

Annex 1: summary of a systematic review of selected publications on measles immunization and recurring measles outbreaks in Ethiopia

Authors/year/Location	Method	Study design	Results	Factors	Study quality
Habtamu Belete Akalu (2016), Addis Ababa, Ethiopia	Published papers were reviewed with measles-related reports on the performance of performance from government sources, history books, and other sources relevant to the study.	Cross-sectional	Steady progress in reducing measles morbidity and mortality. However, despite the efforts put in place to implement the planned strategies, outbreaks of measles continued to occur in most of the country from 2010 and above.	1. Low Routine Immunization	High
"Review on Measles Situation in Ethiopia; Past and Present"				2. Poor Nutritional Conditions	
Teklay K Desta <i>et al.</i> (2018), Addis Ababa, Ethiopia	Secondary analysis of Measles surveillance 2006-2016 data, routine immunization, and post-measles campaign coverage	Cross-sectional	The proportion of measles cases in the age group under five was significantly associated with measles incidence. The proportion of woredas with the highest incidence of measles in the under-five-year-old population (Incidence >240 per million) was 10.6%, 21.3%, 31.6% and 39.7% for woredas with the proportion of under-five cases ≤24%, >24%-<36%, 36%-50% and >50% respectively (X ² = 45.3, p<0.001).	3. Accumulation of Unvaccinated children	
"Measles Epidemiology in Ethiopia from 2006 - 2016 Predictors of High Measles Incidence from Surveillance Data Analysis"				4. Seasonal hot weather conditions	
Kassahun Mitiku et al. (2011)	An in-depth secondary analysis of measles administrative coverage data, the WHO/UNICEF vaccination coverage estimates, Measles SIA, and case-based surveillance data from 2004-2009	Cross-sectional	Increase in measles routine administrative coverage from 37% in 2000 to 76% in 2009. A 92% SIA coverage was recorded in the catch-up campaign, with 88% for the initial (1 st) follow-up campaign, and 92% for the subsequent (2 nd) second follow-up. The two (2) targets for measles case-based surveillance were met from 2005 to 2009	1. Accumulation of Susceptible children due to low routine measles immunization.	High
Addis Ababa, Ethiopia				2. Narrow age scope of measles SIA	
"Progress in measles mortality reduction in Ethiopia, 2002-2009"				1. Sub-optimal measles vaccine coverage (<85%)	
Munira Nasser Hassen et al (2018). Addis Ababa, Ethiopia	Retrospective descriptive analysis of (2005–2014) measles surveillance data using time, place, and person variables.	Cross-sectional	A total of 4203 suspected measles cases were identified. 1,154 (27.5%) were laboratory confirmed, with 512 (12.2%) classified as clinically compatible, 52 (1.2%) were cases epidemiologically linked, while the rest of 2,485 (59.1%) were lab IgM negative for measles, making the total measles cases of 1,718 (40.9%).	2. Accumulation of susceptible children due to low routine vaccination and sub-optimal SIAs.	High
"Epidemiology of measles in the metropolitan setting, Addis Ababa, Ethiopia, 2005-2014, a retrospective descriptive surveillance data analysis"				3. Data quality	
Piero Poletti <i>et al.</i> (2018). Trento, Italy	Modelling Estimates. A dynamic transmission model was developed and calibrated on the time series of	Cross-sectional	1,819 patients and 36 deaths were recorded at the hospital. The mean age was 6.0 years (range, 0–65). The estimated	1. Low and sub-optimal measles routine vaccination coverage.	High
				3. Data quality	
				1. Significant heterogeneity in access to health care infrastructure.	High

	hospitalized measles cases. The disease estimates of transmissibility and incidence was provided at the population level.		reproduction number was 16.5 (95% credible interval (CI) 14.5–18.3) with a cumulative disease incidence of 2.34% (95% CI 2.06–2.66). 3,821 (95% CI 1969–5671) severe cases, including 2,337 (95% CI 716–4009) measles-related deaths were estimated.	2. Low immunization rates in recent birth cohorts.	
"The hidden burden of measles in Ethiopia: how distance to hospital shapes the disease mortality rate"					
Amare Mengistu Mersha <i>et al.</i> (2017), Addis Ababa, Ethiopia	Analysis of measles incidence by year, location, and age groups. Age-specific incidence rate was calculated. Predictors of confirmed measles cases were identified using Logistic regression.	Cross-sectional	Out of the total measles suspected cases of 4,220, 39% were confirmed cases affecting both males and female gender. The peak of the measles cases was in 2010-2013 period, with the incidence being higher in children less than five (5) years. The overall mean affected age was 7.59 years.	1. Strengthening routine immunization 2. Low quality SIA	Moderate
"Measles burden in urban settings: characteristics of measles cases in Addis Ababa city administration, Ethiopia, 2004-2014"					
AnneGeweniger <i>et al.</i> (2020), Freiburg, Germany	Analysis of vaccination coverage using BCG (1-dose), 3-dose DTP3-HepB-Hib and Polio (3-dose), Measles (1-dose -MCV1), 3-dose pneumococcal (PCV3), and rotavirus (2-dose) vaccines) of 2,004 children within the range of 12–23 months.	Cross-sectional	Full vaccination coverage was 33.3% [29.4–37.2] in 2016. Single vaccination coverage ranged from 49.1% [45.1–53.1] for PCV3 to 69.2% [65.5–72.8] for BCG. A 0.30 Wealth and 0.23 maternal education related inequities were pronounced. Children in Diredawa and Addis Ababa were seven times more likely to have full vaccination compared to those living in the region of Afar.	1. Inequality in education and wealth affects vaccination coverage. 2. Sub-optimal vaccination coverage in poor and rural areas.	High
"Childhood vaccination coverage and equity impact in Ethiopia by socioeconomic, geographic, maternal, and child characteristics"					
Koku Sisay Tamirat <i>et al.</i> (2019), Gondar, Ethiopia	An in-depth analysis of the 2016 Ethiopia Demographic and Health Survey (EDHS)	Cross-sectional	The overall immunization coverage was 38.3% (95% CI: 36.7, 41.2). Rural residence (AOR = 0.60, 95% CI: 0.43, 0.84), employed (AOR = 1.62, 95% CI: 1.31, 2.0), female head of households (AOR = 0.58, 95% CI: 0.44, 0.76), wealth index [middle (AOR = 1.44, 95% CI: 1.07, 1.94) and richness (AOR = 1.65, 95% CI: 1.25, 2.19)], maternal education at primary school (AOR = 1.38, 95% CI: 1.07, 1.78), maternal education at secondary school (AOR = 2.19, 95% CI: 1.43, 3.36),	1. Low immunization coverage 2. inequality across Female household head and rural dwellings affecting immunization	High
"Full immunization coverage and its associated factors among children aged 12–23 months in Ethiopia, further analysis from the 2016 Ethiopia demographic and health survey"					
Abadi Girmay <i>et al.</i> (2019). Gondar, Ethiopia	An interviewer-administered questionnaire was used to collect the data and a logistic regression analysis was conducted to identify risk factors associated with measles infection	Case-control	A total of 29 measles cases were identified during the investigation, where the source of the was identified. Five (5) samples were collected, with zero measles-related deaths reported. The median age and controls were 15 years (SD ± 7.8) and 11 years (SD ± 9.8), respectively. An approximate 55% of the cases were in the range of ≥ 15 years of age.	1. Un-vaccinated children 2. History of contacts with suspected or confirmed case of measles	High
"Being unvaccinated and having a contact history increased the risk of measles infection during an outbreak: a finding from measles outbreak investigation in the rural district of Ethiopia"					

Tesfahun Taddege Geremew <i>et al.</i> (2019), Gondar, Ethiopia	In-depth analysis of the 2016 Ethiopia Demographic and Health Survey (EDHS) data	Cross-sectional	MCV1 Spatial heterogeneity in children was found (Global Moran's I = 0.13, p-value < 0.0001), and seven (7) significant areas of SaTScan clusters were detected with low MCV1 coverage. Child age (AOR = 1.53; 95%CI: 1.25–1.88), pentavalent vaccination (1 st dose) (AOR = 9.09; 95%CI: 6.86–12.03) and 3 rd dose (AOR = 7.12; 95%CI: 5.51–9.18, etc.	Low childhood MCV1 coverage	High
"Geographical variation and associated factors of childhood measles vaccination in Ethiopia, a spatial and multilevel analysis"					
Ketema Belda <i>et al.</i> (2017), Oromia, Ethiopia	analysis of the measles outbreak in Guji zone, Oromia region using Microsoft Excel and EPI-Info version 7.1.0.6 for data entry and analysis.	Cross-sectional	Nine woredas were affected and a total of 1059 suspected cases and two deaths were reported. The cumulative attack rate of 81/100,000 population, with a 0.2% case fatality rate. 742 (70%) of the 821 patients (or 77.5%) had never received any measles vaccination. Although all age categories were impacted, children under the age of five were the most afflicted, with 495 (48%) of all age groups.	1. Low access to routine immunization in hard-to-reach areas 2. Low routine immunization coverage	High
"Measles outbreak investigation in Guji zone of Oromia Region, Ethiopia"					
Tesfaye, A. <i>et al.</i> (2017)	Unmatched case-control research including 90 participants (60 controls and 30 cases) was carried out to investigate the measles outbreak. A structured questionnaire was used during a face-to-face interview	Case-control	1.24 cases of measles per 1,000 people were recorded. The age groups <1 years old had the greatest age-specific attack rate (4.76 per 1,000 children), followed by those between 1-4 years old (3.28 per 1000 people).	1. History of contact with measles case 2. Presence of a measles case in the neighborhood	Moderate
"Measles outbreak investigation in Basso Liben District, Amhara Region, Ethiopia"					
Aaron S. Wallace <i>et al.</i> (2014), Keffa Zone, Ethiopia	Data collection through interviews and record reviews and a survey of 100 patients with measles cases and their caregivers	Cross-sectional	The outbreak and response incurred a total economic cost of US\$758,869, with health sector expenses, including an immunization campaign, constituting 80% of the costs, and partner agencies covering 92% of the financial burden. Household economic costs amounted to 6% of the median annual income	1. Sub-optimal measles vaccine coverage 2. Household income and health sector expenditures	High
"Evaluation of economic costs of a measles outbreak and outbreak response activities in Keffa Zone, Ethiopia"					
Abraham Wondimu <i>et al.</i> (2021), Ethiopia	Investigate the existence of Inequalities in measles vaccine uptake using data from the Ethiopian Demographic and Health Surveys conducted in 2005, 2011, and 2016.	Cross-sectional	The nationwide measles vaccine uptake in Ethiopia showed a rising pattern from 2005 to 2016. Nevertheless, the concentration index for measles vaccine uptake, measured at 0.202 (P < .01) in 2005, 0.226 (P < .01) in 2011, and 0.223 (P < .01) in 2016, indicates persistent disparities	1. Maternal educational level and exposure/access to media 2. Use of antenatal care and Institutional delivery	High
"Persistent Socioeconomic Inequalities in Measles Vaccine Uptake in Ethiopia in the Period 2005 to 2016"					
Mekonen Getahun <i>et al.</i> (2017), Southern Nations, Ethiopia	Serum samples from suspected measles cases were tested for Measles IgM at the National Measles Laboratory using ELISA. Patient information was recorded through a case reporting format (CRF), and	Cross-sectional	A total of 4,810 samples were tested for measles IgM using ELISA, with 31.3% (1,507 cases) testing positive, affecting mostly 1-4-year-old children, regardless of sex. Measles-confirmed cases per million population rose from 15 in 2007 to 180 in	1. Age (mostly children 1-4 years) 2. Increased coverage and increased measles mortality	Moderate
"Epidemiology of laboratory-confirmed measles virus cases in the southern nations of Ethiopia, 2007–2014"					

	data analysis was performed using Epi-Info 3.5.4 software		2013, peaking in 2014. The distribution of the cases was widespread across the state		
Belay, B. B. <i>et al.</i> (2016), Ethiopia	Variables from the Ethiopian national measles surveillance database (2005-2009) were analyzed using Epi Info Version 3.5.1 and Microsoft Excel for statistical analysis	Cross-sectional	Between 2005 and 2009, there were 17,521 reported measles cases with 127 deaths (0.71% fatality rate), peaking at 5,771 cases in 2008. Hareri region had the highest attack rate (12%), and most cases (50.7%) were from rural areas. Oromia region reported the most IgM-antibody confirmed cases (40.5%), with 26.9% having no vaccination history. Ages 1 to 4 accounted for 41.7% of suspected cases and 34.4% of confirmed cases.	1. Low Immunization Coverage	High
"National measles surveillance data analysis, 2005 to 2009, Ethiopia"				2. Sub-optimal surveillance (late case detection)	
Getahun, N <i>et al.</i> (2016), Amhara, Ethiopia	Blood samples from suspected measles patients, accompanied by case-based forms, were sent to the Laboratory for testing using ELISA. Data entry and analysis were conducted with Epi-Info 3.5.4 software.	Cross-sectional	6,579 samples from a total of 7,296 collected were tested for measles IgM. 2,412 (36.7%) tested positive, while 3,965 were negative, and 202 were equivocal. Individuals aged ≥ 10 years were the most affected. The highest number of cases occurred in 2014, distributed across the state, with a seasonal peak observed in the hot-dry season	1. Low Immunization Coverage	High
"Epidemiology of laboratory-confirmed measles virus cases in Amhara Regional State of Ethiopia, 2004-2014"				2. Population movement 3. Increased traditional activities	
Geremew Tsegaye <i>et al.</i> (2021), Bale Zone, Ethiopia	A total of 98 cases were utilized for the descriptive study, 60 cases were selected using a simple random method, and 120 controls were studied. Active cases were identified through home-to-home searches, and controls were chosen from neighbors of cases. Serum samples were tested for IgM to confirm cases. Data was collected through structured questionnaires, and logistic regression was used to identify measles-associated factors, with a P-value < 0.05 considered statistically significant in multivariable analysis.	Descriptive/ Case-Control	98 cases had an overall attack rate of 12/1000, with a 7% fatality rate. Children aged < 59 months had the highest attack rate (38/1000) and CFR (57%). Vaccination efficacy was 82.6%. Significant factors associated with measles infection included being unvaccinated (AOR=5.66), contact with a patient (AOR=3.24), moderate malnutrition (AOR=4.34), distance from a health facility (AOR=4.58), and a history of travel to an affected area (AOR=3.99).	1. Low vaccination Coverage	High
"Measles Outbreak Investigation in Guradamole District of Bale Zone, South Eastern Ethiopia, 2021"				2. Contact with cases and moderate malnutrition 3. Distance to and from health facility and history of travel to an outbreak area	
Abubakar Nazir <i>et al.</i> (2023), Ethiopia	Analysis of measles cases and death for 2022	Cross-sectional	Between January and September 2022, Ethiopia recorded 9,850 suspected measles cases, of which 5,806 were confirmed, resulting in 56 deaths (CFR=0.6%). By the end of October 2022, the total number of cases surpassed 10,000.	1. Insecurity leading to service disruption	Moderate
"Measles outbreak in Ethiopia amid COVID-19: an effect of war-induced hampering of vaccination and pandemic"				2. Inadequate vaccination coverage 3. Access to health care services	
Silas Bukuno <i>et al.</i> (2023), Garda-Marta, Southwest, Ethiopia	140 cases were used for descriptive analysis, while 51 cases and 102	Descriptive/ Case-Control	Between October 12, 2021, and March 09, 2022, 140 reported measles cases (54% -	1. Inadequate Immunization coverage	High

	controls were utilized for the case-control study to investigate measles infection factors. Data were coded in Epi-data version 4.6.0.6 and analyzed in SPSS version 27. A standardized questionnaire was used to collect information, and statistical significance for associations was determined using multivariable logistic regression with adjusted odds ratios (AOR) and a 95% confidence interval (CI).		females), with Marta Laddo Kebele being the most affected with 104 cases. The measles outbreak was significantly associated with being unvaccinated (AOR: 2.84), having a travel history (AOR: 4.24), contact history (AOR: 6.34), unaware of the mode of transmission (AOR: 2.68), moderate acute malnutrition (AOR: 4.44).	2. History of travel and contact with known cases 3. Moderate acute malnutrition	
"Measles Outbreak Investigation in Garda Marta District, Southwestern Ethiopia, 2022: Community-Based Case-Control Study"					
Fekede W/Kidan <i>et al.</i> (2021), Southwest, Ethiopia.	Facility-based unmatched case-control study, data collection was collected using a questionnaire, cleaned and entered into Epi-info7, and analyzed with SPSS-20. Logistic regression was used to identify the risk factors associated with the measles outbreak using a p-value ≤ 0.05 .	Case-control	During the investigation, 40 measles cases were traced back to an index case with a travel history to a district with a measles epidemic. No deaths were reported. Key risk factors at Mizan-Tepi University included being unvaccinated [AOR = 5.21], female [AOR = 4.21], age 18-20 [AOR = 0.123], and having a contact history [AOR = 0.149]	1. Sub-optimal vaccination coverage 2. Sex and age 3. History of contact with measles case	High
"Risk Factors of Measles Outbreak Among Students of Mizan-Tepi University, Tepi Campus, Southwest Ethiopia"					
Milkessa Mebrate <i>et al.</i> (2023), South-Eastern Oromia, Ethiopia	37 caregiver-patient pairs and 74 controls were enrolled in a 1:2 case-control ratio using the national standard case definition. Controls, selected from patient neighbors, were interviewed after the second incubation period. Descriptive epidemiology assessed vaccine efficacy, attack rate, and case fatality rate, with multivariate analysis used to identify associated factors.	Case-control	Out of the 109 participants, 37 were cases and 72 controls. The mean age was 58.8 months. Most cases (83.8%) had a known contact history, and 62.2% were unvaccinated. The age-specific attack rates were 36/1000 (<5 years) and 53/100,000 (>15 years). Estimated vaccine efficacy was 73.7%	1. Maternal poor knowledge of measles prevention 2. Unvaccinated children	High
"Measles outbreak investigation in Kasoshekumer kebele, Sinana district, South-Eastern Oromia, Ethiopia: A case-control study"					