Determinants and Trends in Maternal Care and Infant Immunization in Yeka Sub-City (February 2017 – August 2025), Addis Ababa City Administration, Ethiopia

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Research Article

Keywords: Maternal and child health, routine data, EMR/DHIS2, urban health inequities, immunization, ANC, SBA, PNC

Posted Date: May 13th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-9318722/v1

Additional Declarations: No competing interests reported.

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Abstract

Background: Ethiopia has improved maternal and child health (MCH) services yet localized urban disparities in access persist. The study aims to evaluate MCH services and identify key predictors influencing Maternal Health and Immunization coverage in Yeka subcity, Addis Ababa, Ethiopia.

Methods: We conducted a retrospective longitudinal analysis of routine Electronic Medical Record (EMR) data from Yeka Sub-City spanning February 2017 – August 2025. The study included nine public health facilities, four private health facilities, and one non-governmental organization (NGO) health institution. Trends were summarized descriptively. Negative Binomial regression models were considered to examine associations with predictors, both Generalized Linear Model (without random effects) and Generalized Linear Mixed Models (with random effects). Model selection utilized information criteria (AIC/BIC) and adjusted incidence rate ratios (IRRs) with 95% confidence intervals. Multicollinearity was evaluated using Variance Inflation Factor (VIF), and model fit was summarized through pseudo-R^2 and residual-based diagnostic methods.

Results: Majority of cases (81.94%) were reported from public health facilities followed by private health facilities (16.04%) and non-governmental health facilities (2.02%). The trend analysis indicates that while most mothers started their first antenatal care visit, substantial declines for those served by skilled birth attendance (SBA) throughout the study period was observed. For SBA, the initial antenatal care visit has a significant incidence rate ratio (IRR) of 1.003 (95% CI: 1.002 – 1.004, $p < 0.001$). Additionally, postnatal care (PNC), SBA, and the first antenatal care visit (ANC1) are statistically significant predictors. Similarly, for full immunization, predictors include facility type, ANC1, SBA, and the early initiation of infant vaccination.

Conclusion: Early entry into care is critical for sustaining maternal and child health services in urban Ethiopia. Strengthening early ANC, early vaccination, and service integration across facilities is essential, and routine DHIS2 data can inform targeted local action.

Keywords: Maternal and child health; routine data; EMR/DHIS2; urban health inequities; immunization; ANC; SBA; PNC

Background

Maternal and child mortality remain poignant indicators of global health inequity. Despite the Sustainable Development Goals' (SDGs) ambitious targets, many low- and middle-income countries (LMICs) continue to grapple with high rates of preventable maternal and child deaths. The continuum of care from antenatal to postnatal periods is recognized as a critical strategy for saving lives, yet its utilization is often fragmented and inequitable [1]. Across sub-Saharan Africa, persistent challenges such as weak health systems, socioeconomic disparities, and recent shocks like the COVID-19 pandemic have hindered consistent progress. Studies from countries like Nigeria, Ghana, and South Africa have documented how urban centers, while often better resourced, still harbor significant slums and poor populations with alarmingly low coverage of skilled birth attendance and immunization services [2-4].

Ethiopia is often cited for rapid gains in maternal and child health; however, significant gaps remain in achieving the Sustainable Development Goals. Through the largescale deployment of the Health Extension Program (HEP) and Health Development Army, the country achieved a dramatic reduction in its maternal mortality ratio (MMR) and under-five mortality rate (U5MR)[5]. Strategic policy frameworks like the Health Sector Transformation Plan (HSTP) have prioritized MCH, leading to improved service coverage for indicators such as antenatal care (ANC) and immunizations [6]. However, this national narrative of success is complex. Deep-rooted geographical, economic, and educational inequalities persist. Recent multivariate decomposition analyses show that while wealth and education are significant contributors to positive trends in service utilization like health facility delivery, their benefits are not equally distributed, leaving the poor and rural communities behind [7, 8]. Furthermore, the COVID-19 pandemic caused significant disruptions, reversing some of the hard-won gains and exposing vulnerabilities in the health system's resilience [9, 10].

The capital city, Addis Ababa, presents a unique "urban paradox." It hosts the nation's highest concentration of hospitals, skilled professionals, and health infrastructure, leading to aggregate MCH coverage figures that surpass national averages [11]. Yet, this facade of success masks a reality of sharp intra-urban disparities. Recent evidence confirms that significant wealth-related and inter-district inequalities exist within the city, where the urban poor and those in peripheral sub-cities often have coverage levels comparable to rural areas [2, 12]. This makes the analysis of sub-city level data not just an academic exercise, but also a programmatic imperative for equitable resource allocation and targeted interventions.

A fundamental barrier to addressing these challenges is the weakness of routine health information systems. While the introduction of the District Health Information System 2 (DHIS2) was a leap forward, data quality, completeness, and timeliness remain significant concerns, limiting its usability for micro-level planning [13, 14]. Population-based surveys like the EDHS are invaluable for national trends but lack the granularity for sub-city analysis. The 2016 rollout of an Electronic Medical Record (EMR) system in Yeka Sub-City was a visionary step towards overcoming these data limitations. However, the mere existence of data is not enough; its translation into evidence is what empowers change. The eight-year DHIS2 dataset from Yeka Sub-City February 2017 – August 2025 represents an untapped goldmine of information. The absence of a systematic, longitudinal analysis of this dataset constitutes a critical evidence gap, leaving health managers without precise insights needed to celebrate successes, diagnose failures, and optimize programs.

This study is designed to bridge this critical gap. We conduct a comprehensive longitudinal analysis of DHIS 2 dataset for Yeka Sub-City to assess eight-year trends in core MCH service utilization. Our research is not merely a retrospective look at data; it is an active intervention

in public health practice with multi-level impact. It provides a replicable model for data utilization, offering a clear, evidence-based roadmap for improving service quality, addressing specific coverage gaps, and enhancing equity of MCH service delivery at the most local level. It demonstrates the practical application and value of digital health tools such as DHIS2, providing a case study for the other sub-cities and regions to emulate, thereby strengthening the national health information system. It contributes a detailed, longitudinal urban health case study from a rapidly developing context, offering valuable lessons on tracking progress, understanding the impact of health system reforms and external shocks, and pursuing equitable health outcomes at a localized setting in LMIC cities.

By analyzing trends in maternal health services (ANC1, ANC4, SBA, PNC) and child immunization coverage, this study aims to move beyond description to deliver actionable intelligence that will directly inform policy and practice, ultimately contributing to the achievement of Ethiopia's and the world's SDG targets for maternal and child health.

Methods

Study Setting

This study was conducted in Yeka Sub-City, one of the 11 administrative sub-cities of Addis Ababa, the capital and largest city of Ethiopia. Addis Ababa serves as the nation’s political, economic, and health epicenter, and its sub-cities are critical for implementing and monitoring urban health programs. Yeka Sub-City was selected for this analysis due to its diverse demographic profile and the availability of a unique, long-term DHIS2 dataset.

According to Addis Ababa Regional Health Bureau, the estimated population of Yeka Sub-City during the study period was 382,897. The healthcare landscape within the sub-city comprised a mix of public and private facilities. The public sector infrastructure included 10 health centers and 3 specialized hospitals, which form the backbone of primary and secondary healthcare service delivery. The private sector was substantial, with 91 private health facilities operating in the sub-city. Of these, only 5 private facilities were identified as providing a full range of maternal and child health (MCH) services and consistently reporting into the health management information system. This setting provides a representative microcosm of urban MCH service delivery in Ethiopia, characterized by a high density of health facilities yet facing challenges in coordination and data harmonization across sectors.

Study Design and Period

A retrospective longitudinal study design was employed to analyze secondary data on MCH service utilization. The study covered an eight-year period, from February 2017 – August 2025. The longitudinal design was selected as it is the most appropriate for tracking and analyzing trends, patterns, and changes in health service coverage indicators over a significant timeframe.

Data Source and Population

The source of data for this study was the routine Health Management Information System (HMIS) of Yeka Sub-City, specifically the data captured in the DHIS2 system implemented since 2016, with retrospective data entry for preceding years.

Source Population

The source population was defined as all pregnant women and children under one year of age residing in Yeka Sub-City during the eight-year study period February 2017 – August 2025.

Study Population

The study population consisted of all pregnant women and children under one year of age who utilized any of the specified MCH services (e.g., antenatal care, skilled delivery, immunization) at any of the included public or private health facilities within Yeka Sub-City during the study period and whose service records were completely captured in the DHIS2 database.

Eligibility Criteria

Inclusion Criteria

All individual service records for the following MCH indicators were included if they were reported consistently from the same health facilities over the entire eight-year study period:

- Maternal Health: First antenatal care visit (ANC1), fourth antenatal care visit (ANC4), skilled birth attendance (SBA), and postnatal care (PNC).
- Child Health: Immunization coverage for children under one, including BCG, Penta-3, and measles-containing vaccine (MCV).

Exclusion Criteria

Service records were excluded from the trend analysis under the following conditions:

- Data from any health facility that did not report continuously for the entire 96-month (8-year) period, to avoid artificial fluctuations in trends due to the entry or exit of reporting facilities.
- Incomplete or inconsistent monthly reports where key indicators were missing or deemed unreliable (e.g., extreme outliers not plausible for the population size).
- Data from few private facilities that did not provide the full scope of MCH services, to ensure comparability across the reporting units.

Variables and Data Extraction

The primary outcome variables were the annual and monthly aggregated counts of service utilization for each MCH indicator. The key independent variable was the time (year and month) of service delivery. Data were extracted from the sub-city's centralized HMIS database into a structured format using a standardized data extraction tool designed in Microsoft Excel, which captured facility name, month, year, and the numerical values for each MCH indicator.

Data Extraction Tools and Procedures

A secondary data extraction was performed for this study. Aggregated, facility-level monthly data for the period February 2017 – August 2025 were retrieved from the District Health Information System 2 (DHIS2) platform for Yeka Sub-City. A standardized data extraction template was developed in Microsoft Excel to systematically capture data for all pre-defined study variables from each reporting health facility across the 96-month period. The research

team in collaboration with the Yeka Sub-City Health Office HMIS focal person ensured all relevant data were captured accurately conducted the data extraction.

Study Variables

The variables for this study were selected based on their status as key performance indicators for maternal and child health programs in Ethiopia.

- **Dependent Variables:**
  The primary outcomes of interest were:
  1. Skilled Birth Attendance (SBA): The number of all expected deliveries attended by a skilled health professional (doctor, nurse, or midwife) in a health facility.
  2. Postnatal Care (PNC)
  3. Full Immunization Coverage: The number of children under one year of age who received all recommended vaccines by 12 months of age.
- **Independent Variables:**
  To understand the factors associated with the primary outcomes, the following service coverage indicators were analyzed as independent variables:

    - First antenatal care visit (ANC1)
    - Facility Type
    - Skilled Birth Attendance (SBA)
    - Postnatal Care (PNC)
    - Early Childhood Immunization Uptake: These were analyzed as proxies for the strength of the routine immunization system and its potential correlation with full immunization. It conserved BCG vaccine coverage, Penta 1 vaccine coverage, Pneumococcal Conjugate Vaccine (PCV1) coverage and Rotavirus 1 (Rota1) vaccine coverage

Data Quality Management

Prior to analysis, a comprehensive assessment of data quality was undertaken. A preliminary review revealed instances of missing values across several key indicators and time points. The pattern and magnitude of missing data were formally summarized and visualized using the missings table command in STATA. Data cleaning involved checking for internal consistency, correcting obvious entry errors, and formatting variables for analysis.

Data Analysis

The cleaned data were imported into STATA version 16 for statistical analysis. All data management and analytical procedures were documented in a Stata do file to ensure reproducibility. Descriptive statistics (means, standard deviations, frequencies) were calculated to summarize the trends in all variables over the eight-year period.

To examine associations between predictors and the count outcome, we fitted Negative Binomial Generalized Linear Model (NB-GLM) twice, with and without random effects. Model fit and over dispersion were evaluated using the Pearson χ^2/df and residual diagnostics. Model selection relied on information criteria (primarily AIC, with BIC as a sensitivity check) and, for non-nested comparisons (e.g., NB-GLM vs. NB-GLMM), the Vuong test; the model

with the best fit (lowest AIC/BIC or significant Vuong statistic) was retained for inference. Multicollinearity among covariates was assessed via the Variance Inflation Factor (VIF), with VIF < 10 indicating acceptable levels. Results are reported as adjusted incidence rate ratios (IRRs) with 95% confidence intervals and p-values ($\alpha < 0.05$).

Model Descriptions

Negative Binomial Generalized Linear Model (NB-GLM), no random effects

Assumption: all observations are independent

Y_{it} = Count outcome (For example, Skilled Birth Attendance) for observation i at time t.

$$\text{Distribution: } Y_{it} \sim Negative\ Binomial\ (\mu_{it}, k)$$

Where $\mu_{it} = E[Y_{it}]$ and k = over-dispersion (size) parameters

$$\text{Linear predictor (log – link): } \log(\mu_{it}) = \beta_0 + \beta_1 X_{1,it} + \ldots + \beta_p X_{p,it}$$

$Where\ \beta_0$: Global intercept and β_p: fixed effect coefficient

Negative Binomial Generalized Linear Mixed Models (NB-GLMM), with random effects

The present dataset has shown as observations are nested within facilities.

$$\textbf{Distribution: } \boldsymbol{Y_{it} | \ b_j} \sim Negative\ Binomial\ (\mu_{ij}, k)$$

Where j = facility index and i = observations within facility j

$$\textbf{Link predictor (log-link): } \boldsymbol{log(\mu_{ij}) = \beta_0 + \beta_1 X_{1,ij} + \ldots + \beta_p X_{p,ij} + b_j}$$

Where the random intercept is: $\boldsymbol{b_j} \sim N(0, \delta_b^2)$

In the GLMM, two observations from the same facility j, are correlated because they share b_j. $Corr(Y_{ij}, Y_{i'j}) > 0$. This correlation cannot be captured by standard Negative Binomial (NB-GLM).

Result

Majority of the 1,091 Mother and Child Health (MCH) cases were treated at public health facilities (n = 894; 81.94%), followed by private health facilities (n = 175; 16.04%) and non-governmental health institutions (n = 22; 2.02%), Table 1. This suggests that the majority of services for MCH issues have been provided by public health facilities (Table 1).

Table 1. Distribution of cases per type of health facility in Yeka Sub-City, Addis Ababa, Ethiopia

Facility Type	Number of **mother-to-child cases**	Percent
NGO health facilities	22	2.02
Private health facilities	175	16.04
Public health facilities	894	81.94
Total cases	1,091	100

Table2, presents average monthly service volumes per facility, stratified by facility ownership type (NGO, Private, Public). For each indicator, the mean represents the average number of services provided per facility per month, while the standard deviation (SD) reflects variation in service volume across facilities within the same ownership category. Public health facilities generally show higher average service volumes but also substantially greater variability, whereas NGO facilities tend to have more consistent service delivery across facilities.

NGO facilities

Among NGO facilities (#cases = 22), service provision was relatively high and consistent. The average number of first antenatal care visits (ANC1) was 99.6 per facility per month (SD = 19.3), with most facilities reporting between 55 and 134 visits, indicating limited dispersion around the mean. ANC4 visits were higher on average (mean = 140.0; SD = 78.4), but with greater variability, suggesting differences in follow-up care intensity across NGO facilities. Number of pregnant women who used Skilled birth attendance (SBA) and number of postnatal care (PNC) users were comparatively low (means of 17 and 25, respectively), reflecting the more specialized or referral-based role of NGO facilities. No NGO facilities reported fully immunization services during the study period.

Private facilities

Private facilities showed lower average ANC1 volumes (mean = 55.7) compared with NGO and public facilities, alongside high variability (SD = 44.5), indicating substantial heterogeneity in service utilization. Similar patterns were observed for ANC4, SBA, and PNC, where moderate mean values were accompanied by wide ranges, including facilities reporting zero services. Fully immunization services were reported by only a few private facilities (n = 106), with an average of 30.9 services per facility per month (SD = 16.1), suggesting limited but variable engagement in immunization delivery within the private sector.

Public facilities

Public facilities accounted for the largest number of reporting facilities across all indicators and generally exhibited higher average service volumes. Mean ANC1 visits were 88.7 per facility per month (SD = 67.0), with a wide range (2–294), reflecting marked differences in

facility size, catchment population, and service capacity. Similar trends were observed for ANC4, SBA, and PNC, where relatively high means were accompanied by large standard deviations, indicating substantial heterogeneity across public facilities. Fully immunization services were widely provided in public facilities (n = 892), with an average of 79.5 services per facility per month, though again with considerable variability (SD = 53.0).

Table 2: Monthly Maternal and Child Health Service Utilization by Facility Type in Yeka Sub-City, Addis Ababa, Ethiopia, February 2017 – August 2025

Indicators	Number of MCH services	Mean	Standard Deviation	Min	Max
		NGO			
ANC1	22	99.63	19.31	55	134
ANC4	22	140.04	78.38	63	305
SBA	22	17	12.86	1	69
PNC	22	25	14.18	2	72
Fully immunization	0	-	-	-	-
		Private			
ANC1	175	55.65	44.5	0	339
ANC4	170	26.79	23.61	0	97
SBA	174	42.27	32.12	0	108
PNC	172	41.28	36.62	0	180
Fully immunization	106	30.87	16.06	2	66
		Public			
ANC1	894	88.74	67.03	2	294
ANC4	893	61.74	51.09	0	262
SBA	894	37.70	40.04	0	197
PNC	893	52.20	49.08	0	331
Fully immunization	892	79.46	52.97	0	257

Using routine monthly averages from Yeka sub-city's (February 2017 – August 2025), utilization of the services were examined along the maternal continuum of care ANC1, ANC4, SBA, and PNC. ANC1 remained the highest and showed a gradual upward trajectory, indicating increasing early contact with services. Although ANC4 coverage showed steady improvement, the persistent gap with ANC1 highlights significant dropout between initial contact and completion of recommended visits. SBA consistently tracked lowest with only modest gains and some softening toward 2024–2025, suggesting the weakest conversion from antenatal care to facility-based, skilled delivery. PNC exhibited pronounced volatility, with transient surges during 2021–2022 followed by irregular declines, consistent with sensitivity to operational factors at discharge and in community follow-up. Although the COVID-19 period appears to have introduced short-lived disturbances rather than sustained collapse, recovery was uneven and least robust for SBA and PNC. Overall, the step-down from ANC1→ANC4→PNC→SBA highlights gaps in continuity; targeted interventions to strengthen late-pregnancy retention, birth planning and referral, transport support, and standardized discharge-to-PNC linkage are warranted, Figure 1.

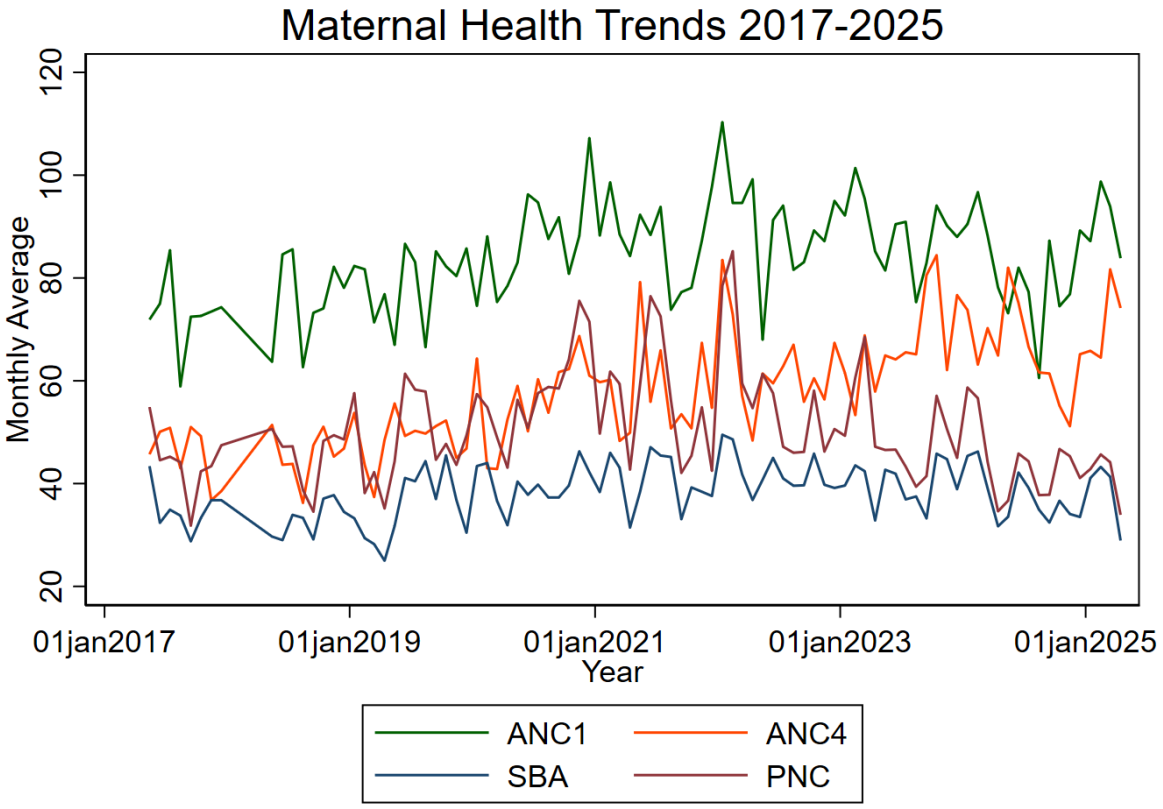

Figure 1. Maternal and child health services during February 2017 – August 2025 in Yeka scub-city, Addis Ababa, Ethiopia

During 2017–2025, Yeka sub-city's routine infant immunization volumes are broadly stable with all first-dose series (Penta1, PCV1, Rota1) co-moving in the ~60–90 monthly-average band, indicating system-level steadiness rather than antigen-specific demand shifts; notable one-off shocks appear a large Penta1 spike around 2020–2021 (likely catch-up/back-entry) and occasional deep troughs (e.g., PCV1) consistent with stockouts or delayed reporting; MCV1 roughly tracks first doses but is more volatile and often lower, implying dropout between early 6–14-week contacts and the 9-month measles visit; Fully immunized (FIC) follows the series with intermittent surges typical of backlog clearance; overall, there's no sustained pandemic-era collapse, but completion to MCV1/FIC remains the fragile point, driven by follow-up adherence and antigen-specific supply reliability, Figure 2.

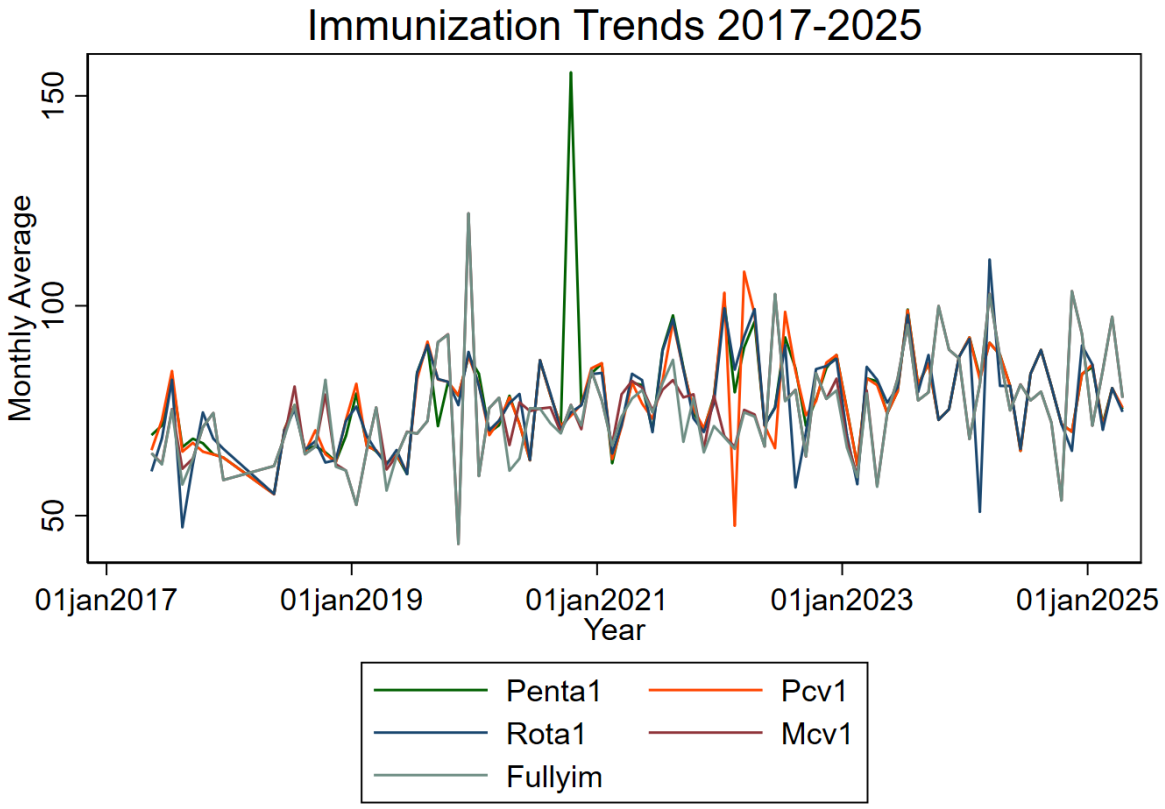

Figure 2. Immunization Services during February 2017 – August 2025 in Yeka scub-city, Addis Ababa, Ethiopia

Correlation Heatmap of Immunization and Mother Child Health (MCH) Indicators

The correlation heatmap demonstrates predominantly strong positive relationships among most immunization and maternal child health (MCH) indicators. This overall pattern suggests that improvements in one service tend to occur alongside improvements in others, reflecting integrated health system performance rather than isolated or fragmented interventions. In settings where service delivery is effective, multiple components of maternal and child health appear to improve simultaneously.

Immunization indicators including BCG, Penta1, PCV1, Rota1, MCV1, and full immunization—form a distinct cluster with strong intercorrelations ($r \approx 0.85–0.98$). The strongest associations are observed between PCV1 and Rota1, as well as between MCV1 and full immunization coverage. These patterns indicate that areas with high uptake of early childhood vaccines tend to achieve relatively higher completion of the full immunization schedule. Nevertheless, persistent gaps between early-dose and later-dose indicators point to ongoing dropout. This suggests that, while service delivery may be broadly systematic, continuity is not fully ensured, and a proportion of children who initiate vaccination do not complete the recommended series.

A particularly strong relationship is observed between the first and fourth antenatal care visits (ANC1 and ANC4), indicating high continuity of antenatal care among women who initiate care early in pregnancy. Both ANC indicators also show positive correlations with childhood

immunization coverage. This implies that populations with better maternal healthcare utilization during pregnancy also tend to have improved child immunization outcomes, highlighting the importance of sustained engagement with health services throughout pregnancy.

Skilled birth attendance (SBA) and postnatal care (PNC) are also strongly correlated with each other, reflecting their close linkage within facility-based maternal health services. However, their correlations with immunization indicators are comparatively moderate when contrasted with ANC services. This suggests that while delivery and postnatal care are interconnected, they may be influenced by distinct access barriers such as geographic constraints or facility availability that differ from those affecting routine immunization and antenatal care.

Full immunization coverage emerges as a particularly strong indicator of overall health system performance. It shows very strong correlations with MCV1 and early immunization indicators, as well as positive associations with antenatal and delivery-related services. As such, full immunization appears to function as a summary measure of health system reach, capturing both demand-side factors, such as care-seeking behavior, and supply-side factors, including service availability and continuity.

From a programmatic perspective, the strong correlations observed across immunization and MCH indicators suggest that so-called vertical programs are in practice highly interconnected. Weaknesses in one area, such as antenatal care attendance or facility-based delivery, are likely to have cascading effects on multiple child health outcomes. These findings support the need for integrated service delivery strategies such as linking immunization follow-up with antenatal, delivery, and postnatal care rather than relying on standalone interventions, Figure 3.

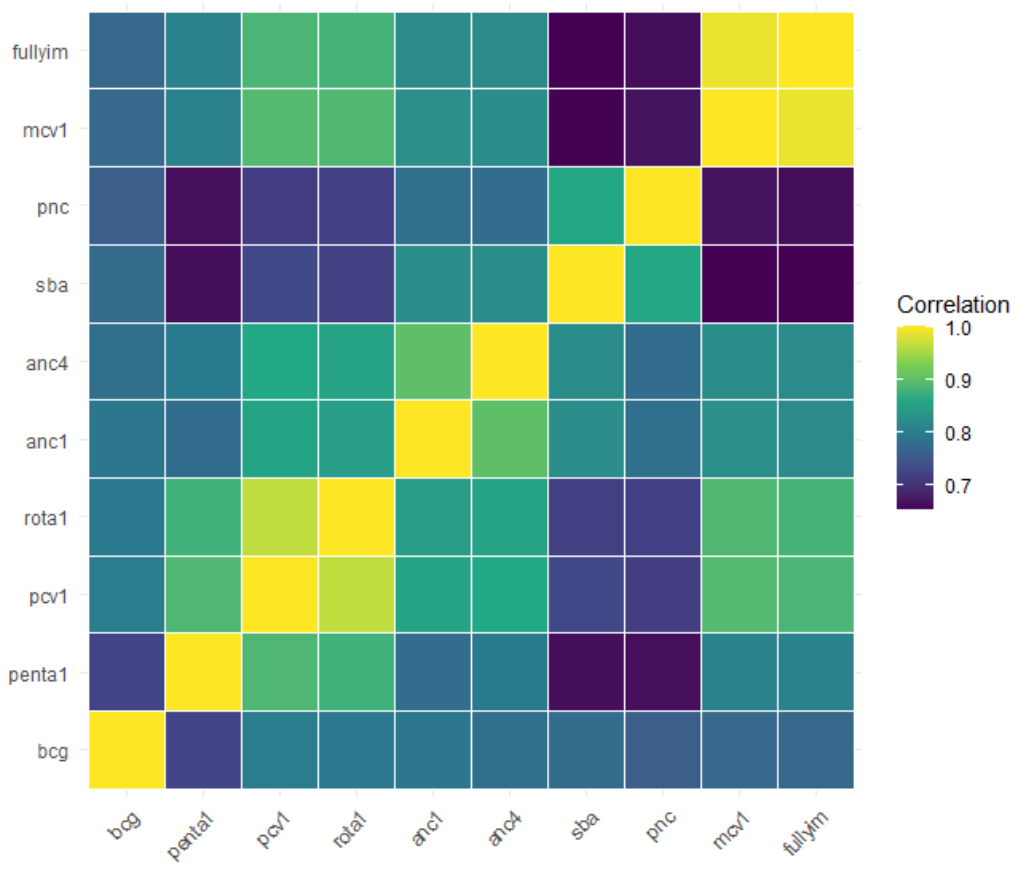

Figure 3: Correlation Heatmap of immunization and Mother Child Health (MCH) Indicators

Still Birth Attendance (SBA)

Generalized linear models with a log link including Poisson, Negative Binomial (to address overdispersion), and Zero-Inflated Negative Binomial (to account for potential excess zeros) were fitted to examine associations between explanatory variables and count outcomes (Still Birth Attendance (SBA), Postnatal Care (PNC) and Full Immunization Coverage). Model diagnostics indicated substantial overdispersion in the Poisson model (deviance-to-degrees-of-freedom ratio = 9.04), violating the Poisson assumption of equidispersion. In contrast, there was no evidence of excess zeros in the outcome distribution. Consequently, the Negative Binomial model, which explicitly accounts for overdispersion, provided the best fit to the data and was therefore used for inference. Additionally, we have taken into consideration the Negative Binomial Generalized Linear Mixed Model (NB-GLMM) due to the fact that it considers facilities to be random effects and observations are nested within facilities. As a result, we have fitted Negative Binomial Generalized Linear Mixed Models (NB-GLMM) with random effects as well as the usual NB-GLM without random effects. Inference was made on NB-GLMM (AIC: 7109.3) due to its smallest AIC as compared to NB-GLM (AIC: 7946.3)

Results from Negative Binomial GLM shows that**,** public facilities had 64% fewer events compared with private facilities (IRR = 0.36, 95% CI: 0.32–0.39; $p < 0.001$). However, after accounting for facility-level random effects in the Negative Binomial GLMM**,** this association was substantially attenuated and no longer statistically significant (IRR = 0.47, 95% CI: 0.14–1.55; $p = 0.233$), suggesting that the strong effect observed in the GLM was largely driven by

between-facility heterogeneity rather than a true facility-type effect. For ANC1 visits**,** both models showed a positive and statistically significant association**,** but the effect size was smaller in the GLMM (IRR = 1.003 vs. 1.014). This indicates that while ANC1 visits are associated with increased outcomes, the GLM likely overestimated the magnitude of the effect by ignoring within-facility correlation, Table 3.

Table 3. Negative Binomial Regression of SBA (Skill Birth Attendance) Visits Yeka Sub-City, Addis Ababa — Model: sba ~ anc1 + health facility type

Predictors	Negative Binomial, GLM			Negative Binomial GLMM		
	Estimate	IRR(95% CI)	P-value	Estimate	IRR(95% CI)	P-value
Public (ref. private)	-1.036	0.36(0.32 – 0.39)	<0.001	-0.758	0.47(0.14 – 1.55)	0.233
ANC1 visits	0.0138	1.014(1.013 – 1.014)	<0.001	0.00343	1.003(1.002 – 1.004)	<0.001

Postnatal Care (PNC)

Similarly, for postnatal care, we have considered both NB-GLM and NB-GLMM. Table 4, in the NB-GLM**,** public facilities was associated with a 22% lower outcome rate compared with private facilities (IRR = 0.78, 95% CI: 0.69–0.88; $p < 0.001$). However, after accounting for facility-level clustering in the Negative Binomial GLMM**,** this association reversed in direction and was no longer statistically significant (IRR = 1.24, 95% CI: 0.63–2.43; $p = 0.529$). This suggests that the apparent disadvantage of public facilities observed in the GLM was largely attributable to between-facility heterogeneity rather than a true facility-type effect**.** For Skilled Birth Attendance (SBA)**,** both models showed a positive and statistically significant association**,** but the estimated effect was stronger in the GLMM (IRR = 1.02 vs. 1.009). This indicates that once unobserved facility-level differences were accounted for, the association between SBA and the outcome became more pronounced. Similarly, ANC1 visits were positively associated with the outcome in both models; however, the magnitude of the association was substantially attenuated in the GLMM (IRR = 1.002 vs. 1.007), suggesting that the GLM overestimated the effect by ignoring within-facility correlation. According to the AIC model comparison criteria, NB-GLMM is taken into consideration for inference since it has an AIC value of 8310.8, while NB-GLM has an AIC value of 8791.5.

Table 4. Negative Binomial Regression of PNC (Postnatal Care) Visits Yeka Sub-City, Addis Ababa — Model: pnc ~ sba + anc1+ health facility type, private health facility type as the reference category.

Predictor	Negative Binomial, GLM			Negative Binomial GLMM		
	Estimate	IRR(95% CI)	P-value	Estimate	IRR(95% CI)	P-value
Public (ref. private)	-0.253	0.78(0.69 – 0.88)	<0.001	0.219	1.24(0.63 – 2.43)	0.529
Still Birth Attendance (SBA)	0.00881	1.009(1.007 – 1.011)	<0.001	0.01545	1.02(1.01 – 1.03)	<0.001
ANC1 visits	0.007	1.007(1.006 – 1.008)	<0.001	0.00151	1.002(1.001 – 1.003)	0.007

Full Immunization

Likewise, we have taken into consideration both NB-GLM and NB-GLMM for full immunization coverage. Table 5, in the NB-GLM, public facilities had a 57% higher outcome rate compared with private facilities (IRR = 1.57, 95% CI: 1.41–1.74; $p < 0.001$). After accounting for facility-level random effects in the Negative Binomial GLMM**,** this association became substantially stronger (IRR = 3.18, 95% CI: 1.48–6.40; $p = 0.003$), indicating that public facilities have a markedly higher outcome rate once unobserved facility-level heterogeneity is controlled for. For ANC1 visits**,** a positive and statistically significant association was observed in both models; however, the effect size was attenuated in the GLMM (IRR = 1.002 vs. 1.005), suggesting that the GLM slightly overestimated the magnitude of the association by ignoring clustering.

The association with Skilled Birth Attendance (SBA) differed by model: the GLM suggested a small negative association (IRR = 0.998), whereas the GLMM showed a small but statistically significant positive association (IRR = 1.002). This reversal implies that facility-level differences masked the true direction of the SBA effect in the simpler model. Similarly, early initiation of infant vaccination was positively associated with the outcome in both models, but the effect was considerably weaker in the GLMM, again indicating inflation of effect sizes in the GLM. Finally, postnatal care (PNC) was not significantly associated with the outcome in either model, and estimates were consistent across modeling approaches. According to the AIC model comparison criteria, NB-GLMM is taken into consideration for inference since it has an AIC value of 8689, while NB-GLM has an AIC value of 9121.

Table 5: Presents the results of the multivariable negative binomial regression examining factors associated with full immunization coverage. Model: fullyim ~ anc1 + sba + pnc + Early initiation of infant vacination + type (Reference: Private)

Predictor	Negative Binomial, GLM			Negative Binomial GLMM		
	Estimate	IRR(95% CI)	P-value	Estimate	IRR(95% CI)	P-value
Public (ref. private)	0.451	1.57(1.41 – 1.74)	<0.001	1.157	3.18(1.48 – 6.40)	0.003
ANC1 visits	0.005	1.005(1.004 – 1.005)	<0.001	0.002	1.002(1.001 – 1.003)	<0.001
SBA	-0.003	0.998(0.996 – 0.998)	0.002	0.0023	1.002(1.00 – 1.004)	0.007
Early initiation of infant vaccination	0.008	1.008(1.007 – 1.009)	<0.001	0.0011	1.001(1.00 – 1.002)	0.003
PNC	0.0007	1.001(0.999 – 1.002)	0.218	-0.00026	1.00(0.999 – 1.001)	0.564

Discussion

This longitudinal analysis of routine health data from Yeka Sub-City provides a critical, evidence-based assessment of the progress and persistent challenges in maternal and child health (MCH) service utilization over an eight-year period (February 2017 – August 2025). While Ethiopia has made significant strides in MCH at the national level, these aggregate figures often mask sub-national disparities and offer limited insight for local-level programming. Furthermore, the reliability of routine health information systems, such as DHIS2, is frequently questioned due to issues of data quality and completeness, undermining their utility for decision-making. This study was therefore imperative to systematically evaluate the wealth of available but under-utilized data from Yeka Sub-City, transforming it into intelligible trends for ANC, PNC, skilled birth attendance and immunization coverage.

The findings serve a dual purpose: they offer the Yeka Sub-City and Addis Ababa City health administrations a precise, localized blueprint for strengthening service delivery, and they contribute a valuable urban case study on the practical use of routine data for monitoring health system performance and advancing equitable MCH outcomes in Ethiopia and similar contexts.

In the present study, we fitted both Negative Binomial Generalized Linear Models (NB-GLM) without random effects and Negative Binomial Generalized Linear Mixed Models (NB-GLMM) with random effects to examine the relationship between predictors and the count outcome. Consistent with routine maternal and child health service analyses in Ethiopia and similar settings [15], count-based regression approaches were applied. Although several count models were explored, the NB-GLMM was selected as the final model due to its lower Akaike Information Criterion (AIC) value, indicating better model fit. This finding is consistent with the results reported in [16], where Negative Binomial models were preferred in the presence of overdispersion without excess zeros. Moreover, the use of mixed-effects modeling allowed us to address unobserved heterogeneity and intra-cluster correlation, which are often ignored in traditional models [17, 18]. This methodological difference may explain any variation in findings between our study and previous reports.

In the NB-GLMM for skilled birth attendance (SBA), first antenatal care indicators was positively associated with SBA, indicating that antenatal care service use, particularly early contacts, strongly predicts delivery taken care of by SBA. This finding aligns with extensive Ethiopian evidence showing antenatal care utilization as a key upstream determinant of facility delivery and skilled birth attendance [17 - 19]. Evidence from Addis Ababa additionally highlights pronounced intra-urban and wealth-related inequalities in maternal health service use, which may explain the concentration of SBA volumes under specific facility types [20]. In the NB-GLMM for PNC visits, higher number of skilled birth attendance and first antenatal care were associated with modest but statistically significant increases in PNC utilization, supporting the concept of partial continuity along the maternal child health continuum [21]. Disruptions observed during the COVID-19 pandemic further demonstrate that postnatal services are particularly vulnerable to breakdowns in continuity of care, even when delivery remain stable [22, 23].

In the NB-GLMM assessing determinants of full immunization in Yeka Sub-City, early maternal health service contact and early infant vaccination emerged as the strongest predictors of immunization completion [24, 25]**.** Similarly, attendance at the first antenatal care visit (ANC1) was significantly associated with higher full immunization, with a 0.2 increase in immunization counts per unit increase in ANC1 coverage (IRR = 1.002; 95% CI: 1.001–1.003; $p < 0.001$), consistent with evidence emphasizing early ANC initiation over visit frequency [22]**.**

Skilled birth attendance (SBA) showed a statistically significant positive association with full immunization (IRR = 1.002; 95% CI: 1.000–1.004; p = 0.007). However, the very small effect size suggests weak linkage across services, indicating fragmentation in the continuum of care pattern previously documented in Ethiopia and further exacerbated during the COVID-19 pandemic [26 - 28].

Facility type was a major determinant of immunization outcomes. Using private facilities as the reference category, children receiving services from public health facilities had substantially higher rate of full immunization (IRR = 3.18; 95% CI: 1.48 – 6.40; p =0.003). This finding highlights substantial performance differences between public and private

facilities and aligns with evidence showing stronger integration of public facilities into national immunization programs and health information systems, as well as similar facility-level disparities reported in multi-country analyses [16, 20, 24].

The observed discrepancy between ANC1 and ANC4 in Figure 1 indicates a substantial dropout along the antenatal care continuum, where many women initiate care but fail to complete the recommended minimum number of visits. This pattern is consistent with evidence from Ethiopian Demographic and Health Survey 2016 and subsequent analyses, which show that although ANC1 coverage is relatively high in Ethiopia, completion of four or more visits remains considerably lower, reflecting poor continuity of care [11, 29]. Such dropout has important implications for maternal and neonatal health outcomes. Adequate antenatal care provides critical opportunities for early detection and management of complications such as hypertensive disorders, anemia, and infections, as well as for preventive interventions including tetanus immunization and iron–folic acid supplementation. Failure to complete recommended visits is associated with increased risks of adverse outcomes, including preterm birth, low birth weight, neonatal mortality, and maternal death [30 - 31]. The World Health Organization recommends a minimum of eight ANC contacts to optimize maternal and fetal outcomes, underscoring that even completion of four visits may be insufficient under current standards [30]. In the Ethiopian context, ANC dropout is often driven by a combination of demand- and supply-side barriers, including limited access to health facilities, low maternal education, socioeconomic constraints, and perceived or actual poor quality of care [29, 31]. From a practical perspective, the gap between ANC1 and ANC4 represents a critical missed opportunity within the maternal health service continuum; therefore, interventions should prioritize improving retention through community-based follow-up, strengthening counseling at first contact, and enhancing service quality to ensure that women not only initiate but also complete antenatal care.

This study has several methodological limitations that should be considered when interpreting the findings. First, the analysis relies on routine health facility data (DHIS2)**,** which, despite improvements over time, may be affected by incomplete reporting, data quality variability, and potential misclassification**,** particularly across facility types and service indicators. Although the longitudinal nature of the data strengthens trend analysis, routine data do not capture individual-level characteristics (e.g., maternal education, household socioeconomic status, migration) that are known to influence maternal and child health service utilization, limiting causal inference and the ability to adjust for important confounders. Second, the use of aggregate counts at the facility or sub-city level precludes assessment of individual care trajectories and may mask within-facility heterogeneity. Third, while negative binomial models were selected based on overdispersion diagnostics and model fit criteria, the observational design does not allow attribution of causality, and unmeasured system-level shocks (such as policy changes or localized service disruptions) may have influenced service volumes over time. Finally, although the study period includes the COVID-19 pandemic, the models do not explicitly disentangle pandemic-related effects from longer-term secular trends.

Despite these limitations, this study has several important strengths. It leverages eight years of longitudinal routine health data to generate actionable, sub-city–level evidence in a large urban setting, addressing a critical gap between national estimates and local programmatic needs. The use of comparative count models and formal model selection criteria enhances the robustness of the findings, while the simultaneous examination of antenatal care, skilled birth attendance, postnatal care, and immunization provides a comprehensive view of the maternal–child health continuum. Future research should build on this work by integrating individual-

level survey data with routine health information to better understand equity dimensions and causal pathways, and by applying interrupted time-series or mixed-methods designs to explicitly assess the impact of shocks such as COVID-19 or policy reforms. Further investigation into facility-level practices, referral mechanisms, and private-sector integration is also warranted to explain observed performance differences and to identify scalable strategies for strengthening continuity of care and improving equitable maternal and child health outcomes in urban Ethiopia and similar contexts.

Conclusion

This study demonstrates that early maternal engagement and early infant vaccination are the strongest drivers of maternal and child health service utilization in Yeka Sub-City. Using eight years of routine data, it shows that timely ANC, skilled delivery, and early immunization are critical for sustaining continuity of care, while notable performance gaps persist across facility types. Importantly, the findings confirm that DHIS2 routine data, when rigorously analyzed, can inform local-level decision-making and support targeted interventions to improve equitable maternal and child health outcomes in urban Ethiopia.

Recommendation

Strengthening early maternal and infant contact with the health system particularly ANC1 and early vaccination offers the greatest opportunity to improve continuity of care in Yeka Sub-City. Targeted use of DHIS2 data, improved post-delivery follow-up, and better integration of private facilities are practical, scalable strategies aligned with Ethiopia's HSTP and EPI goals.

Prioritize Early ANC Entry as a Core Health Sector Transformation Plan (HSTP) Performance Lever

- Interventions should move from primarily concentrating on ANC visit completion to ensuring timely beginning of ANC (ANC1), in line with HSTP's emphasis on early and equitable access to maternal health services.
- Strengthening urban health extension-led pregnancy identification and referral systems, tracking ANC1 timeliness as a critical performance metric alongside ANC4, and incorporating ANC1-focused counseling on delivery planning and baby immunization are all possible practical solutions.

Use Early Infant Vaccination (PCV1) as an Anchor for EPI Performance

- Early infant vaccination should be used as a trigger point for complete immunization completion in accordance with national EPI priorities.
- Incorporate immunization counseling into ANC1 and delivery services; monitor PCV1-to-full-immunization dropout rates using DHIS2 as an early warning indicator; and guarantee ongoing supply of vaccines and skilled staff for early baby doses.

Institutionalize Routine DHIS2 Use for Sub-City Micro-Planning

- This study demonstrates that DHIS2 data can support evidence-based urban health management, a core HSTP objective.
- Potential actionable strategies are conduct regular sub-city data review meetings focusing on ANC–SBA–PNC–immunization linkages**,** Develop simple dashboards

tracking continuity-of-care indicators and Prioritize facilities with high service volume but low follow-up for quality improvement support.

Abbreviations

ANC1	Antenatal care visit one
ANC4	Antenatal care vist four
DHIS2	District Health Information System Version 2
HEP	Health Extension Pacages
HEWs	Health Extension Workers
HSTP	Health Sector Transformation Plan
MCH	Maternal and Child Health
MVC1	Measesle Vaccine 1
PCV	Pnemococal Vacine
SBA	Skilled Birth Attendance
SDGs	Sustainable Development Goals

Author's Contributions

ZGA, AKZ, and GTA conceived and designed the study. MM and TT were responsible for data extraction from the District Health Information System Version 2 (DHIS2). GTA, YFD and MY critically reviewed the manuscript and provided substantial intellectual input. ZGA drafted the initial manuscript. All authors contributed to data analysis and interpretation, participated in manuscript revision, and approved the final version for publication.

Availability of data and materials

The dataset used in this study was extracted from the DHIS2 system. Access to DHIS2 is restricted to authorized users; therefore, the dataset analyzed during the current study is not publicly available. However, it can be obtained from the corresponding author upon reasonable request and with appropriate permission.

Declarations

Consent to participate and Ethics approval

The requirement for informed consent to participate was waived by the Institutional Review Board of Hawassa University College of Medicine and Health Sciences (reference number: IRB/288/15) due to the use of fully anonymized, aggregated secondary data from the government-managed District Health Information System 2 (DHIS2).

Ethical approval for the study was obtained from the same Institutional Review Board (reference number: IRB/288/15). Permission to access and extract the data was granted by the relevant Sub-City Health Office, with additional verbal authorization obtained from responsible unit leads prior to data extraction.

All methods were carried out in accordance with relevant guidelines and regulations, including the Declaration of Helsinki. Data were analyzed and reported in aggregated form to ensure confidentiality and prevent identification of individuals or specific health facilities.

Consent to Publication

N/A

Funding

N/A

Competing interest

The authors declare no conflict of interest

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