

# Epidemiology of measles in Southwest Nigeria: an analysis of measles case-based surveillance data from 2007 to 2012

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Received 19 November 2013; revised 5 January 2014; accepted 6 January 2014

**Background:** In Nigeria, a system of measles case-based surveillance with laboratory confirmation of suspected cases was introduced in 2005 as one of the strategies for the control of measles morbidity and mortality. In this report, we provide an epidemiological distribution of confirmed cases of measles reported from the southwest of the country between 2007 and 2012, and predict the expected number of cases for the ensuing years.

**Methods:** A descriptive analysis of persons and place and time of confirmed measles cases (laboratory and epidemiological link) reported in the case-based surveillance data was carried out. Using an additive time series model, we predicted the expected number of cases to the year 2015, assuming that current interventional efforts were sustained.

**Results:** From the 10 187 suspected cases investigated during the time period, 1631 (16.0%) cases of measles were confirmed. The annual incidence rose from <1 case per million in 2007 to 23 cases per million in 2011. Cases were confirmed from all six states within the zone and most (97.4%) were in individuals aged less than 20 years. Seasonal variation existed with peaks of infection in the first and second quarters of the year. There was an increasing trend in the number of expected cases based on projections.

**Conclusions:** Case-based surveillance provided an insight into understanding the epidemiology of measles infection in Southwest Nigeria. There is a need to work out alternate strategies for control of measles and to strengthen the surveillance system.

**Keywords:** Case-based surveillance, Measles, Southwest Nigeria

## Introduction

Measles is an acute highly communicable viral illness that is characterised clinically by prodromal onset of fever and catarrhal symptoms (including coryza, cough and conjunctivitis) followed by a typical maculopapular rash.<sup>1,2</sup> The illness is associated with high morbidity and mortality in both developing and industrialised countries.<sup>2,3</sup> It is more severe in infants and adults than in children, with complications resulting from viral replication or bacterial superinfection, including otitis media, pneumonia, laryngotracheobronchitis (croup), diarrhoea and encephalitis.<sup>1</sup> 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.<sup>4</sup> Measles case fatality rates in Africa generally range from 3 to 5% and can be as high as 30% during severe outbreaks.<sup>5</sup> The disease is endemic and in Nigeria, it exhibits a seasonal pattern with increasing incidence during the dry season (November–May).<sup>3</sup>

A safe and effective vaccine has been available for the prevention of measles for over 40 years, with global recommendations

for its use through mass campaigns and routine administration.<sup>6</sup> 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 immunisation (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.<sup>6</sup> 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.<sup>5–7</sup> 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%.<sup>6,7</sup> The technical advisory group (TAG) in the African region reviewed the progress of measles control and established new disease reduction targets.<sup>8</sup> A pre-elimination goal was defined as follows:

to reduce measles associated deaths by 98% by 2012, compared with the 2000 estimate, and to reduce the annual incidence to >5 cases per million in all countries in Africa. Other components of the goal included: attaining >90% MCV1 coverage at the national level and >80% coverage in all districts; attaining 95% supplemental immunisation activity (SIA) measles coverage in all districts; achieving a non-measles febrile illness rate  $\geq 2$  cases per 100 000 population per year and  $\geq 1$  suspected cases of measles with serological investigation in  $\geq 80\%$  of districts per year.<sup>5-8</sup> For countries to make informed decisions on their progress towards achieving this goal, analysis of country-specific data on the burden of disease at the national and sub-national level is needed.

The measles morbidity and mortality reduction programme of the WHO African region was adopted in Nigeria in 2005.<sup>3,5,11-13</sup> The country also adopted revisions to the programme goals including the current pre-elimination goal.<sup>5,13</sup> The recommended strategies to achieve the programme goal included strengthening routine measles immunisation coverage of infants, providing a second dose of measles vaccination through SIAs and intensifying measles case-based surveillance with laboratory confirmation and improved case management.<sup>3,5-8,11-13</sup> To strengthen the service-delivery components of the immunisation 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.<sup>14</sup> 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.<sup>5</sup> 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.<sup>5</sup>

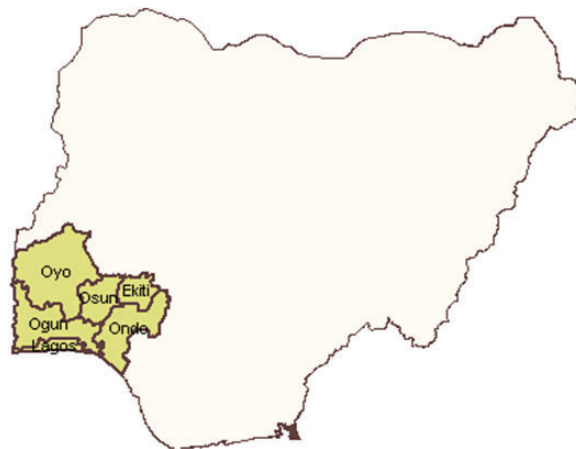
The measles case-based surveillance system included laboratory testing for the detection of measles- and rubella-specific IgM antibodies, which indicate responses to recent infections.<sup>3,5-8,11-13</sup> One national public health laboratory was supported in each of four zones of the country to receive and process serum samples from the six zones for this purpose.<sup>13</sup> Prior to the introduction of the case-based system, the number of measles cases reported annually through the aggregate reporting system ranged from 31 521 in 2004 to 217 151 cases in 1999.<sup>3,5</sup> Between 2006 and 2008, the surveillance performance indicators in Nigeria showed progressive improvements; the annualised rate of reporting per 100 000 population increased from 0.4 in 2006 to 3.5 in 2007, and 3.8 in 2008 (target  $\geq 2$ ), whereas non-measles febrile rash illness per 100 000 population improved from 0 in 2006 to 2.2 in 2007 and 3.0 in 2008 (target  $\geq 2$ ). Districts (LGAs) that investigated at least one case with blood specimens increased from 10% in 2006 to 88%, and 95% in 2007 and 2008, respectively (target >80%). During this period, 21 624 cases of measles were reported through the

national case-based surveillance system, with 383 confirmed in 2006, 2542 in 2007 and 9510 in 2008. The annual measles incidence in 2005 was 1054 cases per million. The incidence of confirmed cases of measles decreased to 2 per million in 2006, and increased to 16 per million in 2007 and 68 per million in 2008. Between January and December 2008, a total of 13 831 suspected cases of measles were investigated and 68.0% were confirmed by laboratory or epidemiological linkage. Of the 9510 cases, 74.0% were in individuals aged less than 2 years and 71.5% were unvaccinated.<sup>5</sup> Analysis of the measles case-based surveillance will help to document the epidemiology of measles and track progress towards control. In this study we summarised the results of measles antibody testing carried out in the measles case-based surveillance system from 2007 to 2012, and provided an epidemiological distribution of confirmed cases of measles reported in Southwest Nigeria. We also modelled the pattern of measles cases for four periods of 3 months each, in a year, and predicted the expected cases for 2013-2015.

## Methods

### Study setting

The study was carried out in Southwest Nigeria. Nigeria is the most populous country in Africa, with a population of 148 million in 2007 and a growth rate of 3.8% per annum. The estimated life expectancy is on average 48 years, with an infant mortality rate of 99 per 1000.<sup>9</sup> Nigeria has six regional zones that reflect varying ecologies, climates and population characteristics. The zones are divided into 36 States and the Federal Capital Territory, which are further divided into 774 LGAs and 8812 administrative wards.<sup>5</sup> Southwest Nigeria falls on latitude 6° to the north and 4° to the south and is marked by longitude 4° to the west and 6° to the east. The geographic location covers approximately 114 271 km<sup>2</sup>, which is about 12% of the total land mass of Nigeria. The zone comprises of six states (Oyo, Osun, Ondo, Ogun, Ekiti and Lagos) with 137 LGAs (Figure 1). With a typical rainforest vegetation, the total population of 27 581 992 is predominantly agrarian and belong to the Yoruba ethnic group.<sup>9,10</sup>



**Figure 1.** Map of Nigeria showing the relative locations of the six Southwest states of Ekiti, Lagos, Ogun, Ondo, Osun and Oyo.

## Measles surveillance

The WHO African Regional Office measles case-based surveillance guidelines were adapted for use in Nigeria in 2005, but implementation did not commence in the southwest geopolitical zone until the last quarter of 2006.<sup>3,5,11–13</sup> A suspected measles case was defined as an illness in a person who presented with fever, generalised rash, cough, coryza, or conjunctivitis. Suspected individuals who presented within 30 days of rash onset were investigated using a standardised form to obtain data, which included age, address, immunisation status, admission history and outcome (alive or dead) within 30 days of rash onset.<sup>13</sup> Serum specimens were collected from all suspected cases, except for those who were epidemiologically linked to a confirmed measles outbreak. The serum specimens with completed forms were sent to the national measles laboratories; one of which was located in each of the three northern zones and one in the southwest serving the remaining three southern zones. Laboratory testing was carried out using a standard commercial indirect ELISA kit (Enzygnost for IgM, Dade Behring, Marburg, Hesse, Germany). The laboratories were subjected to periodic quality control exercises and accredited annually.<sup>5,7</sup>

Specimens that tested positive for measles-specific IgM and were from patients who had not received measles vaccination within 4 weeks prior to specimen collection, were classified as laboratory-confirmed cases. Cases confirmed by epidemiological link were suspected cases of measles in individuals from whom blood specimens were not collected, but who were epidemiologically linked with a laboratory confirmed case of measles and who had onset of skin rash within 1 month of the rash in the laboratory-confirmed case. They would have also resided in the same or an adjacent LGA but with a plausible transmission chain. Compatible cases were suspected cases of measles in individuals from whom blood specimens were not collected or who had equivocal measles IgM test results, and who had no epidemiological link to a laboratory-confirmed case. Discarded cases of measles were suspected cases in individuals with negative laboratory results for measles IgM or IgM positivity, and a history of measles vaccination in the 14 days preceding sample collection. Measles outbreaks were defined as the presence of  $\geq 3$  laboratory-confirmed cases of measles reported from the same LGA or from the same catchment area of a health facility with rash onset within 1 month. Measles-associated deaths were any deaths in individuals with confirmed cases of measles within 30 days of rash onset, without any other contributing cause of death.<sup>5–8,13</sup> Completed individual case investigation forms and laboratory results were entered into an Excel database.

## Data analysis

Data from 2007–2012 cases were extracted and analysed using SPSS (Version 21.0, Armonk, NY, USA), in this report. Two primary measles surveillance indicators were used to measure the performance of the measles case-based surveillance system. These were, the proportion of LGAs that reported at least one suspected case of measles per year with blood (0 would be a valid number; target=80%) and the non-measles febrile rash illness rate. The later, was calculated by dividing the number of discarded measles cases by the official national population estimates and multiplying by 100 000 population (target 2 per 100 000). The annual

measles incidence per million population was calculated by dividing the number of cases of IgM-positive measles by the projected population for each year based on the 2006 census, and multiplied by 1 million.<sup>5–8,13</sup> In order to model the pattern of measles cases for four periods of 3 months each in a year, such that we could predict the expected cases for years 2013–2015, the pattern of laboratory-confirmed cases was plotted to determine if seasonal variation existed in the reported number of cases. We grouped the data into 3 month intervals to make the seasonality seen at finer resolution. The observed pattern of variation suggested an additive time series model. We plotted an autocorrelation to identify whether the time series was stationary. This was done using a correlogram, that is, the plot of sample of autocorrelation coefficient against lag  $k$  (Figure 2).

As shown in Figure 2, the data had error terms that were positively autocorrelated. This was because a positive error term in time period  $t$  tended to produce, or be followed by another positive error term in time period  $t+k$ , and negative error terms tended to be followed over time by other negative error terms. The figure shows that positive autocorrelation in the error terms had the tendency to produce a cyclical pattern over time. As shown in Table 1, we decomposed the data because the parameters describing the data did not change over time.

The basic idea behind decomposition models is to decompose the data into several factors: the trend, seasonal variation, cyclical variation and irregular variation. We used the estimates of these factors to describe the time series. This was done by computing the Centred Moving Average ( $CMA_t$ ) in order to eliminate seasonal variations and irregular variations from the data. The pattern of the data suggested the use of a multiplicative model to decompose the data:

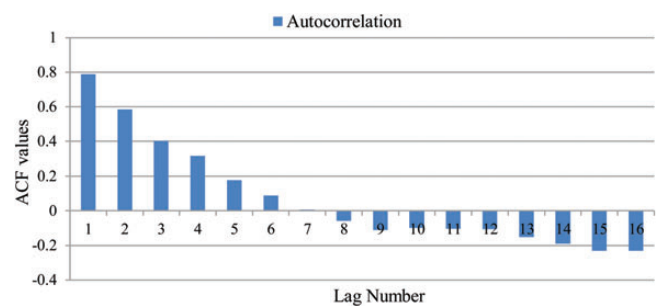
$$y_t = TR_t \times SN_t \times CL_t \times IR_t$$

Therefore, the estimate of the seasonal variation and irregular variation:

$SN_t \times IR_t$  is  $sn_t \times ir_t$ , which is given by

$$sn_t \times ir_t = \frac{y_t}{tr_t \times cl_t} = \frac{y_t}{CMA_t}$$

Thereafter, the average,  $\overline{sn}_t$ , was computed for each quarter. These seasonal factors were then normalised as shown



**Figure 2.** Autocorrelation of the error terms of the reported cases of measles among children in Southwest Nigeria, 2007–2012.

**Table 1.** Estimating the trend line and seasonal variation in the number of measles cases among children in Southwest Nigeria

Year	Qtr	t	$Y_t$	$CMA_t$	$y_t/CMA_t$	$sn_t$	$d_t$	$tr_t$
2007	1	1	3	-	-	1.689	1.776	35.972
	2	2	3	-	-	1.005	2.985	38.547
	3	3	2	7	0.286	0.567	3.527	41.122
	4	4	8	17.75	0.451	0.739	10.825	43.697
2008	1	5	27	32.75	0.824	1.689	15.986	46.272
	2	6	65	54.125	1.201	1.005	64.677	48.847
	3	7	60	79.5	0.755	0.567	105.820	51.422
	4	8	121	85.375	1.417	0.739	163.735	53.997
2009	1	9	117	73.375	1.595	1.689	69.272	56.572
	2	10	22	53.375	0.412	1.005	21.891	59.147
	3	11	7	32.5	0.215	0.567	12.346	61.722
	4	12	14	28	0.5	0.739	18.945	64.297
2010	1	13	57	40.5	1.407	1.689	33.748	66.872
	2	14	46	60.75	0.757	1.005	45.771	69.447
	3	15	83	121.125	0.685	0.567	146.384	72.022
	4	16	100	187.625	0.533	0.739	135.318	74.597
2011	1	17	454	203	2.236	1.689	268.798	77.172
	2	18	181	191.625	0.945	1.005	180.100	79.747
	3	19	71	131.25	0.541	0.567	125.220	82.322
	4	20	21	62.25	0.337	0.739	28.417	84.897
2012	1	21	50	37.5	1.333	1.689	29.603	87.472
	2	22	33	30.375	1.086	1.005	32.836	90.047
	3	23	21	-	-	0.567	37.037	92.622
	4	24	14	-	-	0.739	18.94	95.197

$CMA_t$ : central moving average;  $d_t$ : deseasonalised variation; Qtr: quarter;  $sn_t$ : seasonal variation; t: year;  $tr_t$ : trend;  $Y_t$ : observed cases of measles.

**Table 2.** Estimating the quarterly adjustment factor ( $sn_t$ ) using the decomposed observations ( $y_t/CMA_t$ )

	2007	2008	2009	2010	2011	2012	$\bar{sn}_t$	$sn_t$
Quarter 1	NA	0.824	1.595	1.407	2.236	1.333	1.4790	1.689
Quarter 2	NA	1.201	0.412	0.757	0.945	1.086	0.8802	1.005
Quarter 3	0.286	0.755	0.215	0.685	0.541	NA	0.4964	0.567
Quarter 4	0.451	1.417	0.500	0.533	0.337	NA	0.6476	0.739
							3.5032	

$CMA_t$ : central moving average; NA: not applicable;  $sn_t$ : seasonal variation;  $y_t$ : observed cases of measles.

in Table 1, so that they add to  $L=4$ , the number of seasons in a year.

$$\frac{L}{\sum_{t=1}^L \bar{sn}_t} = \frac{4}{3.5032} = 1.1418132$$

$$sn_t = 1.1418132 \times \bar{sn}_t$$

Deseasonalised observation in time period t was determined as  $d_t = y_t/sn_t$  for better estimate of the trend component  $TR_t$ . We

divided  $y_t$  by the estimated seasonal factor in order to remove seasonality from the data.

$$tr_t = b_0 + b_1t = 33.397 + 2.575t;$$

$$\hat{y}_t = tr_t \times sn_t$$

The quarterly adjustment factors were estimated as shown in Table 2. This was used for predicting cases of measles in each of

the four seasons in 2013–2015, assuming that current interventional efforts in the implementation of pre-elimination goal as recommended by the WHO African TAG remain the same as in 2007–2012.<sup>5–8</sup>

## Results

Between January 2007 and December 2012, 10 187 suspected cases of measles were investigated through the case-based surveillance system. As shown in Table 3, the zone met the targets for each of the two principal measles surveillance performance indicators throughout the period (a non-measles febrile rash illness rate of  $\geq 2$  cases per 100 000 population and  $\geq 80\%$  LGAs reporting one suspected case of measles with a blood specimen per year). Cases investigated with blood specimens increased from 697 in 2007 to 2364 in 2011, and decreased to 1720 in 2012. The mean number of annual investigated cases was 1637. Out of the 10 187 cases investigated, 16.0% (1631/10 187) were confirmed by either laboratory (1579 cases) or epidemiological link (52 cases). A total of 616 cases were classified as clinically compatible with measles. The annual incidence of confirmed cases of measles ranged from  $<1$  case per million in 2007 to about 23 cases per million in 2011.

Confirmed cases of measles were reported from all six states in the southwest zone (Table 4). Of the 1631 confirmed cases during 2007–2012, 321/1631 (19.7%) had information on age. Of these, 21.4% were  $<1$  year, 51.4% were 1–4 years, 19.9% were 5–9 years, 5.0% were 10–19 years and 2.5% were  $\geq 20$  years. There was no significant shift in the age distribution of the confirmed cases of measles between 2007 and 2012. The highest proportion of confirmed cases occurred consistently throughout the period in the age group 1–4 years and ranged from 40.1% in 2009 to 63.6% in 2012. The figure was 60.0% and 49.2% in 2008 and 2007, respectively. The vaccination status of 452/1631 (27.7%) confirmed cases was recorded as unknown, whereas 349/1631 (21.4%) were unvaccinated and 830/10 187 (50.9%) had received  $\geq 1$  dose of measles vaccine. Of 1629 confirmed cases whose admission status was documented, only 126/1629 (7.7%) were admitted into a health facility. Of 1630 confirmed cases with a documented outcome, 2/1630 (0.1%) died within 30 days of rash onset.

During the period under review, 160 outbreaks of measles were confirmed in Southwest Nigeria. Sixty-nine (43.1%) of these comprised three laboratory-confirmed cases (the minimum number needed to declare an outbreak) and all comprised  $<50$  laboratory-confirmed cases. The largest outbreak included 29 laboratory-confirmed cases and occurred in Lagos mainland LGA, Lagos State in February 2011.

Figure 3 shows the variation over time of the reported cases of measles. Decomposition of the data and removal of the seasonality have smoothed out all the irregularities in the data. The data show that there is likely to be an increase in the reported cases of measles in Southwest Nigeria. The predicted number of cases, as shown in Figure 4, is an indication that the disease may increase because there is tendency for the number of reported cases to continue to increase in each quarter. For instance, in 2013, 2014 and 2015, the expected number of reported cases will be 165, 183 and 200, respectively.

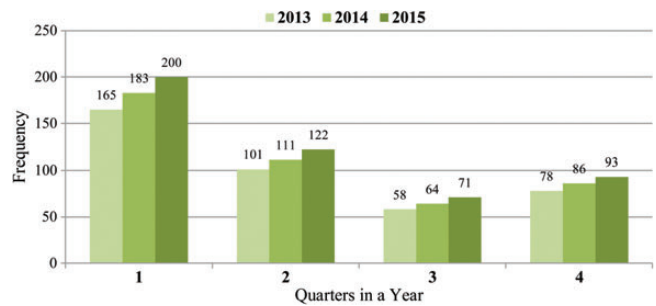
**Table 3.** Measles investigated cases and measles case-based performance, Southwest Nigeria 2007–2012

Year	Number of suspected measles cases investigated	No (%) of suspected measles cases confirmed by laboratory	No (%) of suspected measles cases confirmed by laboratory or epidemiologic link	Incidence of confirmed measles per 1 000 000 population	Non-measles febrile rash illness rate per 100 000 population	No (%) of LGA reporting $\geq 1$ suspected measles case with a blood specimen n=137
2007	697	16 (2.3)	16 (2.3)	0.56	2.4	121 (88.3)
2008	1814	272 (15.0)	296 (16.3)	10.07	5.2	137 (100)
2009	1467	160 (10.9)	168 (11.4)	5.54	4.3	136 (99.3)
2010	2125	286 (13.5)	305 (14.4)	9.74	5.8	137 (100)
2011	2364	727 (30.8)	728 (30.8)	22.53	5.1	137 (100)
2012	1720	118 (6.9)	118 (6.9)	3.54	4.8	136 (99.3)
Total	10 187	1579 (15.5)	1631 (16.0)	8.81	4.6	137 (100)

LGA: Local Government Area.

**Table 4.** Distribution of confirmed measles cases by selected health and demographic characteristics in Southwest Nigeria, 2007–2012

Characteristics	Number of confirmed measles cases	% of confirmed measles cases
States	n =1631	
Ekiti	25	1.5
Lagos	402	24.7
Ogun	506	31.0
Ondo	77	4.7
Osun	172	10.6
Oyo	449	27.5
Age grouping	n=321	
<28 days	59	18.3
28 days -<1 year	10	3.1
1 year-<5 years	164	51.1
5 years-<10 years	64	19.9
10 years-<20 years	16	5.0
≥20 years	8	2.5
Number of vaccination doses	n=1631	
None	349	21.4
≥1	830	50.9
Unknown	452	27.7
Admission status	n=1629	
Admitted	126	7.7
Outpatient	1503	92.3
Outcome status	n=1630	
Alive	1608	98.7
Dead	2	0.1
Unknown	20	1.2

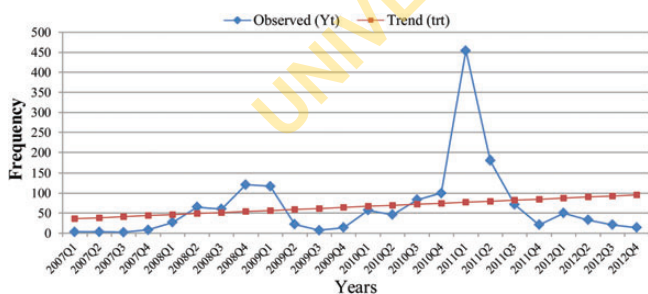


**Figure 4.** Multiple bar chart of the quarterly display of the predicted number of measles cases for the period 2013–2015.

review, which included data from aggregated and case-based reporting.<sup>7</sup> Although the population of Southwest Nigeria is not comparable to that of Ethiopia, the higher mean number of annual reported cases from Ethiopia might have included aggregated reporting. It has been reported that measles reporting dropped following adoption of case-based reporting with laboratory confirmation.<sup>5</sup> Southwest Nigeria met the targets for each of the two principal measles surveillance performance indicators. The surveillance performance indicators in Nigeria have shown progressive improvement since 2006 when the case-based surveillance was established. Annualised non-measles febrile rash illness rates per 100 000 population improved from 0 in 2006 to 2.2 in 2007 and 3.0 in 2008, whereas the rates in LGAs that investigated blood specimens increased from 10% in 2006 to 88.0% and 95.0% in 2007 and 2008, respectively.<sup>5</sup> The achievements of the targets for the two main surveillance performance indicators are parts of the components of the pre-elimination goal by the year 2012 set by WHO African TAG.<sup>5–8</sup>

Only 16% of suspected cases of measles investigated were confirmed by laboratory or epidemiological link, giving an annual incidence of <1 case per million in 2007 to 23 cases per million in 2011. In 2008 alone, 68% of 13 831 suspected cases of measles investigated through the case surveillance system in the entire country were confirmed.<sup>5</sup> The annual incidence of confirmed cases of measles fluctuated and was higher than the pre-elimination target of <5 cases per million in all the years except 2007 and 2012. The inconsistency in the quality of routine and supplemental immunisation activities might have been responsible. It is also possible that cases are reducing but capturing them is getting better due to improved surveillance sensitivity. The WHO and UNICEF estimates of MCV coverage for the period showed an increase from 41% in 2007 to 64% in 2009, then a decline to 42% in 2012.<sup>15</sup> Low coverage at sub-national levels in routine and supplemental immunisation has also been observed.<sup>14</sup> Inadequate community awareness, poor quality services and weak social mobilisation have been reported among the reasons for low coverage.<sup>5</sup> In addition, the pattern of high incidence of measles following a low incidence period is not uncommon.<sup>5,14</sup>

Measles occurred widely within the zone and primarily affected children. This finding is consistent with the results of studies on the epidemiology of measles in Nigeria, which suggest that the disease occurs widely in the country.<sup>3–6,8,11–19</sup> Although the surveillance performance indicators suggested that the measles



**Figure 3.** Line graphs of the observed ( $Y_t$ ) and trend ( $tr_t$ ) of the cases of measles over the period 2007 through 2012 in Southwest Nigeria.

## Discussion

Analysis of the measles case-based surveillance in Southwest Nigeria for 2007–2012 revealed that 10 187 suspected cases were investigated with an average 1637 blood specimens collected per year. This was slightly lower than the mean number of annually reported cases of 1943 in Ethiopia from a 13-year

case-based surveillance provided useful information for monitoring programme impacts, information on age was available for <20% of the confirmed cases, indicating poor data quality. Age of cases is a critical variable for rapid outbreak investigation and response, hence there is a need for training of those involved in data collection.<sup>7,12</sup> However, from the information available on this variable, >70% were aged <5 years and there was no significant shift in the age distribution of affected persons over the period. These findings are consistent with a similar analysis in Ethiopia, where information on age was available for nearly all the cases in the surveillance data.<sup>7</sup> The zero dose status of cases was similar to that reported previously from the zone and indicated that missed children abound despite the routine and supplemental immunisation implemented during the period.<sup>4,17</sup> The population immunity required to limit the spread of measles is high, especially in communities where people are in daily contact with a high number of people.<sup>4</sup> There exists a strong need to implement quality immunisation to improve herd immunity.

Although information about measles with complications is not provided in the surveillance form in use, insight into the severity or burden of the disease could be obtained from the admission status of the cases, the case fatality rate and the number of outbreaks that occurred during the period. Those admitted were likely to be severe cases. In a report from outbreaks in the USA, in 2013, complication rates were high with 11% hospitalisations.<sup>20</sup> In this study, it is lower (7.7%) and this could be due to less severe disease or differences in the admission criteria. In a small-scale outbreak previously reported in the zone, all cases were treated as outpatients.<sup>4</sup> In general, information on case outcome is difficult to collect through surveillance.<sup>7</sup> The 0.1% case fatality reported is similar to a previous report in Nigeria.<sup>4,5</sup> In several studies in other countries, a case fatality ratio of  $\geq 2.4\%$  was found, including a case fatality ratio of 18.2% among cases aged 5 years during an outbreak in Niger.<sup>7</sup> In our series, 160 outbreaks were confirmed with 43.1% comprised of three laboratory confirmed cases and the largest outbreak occurred in a densely populated area in February 2011, with 29 laboratory confirmed cases. In a review of measles case-based surveillance data for the whole of Ethiopia between 2004 and 2009, 302 outbreaks were confirmed with 30% comprising of three confirmed cases and the largest outbreak involved 1619 confirmed cases occurring in January–April 2008.<sup>7</sup>

From our modelling, an increasing trend in the incidence of measles was observed during 2007–2012, and our projection showed that this trend will persist until 2015. However, this is interesting bearing in mind that specific preventive measures, including routine and supplemental immunisation, are in place to control the disease.<sup>3–5</sup> The quality of these activities is doubtful.<sup>5</sup> A follow-up measles campaign is planned for the last quarter of 2013. If a qualitative implementation is carried out, and the coverage is adequate, the inter-epidemic periods should lengthen and the epidemics will hopefully be milder. With sustenance of proper coverage with routine measles vaccination, the epidemics are expected to stop altogether and transmission will be interrupted. However, if vaccine coverage is poor, vaccine immunity will not be sufficient, and the susceptible age group in adults will increase. The increasing trend may also be explained by the possibility that reporting might just be getting better as clinics are improving and learning more about reporting. Some sort of validation would need to be in place to differentiate between

increases due to improving surveillance and failed prevention. In addition, we observed annual seasonality of measles, with an increase in the number of cases in the first and second quarters. Similar patterns have been reported in the country and the WHO Africa region.<sup>1–19</sup> It appears that one peak in 2011, when the largest outbreak occurred, is likely driving the upward trend seen overall. The contributions of failed prevention and surveillance sensitivity of the observed peak could also not be clarified from the data; however, the non-measles febrile rash rates for the years reviewed appeared similar, except for the 2007 when the lowest rate was recorded.

A high proportion of suspected measles cases reported to the surveillance system had negative results for measles antibodies, suggesting that the case definition had low positive predictive value for the disease. Three factors may have been responsible. The first factor was the timing of specimen collection. It is known that specimens collected within the first 3 days of rash onset or after 28 days may not have IgM antibody levels high enough to be detected using standard methodology.<sup>1,13,20</sup> However, according to the surveillance protocols, the collection of a specimen is encouraged anytime within the first month after rash onset, so that opportunities for laboratory testing are not missed.<sup>13</sup> Second, the rash may not be due to measles but to some other diseases that usually present with febrile rash illnesses, such as rubella, chickenpox, erythema infectiosum, roseola infantum, meningococcal infections, scarlet fever, enteroviral infections or drug rashes.<sup>1,13</sup> The confirmatory tests for these illnesses apart from rubella are not part of the surveillance system. Finally, the high proportion of suspected measles cases having negative results for measles antibodies may be a result of clinicians testing more people that are borderline for clinically symptomatic measles.

Our study had some limitations. First, not all measles cases, especially during confirmed outbreaks, were reported through the case-based surveillance system. Moreover, studies estimating the completeness/sensitivity and representativeness of the measles surveillance system within the country indicated that only a small fraction of suspected cases were actually reported and the quality of the system was low.<sup>3,11</sup> Therefore, our results may not be representative of all cases of measles and may be biased toward areas and populations with access to care and adequate reporting efficiency. Second, the vaccination status was not documented in a large proportion of confirmed cases of measles, and this limited our interpretation and understanding of disease susceptibility. Third, the number of measles deaths was likely grossly under-reported. In general, confirmed cases come into contact with the surveillance system only briefly at the time of onset of rash and fever. Unless cases were hospitalised for post-measles complications, it was not possible to obtain accurate information on the outcome of the cases within 30 days after rash onset.<sup>7</sup> Finally, time-series data are often used to make sense of millions of data entries over long periods of time in order to monitor correctly, and therefore, forecast trends. The assumption that the quality of intervention would remain the same may not be true despite efforts by stakeholders to meet the programme goal of pre-elimination in Nigeria. The analysis, however, determined that more effort needs to be put in in order to achieve the programme goal.

In conclusion, the analysis of the measles case-based surveillance provides an opportunity to gain insight into the

epidemiology of measles in Southwest Nigeria. Although the surveillance performance indicators increased gradually over the time period reviewed, the quality of data in terms of completeness of entry of certain critical variables was low, thus limiting our interpretation of disease susceptibility. Measles occurred widely within the zone and primarily affected children aged <5 years. The annual incidence rose from <1/million in 2007 to 23/million in 2011. Vaccinations are being missed by children despite activities to strengthen coverage. These elements are necessary for planning, implementing and evaluating current control strategies for the disease in order to achieve pre-elimination targets. There is a need to work out alternate strategies and to strengthen the surveillance system.

**Authors' contributions:** AAF was responsible for conceptual design and all authors were involved in data analysis; AAF drafted the manuscript and all authors revised and approved the final manuscript. AAF is the guarantor of the paper.

**Acknowledgements:** The authors thank the surveillance officers at the various levels and the laboratory personnel involved in measles case-based surveillance system for their work in reporting, investigating and identification of suspected cases, as well as laboratory confirmation.

**Funding:** None.

**Competing interests:** None declared.

**Ethical approval:** Not required.

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