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Factors contributing to the measles outbreak reported at Kabinga Rural Health Centre in Kanchibiya District.

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Abstract

Background

Measles outbreaks continue to occur in rural Zambia despite progress in immunization. In 2024, an increase in suspected cases was reported at Kabinga Rural Health Centre (RHC) in Kanchibiya District. This study examined demographic, vaccination-related, and health system factors linked to confirmed or epidemiologically linked measles cases.

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Methods

A retrospective analysis of 240 suspected measles cases recorded at Kabinga RHC from January 2023 to December 2024 was conducted. Data were extracted from facility registers and the DHIS2. We performed descriptive statistics, chi-square tests for associations, Spearman correlation for selected relationships, and multivariable logistic regression to identify independent predictors of case confirmation (laboratory-positive or epidemiologically linked versus test-negative). Basic geospatial summaries of village-level distribution were also included.

Results

Children aged 1–4 years (40.4%) and 5–14 years (39.2%) accounted for most of the suspected cases, with infants under 1-year accounting for 15.8%. Half of cases (50.0%) had incomplete vaccination status. In multivariable analysis, incomplete vaccination was independently associated with higher odds of confirmed or epidemiologically linked status (adjusted odds ratio [aOR] 3.12, 95% CI 1.71–5.69). Residence in areas classified as inaccessible (aOR 2.03, 95% CI 1.16–3.56) and living 5–10 km from the facility (aOR 1.78, 95% CI 1.01–3.15) were also significant predictors. A weak inverse correlation existed between distance to the facility and vaccination completeness (Spearman's rho = −0.15, p = 0.021). Villages such as Malombola, Chalo, and Kalulu showed relatively higher case concentrations. Laboratory confirmation was limited (10.8% IgM/PCR positive), with 51.7% classified as epidemiologically linked.

Conclusions

Incomplete vaccination, geographic inaccessibility, and moderate distance from health services contributed to transmission during this period. These findings underscore the need to strengthen routine two-dose measles-rubella coverage, maintain cold chain reliability in remote settings, and expand outreach services to improve access in dispersed rural communities.

Keywords: *Measles; Vaccination coverage; Health system access; Rural health; Zambia; Outbreak investigation*

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Background

Measles remains a significant public health challenge globally despite the availability of safe and effective vaccines(1). With a basic reproduction number (R_0) of 12–18, making it one of the most contagious infectious diseases known, measles requires approximately 95% population immunity to interrupt transmission(2). This highly contagious viral disease disproportionately affects children, with potential complications including pneumonia, blindness, and death(3). Globally, cases increased by 20% in 2023, reaching 10.3 million compared to 8.65 million in 2022, primarily attributed to inadequate vaccination coverage in impoverished and conflict-afflicted regions. While the global death rate decreased by 8%, with 107,500 deaths recorded in 2023, this decline was largely observed in high-income countries, as measles-related deaths in lower-income countries continued to rise, highlighting healthcare access disparities(4).

Africa has been particularly affected, with measles death rates increasing by 37% in 2022(5). Countries like Nigeria and Zambia have experienced recurring outbreaks due to low vaccination coverage and health system challenges(6). The WHO and CDC recommend achieving 95% vaccination coverage for both first and second doses of the measles vaccine to prevent outbreaks, yet many countries fail to reach this target, with several sub-Saharan African nations reporting second-dose coverage below 70% (7).

Despite nationwide vaccination campaigns, including one in September 2024 targeting four million children aged 9 months to 5 years, Zambia continues to experience measles outbreaks across various districts(8). Epidemiological trends indicate that the first-dose coverage had stagnated at approximately 93%, below the 95% herd immunity threshold, while the second-dose coverage remained critically low at 66%(9). Subnational disparities leave certain districts and rural villages with coverage as low as 50-70%, and COVID-19-related disruptions have created an accumulated cohort of susceptible children(10). This study aimed to assess the factors contributing to the measles outbreak at Kabinga RHC in Kanchibiya District.

Methodology

Study Design and Setting

A retrospective cross-sectional study was conducted at Kabinga Rural Health Centre (RHC), located in Kanchibiya District, Muchinga Province, Zambia. The facility serves a predominantly rural population of approximately 12,000 people distributed across 35 villages within its catchment area. Healthcare access is limited by scattered settlements across challenging terrain, with seasonal accessibility issues worsening during the rainy season when roads become impassable.

The study analysed existing records of patients diagnosed with measles at the facility between January 2023 and December 2024. This retrospective design allowed immediate access to outcome data without prospective follow-up and enabled simultaneous exploration of associations between demographic factors, vaccination status, and geographical location (11)**.**

Study Population and Eligibility

The study population comprised all individuals residing within the Kabinga Rural Health Centre catchment area in Kanchibiya District, approximately 12,000 people across 35 villages, whose livelihoods primarily involve subsistence farming and small-scale trade(12).

The study sample was drawn from all individuals diagnosed with measles at the facility between January 2023 and December 2024. Eligible cases included laboratory-confirmed, epidemiologically linked, and test-negative cases meeting the standard measles case definition. Cases with incomplete essential data, those not meeting case definition criteria, patients residing outside the catchment area, and cases outside the study timeframe were excluded. A simple random sample of 240 cases was selected from the eligible pool; any selected case subsequently found ineligible was replaced by further random sampling to maintain the target sample size (13).

Study Variables

Outcome Variable

The primary outcome was confirmed measles case status, defined as a suspected case that was either laboratory-confirmed (positive measles IgM) or epidemiologically linked to a

laboratory-confirmed case. The reference category comprised suspected cases that tested negative and were not epidemiologically linked.

Independent Variables

Independent variables were grouped into three domains:

Demographic factors: Age group (<1, 1–4, 5–14, ≥15 years) and sex (male, female).

Vaccination status: Categorized as fully vaccinated (documented receipt of two MR vaccine doses), incomplete (one dose only), unvaccinated, or unknown.

Health system and geographic factors:

Distance to facility: Categorized as <5 km, 5–10 km, and >10 km.

Accessibility: A binary variable (accessible, inaccessible) based on documented physical access barriers such as seasonal road conditions and terrain challenges.

Residential area: Village of residence.

Admission status: Whether the case required inpatient admission (yes, no).

Sample Size and Sampling Strategy

The sample size was calculated to ensure adequate statistical power for the primary analyses. Using the formula for cross-sectional studies, assuming a 50% prevalence of the key risk factors to maximise sample size, a 95% confidence level, and 80% power to detect an odds ratio of 2.0, the minimum required sample was 220. To account for incomplete records, the target was set at 240.

From an estimated 300–350 measles cases recorded at Kabinga Rural Health Centre between January 2023 and December 2024, a simple random sample of 240 cases was drawn. All eligible cases were enumerated from the line list, assigned unique numbers, and 240 were selected using computer-generated random numbers. This approach maintained statistical power for chi-square tests and logistic regression while ensuring representativeness and minimising selection bias

Data Collection and Management

Data were extracted from existing health facility records using a structured, pre-tested extraction form. Primary sources included outpatient and inpatient registers, notifiable disease registers, immunisation records, laboratory reports, and the District Health Information System 2 (DHIS2).

Key variables extracted encompassed demographic characteristics, vaccination status, geographical information, and clinical data. The process involved systematic identification of all measles cases, cross-referencing across multiple registers to verify vaccination status, and extraction of relevant information into a password-protected spreadsheet with built-in validation rules to minimise entry errors. Data cleaning comprised range checks, consistency verification, and appropriate handling of missing information. All electronic data were securely stored with regular backups, while physical extraction forms were kept in locked cabinets with restricted access(7,10,14).

Data Analysis

Data were analyzed in Stata v14. After cleaning and descriptive summaries (means/SD for continuous; frequencies/% for categorical), bivariate associations were tested (chi-square/Fisher's exact; t-tests). Multivariable logistic regression identified independent predictors (aORs, 95%CIs), with model fit assessed via Hosmer-Lemeshow and AUC. Geospatial analyses included village-level attack rates, Moran's I/SaTScan for clustering, and Spearman correlations for facility distance vs. coverage. $P<0.05$ significant; DAG-guided adjustments.

Results

A total of 240 suspected measles cases reported at Kabinga Rural Health Centre between January 2023 and December 2024 were included in the analysis. Table 1 summarises the demographic and clinical characteristics of the study population.

By age group, the highest proportion of cases occurred among children aged 1–4 years (40.4%), followed by those aged 5–14 years (39.2%). Infants under one year accounted for 15.8% of cases, while individuals aged 15 years and older represented the smallest proportion (4.6%). With respect to sex, males constituted a slight majority (52.5%) compared to females (47.5%).

Geographically, cases were distributed across multiple residential sub-areas. The highest proportions were reported in Kabinga (16.7%), Malombola (15.0%), and Munkunta (13.8%), while the remaining 35.3% of cases originated from smaller surrounding villages.

Regarding vaccination status, half of the cases (50.0%) had incomplete vaccination, 35.4% were fully vaccinated, 13.8% were unvaccinated, and 0.8% had unknown status. By case classification, 10.8% were laboratory-confirmed positive, 51.7% were epidemiologically linked to a confirmed case, and 37.5% tested negative.

In terms of health system access, 50.4% of cases resided 5–10 km from the health facility, 43.3% lived within 5 km, and 6.3% lived beyond 10 km. Nearly half (45.8%) of cases were from areas classified as inaccessible, and 20.4% of cases required hospital admission

Table 1: Demographic and Clinical Characteristics of Suspected Measles Cases at reported Kabinga RHC (N=240)

Characteristic	Category	n	(%)
Age group			
	<1 year	38	15.8
	1–4 years	97	40.4

	5–14 years	94	39.2
	≥15 years	11	4.6
Sex			
	Male	126	52.5
	Female	114	47.5
Residential area			
	Kabinga	40	16.7
	Malombola	36	15.0
	Munkunta	33	13.8
	Kalulu	30	12.5
	Chalo	16	6.7
	Other villages	85	35.3
Vaccination status			
	Fully vaccinated	85	35.4

	Incomplete	120	50.0
	Not vaccinated	33	13.8
	Unknown	2	0.8
Measles case status			
	Laboratory confirmed (positive)	26	10.8
	Epidemiologically linked	124	51.7
	Negative	90	37.5
Distance to facility			
	<5 km	104	43.3
	5–10 km	121	50.4
	>10 km	15	6.3
Accessibility			
	Accessible	130	54.2
	Inaccessible	110	45.8

Admitted to facility			
	Yes	49	20.4
	No	191	79.6

Data are presented as frequencies (n) and percentages (%).

Table 2 presents the bivariate associations between demographic, vaccination, and health system factors and confirmed measles case status (laboratory-positive or epidemiologically linked vs. negative).

Vaccination status was significantly associated with measles case status ($\chi^2 = 27.41$, $p < 0.001$). The highest proportion of confirmed cases (75.0%) was observed among incompletely vaccinated individuals, compared to 57.6% among fully vaccinated and 45.5% among unvaccinated individuals.

Accessibility was also significantly associated with case status ($\chi^2 = 6.42$, $p = 0.040$). Confirmed cases accounted for 70.9% of individuals from inaccessible areas versus 55.4% from accessible areas.

No statistically significant associations were observed for age group ($p = 0.094$), sex ($p = 0.619$), residential area ($p = 0.798$), distance to facility ($p = 0.316$), or admission status ($p = 0.086$).

Table 2: Bivariate Association Between Demographic, Vaccination, and Health System Factors and Confirmed Measles (Positive/Epi-Linked vs. Negative)

Variable	Category	Confirmed Cases (n=150) n (%)	Negative (n=90) n (%)	χ^2	p-value

Age group				10.82	0.094
	<1 year	29 (76.3)	9 (23.7)		
	1–4 years	63 (64.9)	34 (35.1)		
	5–14 years	53 (56.4)	41 (43.6)		
	≥15 years	5 (45.5)	6 (54.5)		
Sex				0.96	0.619
	Male	76 (60.3)	50 (39.7)		
	Female	74 (64.9)	40 (35.1)		
Residential area				14.67	0.798
	Kabinga	22 (55.0)	18 (45.0)		
	Malombola	26 (72.2)	10 (27.8)		
	Munkunta	21 (63.6)	12 (36.4)		
	Kalulu	21 (70.0)	9 (30.0)		

	Chalo	13 (81.3)	3 (18.8)		
	Other villages	47 (55.3)	38 (44.7)		
Vaccination status				**27.41**	**<0.001**
	Fully vaccinated	49 (57.6)	36 (42.4)		
	Incomplete	90 (75.0)	30 (25.0)		
	Not vaccinated	15 (45.5)	18 (54.5)		
Distance to facility				4.73	0.316
	<5 km	60 (57.7)	44 (42.3)		
	5–10 km	82 (67.8)	39 (32.2)		
	>10 km	8 (53.3)	7 (46.7)		
Accessibility				**6.42**	**0.040**
	Accessible	72 (55.4)	58 (44.6)		

	Inaccessible	78 (70.9)	32 (29.1)	
Admitted to facility			4.91	0.086
	Yes	36 (73.5)	13 (26.5)	
	No	114 (59.7)	77 (40.3)	

Confirmed cases include laboratory-positive and epidemiologically linked cases. Bold p-values indicate statistical significance at p<0.05.

Table 3 shows the results of multivariable logistic regression identifying independent predictors of confirmed measles, adjusting for age, sex, vaccination status, distance, accessibility, and admission status.

Incomplete vaccination emerged as the strongest independent risk factor. Individuals with incomplete vaccination were more than three times as likely to have confirmed measles compared to fully vaccinated individuals (aOR = 3.12, 95% CI: 1.71–5.69, p < 0.001).

Geographic inaccessibility also significantly increased the risk of confirmed measles. Individuals from inaccessible areas had twice the odds of confirmed measles compared to those from accessible areas (aOR = 2.03, 95% CI: 1.16–3.56, p = 0.013).

Distance to a health facility of 5–10 km was associated with a 78% increased risk of confirmed measles compared to living within 5 km (aOR = 1.78, 95% CI: 1.01–3.15, p = 0.046). Distance greater than 10 km was not significantly associated (aOR = 1.22, 95% CI: 0.41–3.64, p = 0.726).

Age (p = 0.124), sex (p = 0.326), unvaccinated status (p = 0.361), and hospital admission (p = 0.162) were not independent predictors in the adjusted model.

Table 3: Crude and Adjusted Odds Ratios for Factors Associated with Confirmed Measles (Positive/Epi-Linked vs. Negative)

Predictor	Category	cOR	95% CI	p-value	aOR	95% CI	p-value
Age	<1 vs. ≥15 years	3.87	1.10 – 13.62	0.035	2.45	0.78 – 7.69	0.124
	1–4 vs. ≥15 years	2.23	0.64 – 7.77	0.208	1.89	0.60 – 5.96	0.278
	5–14 vs. ≥15 years	1.55	0.44 – 5.46	0.494	1.34	0.42 – 4.28	0.623
Sex	Female vs. Male	1.13	0.66 – 1.94	0.655	1.32	0.76 – 2.29	0.326

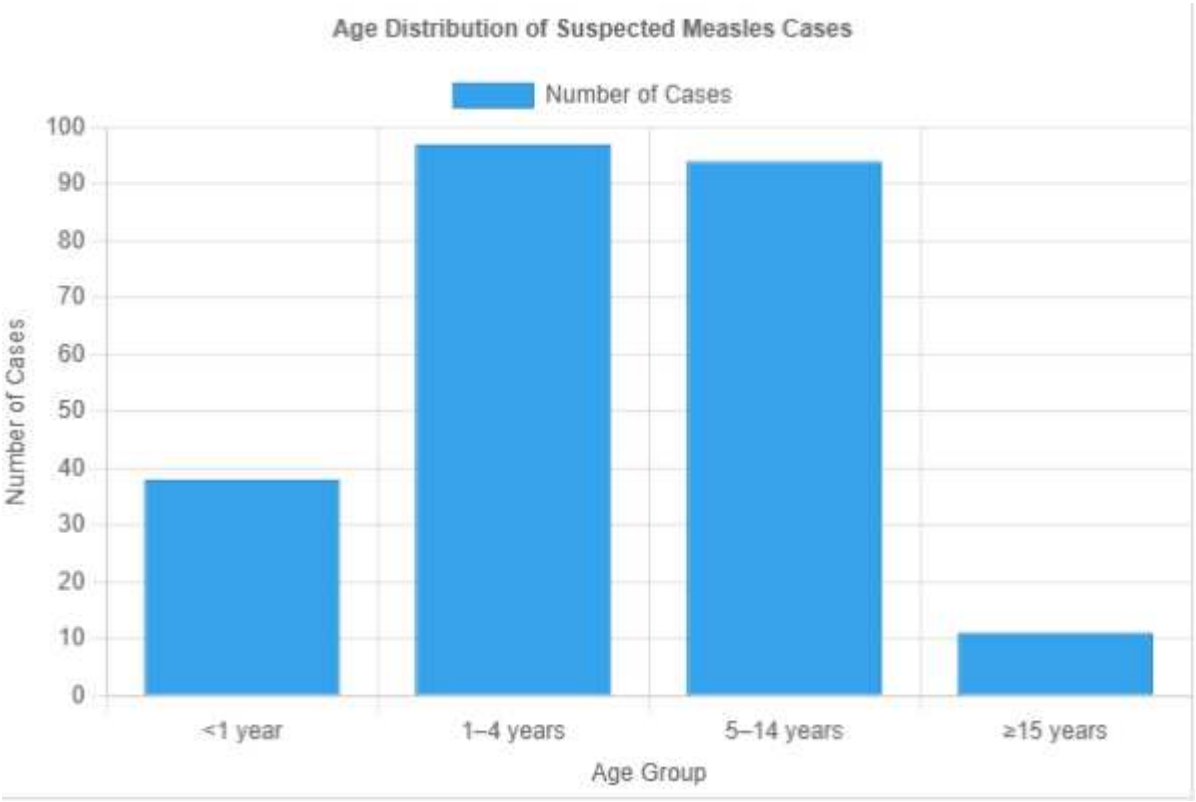
Vaccination status	Incomplete vs. Fully vaccinated	2.20	1.27 – 3.82	0.005	**3.12**	**1.71 – 5.69**	**<0.001**
	Not vaccinated vs. Fully vaccinated	0.61	0.29 – 1.31	0.206	1.45	0.65 – 3.24	0.361
Distance	5–10 km vs. <5 km	1.54	0.90 – 2.64	0.113	**1.78**	**1.01 – 3.15**	**0.046**
	>10 km vs. <5 km	0.84	0.29 – 2.44	0.746	1.22	0.41 – 3.64	0.726
Accessibility	Inaccessible vs. Accessible	1.96	1.15 – 3.36	0.014	**2.03**	**1.16 – 3.56**	**0.013**
Admitted	Yes vs. No	1.88	0.94 – 3.75	0.074	1.67	0.81 – 3.44	0.162

cOR = crude odds ratio; aOR = adjusted odds ratio; CI = confidence interval. Bold values indicate statistical significance at p<0.05. Model adjusted for all variables shown.

The majority of suspected measles cases were identified among children aged 1–4 years (40.4%) and 5–14 years (39.2%), followed by those under 1 year (15.8%) and those aged 15 years and above (4.6%), suggesting that measles predominantly affected the pediatric

population. A slight male predominance was observed (52.5% vs. 47.5%). Geographically, cases were dispersed across residential sub-areas, with the highest proportions reported in Kabinga (16.7%), Malombola (15.0%), and Munkunta (13.8%). Smaller clusters of equal and lower caseloads were noted in Chisesa, Mutungo, and Yamanga (2.9% each), while 13.8% of cases were classified under "others." This distribution indicates a geographically dispersed yet heterogeneous clustering pattern of measles cases in the district, with a predilection for younger age groups, as shown in Figure 1.

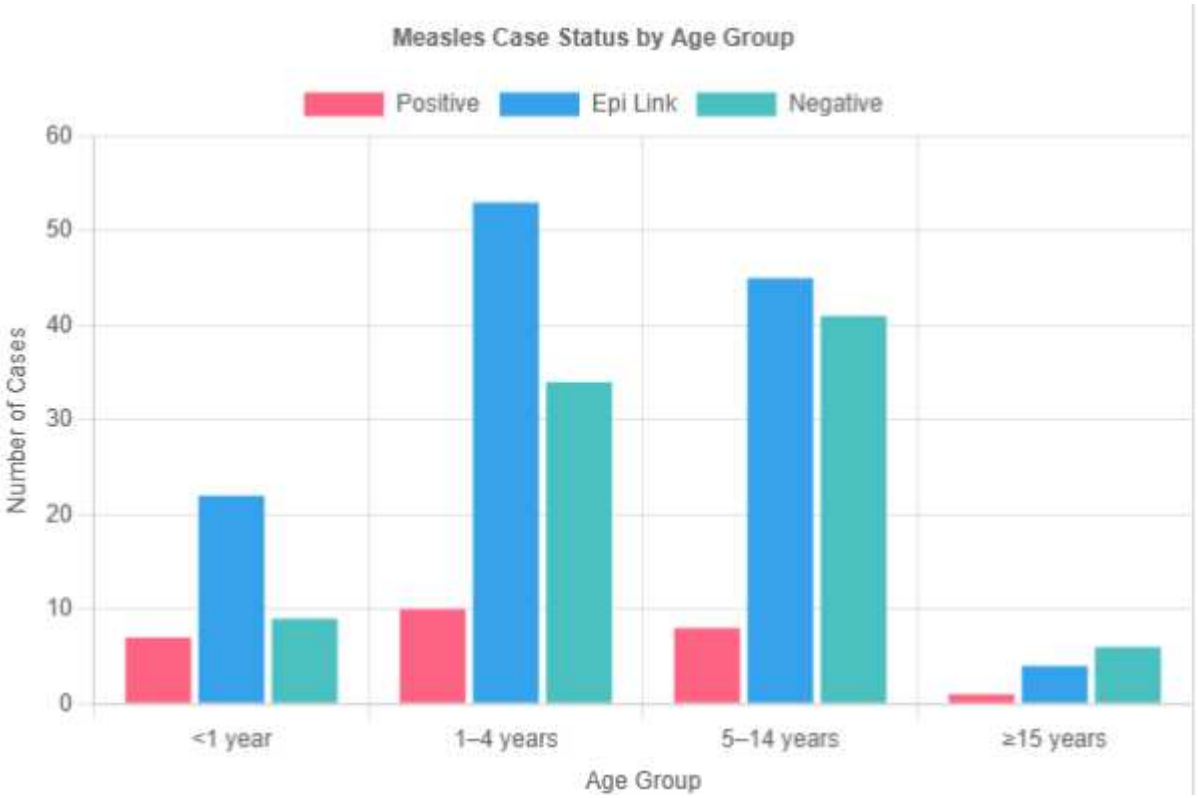
Figure 1: Age Distribution of Suspected Measles Cases



Stata output 2025

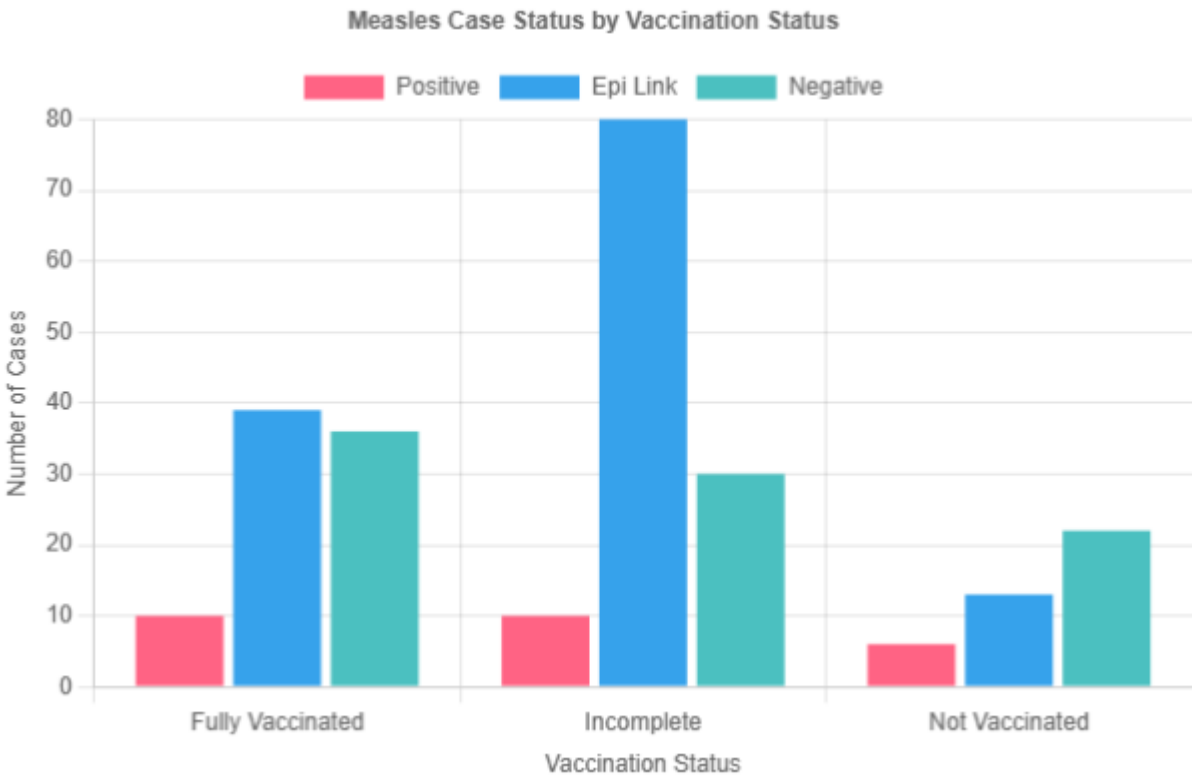
The bar chart showed measles case status (Positive, Epidemiologically Linked, Negative) by age group, revealing distinct patterns. As shown in Table 2, the highest proportions of confirmed positive (18.4%) and epidemiologically linked cases (57.9%) were observed among children under one year of age, followed by those aged 1–4 years (positive: 10.3%; epi-linked: 54.6%) and 5–14 years (positive: 8.5%; epi-linked: 47.9%). The ≥15 years age group, despite a small sample size (n = 11), showed lower proportions of positive (9.1%) and epi-linked (36.4%) cases. The high frequency of epidemiologically linked cases in younger age groups suggests limited laboratory confirmation capacity, necessitating reliance on epidemiological linkage for diagnosis(15). Nevertheless, the trend toward higher susceptibility among infants is consistent with incomplete immunization coverage in this age group(14), as shown in Figure 2

Figure 2 Measles Case Status by Age Group



Analysis of case status by vaccination status revealed that partially vaccinated individuals had the highest proportion of epidemiologically linked cases (66.7%), compared to fully vaccinated (45.9%) and unvaccinated individuals (31.7%). Confirmed positive case rates were comparable across the three groups (incomplete: 8.3%; fully vaccinated: 11.8%; unvaccinated: 14.6%). The disproportionately high rate of epidemiologically linked cases among partially vaccinated individuals suggests that incomplete vaccination is a major risk factor for infection. This finding was supported by a chi-square test ($p < 0.001$) and logistic regression (odds ratio = 3.12, $p < 0.001$), consistent with evidence that two-dose regimens are necessary for full protection(16). Low vaccine effectiveness (19.2%) points to potential issues such as waning immunity or improper vaccine storage(10,17). Collectively, these findings underscore the urgency of achieving complete vaccination coverage to attain herd immunity, as shown in Figure 3.

Figure 3: Measles Case Status by Vaccination Status



(Stata output, 2025)

Mapping Case Distribution

Case mapping was adopted to represent the spatial distribution of reported measles cases across different residential areas.

Geographical distribution of suspected measles cases (N=240) by village, Kabinga RHC catchment area, Kanchibiya District (2023–2024).

Kabinga (16.7%), Malombola (15.0%), and Munkunta (13.8%) accounted for nearly half (45.5%) of all cases, followed by Kalulu (12.5%) and Chalo (6.7%). The remaining 35.3% of cases originated from smaller villages ("Others" category). High epidemiologic linkage rates were observed in Malombola (61.1%) and Chalo (62.5%; Table 2), suggesting localised transmission clusters, although the chi-square test for residential area was not statistically significant ($p = 0.798$; Table 2). Kalulu village had the highest attack rate (3.0%; Figure 1), with 80% of its cases classified as inaccessible. Global spatial clustering was not significant (Moran's $I = 0.08$, $p = 0.412$; Figure 1), indicating a diffuse overall outbreak pattern. However, local hotspots in Malombola, Chalo, and Kalulu warrant targeted interventions, including mobile clinics and outreach services(18).as shown in figure 4.

Figure 4: Case Distribution by Village



(Stata output, 2025)

Attack Rates by Village

Attack rates were calculated using artificially computed village population estimates in Stata 17 (proportion command). Kalulu village had the highest attack rate (3.0%), likely attributable to poor healthcare access, as 80% of cases in this village were classified as inaccessible, a known determinant of delayed vaccination and case detection*(19)*. Munkunta and Malombola had attack rates of 2.2% and 2.0%, respectively, concordant with their high epidemiologic linkage rates (60.6% and 61.1%; Table 2). These findings suggest localised transmission clusters in areas of medium population density with limited health system access. Lower attack rates were observed in Kabinga (2.0%) and Chalo (1.6%), indicating relatively better surveillance or immunisation coverage. Overall, this attack rate pattern demonstrates that geographic and health system factors rather than crude case counts determine measles transmission burden in rural settings, consistent with findings from Tanzania and Nigeria*(8,19)*. As shown in table 4.

Table 4: Attack Rates by Village

Village	Cases	Population	Attack Rate (%)
Kabinga	40	2000	2.0
Malombola	36	1800	2.0
Munkunta	33	1500	2.2
Kalulu	30	1000	3.0
Chalo	16	1000	1.6

(Stata output, 2025)

The spatial clustering analysis with Moran's I provided a statistic of 0.08 and a p-value of 0.412, indicating that there is no statistically significant spatial clustering of cases. This indicates that cases are quite evenly distributed within the study area. The extremely high rates of epidemiological linkage for the Malombola and Chalo villages, however, indicate that there is a need for strong public health intervention in the two villages. As shown in table 5.

Table 5: Spatial Clustering Analysis

Analysis	Statistic	p-value
Moran's I	0.08	0.412

(Stata output, 2025)

Discussion

This study investigated factors contributing to the 2024 measles outbreak at Kabinga Rural Health Centre in Kanchibiya District, Zambia. The key findings reveal that incomplete vaccination (OR=3.12, p<0.001) and health system barriers, particularly perceived inaccessibility (OR=2.03, p=0.013) and living 5–10 km from a facility (OR=1.78, p=0.046), were the primary drivers of the outbreak. Demographic factors (age, sex, residence) were not statistically significant(13).

Infants under one year showed the highest proportion of laboratory-confirmed (18.4%) and epidemiologically linked (57.9%) cases, consistent with global evidence that pre-immunisation infants remain highly vulnerable (WHO, 2020; Patel et al., 2019). However, chi-square tests

revealed no significant association between age and case status (p=0.094), likely due to small sample sizes in older age groups (≥15 years, n=11). The absence of significant sex differences aligns with CDC (2019) findings that measles susceptibility does not differ by gender when vaccination history is considered. Geographically, Malombola (61.1% epi-linked) and Chalo (62.5% epi-linked) emerged as transmission hotspots, though global spatial clustering was non-significant (Moran's I=0.08, p=0.412). This contrasts with urban studies (Sundaram et al., 2020) that report significant clustering, but reflects the dispersed rural population of Kanchibiya, which reduces statistical power to detect spatial patterns(14).

Vaccination status was strongly associated with case status (χ^2=27.41, p<0.001). Incompletely vaccinated individuals had the highest epi-linked rate (66.7%) and were three times more likely to have confirmed measles than fully vaccinated individuals (OR=3.12). This supports global evidence that two-dose measles vaccination is critical for herd immunity(14). However, vaccine effectiveness was alarmingly low (19.2%), far below the expected 85–95% (WHO, 2020). This discrepancy strongly suggests cold chain failures or vaccine mishandling, a known problem in rural Zambian settings(15). Notably, unvaccinated status was not a significant independent predictor (OR=1.45, p=0.361), possibly due to small numbers (n=41) or misclassification of vaccination records a common limitation in rural retrospective studies(16).

Health system barriers were significant contributors. Perceived inaccessibility doubled the odds of confirmed measles (OR=2.03), while living 5–10 km from the facility increased risk by 78% (OR=1.78). Distance was inversely correlated with vaccination status (ρ=-0.15, p=0.021), indicating that geographic barriers directly reduce vaccine uptake. These findings mirror studies from Uganda and rural Democratic Republic of Congo, where access limitations delayed case detection and facilitated spread. Kalulu village, which had the highest attack rate (3.0%), also had 80% of cases classified as inaccessible. The mean delay from symptom onset to facility presentation (3.3 days) suggests moderate but consequential delays in outbreak control. Unlike some studies, we found no significant global spatial clustering, again reflecting the dispersed rural geography(17).

Strengths and Limitations

Strengths of this study include the use of a census approach (all suspected cases included), the integration of geospatial methods with traditional epidemiological analyses, and the

identification of specific, actionable risk factors (incomplete vaccination, inaccessibility, distance) with precise effect estimates.

Limitations warrant consideration. First, the retrospective cross-sectional design precludes causal inference; associations should be interpreted as correlates of infection risk. Second, the single-facility focus limits generalisability to other districts with different demographic or health system profiles. Third, vaccination status was based on facility records and caregiver recall, both subject to misclassification bias. Fourth, the small sample size in certain subgroups (e.g., unvaccinated individuals, n=33; distance >10 km, n=15) reduced statistical power for some comparisons. Fifth, laboratory confirmation was available for only 10.8% of cases, with the remainder classified epidemiologically, potentially introducing classification error. Sixth, population denominators for attack rate calculations were estimated, as precise village-level census data were unavailable.

Conclusion

This study identified incomplete vaccination and health system barriers as the primary drivers of the 2024 measles outbreak at Kabinga Rural Health Centre in Kanchibiya District, Zambia.

While infants remain vulnerable, structural factors, particularly incomplete vaccination and geographic inaccessibility, drive outbreak dynamics in rural Kanchibiya. Strengthening cold chain integrity, achieving ≥95% two-dose MR coverage, and reducing access barriers are essential to prevent future outbreaks(18).

List of Acronyms

- **CDC**: Centers for Disease Control and Prevention
- **DHIS2**: District Health Information System 2
- **DIT**: Diffusion of Innovations Theory
- **HBM**: Health Belief Model
- **MR**: Measles-Rubella

- **RHC**: Rural Health Centre
- **SEM**: Socio-Ecological Model
- **WHO**: World Health Organization

Competing interests

The authors declare that no competing interests exist.

Clinical trial number: Not applicable.

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Authors Contribution

VM and JH conceptualised the study. MC, EN, CL, and AK performed data curation. VM, KZ, and BH conducted the formal analysis. VM, KZ, BH, and KS developed the methodology. CM, JH, and CC provided supervision. VM, KZ, and AK created visualisations. VM, KS, and BH drafted the original manuscript. KZ, MC, EN, CL, CC, AK, JH, and CM critically reviewed and edited the manuscript. All authors approved the final Version.

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Availability of data and materials

The datasets generated and/or analyzed during the current study are not publicly available due to patient confidentiality and restrictions imposed by the Zambian Ministry of Health, but are available from the corresponding author (Virginia Maposa, virginiamaposa@gmail.com,

Department of Public Health, University of Lusaka, Lusaka, Zambia) on reasonable request and with institutional permission.

Declaration

Ethical Considerations

This study was conducted in accordance with the Declaration of Helsinki and followed applicable national guidelines for research involving human participants. Ethical approval was obtained from the University of Lusaka Biomedical Research Ethics Committee (FWA00033228-591(08)/(08)/{2024}) and the National Health Research Authority (NHRA-2214/09/05/2025). Permission to use DHIS2 data was granted by the Ministry of Health and Kanchibiya District Health Office. Patient confidentiality was maintained by removing personal identifiers and assigning unique study codes. As a retrospective review of existing records without direct participant contact, an individual consent waiver was justified by no risk to participants and strict confidentiality measures throughout the research process.

Consent to Participate

This retrospective study analyzed de-identified data from routine medical records. No direct participant contact occurred. A waiver of individual informed consent was granted by the University of Lusaka Research Ethics Committee and the National Health Research Authority (FWA00033228-591(08)/ (08)/{2024}, NHRA-2214/09/05/2025) due to the retrospective, anonymized nature of the data and the public health importance of the research during an outbreak setting.

Consent for publication

Not applicable

REFERENCES

1. Aworabhi-Oki, G. B., Fatiregun, A. A., & Adewumi, M. O. (2021). Measles Outbreak investigation in a remote, unvaccinated population in Nigeria, 2018–2019. *Pan African Medical Journal*, 39, 123. https://doi.org/10.11604/pamj.2021.39.123.28345
2. Belda, K., Tegegne, A. A., Mersha, A. M., Bayenessagne, M. G., Hussein, I., & Bezabeh, B. (2017). Measles outbreak investigation in the Guji zone of Oromia Region, Ethiopia. *Pan* African Medical Journal, 27(Suppl 2), 9. https://doi.org/10.11604/pamj.supp.2017.27.2.11305
3. Bronfenbrenner, U. (1994). Ecological models of human development. *International Encyclopedia of Education*, 3(2), 1643–1647.
4. Centers for Disease Control and Prevention (CDC). (2019). Measles (Rubeola): For healthcare professionals. Retrieved from https://www.cdc.gov/measles/hcp/index.html
5. Chileshe, M., Mulenga, D., & Mwansa, F. D. (2022). Measles outbreak patterns in rural Zambian health facilities. *Zambian Journal of Public Health*, 4(1), 45–52.
6. Dearing, J. W., & Cox, J. G. (2018). Diffusion of innovations theory, principles, and practice. *Health Affairs*, 37(2), 183–190. https://doi.org/10.1377/hlthaff.2017.1104
7. Durrheim, D. N., Crowcroft, N. S., & Strebel, P. M. (2020). Measles – The epidemiology of elimination. *Vaccine*, 38(51), 8079–8083. https://doi.org/10.1016/j.vaccine.2020.10.054
8. Efunshile, A. M., Oduyebo, O. O., & Audu, R. A. (2021). Measles outbreak in Nigeria: Clinical and laboratory findings. *African Journal of Clinical and Experimental Microbiology*, 22(2), 145–152.
9. Glanz, K., Rimer, B. K., & Viswanath, K. (Eds.). (2015). *Health behavior: Theory, research, and practice* (5th ed.). Jossey-Bass.
10. Goodson, J. L., Masresha, B. G., & Dosseh, A. (2011). Measles outbreak in Tanzania, 2006–2007. *Vaccine*, 29(16), 3047–3053. https://doi.org/10.1016/j.vaccine.2011.02.028
11. Green, L. W., & Kreuter, M. W. (2005). *Health program planning: An educational and ecological approach* (4th ed.). McGraw-Hill.
12. Ibrahim, B. S., Usman, R., & Mohammed, Y. (2021). Risk factors for measles outbreak in northern Nigeria, 2019. *Journal of Infectious Diseases and Epidemiology*, 7(3), 192. https://doi.org/10.23937/2474-3658/1510192

13. Kabongo, M. M., Luman, E. T., & Maurice, J. (2022). Measles outbreak in the Democratic Republic of Congo: Vaccination coverage and health system challenges. *Global Health: Science and Practice*, 10(2), e2100567. https://doi.org/10.9745/GHSP-D-21-00567
14. Kriss, J. L., Stanescu, A., & Pistol, A. (2021). Health system barriers to measles elimination: Lessons from Romania and beyond. *Bulletin of the World Health Organization*, 99(4), 297–304. https://doi.org/10.2471/BLT.20.267849
15. Lanke, S., & Chimurkar, V. (2024). Measles outbreaks in diverse populations: A global review of demographic patterns. *International Journal of Epidemiology and Health Sciences*, 5(2), 45–56.
16. Masresha, B. G., Braka, F., Onwu, N., & Oteri, J. (2020). Measles in Ethiopia: Epidemiology and response to outbreaks. *Pan African Medical Journal*, 36, 67. https://doi.org/10.11604/pamj.2020.36.67.22589
17. Masresha, B. G., Dixon, M. G., & Kriss, J. L. (2021). Progress towards measles elimination in the African region, 2017–2020. *Weekly Epidemiological Record*, 96(36), 421–428.
18. McLeroy, K. R., Bibeau, D., Steckler, A., & Glanz, K. (1988). An ecological perspective on health promotion programs. *Health Education Quarterly*, 15(4), 351–377. https://doi.org/10.1177/109019818801500401
19. Minta, A. A. (2024). Measles vaccination coverage and challenges in low-income countries. *The Lancet Global Health*, 12(3), e345–e350. https://doi.org/10.1016/S2214-109X (23)00567-2