Survey. *PLoS ONE*, *15*(8 August), 1–16. https://doi.org/10.1371/journal.pone.0236955

Ahafo Regional Coordinating Council. (2021). *Ahafo Regional Coordinating Annual Progress Report for the Year 2020*. https://ndpc.gov.gh/media/Ahafo_Region_APR_2020.pdf

Alhassan, R. K., Owusu-Agyei, S., Ansah, E. K., Gyapong, M., Ashinyo, A., Ashinyo, M. E., Nketiah-Amponsah, E., Akorli-Adzimah, E., & Ekpor, E. (2020). Trends and correlates of maternal, newborn and child health services utilization in primary healthcare facilities: An explorative ecological study using DHIMSII data from one district in the Volta region of Ghana. *BMC Pregnancy and Childbirth*, *20*(1), 1–15. https://doi.org/10.1186/s12884-020-03195-1

Baguune, B., Ndago, J. A., & Adokiya, M. N. (2017). Immunization dropout rate and data quality among children 12-23 months of age in Ghana. *Archives of Public Health*, *75*(1), 1–8. https://doi.org/10.1186/s13690-017-0186-8

Bassoum, O., Kimura, M., Dia, A. T., Lemoine, M., & Shimakawa, Y. (2020). Coverage and timeliness of birth dose vaccination in sub-Saharan Africa: A systematic review and meta-analysis. *Vaccines*, *8*(2), 1–16. https://doi.org/10.3390/vaccines8020301

Bassoum, O., Sougou, N. M., Ba, M. F., Anne, M., Bocoum, M., Dieye, A., Sokhna, C., & Tal-Dia, A. (2022). Vaccination against tuberculosis, polio and hepatitis B at birth in Podor health district, Northern Senegal: cross-sectional study of vaccination coverage and its associated factors. *BMC Public Health*, *22*(1), 1–13. https://doi.org/10.1186/s12889-022-12535-z

Bhandari, P. (2023). *Ethical Considerations in Research, Types and Examples*. https://www.scribbr.com/methodology/research/ethics/

Bobo, F. T., Asante, A., Woldie, M., Dawson, A., & Hayen, A. (2022). Child vaccination in sub-Saharan Africa: Increasing coverage addresses inequalities. *Vaccine*, *40*(1), 141–150. https://doi.org/10.1016/j.vaccine.2021.11.005

Boisson-Walsh, A., Thompson, P., Fried, B., Shea, C. M., Ngimbi, P., Lumande, F., Tabala, M., Kashamuka, M. M., Babakazo, P., Domino, M. E., & Yotebieng, M. (2023). Childhood immunization uptake determinants in Kinshasa, Democratic Republic of the Congo: ordered regressions to assess timely infant vaccines administered at birth and 6-weeks. *Global Health Research and Policy*, *8*(1). https://doi.org/10.1186/s41256-023-00338-7

Bolton, N. (2022). Theory of Change and Logic Models. *Evaluation in Sport and Leisure*, 95–114. https://doi.org/10.4324/9781003000204-7

Budu, E., Darteh, E. K. M., Ahinkorah, B. O., Seidu, A. A., & Dickson, K. S. (2020). Trend and determinants of complete vaccination coverage among children aged 12-23 months in Ghana: Analysis of data from the 1998 to 2014 Ghana Demographic and Health Surveys. *PLoS ONE*, *15*(10 October), 1–12. https://doi.org/10.1371/journal.pone.0239754

DHIMS2. (2024). *District Health Information Management System*.

Dimitrova, A., Carrasco-Escobar, G., Richardson, R., & Benmarhnia, T. (2023). Essential childhood immunization in 43 low- and middle-income countries: Analysis of spatial trends and socioeconomic inequalities in vaccine coverage. *PLoS Medicine*, *20*(1), 1–20. https://doi.org/10.1371/journal.pmed.1004166

Gbenga, K., Amoako-Coleman, M., Brown-Davis, C., & Klipstein-Grobusch, K. (2014). *Completeness and accuracy of DHIMS-2 data*.

Gebremedhin, S., Shiferie, F., Tsegaye, D. A., Alemayehu, W. A., Wondie, T., Donofrio, J., DelPizzo, F., Belete, K., & Biks, G. A. (2023). Oral and Inactivated Polio Vaccine Coverage and Determinants of Coverage Inequality Among the Most At-Risk Populations in Ethiopia. *American Journal of Tropical Medicine and Hygiene*, *109*(5), 1148–1156. https://doi.org/10.4269/ajtmh.23-0319

Ghana Health Service. (2023). *Ahafo Regional Health Directorate*.

Goldstein, J. N., Ibrahim, S. A., Frankel, E. S., & Mao, J. J. (2015). Race, Pain, and Beliefs Associated with Interest in Complementary and Alternative Medicine among Inner City Veterans. *Pain Medicine (United States)*, *16*(8), 1467–1474. https://doi.org/10.1111/pme.12756

GSS GHS and ICF. (2023). Ghana Demographic and Health Survey 2022: Key Indicattors Report. *Accra, Ghana, and Rockville, Maryland, USA: GSS and ICF.*, 5–24.

Huang, J., Cheung, C. K. M., Keung, V. M. W., Lo, A. S. C., Chan, S. C., Pang, W. S., Li, Q. H. Y., Mui, L. W. H., Lee, A., & Wong, M. C. S. (2023). Factors Associated with Vaccination Uptake among Young Children: A Follow-Up Study of 1799 Toddlers. *Vaccines*, *11*(3), 1–13. https://doi.org/10.3390/vaccines11030535

Iverson, B. L., & Dervan, P. B. (2021). Ghana 2021 Population and Housing Census: General Report. *Ghana Statistical Service*, *3A*, 7823–7830.

Khalifa, M. (2020). What are sampling methods and how do you choose the best one? *Cochrane UK*. https://s4be.cochrane.org/blog/2020/11/18/what-are-sampling-methods-and-how-do-you-choose-the-best-one/

McCombes. (2023). Descriptive Research Definition, Types, Methods & Examples. *Scribbr*. https://www.scribbr.com/methodology/descriptive-research/

Nkontchou, B. W., Guenou, E., Nkum, C. B., Tchida, C. M., Nono, A. M., & Ateudjieu, J. (2024). *The Polio Vaccination Status of Non-polio Acute Flaccid Paralysis Cases in the Far North Region of Cameroon : A Five-Year Retrospective Study From 2015 to 2019*. *16*(1), 1–11. https://doi.org/10.7759/cureus.52740

Profillidis, V. A., & Botzoris, George, N. (2019). Trend Projection and Time Series Methos. *ResearchGate*, 225–270. https://doi.org/10.1016/B978-0-12-811513-8.00006-6

Sally, E. T., & Kenu, E. (2017). Evaluation of access and utilization of EPI services amongst children 12-23 months in Kwahu Afram Plains, Eastern region, Ghana. *The Pan African Medical Journal*, *28*, 238. https://doi.org/10.11604/pamj.2017.28.238.11538

Tesfaye, B., Sowe, A., Kisangau, N., Ogange, J., Ntoburi, S., Nekar, I., Muitherero, C., Camara, Y., Gathenji, C., Langat, D., Sergon,

K., Limo, H., Nzunza, R., Kiptoon, S., Kareko, D., & Onuekwusi, I. (2020). An epidemiological analysis of Acute Flaccid Paralysis (AFP) surveillance in Kenya, 2016 to 2018. *BMC Infectious Diseases*, *20*(1), 1–11. https://doi.org/10.1186/s12879-020-05319-6

Verma, R. K., & Kadyan, A. (2022). Barriers of Newborn Vaccination Coverage among Institutional Deliveries: A Mixedmethod Study from Sonepat, Haryana. *Journal of Clinical and Diagnostic Research*, 1–5. https://doi.org/10.7860/jcdr/2022/57117.16556

Verrier, F., de Lauzanne, A., Diouf, J. B. N., Zo, A. Z., Ramblière, L., Herindrainy, P., Sarr, F. D., Sok, T., Vray, M., Collard, J. M., Borand, L., Kermorvant-Duchemin, E., Delarocque-Astagneau, E., Guillemot, D., & Huynh, B. T. (2023). Vaccination Coverage and Risk Factors Associated With Incomplete Vaccination Among Children in Cambodia, Madagascar, and Senegal. *Open Forum Infectious Diseases*, *10*(4), 1–11. https://doi.org/10.1093/ofid/ofad136

Yeboah, B. K., Letsa, T., Asor, E., & Odame-ankrah, E. (2019). Progress of Community-Based Health Planning and Services in Ghana. *Global Scientific*, *7*(12), 1212–1228.