PREDICTING THE PREVALENCE OF MEASLES IN NIGERIA USING TIME SERIES APPROACH

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ABSTRACT: Measles is a highly contagious disease caused by a virus. It is an acute highly communicable viral illness that is characterized clinically by prodromal onset of fever and catarrhal symptoms (including coryza, cough and conjunctivitis) followed by a typical maculopapular rash. The study was carried out to predict the prevalence of measles in Nigeria for 2024 and 2025. The study population include confirm measles cases, measles immunization and deaths that occur due to measles in Nigeria. The data collected was analyzed in SPSS using ARIMA, Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC). The results of this research also shows that measles prevalence in Nigeria is not progressing as there are still significant gaps in coverage of measles vaccine. The study shows that Measles vaccine is still very low to the number of children and the measles vaccine are only available for children age 12-59 months. The predictions for 2024 are 79 86 110 136 136 126 113 110 111 116 116 115 and 2025 are 112 110 109 109 108 107 106 105 104 103 102 101. The AIC and BIC output for measles cases: 2601.320 and 2613.199 respectively, The AIC and BIC output for number of deaths that occur due to measles cases: 141.037 and 142.492 respectively, The AIC and BIC output for MCV1 and MCV2 immunization; 61.877, 41.234 and 63.323, 40.062 respectively. Based on the analysis and conclusions drawn from the ARIMA modeling of measles prevalence in Nigeria, here are some few recommendations: There should be Implementation of ARIMA model developed in this analysis to generate reliable monthly forecasts of measles prevalence in Nigeria, there should be Implementation of ARIMA model developed in this analysis to generate reliable monthly forecasts of measles prevalence in Nigeria, there should be more public physical health campaigns and initiatives on Measles especially in rural areas.
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Keywords: Measles; ARIMA; Akaike Information Criterion (AIC); Bayesian Information Criterion (BIC); Forecast and immunization.

1. INTRODUCTION

Measles is a highly contagious disease caused by a virus. It is an acute highly communicable viral illness that is characterized clinically by prodromal onset of fever and catarrhal symptoms followed by a typical maculopapular rash. The illness is associated with high morbidity and mortality in both developing and industrialized countries. It is more severe in infants and adults than in children, with complications resulting from viral replication or bacterial super infection, including, pneumonia, laryngotracheobronchitis (croup), diarrhea and encephalitis. An estimated 197 000 deaths from measles occurred globally in 2007, with 136 000 (69%) and 45 000 (23%) occurring in Southeast Asia and Africa, respectively. Measles case fatality rates in Africa generally range from 3 to 5% and can be as high as 30% during severe outbreaks. It is one of the leading causes of vaccine-preventable deaths among children worldwide.

The disease is endemic and in Nigeria, it exhibits a seasonal pattern with increasing incidence during the dry season (November- May). A safe and effective vaccine has been available for the prevention of measles for over 40 years, with global recommendations.

Measles can affect anyone but is most common in children. Being vaccinated is the best way to prevent getting sick with measles or spreading it to other people. The vaccine is safe and helps your body fight off the virus.

Before the introduction of measles vaccine in 1963 and widespread vaccination, major epidemics occurred approximately every two to three years and caused an estimated 2.6 million deaths each year. An estimated 136 000 people died from measles in 2022 mostly children under the age of five years, despite the availability of a safe and cost-effective vaccine. Despite the availability of a safe and effective vaccine, measles remains a significant public health challenge in many developing countries, including Nigeria. The prevalence of measles in Nigeria has fluctuated over the years, with outbreaks occurring regularly. This literature review aims to provide an overview of the

factors influencing the prevalence of measles in Nigeria and the methods used to predict its spread.

The study was carried out in Nigeria. Nigeria is the most populous country in Africa, with a population of 232,679,478 million as at mid-year 2024 a 2.39% increase from 2023. The zones are divided into 36 States and the Federal Capital Territory, which are further divided into 774 LGAs.

The aim of the study is to predict the prevalence of measles in Nigeria for 2024 and 2025 and the Objectives of the study are to: Collect and preprocess data on the prevalence of measles in Nigeria from 2012 to 2023, apply trend analysis, seasonal analysis, and forecasting techniques to the time series data to predict the prevalence of measles in Nigeria for the next 2 years and provide insights into the dynamics of measles in Nigeria and inform public health interventions to control and prevent the disease. 12 years monthly data was collected on measles from WHO site, Death that occur due to measles yearly data was extracted from Nigerian Centre for Disease Control (NCDC) for 12 years and immunization data was also extracted from WHO and

2. LITERATURE REVIEW

Measles is an acute highly communicable viral illness that is characterized clinically by prodromal onset of fever and catarrhal symptoms (including coryza, cough and conjunctivitis) followed by a typical maculopapular rash.

The illness is associated with high morbidity and mortality in both developing and industrialized countries. It is more severe in infants than in children, with complications resulting from viral replication or bacterial superinfection, including otitismedia, pneumonia, laryngotracheobronchitis (croup), diarrhoea and encephalitis. An estimated 197000 deaths from measles occurred globally in 2007, with 136000 (69%) and 45000 (23%) occurring in Southeast Asia and Africa, respectively. Measles case fatality rates in Africa generally range from 3 to 5% and can be as high as 30% during severe outbreaks. The disease is endemic and in Nigeria, it exhibits a seasonal pattern with increasing incidence during the dry season (November-May). A safe and effective vaccine has been available for the prevention of measles for over 50 years, with global recommendations for its use through mass campaigns and routine administration. For instance, measles vaccination was introduced in Africa during the 1960s through mass campaigns as part of smallpox eradication and measles control. In 1978, the expanded programme on immunization (EPI) facilitated the introduction of a first dose of measles-containing vaccine (MCV1) for infants through routine health services in the countries of the WHO African region, including Nigeria. In 2001, a global goal was set by the WHO member states to reduce measles mortality by 50% by 2005, compared with the 1999 estimate. Implementation of the recommended strategies led to an estimated 60% reduction in measles associated mortality and a 75% reduction in the African region. Following the reported progress, the WHO African region adopted a goal in 2006 to achieve a 90% reduction in measles associated mortality by 2010, compared with the 2000 estimate. By 2008, reported measles cases had decreased by 93% and the estimated measles-associated mortality was reduced by 92%. The technical advisory group (TAG) in the African region reviewed the progress of measles control and established new disease reduction targets.

The measles morbidity and mortality reduction programme of the WHO African region was adopted in Nigeria in 2005. The country also adopted revisions to the programme goals including the current pre-elimination goal. The recommended strategies to achieve the programme goal included strengthening routine measles immunization coverage of infants, providing a second dose of measles vaccination through SIA sand intensifying measles case-based surveillance with laboratory confirmation and improved case management. To strengthen the service-delivery components of the immunization system, the country adopted the reaching every district (RED) approach of the WHO with its five strategic components and renamed it the reaching every ward (REW) approach, to reflect the administrative structure in Nigeria. According to the WHO–UNICEF estimates, MCV1 coverage in Nigeria increased from 33% in 2000 to 44% in 2006 and remained at 41% during 2007–2008.5 A nationwide measles catch-up SIA was conducted in two phases in December 2005 and October 2006 for the 19 northern and 18 southern states. An administrative coverage of 90% of children aged 9 months to 14 years was reported. Since then, follow-up campaigns have been conducted targeting children aged 9–59 months in 2008, 2011 and 2013; all with high administrative coverage at the national level but sub-optimal coverage at the Local Government Area (LGA) level. For instance, in 2008, although an administrative coverage of 112% of the target population estimate was reported, only 48% of the 774 LGAs had coverage of over 95%. The 2008 Demographic Health Survey (DHS) in Nigeria estimated that the national measles coverage for children aged 12–13 months was 46% nationally, 60% in urban areas and 33% in rural areas.

Several factors contribute to the prevalence of measles in Nigeria, including low vaccination coverage, inadequate healthcare infrastructure, and limited access to healthcare services. Another study published

in the BMC Public Health journal identified factors such as limited access to healthcare services and inadequate surveillance systems as contributing to the persistence of measles in the country (Okeke et al., 2017).

Predicting the prevalence of measles in Nigeria requires a comprehensive understanding of the factors influencing its spread. Several methods have been used to predict measles outbreaks, including mathematical modeling and machine learning algorithms.

In an attempt to look at the epidemiology of measles in South-West Nigeria, Fatiregun, et al. analyzed measles case-based surveillance data from 2007 to 2012.[27] The authors used a descriptive analysis (persons, place, and time) of measles cases and which was confirmed through laboratory and epidemiological link. Fatiregun et al. predicted expected measles cases in 2015 using additive time series model.

Furthermore, in a similar study on trends and patterns of under-fives vaccination in Nigeria, using four National Demographic and Health surveys datasets involving a total of 44,071 (weighted) children from 1990 to 2008; the authors examined child health information including the proportion of those who had some or completed their routine childhood vaccinations, the trends, as well as a pattern of vaccination over 18 years. The authors also selected certain factors and regressed them to obtain predictors of child vaccinations in Nigeria. Considering the importance of timeliness and completeness of reporting on all suspected infectious diseases, a retrospective review of surveillance records was conducted between January 1, 2007 and June 30, 2008. This was done by review of records of suspected measles from the registers of 23 health facilities in Nigeria.

Odega et al. used a capture-recapture method to obtain an estimate of the total number of measles cases required for the study area within the period under review. Completeness of reporting was by calculating the ratio of a number of measles reported by hospitals to the number of estimated cases using the capture-recapture method. Although there are safe and effective vaccines against measles, measles remains a significant cause of childhood morbidity and mortality in Nigeria. In a review conducted on the current status of measles in a tertiary health center aimed at strengthening strategies for intervention, a 10-year retrospective study spanning from 1994 to 2004 was conducted.

In another African country, Tunisia, Bahri et al. assessed measles surveillance and control from 1979 to 2000; the authors analyzed measles epidemiology in the country after the introduction of a specific vaccine in 1979, as well as the results of the serological investigation of suspected measles cases. Available data on measles were used to examine the epidemiological trend from 1979 to 2000. The criteria used include reported cases, age, date reported, epidemiological link with similar cases, and laboratory confirmation. The serological investigation was based on the detection of measles and rubella IgM using ELISA in 542 suspected measles cases from 1997 to 2000.

3. METHODOLOGY

MODEL

The mathematical model for an ARIMA (p, d, q) model is given by:

$$\left(1-\emptyset_1\beta^1-\emptyset_2\beta^2-\cdots-\emptyset_p\beta^q\right)(1-B)^d y_t=\left(1+\theta_1\beta^1+\theta_2\beta^2+\cdots+\theta_p\beta^q\right)\varepsilon_t$$

Where:

y_t is the time series data at time t

B is the backshift operator, which represent the lag operator (i.e. $\beta^k y_t = y_{t-k}$)

$\emptyset_1, \emptyset_2, \ldots, \emptyset_p$ are the autoregressive parameters or coefficient.

$\theta_1, \theta_2, \ldots, \theta_q$ are the moving average parameters or coefficient.

ε_t is the error term at time t

d is the degree of differencing

The AIC and BIC values are calculated using the following formulas:

AIC = -2 log(L) + 2k

BIC = -2 log(L) + k log(n)

Where:

L is the likelihood function of the model

k is the number of estimated parameters in the model

(n) is the sample size or the number of observations in the data.

In this formula, -2 × ln(L) represents the goodness of fit term, which penalizes the likelihood by a factor that increases with the number of parameters in the model. The term k × ln(n) represents the penalty for model complexity, where (k) is the number of parameters and ln(n) is the natural logarithm of the sample size.

The performance of the ARIMA model, AIC, and BIC in predicting measles was assessed using statistical measures. These metrics provided insights into the accuracy and reliability of the predictive models.

4. ANALYSIS AND RESULT

Table 1: The table below shows confirm measles cases in Nigeria from Jan 2012 to 2023

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Se p	Oct	Nov	Dec
2012	331	786	1056	506	169	111	99	127	145	131	292	195
2013	6608	12246	17797	9416	4393	1507	972	687	543	553	507	219
2014	1560	1881	1285	687	451	288	69	79	53	115	244	145
2015	641	1558	1927	1686	1390	932	691	599	664	969	924	410
2016	2638	3947	3052	1823	1547	972	699	976	781	581	316	249
2017	1142	1142	1913	1548	1231	1041	696	805	696	578	242	154
2018	1217	1455	1700	847	312	228	164	85	115	206	327	180
2019	3004	4935	7344	5808	3570	1325	825	318	305	340	292	236
2020	2415	3046	2860	831	201	141	133	118	140	138	123	81
2021	690	878	1161	1511	1384	1049	956	667	756	663	517	639
2022	4726	5541	5104	2139	1161	476	349	222	237	271	238	284
2023	2013	1649	2395	1747	1598	1113	613	321	196	245	200	134

Sources: World health organization 2024

Chart 1: The chart below shows confirm measles cases in Nigeria from Jan 2012 to 2023

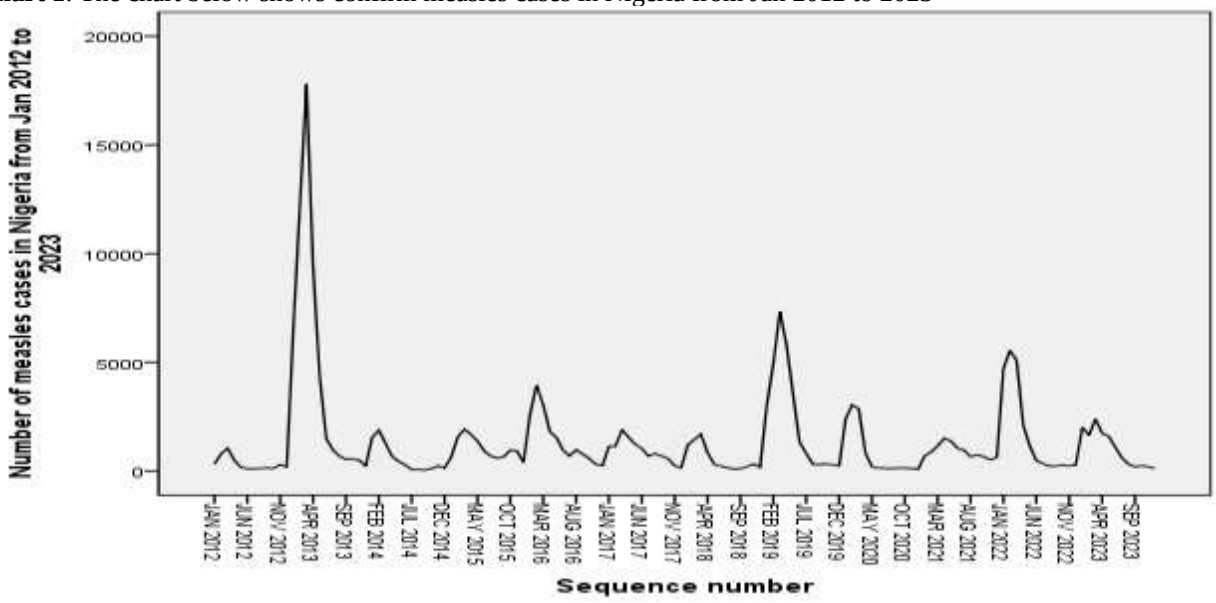

Figure 1

Table 2: Yearly Number of deaths that occur due to measles cases in Nigeria from Jan 2012 to 2023

YEAR	DEATHS
2012	158
2013	348
2014	85
2015	127
2016	99
2017	160
2018	32
2019	138
2020	143

2021	151
2022	86
2023	74

Source: Nigerian Centre for Disease Control (NCDC)

Chart 2: Yearly chart of number of deaths that occur due to measles cases in Nigeria from Jan 2012 to 2023

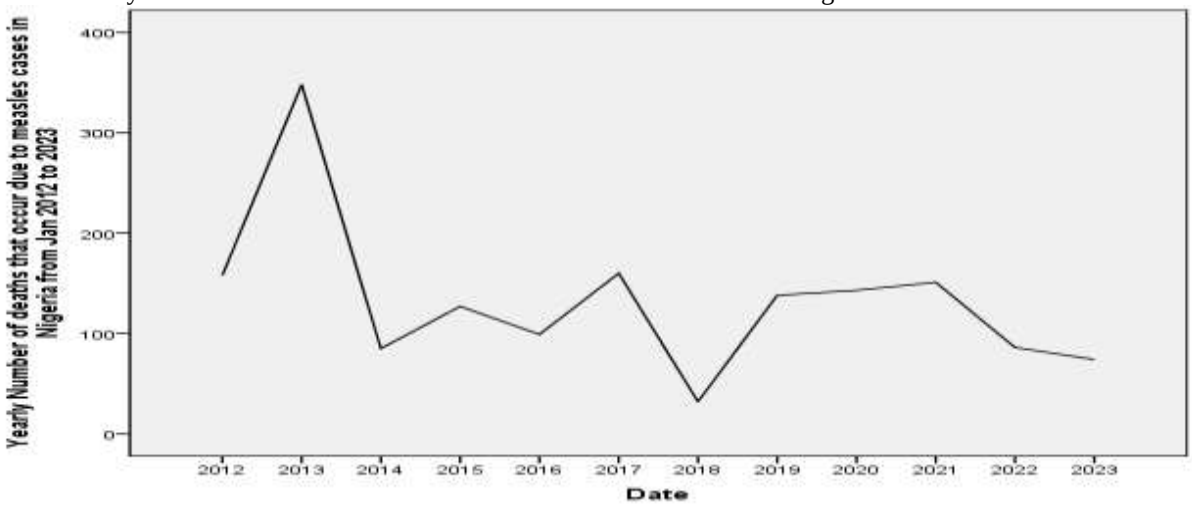

Figure 2

Table 3: Yearly number of MCV1 and MCV2

Immunization (Per 1000)	2023	2022	2021	2020	2019	2018	2017	2016	2015	2014	2013	2012
MCV1	60	60	60	60	58	56	54	48	42	44	43	42
MCV2	38	38	38	38	9							

Sources: **WHO and UNICEF Estimates of National Immunization Coverage (WUENIC), 2 023 revision**

Chart 3: Yearly chart of MCV1 and MCV2 for 12years and 5 years respectively.

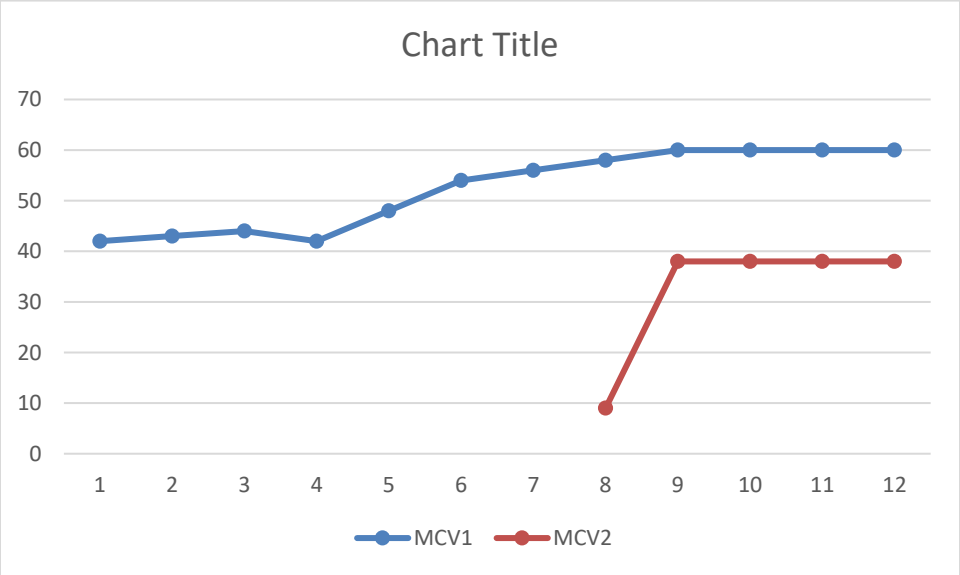

Figure 3

4.2 **Data Management**

Data obtained was analyzed using SPSS Window 23. ARIMA 3,1,0, AIC and BIC test was applied and Sequence chart was used for the graphs.

Table 4: The AIC and BIC output for measles cases

	Value
Akaike's Information Criterion (AIC)	2601.320
Bayesian Information Criterion (BIC)	2613.199

Table 5: The AIC and BIC output for number of deaths that occur due to measles cases

	Value
Akaike's Information Criterion (AIC)	141.037
Bayesian Information Criterion (BIC)	142.492

Table 6: The AIC and BIC output for MCV1 and MCV2 immunization

	MCV1 Value	**MCV2 Value**
Akaike's Information Criterion (AIC)	61.877	41.234
Bayesian Information Criterion (BIC)	63.323	40.062

Table 7: The forecast Using ARIMA 3,1,0

Model		Jan 2024	Feb 2024	Mar 2024	Apr 2024	May 2024	Jun 2024	Jul 2024	Aug 2024	Sep 2024	Oct 2024	Nov 2024	Dec 2024
measles cases	Forecast	**79**	**86**	**110**	**136**	**136**	**126**	**113**	**110**	**111**	**116**	**116**	**115**
	UCL	**2509**	**4288**	**5722**	**6395**	**6795**	**7085**	**7464**	**7906**	**8381**	**8797**	**9162**	**9487**
	LCL	**-2352**	**-4115**	**-5502**	**-6123**	**-6523**	**-6832**	**-7238**	**-7687**	**-8159**	**-8565**	**-8929**	**-9258**

Model		Jan 2025	Feb 2025	Mar 2025	Apr 2025	May 2025	Jun 2025	Jul 2025	Aug 2025	Sep 2025	Oct 2025	Nov 2025	Dec 2025
measles cases	Forecast	**112**	**110**	**109**	**109**	**108**	**107**	**106**	**105**	**104**	**103**	**102**	**101**
	UCL	**9809**	**10131**	**10455**	**10768**	**11068**	**11355**	**11635**	**11909**	**12179**	**12443**	**12702**	**12954**
	LCL	**-9586**	**-9912**	**-10238**	**-10551**	**-10852**	**-11141**	**-11423**	**-11700**	**-11972**	**-12238**	**-12498**	**-12752**

Chart 4:

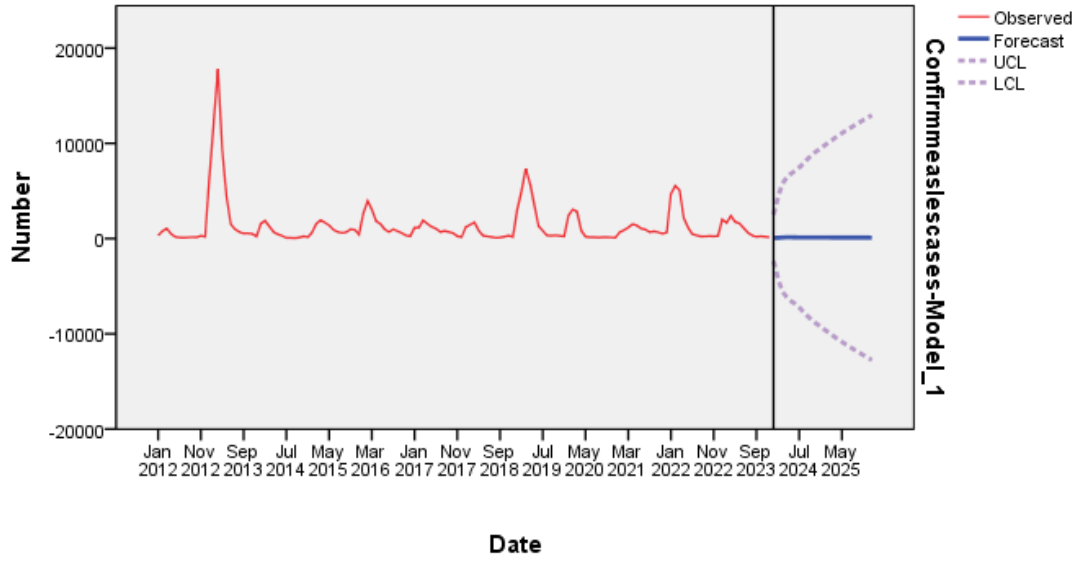

Figure 4

Results and discussion

Table 1 and chart 1 shows the monthly number of confirm measles cases in Nigeria from Jan 2012 to 2023, **Table 2 and chart 2** shows the Yearly Number of deaths that occur due to measles cases in Nigeria from Jan 2012 to 2023, **Table 3 and chart 3** shows the Yearly number of measles vaccine {MCV1 and MCV2}, **Table 4** shows the AIC and BIC output for measles cases, **Table 5** shows the AIC and BIC output for number of deaths that occur due to measles cases, **Table 6** shows the AIC and BIC output for MCV1 and MCV2 immunization, **Table 7 and chart 5** shows the forecast for measles Using ARIMA 3,1,0.

Summary

The purpose of this study was to predict the prevalence of measles in Nigeria for 2years 2024 and 2025, to analyze historical data to identify measles, immunization and deaths that occur due to measles trend. To use AIC and BIC and select the best one and to apply time series models for prediction.

The findings from this research show that despite the availability of a vaccine that protect from measles infection delivered through routine immunization, Nigeria still record sporadic outbreaks of measles infection. Several researches both on the African continent and beyond have shown that measles disease in those immunized tends to be milder in presentation with little or no complications. However, greater burden with a wide range of complications and increase mortality is seen in Nigeria. In Nigeria, it is clear that the severity of the measles disease is still much, it is disheartening to note that in spite of availability of health facilities that offer routine immunizations, there are a great number of parents who do not utilize these services.

The results of this research also shows that measles prevalence in Nigeria is not progressing as there are still significant gaps in coverage of measles vaccine

5. CONCLUSION

Measles prevalence in Nigeria seems to be lacking in some areas, after demonstrating ARIMA (Autoregressive Integrated Moving Average) time series model to predict the measles cases in Nigeria. The study shows that Measles vaccine is still very low to the number of children and the measles vaccine are only available for children age 12-59 months. Effort should not be relent on it.

Measles tends to reduce during cold weather and there are still significant gaps in coverage, particularly in certain regions and among certain demographic groups, which can leave individuals vulnerable to measles.

Overall, the ARIMA time series modeling approach has proven to be a useful tool for predicting the prevalence of measles in Nigeria. The model's ability to capture the underlying patterns and trends in the data, coupled with the reliable forecasting capabilities, makes it a valuable technique for public health authorities to monitor and manage the spread of this childhood disease.

The insights gained from this analysis can be further leveraged to develop targeted interventions, allocate resources effectively, and enhance disease surveillance and control efforts in the region. The methodology demonstrated in this research can also be

applied to other diseases, contributing to the overall improvement of public health outcomes.

6. RECOMMENDATIONS

Based on the analysis and conclusions drawn from the ARIMA modeling of measles prevalence in Nigeria, here are some few recommendations:

1. Utilizing ARIMA Model for Forecasting:

There should be Implementation of ARIMA model developed in this analysis to generate reliable monthly forecasts of measles prevalence in Nigeria.

We should Incorporating these forecasts into the region's public health planning and decision-making processes to enhance preparedness and resource allocation.

2. Government should Enhance Disease Surveillance and Data Collection:

Strengthen the region's disease surveillance systems to ensure timely and accurate reporting of measles cases.

Improve data collection methods and maintain a comprehensive, high-quality database of measles prevalence data.

Regularly review and update the ARIMA model as new data becomes available to keep the forecasts accurate and relevant.

3. There should be more public physical health campaigns and initiatives on Measles especially in rural areas

By implementing these recommendations, the public health authorities in Nigeria can leverage the insights and forecasting capabilities of the ARIMA model to enhance their measles prevention and control efforts, ultimately leading to improved health outcomes and reduces deaths rate.

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