

Understanding Measles: Roles of Individual Characteristics, Seasonal Patterns, and Surveillance Drivers in Burundi. A Case-based Surveillance Data Analysis, 2019–2023

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Abstract

Introduction: Although measles is a vaccine-preventable disease, it remains a significant cause of morbidity and mortality worldwide. In 2023, 10.34 million cases and 107,000 deaths were reported and disruptive measles outbreaks occurred in 57 countries across 5 WHO Regions. This study aims to contribute to the improvement of detection, prevention, and control of measles outbreaks in Burundi by identifying underlying factors.

Methods: We performed a secondary data analysis of measles case-based surveillance data in Burundi from January 2019 to December 2023, using WHO standard case definitions. Data analysis was carried out using R, and frequencies, proportions and trends were computed. Bivariate and multivariate associations were assessed using generalized linear models (GLMs).

Results: Between January 2019 and December 2023, 5257 suspected measles cases were reported, of which 4046 (76.9%) were confirmed. Among those confirmed, 526 (13%) were laboratory-confirmed, 3332 (82.4%) epidemiologically linked, and 186 (4.6%) clinically compatible. Measles infection was significantly associated with factors such as age over five years (AOR: 1.42; IC: 1.20, 1.70), being vaccinated (AOR: 0.13; IC: 0.10, 0.16), and residing in an urban area (AOR: 1.28; IC: 1.04, 1.60). There was a significant association between hospitalisation and being unvaccinated ($P<0.001$) and age ($P<0.05$). Mortality was higher in children under five years old ($P<0.001$), in those with fewer vaccine doses received ($P<0.001$) and those living in rural areas ($P<0.05$). Measles outbreaks are more likely to occur during the hot, rainy season, and there was a notable delay in providing measles laboratory results to the health facilities.

Conclusion: Although mortality was higher in children under five, this age group was a protective factor against acquiring measles infection. Individuals residing in urban areas and unvaccinated were significantly more likely to contract a measles infection. Mortality was higher in unvaccinated and those living in rural areas. Measles outbreaks mostly occurred during the fourth quarter, and there was a notable delay in providing measles laboratory results. We recommend to the government to prioritise urban-based strategy, booster vaccination strategies for adults, and to enhance surveillance during the fourth quarter of the year.

Background

Measles is an extremely contagious disease affecting humans, caused by a virus from the *Morbillivirus* genus within the paramyxovirus family. It spreads mainly through tiny droplets released into the air when an infected person coughs or sneezes in a closed area (1).

Although measles is a vaccine-preventable disease, it remains a significant cause of morbidity and mortality worldwide, with the highest incidence of cases and deaths occurring in children under 5 years and particularly in the African Region (2).

Measles can be prevented by the administration of the measles-containing vaccine (MCV). The initial dose typically offers around 93% protection, which can rise to 97% following the second dose. Reaching this level of effectiveness across 95% of the population helps establish herd immunity (3). Sociodemographic factors such as age, particularly children under 5, low level of education and income, malnutrition and high population density, play a key role in measles transmission. Measles is also likely to occur in a migration context where immigrants encounter difficulties in accessing vaccination services (4).

Globally, in 2023, the number of estimated cases rose by 20%, compared to the 8.65 million cases reported in 2022. Despite the commitment from all six World Health Organisation (WHO) Regional Offices to eliminate measles, no region has successfully achieved and maintained measles elimination as of the end of 2023. Large-scale or disruptive measles outbreaks (exceeding standard measles outbreak thresholds) occurred in 57 countries across five of the WHO regions during 2023, representing a 58% increase compared to 2022, with 36 countries in four Regions affected (5).

In Burundi, the incidence of measles increased significantly from 9.1 to 123 cases per million people between 2019 and 2023 (6). WHO and UNICEF estimate that coverage with the first dose of MCV1 dropped from 92% in 2019 to 86% in 2023, while coverage for the second dose (MCV2) has remained stagnant at 80% (6). The country has therefore not reached the 95% target recommended by the WHO Agenda for Immunisation for both antigens (7).

According to the national Expanded Programme on Immunisation (EPI)[1], Burundi introduced the Integrated Disease Surveillance and Response (IDSR) strategy in 1999 and, as part of measles surveillance, both active and passive surveillance are implemented in health facilities and at the community level. The EPI has designated focal points responsible for passive and active vaccine-preventable disease surveillance and these health workers report suspected and confirmed cases through the District Health Information Software 2 (DHIS2) platform. Usually, after an outbreak is confirmed by laboratory results, the subsequent cases are mostly confirmed either epidemiologically or clinically. Then a linear list— including laboratory information—is submitted to the program for entry into the measles database[2].

The country experienced a significant measles outbreak since November 2019, originating from a transit camp for Congolese refugees in the Cibitoke health district, which borders the Democratic Republic of Congo (DRC). The outbreak subsequently spread and, by the end of 2020, had reached 23 health districts. In response, the Ministry of Health (MoH), after two subnational supplementary immunisation activities in 2019 and 2020, organised nationwide vaccination campaigns in 2022, which reduced the number of affected districts to six. However, additional districts were impacted again in 2023. To address this resurgence, the country conducted two subnational campaigns in April and August 2023, but these efforts did not fully stop the spread of the outbreak. The most recent nationwide campaign was undertaken in June 2024, yet some districts remain affected[3].

This study analysed individual, seasonal, and surveillance factors in relation to measles infection and its outcomes in Burundi, to identify challenges in both surveillance and immunisation system and to provide evidence-based recommendations to the government for strengthening measles detection,

control and prevention.

[1] Plan for strengthening surveillance of acute flaccid paralysis, EPI, 2023.

[2] Comprehensive Multi-Year Plan 2019–2023, EPI, 2019.

[3] Action Plan for the Response to Measles and Rubella in Burundi, EPI, 2024.

Methods

Study area

Burundi is a landlocked country with 27,834 km² located between East and Central Africa. It borders Rwanda to the North, Tanzania to the South and East, and the Democratic Republic of Congo (DRC) to the West (8).

The climate is characterised by a dry season from June to September, followed by a long rainy season from October to May. January typically experiences a brief dry period lasting around 2 weeks. The average maximum temperature generally peaks at the end of the dry season (September), while average minimum temperatures are lowest during the dry season (July).

The population is estimated at 13 097 400 (28) with a median age of 16.4 and only 3% aged 65 and over. The working population (aged 15-64) accounts for 48% of the total population. Essentially concentrated in rural areas (87%), the majority of the population are subsistence farmers, with 84% and 66% of women and men respectively (9). The main subsistence crops account largely for roots and tubers which represent 51% of production value, followed by fresh fruits and vegetables (22%), pulses (6%), and cereals (6%). Commercial farms, including exports, consist of coffee, tea, palm fruit, and vegetables (10). Burundi is divided into 18 provinces and 114 communes. The administrative center of each commune is a city, while provincial capitals are the biggest cities, Bujumbura is the biggest city, with an estimated population of 500,000 inhabitants and accounting for 61% of the country's urban population. It is followed by Gitega, Ngozi and Bururi each with approximately 40,000 and 50,000 inhabitants (11).

Burundi comprises 50 health districts with 1,159 Health Centres (HCs) for outpatients and with 271 hospitals providing out- and inpatient healthcare services. Routine immunisation is provided in 708 HCs[4] . At a HC, in case of a suspected measles case, blood samples for antibody detection are collected during the first visit and within 28 days of onset of rash. Laboratory confirmation is performed at the National Institute of Public Health, the only accredited laboratory for serological diagnosis of measles and rubella in the country[5] .

Study design

We performed a secondary data analysis of measles case-based surveillance data in Burundi, from January 2019 to December 2023.

Data source

The WHO electronic database, containing the data on measles case-based surveillance for Burundi was obtained from the national Expanded Program on Immunization (EPI). Cases were classified according to the WHO standard case definitions (12) :

Suspected measles case: a patient with a generalized maculopapular (non-vesicular) rash and fever, plus at least one of the following: cough, coryza, or conjunctivitis; or any individual whom a healthcare provider suspects of having measles

Laboratory-confirmed measles case: a suspected measles case with a positive result after testing in a proficient laboratory.

Epidemiologically linked measles case: a clinical case without laboratory confirmation but occurring in the same geographic area and timeframe as a laboratory-confirmed or another epidemiologically linked case.

Clinically compatible measles case: a case satisfying clinical definition, but no adequate clinical specimen was collected and no epidemiological link has been identified.

Data management

The case-based surveillance data from the WHO database were extracted and converted into Microsoft Excel. The data was then anonymized and cleaned. The variables included age, sex, place of residence, district of residence, reporting health facility, clinical outcome status, rash onset date, number of vaccine doses, notification date, specimen collection date, date the specimen was received by laboratory, and the date laboratory result was received by the district.

Data analysis

Using R, we computed frequencies, proportions and trends. Graphs were used to visualise annual and seasonal trends of case occurrence, and surveillance indicators were calculated using data from the projected population .

We performed bivariate analysis using generalised linear model (GLM) to estimate odds ratios (OR) and 95% confidence intervals (CI) to identify risk factors for measles infection and its outcomes/complications in the population under study. Multivariable analysis was performed using GLMs to identify independent risk factors. We used logistic regression with a binomial distribution to model measles infection as outcome variable, and independent variables included age, sex, vaccination status, and residence.

Ethical consideration

Ethics approval was obtained from the Institute of Tropical Medicine, Antwerp Institutional Research Board (1868/25), and the authorisation of using data with reference number No 633.2/66/PEV/2025 was obtained from the Expanded Programme on Immunisation of Burundi. To guarantee confidentiality and anonymity, we removed any information that might identify the patients (date of birth, names, addresses). The databases were then stored securely by researchers on a password-protected computer.

[4] Health Statistics Yearbook 2023, Health Information System Department, 2024

[5] Comprehensive Multi-Year Plan 2019–2023, EPI, 2019

Results

Between January 2019 and December 2023, 5257 suspected measles cases were reported, of which 4046 (76.9%) were confirmed. Among those confirmed cases, 526 (13%) were laboratory-confirmed, 3332 (82.4%) epidemiologically linked, and 186 (4.6%) clinically compatible.

Most cases occurred in young children. Nearly two-thirds (2608, 64.4%) were under five years old, including 45.7% (1851) who were under one year. The median age was two years. More cases were male (2190, 54.3%), and most patients lived in rural areas (2803, 69.3%) (**Table 1**).

Table 1. Socio-demographic characteristics of confirmed measles cases in Burundi, 2019–2023.

Variables	Frequency (n)	Percentage (%)
Age (in years)		
Under 1	1851	45.7
1-4	757	18.7
5-9	529	13.1
10-14	230	5.7
≥15	679	16.8
Total	4046	100%
Sex		
Female	1843	45.7
Male	2190	54.3
Total	4033	100%
Area of residence		
Rural	2803	69.3
Urban	1240	30.7
Total	4043	100%

Measles incidence (%) was significantly higher in the western part of Burundi, which borders the Democratic Republic of Congo.

The vaccination status was known in 2540 cases, and the highest number of patients was unvaccinated (1436, 38.4%), followed by those with at least two doses (616, 16.5%) and those with one dose (488, 13.1%). Seventy-seven percent of the cases in urban areas had no vaccination doses, versus 49.8% in rural areas, and patients with at least two doses were much higher in rural (30,8%) than in urban areas (4.3%) (**Figure 1**). The proportion of zero-dose cases was higher in individuals over 15 years of age (44.7%) compared to those in the 1–4, 5-9 and 10-14 year age groups with 28%, 36%, and 38.2%, of non-vaccinated individuals respectively (**Figure 2**).

Among the 4046 confirmed measles cases, data were available for 2977 and 3018 cases for admission and survival status, respectively. Of those with admission data, 702 (23.6%) were inpatients. Hospitalisation was more frequent among individuals aged five years and older, males, unvaccinated individuals (**Figure 3**), and residents in rural areas compared to their respective counterparts. This difference was statistically significant for age (P<0.05) and the number of vaccine doses received (P<0.001).

Nineteen deaths were reported (1%) and they all occurred in children under 5 years from rural areas. Among those who died, most were unvaccinated (63.3%) and males (63.1%). There was a statistically significant association between mortality and age ($P<0.001$), the number of vaccine doses received ($P<0.001$) and the area of residence ($P<0.05$).

The yearly trend showed a considerable evolution over the five years in which 2019 began with a relatively low number of cases (46), and then 2020 saw a large increase to 1,702 cases, representing an important outbreak. There was a decrease in 2021 and 2022 to 372 and 226 cases respectively before experiencing another major peak of 1,700 cases in 2023, almost matching the 2020 level. There was some seasonality in Burundi: monthly variation indicated that measles cases began to rise in October, coinciding with the start of the rainy season, peaked in December, and then decreased after, marking the transition from the dry season to the rainy season in most regions of Burundi (**Figure 4**).

Although most surveillance indicators met the recommended WHO targets, the incidence rate was over the target of below one case per million in any of the past five years. The proportion of laboratory results reported within four days of specimen receipt fell below the WHO-recommended target of 80% in 2019, 2021, and 2022, as well as the proportion of laboratory-confirmed suspected cases, which never reached 80% (**Table 2**).

Table 2. Surveillance indicators for measles infection, Burundi, 2019-2023.

Measles Surveillance Indicators	Target	2019	2020	2021	2022	2023
Annual reporting rate of discarded measles cases /100 000 population	≥ 2	1.0	2.1	2.2	2.7	2.3
Percentage of specimens received at the laboratory within 5 days of collection	$\geq 80\%$	82.4	97.4	94.3	93.4	97.3
The proportion of results reported by the laboratory within 4 days of specimen receipt	$\geq 80\%$	31.5	82.7	69.1	61.4	84.1
Proportion of Specimen reaching Laboratory in good condition	$\geq 80\%$	99.6	99.8	99.7	99.8	99.7
The proportion of laboratory-confirmed suspected cases	$\geq 80\%$	23.6%	43%	23.3%	16%	24.3%
The proportion of specimens collected within 28 days of rash onset	$\geq 80\%$	98.4	99	97.9	96.8	97.7
Proportion of districts that have reported at least 1 suspected case of measles with a blood specimen per year	$\geq 80\%$	84	100	85	88	98
Incidence rates	< 1 per million	4.4	158.5	29.6	17.6	128.8
Reporting completeness (%)		96.8	72.2	86.8	92	76.9

At the multivariate level (**Table 3**), the probability of having a confirmed measles infection increased by 42% in individuals of five years of age and above, compared to those younger (AOR: 1.42; IC:1.20,1.70); people who received at least one dose of vaccine saw the odds of having confirmed measles infection reduced by 87%, compared to the unvaccinated (AOR: 0.13; IC:0.10, 0.16). Finally, the odds of having measles confirmed among those residing in urban areas was increased by 28%, compared to their rural counterparts (AOR: 1.28; IC:1.04, 1.60).

Table 3. Analysis of exposure factors for measles infection in Burundi, 2019-2023.

Variables	Frequency		COR	95%CI	P- value	AOR	95%CI
	Yes	No					
Age (in years)					<0.01		
< 5	2608	816	1				
≥ 5	1436	365	1.23	1.07, 1.42		1.42	1.20, 1.70
Sex					=0.87		
Female	1843	540	1				
Male	2190	640	1.002	0.88, 1.14			
Vaccine doses					<0.001		
Zero dose	1436	163	1				
One dose	488	408	0.13	0.11, 0.16		0.13	0.10, 0.16
At least 2 doses	616	520	0.13	0.11, 0.16		0.13	0.10, 0.16
Area of residence					<0.001		
Rural	2803	1005	1				
Urban	1240	171	2.60	2.18, 3.10		1.28	1.04, 1.60

Discussion

Burundi has experienced a persistent measles outbreak since 2019, with seasonal peaks during the hot, rainy periods. Our analysis highlights that infection and severe outcomes are strongly associated with age, vaccination status, and place of residence. Interestingly, the likelihood of laboratory confirmation also varies by residence, suggesting that better access to health facilities and transport in urban areas may facilitate timely sample submission and diagnostic testing.

This study found that the majority of suspected measles cases involved young individuals, with nearly two-thirds (64.4%) being under five years old. Studies conducted in Nigeria (13) and Niger (4), reported similar results. However, our analysis showed that suspected cases in children under five years of age had lower odds of measles confirmation, indicating that younger children may be clinically suspected but not always laboratory confirmed due to diagnostic and surveillance system factors. In Eritrea, an 18-year retrospective analysis also shows age-related differences in measles confirmation and surveillance findings, including how age influences laboratory confirmation patterns, which is consistent with the idea that younger children may be clinically suspected but not always laboratory confirmed due to diagnostic and surveillance system factors (14). This was also concluded in a similar study from Nigeria (13). In Burundi's surveillance system, cases in adults are mostly confirmed clinically, which may have increased the number of false positives in this group of adults. Certainly, the SIAs conducted during the period under investigation, targeting children under five, may have offered an added layer of protection. Findings from studies conducted in Malaysia (4), Italy (15), and the USA (16), indicated that measles immunity declines over time, rendering adults more susceptible.

Our research indicated that the chance of having measles confirmed among those residing in urban areas was increased by 28%, compared to their rural counterparts. Previous studies done in Nigeria, Malaysia and Liberia (4,17,18) also reported higher rates of confirmed measles infection among urban residents. This may be due to high population density (19), and the relatively low immunisation status in urban settings, as reflected in our findings (30.8% in rural versus 4.3% in urban). Urban environments tend to have increased contact rates, which can accelerate transmission when vaccine coverage is suboptimal. Additionally, disparities in access to health services and laboratory diagnostics may mean that suspected cases in urban areas are more likely to be sampled and confirmed, whereas logistical barriers in rural regions can reduce confirmation rates despite clinical suspicion.

Our findings showed that measles incidence was particularly high in Cibitoke and other western districts. This may be due to these districts' proximity to the DRC—where 311,471 confirmed cases and 6,045 deaths were reported in 2019 (20)—as well as their relatively high temperatures and dense populations (8).

Although the measles vaccine is available and provided free of charge, 56% of cases with documented vaccination status had not received any dose. Unvaccinated individuals had nearly ten times the risk of confirmed measles infection compared with those who had received at least one dose. This aligns with the findings from studies conducted in Nigeria (13) Uganda (21) and a study carried out in Burundi, which concluded that "the lack of effective coverage in MCV2 could well explain the reason for the measles outbreaks" (22).

In our study, most of the hospitalised cases were unvaccinated individuals and those under five years old. All the 19 reported deaths occurred in children under five living in rural areas, with two-thirds of the deaths occurring among individuals who had not received any vaccine doses. Similar studies conducted in the Democratic Republic of Congo and in Ethiopia (23,24) also found that younger age and lack of vaccination were statistically associated with a higher risk of measles-related mortality. The higher proportion of deaths in rural areas reflect limited health facility coverage and shortages in the health workforce, which are especially pronounced in these settings, highlighting the heightened vulnerability of children under five to measles mortality (25).

Our study revealed some seasonality in measles trends. Cases began to rise in October, peak in December, and then decrease after suggesting that measles outbreaks occur mostly during the rainy season, when the temperature is higher. It also coincides with the beginning of the school year, resulting in close contact among pupils. Our findings are in line with the WHO, which states that, in tropical settings, measles incidence is more likely to be higher during the hot seasons (12). This is consistent with findings from studies conducted in Ethiopia and Nigeria (26,27), where measles incidence was higher during the dry seasons, which are typically characterised by hot temperatures. The lack of vaccination campaigns during 2020 and 2023 may explain the high number of cases observed during those two years[6].

Our analysis found that the country has met at least some of the WHO-recommended targets. However, the proportion of laboratory results reported within four days of specimen receipt fell below the WHO-recommended target and was just 65.7% on average. This is similar to the finding of studies conducted in Nigeria (13) and Niger (28)(31). Shortages of testing kits, particularly reagents, along with the weak health information system that fails to integrate data from the national reference laboratory, may have been the primary reasons for this gap.

This study has several limitations that may have influenced the results. The surveillance database contained missing and inconsistent data for key variables, and records with incomplete information, negative time periods, or implausible ranges were treated as unknown or missing. As secondary surveillance data were used, there may have been recall bias in reporting vaccination status, including the number of doses received and other related details. Additionally, some cases—such as adult cases or deaths occurring in the community—may have been underreported, so our findings may not fully capture the total burden of measles. Nevertheless, to our knowledge, this is the first study of its kind in Burundi. Its major strength lies in its comprehensive assessment of determinants of confirmed measles cases, case outcomes, and the performance of the surveillance system.

[6] Action Plan for the Response to Measles and Rubella in Burundi, EPI, 2024.

Conclusion

Our study successfully met its primary goal by enhancing the understanding of measles outbreaks in Burundi, through identification of key factors that contribute to their persistence in the country. Providing quantified protection and risk factors and identifying geographic and contextual drivers, this research provided critical evidence highlighting new findings beyond routine reporting. In fact, low coverage in vaccination was the main risk factor for measles infection and its complications: unvaccinated individuals were significantly more likely to contract a measles infection and were significantly associated with hospitalisation and mortality. Residence areas revealed two risk profiles: individuals residing in urban areas were more likely to be affected by the measles infection, probably due to high population density and lower coverage in vaccination (4.3% in urban versus 30.8% in rural), while mortality was higher in those living in rural areas where the coverage in health facilities and human resources is lower. Children under five represented most suspected cases, but had lower odds of being confirmed measles, possibly reflecting higher vaccination coverage and differences in surveillance and testing practices.

Our study finally revealed that measles outbreaks are more likely to occur during the fourth quarter, and there was a notable delay in providing measles laboratory results to the health facilities. We recommend the implementing of an urban-based strategy for improving vaccination coverage in this area, and considering booster vaccination strategies for adults, particularly during the vaccination campaigns. The ministry of health should implement a cross-border surveillance system, strengthen the capacities of the national reference laboratory, and enhance surveillance during the fourth quarter of the year.

Abbreviations

WHO

World Health Organization

USA

United States of America

UNICEF

United Nations International Children's Emergency Fund

SIAs

Supplemental Immunization Activities

MCV

Measles-Containing Vaccine

IDSR

Integrated Disease Surveillance and Response

EPI

Expanded Programme on Immunisation

DHIS2

District Health Information Software 2

Declarations

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Authors' contributions

NC & KK Study conceptualisation, analysis, interpretation and discussion of results. NC literature review, data curation and original draft preparation. KK Supervision. BT critical revision of the final draft. NE contributed to the discussion. All authors read and approved the final manuscript.

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Availability of data and materials

The routinely collected surveillance data used during the current study were obtained with permission from the Burundi Ministry of Health. These data are not publicly available due to institutional data protection policies but may be made available from the corresponding author on reasonable request

Ethics approval and consent to participate

Ethics approval was obtained from the Institutional Research Board of the Institute of Tropical Medicine, Antwerp (Reference No.1868/25). Authorisation to use data was obtained from the Expanded Programme on Immunisation of Burundi (Reference No. 633.2/66/PEV/2025). The consent to participate

was waived by the Institutional Research Board of the Institute of Tropical Medicine because the study involved a retrospective secondary analysis of routinely collected surveillance data. All methods were performed in accordance with applicable ethical guidelines and regulations

Consent for publication

Not applicable. The manuscript does not contain any person's data in any form.

Competing interests

The authors declare that they have no competing interests.

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Clinical trial number

Not applicable.

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Figures

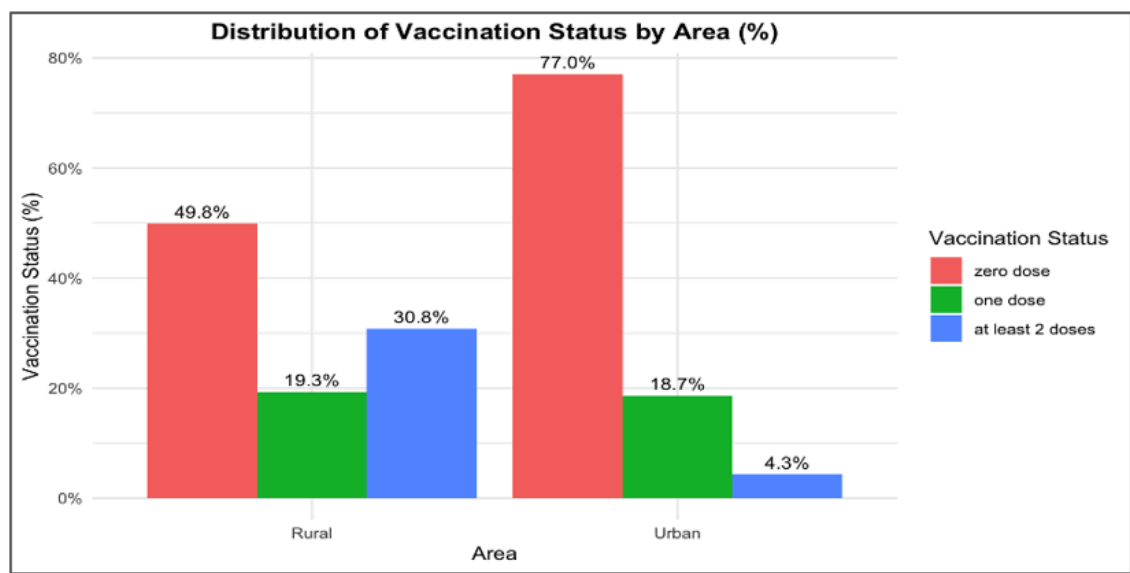


Figure 1
Comparison of measles vaccination status by area of residence, Burundi, 2019–2023

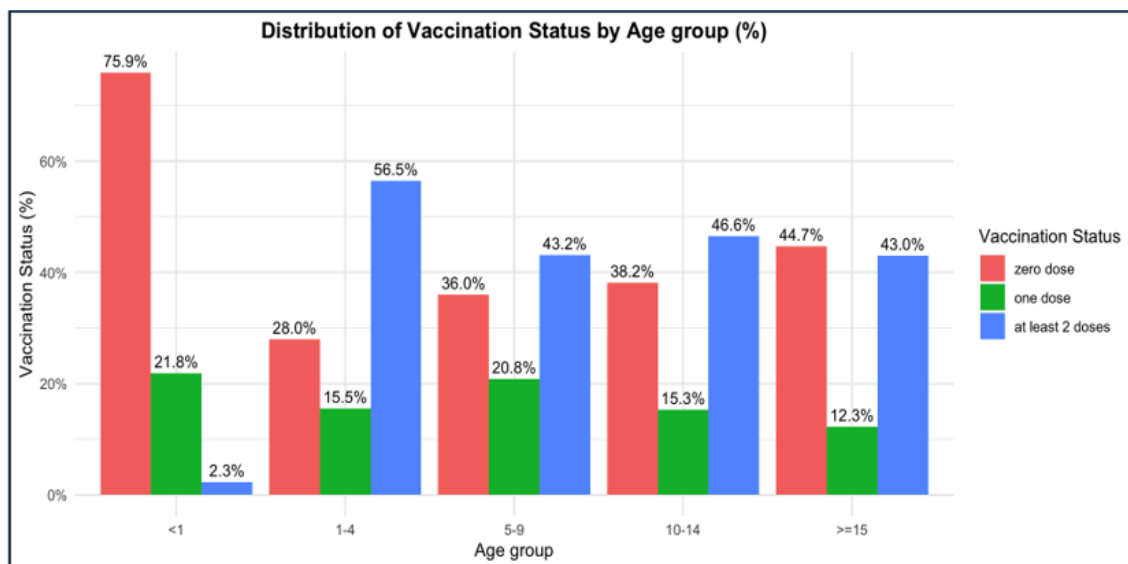


Figure 2

Comparison of measles vaccination status with age groups in Burundi, 2019–2023

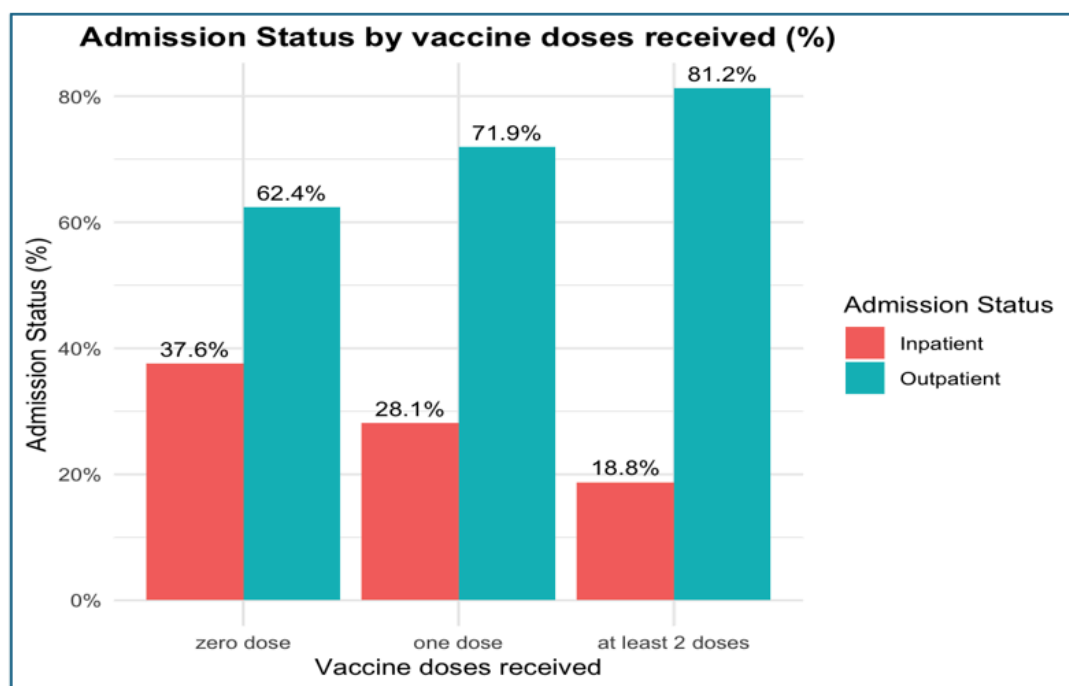


Figure 3

Comparison of admission and vaccine dose received, Burundi, 2019-2023.

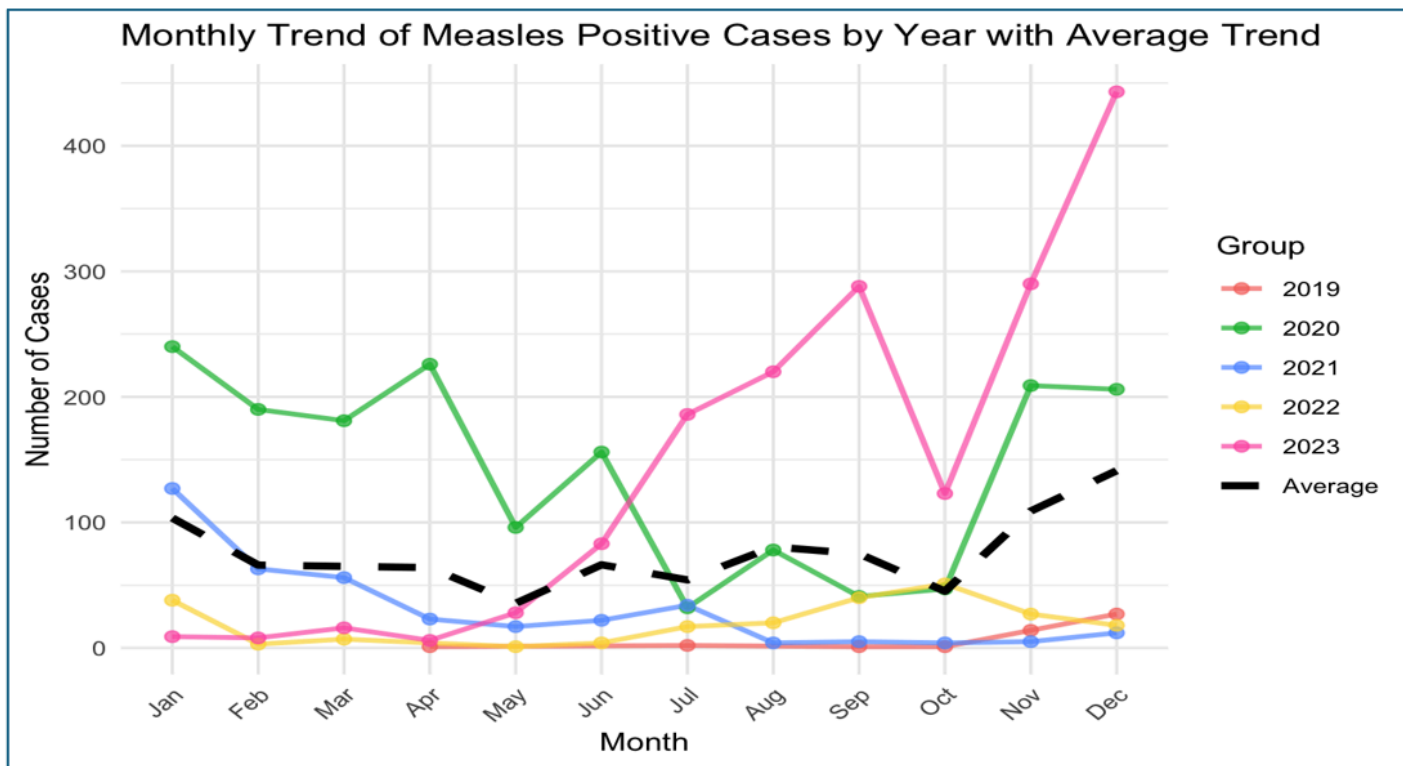


Figure 4

Trends of reported measles cases by month over five years, Burundi, 2019–2023