

Factors Associated with Multiple Micronutrient Supplementation Achievement During National Scale-Up in Ethiopia: A Longitudinal Analysis of Routine Monitoring Data

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Cite this article as: Abnet Tesfaye Kebede. Factors associated with multiple micronutrient supplementation achievement during national scale-up in Ethiopia: A longitudinal analysis of routine monitoring data. Texila Int J Acad Res. 2026;13(4).
<https://doi.org/10.21522/TIJAR.2014.13.04.Art023>

Received: 09.09.2026

Accepted: 08.10.2026

Published: 30.10.2026

Article Type: Original Research

Abstract Maternal micronutrient deficiencies remain a major public health challenge in Ethiopia and contribute to adverse maternal and newborn outcomes. Ethiopia introduced Multiple Micronutrient Supplementation (MMS) through routine antenatal care services and progressively expanded implementation nationwide. However, evidence regarding factors associated with implementation performance during large-scale program expansion remains limited. This study examined implementation and health-system factors associated with MMS achievement during national scale-up in Ethiopia. A longitudinal secondary analysis was conducted using routine MMS monitoring data collected between January 2023 and August 2026. The unit of analysis was the woreda-month observation. MMS achievement, defined as the percentage of pregnant women newly supplemented with MMS relative to the reported monthly target, was the primary outcome. Mixed-effects regression models with random intercepts for woredas were used to assess associations between MMS achievement and implementation factors. The analytical dataset included 2,268 implementation observations from 75 woredas across 13 regions, of which 1,724 (76.0%) had available MMS achievement data. Mean MMS achievement was 100.2% (SD 56.3), while the median was 94.6% (IQR 70.5–120.4). In adjusted analyses, community dialogue was associated with a 17.99-percentage-point higher MMS achievement (95% CI: 3.11–32.86; $p = 0.018$), and commodity availability was associated with a 23.50-percentage-point higher MMS achievement (95% CI: 14.08–32.92; $p < 0.001$). Health-worker training, supportive supervision, implementation status, reporting period, and regional comparisons were not independently associated with achievement after adjustment. Substantial between-woreda variation remained (ICC = 0.358). Commodity availability and community engagement were the strongest factors associated with higher MMS achievement. Strengthening supply-chain reliability, community engagement, and routine monitoring systems may improve MMS implementation performance during national scale-up in Ethiopia.

Keywords Community Engagement, Ethiopia, Health Systems, Implementation Performance, Implementation Science, Maternal Nutrition, Multiple Micronutrient Supplementation, Routine Monitoring.

Introduction

Maternal micronutrient deficiencies remain a major public health challenge globally and are associated with adverse maternal and neonatal outcomes, including maternal anemia, low birth weight, preterm birth, fetal growth restriction, stillbirth, and neonatal mortality [2-6, 14, 15]. Despite substantial progress in maternal and child health services, micronutrient deficiencies continue to contribute significantly to the burden of maternal and child morbidity and mortality in low- and middle-income countries, where inadequate dietary diversity and multiple nutritional deficiencies frequently coexist [2-6, 14, 15].

Maternal nutrition remains a priority public health issue in Ethiopia. Previous national surveys have consistently documented the persistence of maternal and child nutritional challenges as well as regional disparities in maternal healthcare utilization across Ethiopia [16, 17]. Findings from the 2024–25 Ethiopia Demographic and Health Survey (EDHS) indicate that maternal and child malnutrition continues to present substantial challenges. Approximately 40% of children under five years of age remain stunted, while inadequate dietary diversity among women remains common, reflecting persistent nutritional vulnerabilities that may negatively affect maternal and newborn health outcomes. Maternal mortality also remains an important concern, with the 2024–25 EDHS reporting a maternal mortality ratio of 141 deaths per 100,000 live births [22]. These findings underscore the continued need for effective maternal nutrition interventions throughout pregnancy and highlight the importance of strengthening nutrition-related services within the healthcare system.

The continued expansion of maternal healthcare services provides an important opportunity to strengthen maternal nutrition programs. The 2024–25 EDHS reported that approximately 64% of births were attended by skilled health personnel and that antenatal care

utilization has improved substantially over recent years [22]. These improvements create favorable conditions for integrating evidence-based maternal nutrition interventions into routine antenatal care. However, the success of such interventions depends not only on their clinical effectiveness but also on the ability of health systems to implement them effectively under routine program conditions [18-21].

Iron-Folic Acid (IFA) supplementation has historically been the standard antenatal nutrition intervention used to prevent maternal anemia and neural tube defects. However, increasing evidence from randomized trials, systematic reviews, and meta-analyses demonstrates that Multiple Micronutrient Supplementation (MMS) provides broader maternal and neonatal benefits than IFA alone [2-6, 14, 15]. MMS, commonly delivered using the United Nations International Multiple Micronutrient Antenatal Preparation (UNIMMAP), provides a combination of 15 essential vitamins and minerals designed to address the multiple micronutrient deficiencies frequently experienced during pregnancy [13]. Research has demonstrated that MMS reduces the risk of low birth weight, small-for-gestational-age births, and preterm delivery while improving maternal micronutrient status [2-6, 14, 15]. Consequently, MMS is increasingly recognized as an effective maternal nutrition intervention in settings characterized by widespread micronutrient deficiencies.

Recognizing these benefits, Ethiopia initiated a phased transition from IFA supplementation to MMS through routine antenatal care services beginning in 2023. The program was introduced in pilot implementation woredas and subsequently expanded as part of a broader national scale-up effort. Scale-up activities included health-worker training, supportive supervision, social and behavior change interventions, community engagement, routine monitoring, and supply-chain strengthening activities [1,7–12]. As

implementation expanded across increasingly diverse geographic and health-system contexts, understanding implementation performance became critical for informing program improvement, resource allocation, and equitable national expansion.

Although the effectiveness of MMS is well established, less evidence exists regarding implementation performance during program scale-up, particularly in low- and middle-income countries. Implementation-science literature suggests that program outcomes are shaped by interactions among implementation strategies, organizational readiness, health-system functionality, monitoring systems, and contextual characteristics [18-21]. Factors such as health-worker training, supportive supervision, community engagement, commodity availability, leadership, and program monitoring may influence implementation performance. However, the extent to which these factors contribute to MMS achievement under routine implementation conditions remains insufficiently understood [18-21].

Implementation-science frameworks proposed by Peters et al., Proctor et al., and the PRISM framework emphasize that successful program implementation depends on both implementation strategies and health-system readiness [18-21]. These frameworks provide a useful lens for understanding variation in program achievement across settings, time periods, and health systems. Community engagement, workforce capacity, commodity availability, and routine monitoring systems have frequently been identified as important influences on implementation outcomes, yet evidence from large-scale maternal nutrition programs remains limited [18-21].

Despite Ethiopia's ongoing transition from IFA supplementation to MMS, no national longitudinal study has comprehensively examined implementation and health-system factors associated with MMS achievement using routine program-monitoring data.

Understanding these factors is important for strengthening program effectiveness, informing implementation-support strategies, identifying operational bottlenecks, and ensuring equitable expansion of MMS services across implementation settings. Therefore, this study aimed to identify implementation and health-system factors associated with MMS achievement during national MMS scale-up in Ethiopia using routine program-monitoring data.

Objective

To identify implementation and health-system factors associated with MMS achievement during national scale-up in Ethiopia.

Methods

Study Design and Data Source

This study used routinely reported program implementation data to assess MMS implementation performance and factors associated with MMS achievement in Ethiopia. The analytical dataset comprised monthly implementation observations reported by woredas participating in MMS implementation between 2023 and 2026. Each observation represented a woreda-level reporting record for a given reporting period.

The dataset included information on region, woreda, implementation status, the monthly number of pregnant women targeted for MMS, the number newly supplemented with MMS during the month, cumulative MMS supplementation, community dialogue activities, health-worker training, supportive supervision, and commodity availability.

Duplicate records were removed during data preparation. The final analytical dataset contained 2,268 implementation observations from 75 woredas across 13 regions.

Outcome Measure

The primary outcome was monthly MMS achievement (%), calculated as the number of

pregnant women newly supplemented with MMS during the reporting month divided by the reported monthly target for MMS, multiplied by 100:

$$\text{MMS achievement (\%)} = \frac{\text{Number of pregnant women newly supplemented with MMS during the reporting period}}{\text{Reported monthly MMS targets}} \times 100$$

Achievement values greater than 100% were retained because the reported number of women supplemented could exceed the reported monthly target. Such values may occur in routine program monitoring when supplementation during a reporting period exceeds the reported target. No observations were capped, truncated, or excluded from the primary analysis on the basis of achievement values.

Explanatory Variables

Four program implementation factors were examined as the primary explanatory variables: health-worker training, supportive supervision, community dialogue, and commodity availability.

Health-worker training was classified as Yes when the reported number of health workers trained on MMS during the relevant reporting period was greater than zero and No when the reported number was zero. Missing values remained missing.

Supportive supervision was similarly classified as Yes when at least one supportive supervision activity was reported and No when none was reported. Missing values were retained as missing.

Community dialogue was classified as Yes when the reported number of community dialogues or pregnant-women conferences conducted so far was greater than zero and No when the reported value was zero. Because this variable represented activities conducted cumulatively up to the reporting period, the binary indicator was used for the primary analysis rather than interpreting the reported cumulative count as a monthly exposure.

Commodity availability was classified as Yes when the woreda reported having sufficient MMS supplies to cover the needs of the coming three months and No when the response was explicitly reported as no. Responses recorded as "0" could not be reliably interpreted as either yes or no and were therefore treated as missing rather than recoded as inadequate availability.

Additional covariates included implementation status (existing versus expansion), year, and region. Existing implementation, 2023, and Addis Ababa were used as the reference categories, respectively.

Data Management and Missing Data

Data cleaning and analysis were conducted in R using RStudio. Duplicate observations were identified and removed before analysis. Variable formats and categorical response values were standardized during data preparation.

Missing values were not imputed for the primary analyses. Descriptive and bivariable analyses used all observations with available values for the outcome and variables included in each analysis.

For the multivariable analysis, a complete-case approach was used. Observations were included only when MMS achievement, all four primary implementation factors, implementation status, year, region, and woreda were simultaneously available. This resulted in 1,246 complete observations from 58 woredas, representing 54.9% of the 2,268 implementation observations. The extent of missing information was considered when interpreting the adjusted results.

Statistical Analysis

Descriptive statistics were used to summarize implementation observations and MMS achievement. Because MMS achievement was non-normally distributed and showed substantial variability, both mean with standard deviation and median with interquartile range were reported.

For comparisons of MMS achievement between the two categories of each implementation factor, the Wilcoxon rank-sum test was used because the outcome distribution was skewed and included extreme values. Results were summarized using the sample size, mean $\pm$ standard deviation, median and interquartile range, together with the corresponding Wilcoxon test p -value.

Bivariable associations between MMS achievement and each explanatory variable were examined using linear regression models. For binary variables, regression coefficients (β) represent the estimated difference in MMS achievement percentage points between the specified category and the reference category. For multi-category variables such as year and region, the overall significance of the variable was assessed using the model's overall test, and no single β coefficient was reported for the variable as a whole.

Multivariable Mixed-Effects Analysis

Because implementation observations were repeatedly reported from the same woredas over time, observations were not assumed to be statistically independent. A linear mixed-effects regression model with a random intercept for woreda was therefore fitted to account for clustering of observations within woredas.

The primary multivariable model included health-worker training, supportive supervision, community dialogue, commodity availability, implementation status, year, and region as fixed effects, with a random intercept for woreda:

$$Y_{ij} = \beta_0 + \beta_1 \text{ Training } ij + \beta_2 \text{ Supervision } ij + \beta_3 \text{ Community Dialogue } ij + \beta_4 \text{ Commodity Availability } ij + \beta_5 \text{ Implementation Status } ij + \beta_6 \text{ Year } ij + \beta_7 \text{ Region } ij + u_j + \varepsilon_{ij}$$

where:

- Y_{ij} = MMS achievement (%) for observation i in woreda j ;
- β_0 = model intercept;
- $\beta_1 - \beta_7$ = fixed-effect coefficients;

- u_j = woreda-level random intercept;
- ε_{ij} = residual error term.

The model was fitted using maximum likelihood estimation. Adjusted regression coefficients, 95% confidence intervals, and p -values were reported. The intraclass correlation coefficient (ICC) was calculated to quantify the proportion of residual variation attributable to differences between woredas.

Overall model improvement was assessed by comparing the full mixed-effects model with a random-intercept-only model using a likelihood-ratio test.

Assessment of Multicollinearity

Potential multicollinearity among explanatory variables was evaluated using variance inflation factors (VIFs). No evidence of problematic multicollinearity was observed (all VIF values < 5).

Assessment of Model Assumptions and Sensitivity Analysis

The distribution of MMS achievement and model residuals was examined because the outcome demonstrated substantial right-skewness and included values considerably greater than 100%. Multicollinearity among explanatory variables was assessed using variance inflation factors.

Extreme achievement values were retained in the primary analysis because they represented observed program -monitoring data and could not be assumed to be erroneous solely because they exceeded 100%. However, to assess whether extreme observations materially influenced the findings, a prespecified sensitivity analysis was conducted by excluding observations with MMS achievement $> 300\%$.

The sensitivity analysis used the same complete-case mixed-effects modelling approach and covariates as the primary model. Estimates from the sensitivity model were compared with the primary model to assess

whether the direction and substantive conclusions of the associations were robust.

Statistical significance was assessed using a two-sided *p*-value threshold of <0.05. Given the observational nature of the routine monitoring data, associations were interpreted as statistical associations rather than causal effects.

Results

Characteristics of Implementation Observations

The final analytical dataset comprised 2,268 implementation observations from 75 woredas across 13 regions, covering the period from 2023 to 2026. Of these observations, 1,533 (67.6%) were from woredas classified as having existing MMS implementation, while 735 (32.4%) were from expansion woredas. The dataset contained 13 distinct reporting-month labels across the study period. These characteristics are summarized in Table 1.

Table 1. Characteristics of MMS Implementation Observations

Characteristic	Value
Implementation observations	2,268
Regions	13
Woredas	75
Existing implementation	1,533 (67.6%)
Expansion implementation	735 (32.4%)
Years covered	2023–2026
Distinct reporting-month labels	13

Distribution of Implementation Factors

The frequency distribution of the primary implementation factors is presented in Table 2.

Table 2. Distribution of Primary Implementation Factors

Variable	Category	n (%)
Health-worker training	Yes	311 (22.6)
Health-worker training	No	1,063 (77.4)
Supportive supervision	Yes	918 (67.9)
Supportive supervision	No	433 (32.1)
Community dialogue	Yes	1,370 (94.5)
Community dialogue	No	79 (5.5)
Commodity availability	Yes	1,176 (86.2)
Commodity availability	No	189 (13.8)

MMS Achievement and Implementation Factors

Overall, MMS achievement was available for 1,724 of the 2,268 observations. Among

observations with available achievement data, the mean MMS achievement was 100.2% (SD 56.3), while the median was 94.6% (IQR 70.5–120.4). Achievement ranged from

0% to approximately 729%. Values exceeding 100% were retained because the number of pregnant women supplemented during a reporting month could exceed the reported monthly target.

MMS achievement differed significantly according to training status, supportive supervision, and commodity availability in the unadjusted group comparisons. Median achievement was lower among observations reporting health-worker training (89.3%) than among those reporting no training (98.0%; $p = 0.002$). In contrast, achievement was higher among observations with supportive

supervision (97.5%) than those without supervision (93.1%; $p = 0.010$).

Community dialogue showed a higher median achievement among observations with dialogue activities (95.9%) compared with those without (86.1%), although the difference did not reach conventional statistical significance ($p=0.063$). Similarly, median achievement was higher where sufficient MMS commodities were reported to be available for the coming three months (96.2%) than where commodities were unavailable (90.6%; $p = 0.022$). The complete descriptive comparisons are presented in Table 3.

Table 3. MMS Achievement by Implementation Factors

Factor	Category	n	Mean $\pm$ SD (%)	Median (IQR) (%)	p-value
Training	No	1,063	103.9 $\pm$ 59.2	98.0 (73.0–123.4)	0.002
	Yes	311	96.7 $\pm$ 56.7	89.3 (72.3–106.5)	
Supportive supervision	No	433	99.9 $\pm$ 64.0	93.1 (66.4–122.5)	0.010
	Yes	918	104.8 $\pm$ 55.4	97.5 (77.9–121.4)	
Community dialogue	No	79	87.7 $\pm$ 59.2	86.1 (41.3–133.5)	0.063
	Yes	1,370	102.5 $\pm$ 57.9	95.9 (73.7–119.2)	
Commodity availability	No	189	96.1 $\pm$ 55.9	90.6 (63.6–111.7)	0.022
	Yes	1,176	104.2 $\pm$ 58.5	96.2 (74.7–121.6)	

Note: *p*-values are from Wilcoxon rank-sum tests. Percentages above 100% were retained in the primary analysis.

Percentages are based on observations with available values for the corresponding variable. Community dialogue activities were widely reported across implementation observations, whereas health worker training occurred less frequently. Supportive supervision and commodity availability were reported in the majority of eligible implementation observations.

The distribution of MMS achievement across the four implementation factors is further illustrated in Figure 1. The figure demonstrates substantial variability within all groups and highlights the presence of high achievement values, particularly among observations reporting commodity availability and community dialogue.

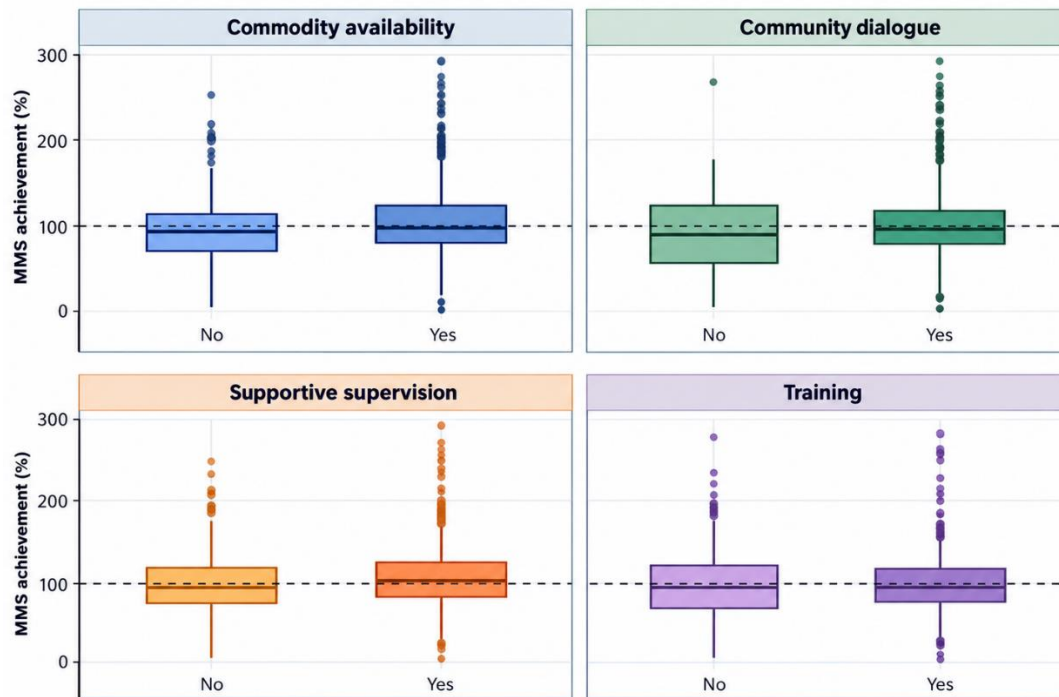


Figure 1. Distribution of MMS Achievement According to Implementation Factors, Ethiopia, 2023–2026

Note: The figure illustrates the distribution of MMS achievement across categories of health-worker training, supportive supervision, community dialogue, and commodity availability. Percentages greater than 100% were retained in the primary analysis.

Bivariable Relationships with MMS Achievement

Bivariable linear regression was subsequently used to quantify the unadjusted relationship between MMS achievement and each explanatory variable. Community dialogue was positively associated with MMS achievement, with observations reporting community dialogue having an estimated 14.8-percentage-point higher achievement than observations without reported dialogue ($\beta = 14.81$, $p = 0.027$).

Training status was associated with a 7.20-percentage-point lower achievement among observations reporting training compared with those reporting no training, although this association was not statistically significant

($\beta = -7.20$, $p = 0.057$). Supportive supervision was associated with a 4.88-percentage-point higher achievement, but this was also not statistically significant ($p = 0.152$).

Commodity availability was associated with an estimated 8.11-percentage-point higher achievement among observations reporting sufficient commodities, although the association was not statistically significant at the 5% level ($p = 0.076$). Implementation status was not associated with achievement ($\beta = -2.31$, $p = 0.438$). Year was not significantly associated with MMS achievement overall ($p = 0.117$), whereas region showed strong overall evidence of geographic variation ($p < 0.001$). The bivariable findings are summarized in Table 4.

Table 4. Bivariable Relationships with MMS Achievement

Variable	β	p-value
Training (Yes vs No)	-7.20	0.057
Supportive supervision (Yes vs No)	4.88	0.152

Community dialogue (Yes vs No)	14.81	0.027
Commodity availability (Yes vs No)	8.11	0.076
Implementation status (Expansion vs Existing)	−2.31	0.438
Year	—	0.117
Region	—	<0.001

Note: β represents the unadjusted mean difference for binary variables. For year and region, the p-value represents the overall test from the corresponding bivariable regression model.

Multivariable Mixed-Effects Analysis

Because observations were repeatedly reported within woredas, a linear mixed-effects model incorporating a woreda-level random intercept was fitted to account for clustering. The multivariable analysis was based on 1,246 complete observations from 58 woredas, representing 54.9% of the full analytical dataset.

After simultaneous adjustment for training, supportive supervision, community dialogue, commodity availability, implementation status, year, and region, community dialogue and commodity availability remained significantly associated with MMS achievement.

Observations reporting community dialogue had an estimated 18.0-percentage-point higher MMS achievement compared with observations without reported dialogue ($\beta = 17.99$, 95% CI: 3.11–32.86; $p = 0.018$). Similarly, observations reporting sufficient commodity availability had an estimated 23.5-percentage-point higher MMS achievement compared with those reporting insufficient commodity availability ($\beta = 23.50$, 95% CI: 14.08–32.92; $p < 0.001$).

Training status, supportive supervision, implementation status, year, and individual regional comparisons were not statistically significant after adjustment. The adjusted associations are presented in Table 5.

Table 5. Multivariable Mixed-Effects Model of MMS Achievement

Variable	β	95% CI	p-value
Intercept	57.2	8.89 to 106	0.021
Training (Yes vs No)	−1.78	−10.45 to 6.89	0.687
Supportive supervision (Yes vs No)	−1.67	−8.69 to 5.34	0.640
Community dialogue (Yes vs No)	18.0	3.11 to 32.9	0.018
Commodity availability (Yes vs No)	23.5	14.08 to 32.9	<0.001
Implementation status (Expansion vs Existing)	−2.94	−29.71 to 23.8	0.827
Year 2024 vs 2023	0.91	−8.8 to 10.6	0.854
Year 2025 vs 2023	−2.04	−11.43 to 7.34	0.669
Year 2026 vs 2023	4.34	−6.49 to 15.2	0.431
Afar vs Addis Ababa	0.61	−74.77 to 76.0	0.987
Amhara vs Addis Ababa	4.11	−49.96 to 58.2	0.880
BG vs Addis Ababa	−11.3	−105.0 to 82.3	0.810
Gambela vs Addis Ababa	2.15	−83.3 to 87.6	0.960
Oromia vs Addis Ababa	14.5	−34.63 to 63.7	0.557

SER vs Addis Ababa	19.2	−74.58 to 113	0.684
Sidama vs Addis Ababa	−3.93	−72.57 to 64.7	0.909
SNNP vs Addis Ababa	11.4	−42.48 to 65.3	0.674
Somali vs Addis Ababa	−12.4	−69.19 to 44.4	0.664
Tigray vs Addis Ababa	34.5	−22.86 to 91.9	0.233

Note: The model included a random intercept for woreda. Reference categories were No training, No supportive supervision, No community dialogue, No commodity availability, Existing implementation, 2023, and Addis Ababa.

Temporal Variation in MMS Achievement

MMS achievement demonstrated variation over time across the observed reporting periods. Monthly mean achievement ranged from 84.0% to 127.0%, with a median monthly mean of 102.6%. Overall, the monthly estimates

fluctuated around the 100% achievement benchmark, with no statistically significant independent effect of year in the multivariable model.

The temporal pattern of mean MMS achievement across the observed reporting periods from 2023 through 2026 is presented in Figure 2.

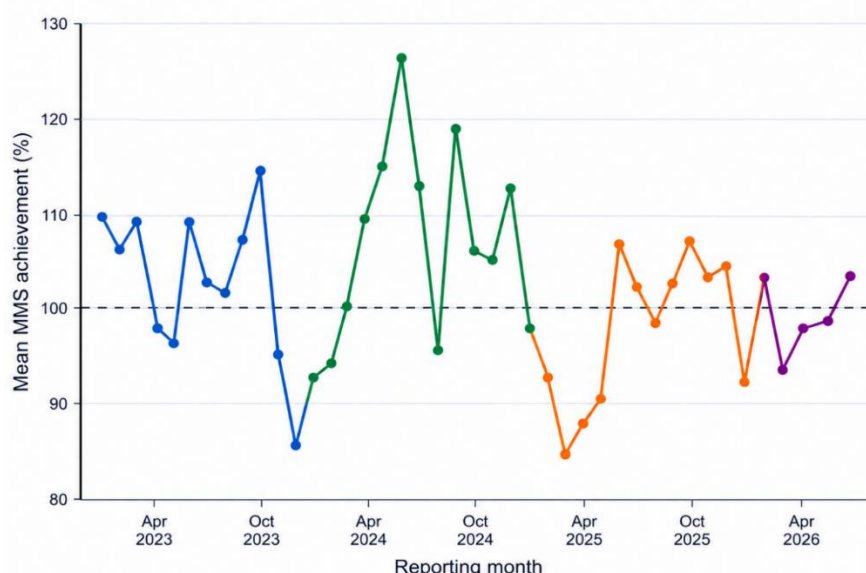


Figure 2. Monthly Mean MMS Achievement Across Reporting Periods, Ethiopia, 2023-2026

Note: Only reporting periods with available MMS achievement observations are shown. Months without observations were not interpreted as zero achievement.

Geographic Variation in MMS Achievement

There was substantial geographic variation in MMS achievement. Median achievement was highest in Oromia and Dire Dawa (102.0% each), followed by SNNP (100.0%) and Addis Ababa (98.2%). The lowest median achievement was observed in Somali (64.1%),

followed by Tigray (77.3%), Afar (79.4%), Harari (81.1%), and BG (82.1%).

The regional distributions are shown in Figure 3. Although the bivariable analysis indicated strong overall regional variation, individual regional coefficients were not statistically significant after adjustment for the implementation factors, year, and woreda-level clustering.

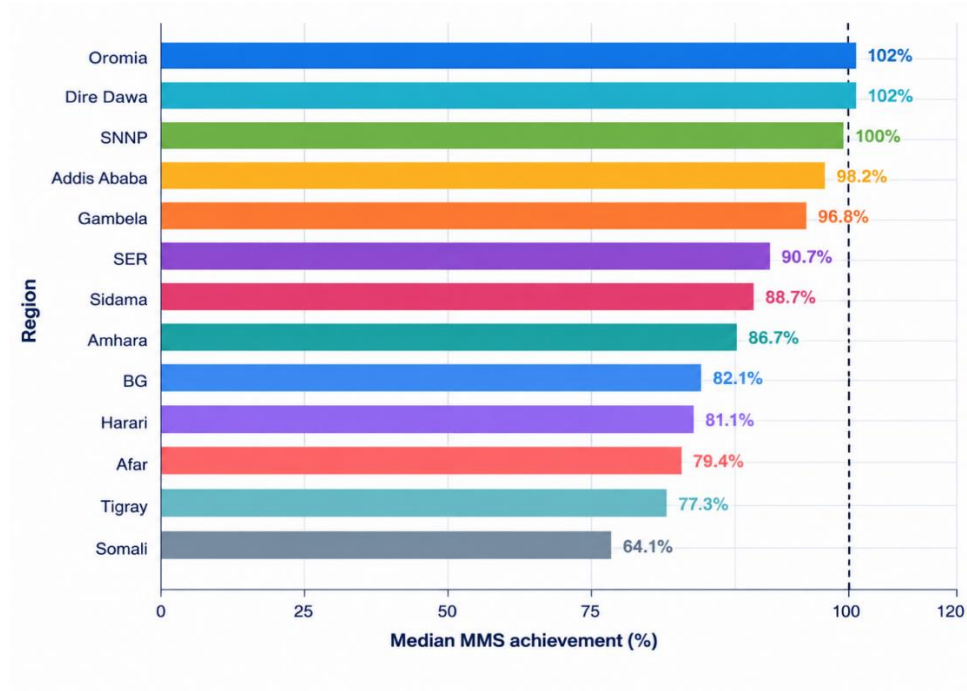


Figure 3. Regional Variation in Median MMS Achievement, Ethiopia, 2023-2026

Model Fit, Clustering, and Sensitivity Analysis

The random-intercept model indicated substantial clustering of MMS achievement within woredas. The adjusted intraclass correlation coefficient (ICC) was 0.358, indicating that approximately 35.8% of the residual variation in MMS achievement was

attributable to differences between woredas after accounting for the fixed effects in the model.

The full mixed-effects model provided a significantly better fit than the woreda-only random-intercept model (likelihood-ratio $\chi^2 = 37.6$, $df = 18$, $p = 0.0044$). The model had an AIC of 13,359 and BIC of 13,466. These model-fit statistics are summarized in Table 6.

Table 6. Overall Model Fit and Clustering Statistics

Statistic	Value
Observations	1,246
Woredas	58
Random-intercept variance	1,274
Residual variance	2,288
Adjusted ICC	0.358
AIC	13,359
BIC	13,466
Likelihood-ratio χ^2	37.6
Degrees of freedom	18
Overall model p-value	0.0044

Because the distribution of MMS achievement was strongly right skewed and included extreme values, a sensitivity analysis was conducted excluding observations with achievement >300%. This removed 12 of the 1,246 complete-case observations (1.0%), leaving 1,234 observations.

The principal findings were unchanged. Community dialogue remained positively associated with achievement ($\beta = 12.38$, $p = 0.027$), while commodity availability remained strongly associated with higher achievement ($\beta = 12.50$, $p < 0.001$). Training ($\beta = -0.49$, $p = 0.880$), supportive supervision ($\beta = -0.32$, $p = 0.904$), and implementation status ($\beta = -3.90$, $p = 0.705$) remained non-significant. The adjusted ICC was 0.380, compared with 0.358 in the primary model.

Overall, the sensitivity analysis supported the robustness of the two principal adjusted associations despite the presence of extreme achievement values.

Model Diagnostics

No evidence of problematic multicollinearity was identified among explanatory variables. Variance inflation factors for all predictors were below the accepted threshold of 5, indicating that the regression coefficients were not materially affected by collinearity.

Discussion

Principal Findings

This study examined routine implementation data generated during the national scale-up of multiple micronutrient supplementation (MMS) among pregnant women in Ethiopia. The analysis included 2,268 implementation observations from 75 woredas across 13 regions and examined MMS achievement in relation to key implementation and health-system factors.

Overall, MMS achievement showed substantial variability, with a median achievement of 94.6% and a mean of 100.2%. Achievement values above 100% were

observed in a proportion of implementation observations, indicating that the number of women supplemented during a reporting period sometimes exceeded the reported monthly target. Rather than treating these values as erroneous a priori, they were retained in the primary analysis because they may reflect changes in target estimates, intensified implementation activities, or supplementation of women not captured in the monthly target denominator.

The most important finding was that commodity availability and community dialogue were the only implementation factors independently associated with higher MMS achievement after adjustment.

In the multivariable mixed-effects model, availability of sufficient MMS commodities was associated with an approximately 23.5-percentage-point higher achievement, while reporting community dialogue was associated with an approximately 18.0-percentage-point higher achievement. These associations remained statistically significant after adjustment for training, supportive supervision, implementation status, year, region, and clustering at woreda level.

These findings suggest that sustained implementation performance depends not only on introducing MMS into routine services but also on ensuring that the essential inputs and demand-side mechanisms required for implementation are functioning. In particular, reliable commodity availability represents a fundamental prerequisite for service continuity, while community dialogue may strengthen awareness, acceptance, demand, and utilization of MMS services.

The analysis also demonstrated substantial variation between woredas. The adjusted ICC of 0.358 indicates that a meaningful proportion of unexplained variation in MMS achievement occurred at the woreda level. This suggests that local health-system capacity, management practices, implementation context, and other woreda-level characteristics may influence

implementation performance beyond the individual implementation factors measured in the routine monitoring system.

Implementation Strategies

Training

Health-worker training was associated with MMS achievement in the descriptive and bivariable analyses, but the direction of association was not consistent with the expectation that training alone would improve performance. In the bivariable analysis, observations reporting training had lower mean and median achievement than those without reported training, although the adjusted association was no longer statistically significant.

This finding should not be interpreted as evidence that training is ineffective. Rather, training status in the routine dataset was defined by whether training was reported during the observation period and does not capture important dimensions such as training quality, timing, competency, refresher training, staff turnover, post-training mentoring, or whether trained personnel were actually delivering MMS services. In addition, training may have been prioritized in lower-performing or newly expanding areas, creating a plausible reverse-causality or targeting effect.

For national scale-up, training should therefore be viewed as one component of a broader implementation package rather than as a stand-alone intervention. Training should be linked to competency assessment, supportive supervision, practical mentoring, job aids, and mechanisms to orient newly deployed health workers.

Supportive Supervision

Supportive supervision was associated with slightly higher MMS achievement in the descriptive comparison and bivariable analysis, but the association was not statistically significant after adjustment. This suggests that the presence of supervision alone may not be

sufficient to explain differences in MMS implementation performance.

The routine monitoring indicator captures whether supportive supervision occurred and the number of supervision activities but does not assess the quality or content of supervision. Effective supportive supervision may depend on whether supervisors identify implementation bottlenecks, provide immediate technical assistance, review data quality, address commodity problems, and follow up on agreed corrective actions.

Consequently, future implementation monitoring should move beyond counting supervision visits and capture selected measures of supervision quality and follow-up. A supervision system that is linked to performance review and problem-solving may have greater value than supervision measured only by frequency.

Community Engagement

Community dialogue emerged as one of the strongest predictors of MMS achievement. Observations reporting community dialogue had substantially higher achievement than those without reported dialogue, and this association remained significant after adjustment.

This finding highlights the importance of demand creation and community engagement as part of MMS implementation. Community dialogue may improve understanding of the benefits of MMS, address concerns or misconceptions, encourage antenatal care attendance, and increase acceptance and uptake among pregnant women.

The finding is particularly relevant because the community dialogue indicator was cumulative, representing activities conducted "so far." Therefore, the association should be interpreted as evidence that implementation environments with established community engagement were associated with better MMS achievement, rather than as evidence that one additional dialogue session directly increased achievement.

Future programming should strengthen structured community engagement through pregnant-women forums, community leaders, health extension workers, women's groups, and other locally appropriate platforms. Importantly, community engagement should be linked to service availability so that increased demand can be translated into actual supplementation.

Health-System Readiness

Commodity Availability

Commodity availability emerged as the strongest factor associated with higher MMS achievement. Woredas reporting sufficient MMS supplies for the subsequent three months achieved approximately 23.5 percentage points higher MMS achievement than woredas reporting inadequate supplies, after adjustment for implementation factors, reporting period, region, and woreda-level clustering. This finding underscores the importance of supply-chain readiness in sustaining implementation performance. The association remained significant after adjustment, suggesting that commodity availability is not merely a characteristic of better-performing implementation areas but a critical health-system condition supporting effective MMS delivery. Similar findings have been reported in implementation research, where uninterrupted availability of commodities has been identified as a prerequisite for achieving high service coverage and maintaining program continuity [2, 18, 19].

For Ethiopia's national MMS scale-up, strengthening forecasting, procurement, distribution, stock monitoring, and redistribution mechanisms should remain a priority. Ensuring adequate buffer stocks may be particularly important in areas experiencing logistical constraints, emergencies, or disruptions to routine supply systems [2, 18, 19].

Reporting Systems

The study also highlights the importance of routine monitoring and reporting systems for implementation performance. Although the routine monitoring database enabled assessment of MMS implementation across multiple years and regions, substantial missing information was observed for several implementation indicators, and complete-case analysis was possible for only 1,246 of the 2,268 implementation observations.

Incomplete reporting may limit the ability of routine monitoring systems to accurately reflect implementation performance and may reduce their usefulness for program decision-making. Strengthening reporting systems through standardized indicator definitions, routine data-quality checks, timely feedback mechanisms, and integration with existing health information systems could improve both data completeness and program monitoring capacity [20, 21].

Together, these findings suggest that health-system readiness extends beyond commodity availability alone and depends on functional monitoring systems capable of generating reliable information for implementation planning, adaptive management, and performance improvement [20, 21].

Program Implications

The findings have practical implications for the major institutions supporting maternal nutrition and MMS scale-up in Ethiopia.

Ministry of Health: The Ministry should strengthen MMS institutionalization within routine maternal and antenatal nutrition services, with particular attention to commodity security, standardized implementation guidance, routine performance monitoring, and integration of MMS indicators into national monitoring systems. Regional and woreda health offices should use routine data to identify low-performing areas and implement targeted corrective actions.

Ethiopian Public Health Institute (EPHI): EPHI can support national learning through

analysis of routine MMS monitoring data, development and strengthening of data-quality systems, operational research, and evaluation of implementation strategies. EPHI can also contribute to establishing standardized approaches for interpreting routine MMS performance indicators and documenting lessons from different implementation contexts.

UNICEF: UNICEF can support government-led scale-up through technical assistance on maternal nutrition, health-system strengthening, supply-chain readiness, monitoring and evaluation, capacity development, and evidence generation. The findings particularly support continued investment in systems that ensure commodity availability and strengthen community engagement rather than focusing exclusively on training activities.

Nutrition International: Nutrition International can contribute technical and implementation expertise in maternal nutrition and MMS programming, including support for evidence-based implementation approaches, capacity strengthening, demand generation, and learning from implementation across different settings. Collaboration with government systems will be important to ensure that successful approaches can be institutionalized and sustained.

Children's Investment Fund Foundation (CIFF): CIFF and other development partners can support scale-up through strategic investment in interventions that strengthen the enabling systems for MMS implementation, including supply-chain reliability, data and learning systems, implementation research, and approaches that improve equitable access and sustained program performance. Investments should increasingly emphasize system capacity and sustainability alongside short-term coverage gains.

Across all partners, the findings support a shift from viewing MMS scale-up primarily as a commodity-delivery intervention toward a systems-oriented implementation approach in

which supply availability, community engagement, workforce capacity, supervision, and routine data systems are addressed together.

Continued implementation performance is likely to depend on reliable commodity availability, continued community engagement, and strong monitoring systems.

Strengths

This study has several important strengths. First, it used national routine monitoring data, providing a real-world assessment of MMS implementation under routine program conditions rather than under controlled research conditions. This increases the practical relevance of the findings for national program management.

Second, the dataset included observations collected across multiple years, allowing assessment of longitudinal implementation performance and temporal patterns during the national MMS scale-up.

Third, the study had broad geographic coverage, including 75 woredas across 13 regions. This allowed assessment of geographic variation and increased the relevance of the findings across diverse implementation contexts.

Fourth, the analysis incorporated an implementation science-oriented framework, examining implementation strategies, health-system readiness, community engagement, and contextual characteristics rather than focusing solely on coverage outcomes.

Finally, the use of a woreda-level random intercept accounted for the repeated nature of observations within woredas and demonstrated substantial clustering in implementation performance. Sensitivity analysis excluding observations with achievement above 300% produced similar substantive conclusions, supporting the robustness of the principal findings.

Limitations

Several limitations should be considered when interpreting the findings. First, the study relied on routine program data, which may be affected by differences in data completeness, accuracy, indicator interpretation, and reporting practices across regions and woredas. The observed achievement values above 100% and substantial missingness in several indicators illustrate some of these challenges.

Several implementation constructs were measured using binary or simplified routine indicators that may not adequately capture implementation dose, quality, fidelity, timing, or intensity. Consequently, the observed associations may underestimate or obscure relationships between higher-quality implementation strategies and MMS performance.

Second, missing observations were substantial. The primary multivariable analysis used a complete-case approach, resulting in 1,246 observations from 58 woredas compared with 2,268 observations in the overall analytical dataset. If observations with missing information differed systematically from complete observations, selection bias may have occurred.

Third, observational design prevents causal inference. Associations between commodity availability, community dialogue, and MMS achievement should not be interpreted as proof that these factors directly caused higher achievement. Unmeasured contextual and organizational factors may have contributed to the observed relationships.

Fourth, the study may be affected by reporting bias. Implementation activities such as training, supervision, and community dialogue were based on routine reporting and may not always reflect the quality, intensity, or actual implementation of the reported activities. Similarly, commodity availability was based on reported status rather than independent verification of stock levels.

Finally, some implementation variables were measured using relatively broad indicators. For

example, training status did not capture training quality or competency, while the community dialogue measure was cumulative rather than period specific. These measurement limitations may have attenuated or obscured some associations.

Despite these limitations, the consistency of the principal findings in the sensitivity analysis and the use of a mixed-effects approach to account for woreda-level clustering strengthen confidence that commodity availability and community engagement are important correlates of MMS implementation performance.

Conclusion

MMS implementation performance during national scale-up was most strongly associated with commodity availability and community engagement activities. Strengthening these implementation and health-system factors may improve the effectiveness of MMS implementation in Ethiopia.

The findings suggest that successful MMS implementation requires more than expanding service availability. Reliable commodity supply, meaningful community engagement, functional monitoring systems, and locally responsive health-system management are central to maintaining implementation performance. Strengthening these components within routine maternal nutrition and antenatal care systems may improve the consistency, equity, and sustainability of MMS delivery.

These findings provide practical evidence for the Ministry of Health, EPHI, UNICEF, Nutrition International, CIFF, and other partners to prioritize health-system readiness, supply-chain reliability, community engagement, data-quality improvement, and institutionalization of MMS within routine services as Ethiopia continues national MMS scale-up.

Conflict of Interest

The author declares no conflict of interest regarding the publication of this study.

Data Availability

The data used in this study were obtained from the national MMS routine monitoring system and are not publicly available. Access may be granted by the relevant program authorities subject to applicable data-sharing requirements.

Ethics Approval

This study utilized secondary analysis of routinely collected, aggregated MMS program monitoring data and did not involve direct contact with human participants. The dataset contained no personal identifiers and was analyzed solely for research purposes.

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Author Contributions

Abnet Tesfaye Kebede conceived the study, conducted the data analysis, interpreted the findings, and prepared the manuscript.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Acknowledgements

The author acknowledges the Ministry of Health, the Ethiopian Public Health Institute (EPHI), and partners supporting the national MMS program for facilitating access to routine monitoring data (UNICEF). Appreciation is also extended to academic supervisors and colleagues who provided technical guidance during the study.

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