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Effectiveness of behavioral interventions on knowledge, attitude, and adherence to prenatal MMSs among pregnant women in Ethiopia: a post-test only cluster randomized controlled trial

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Abstract

Multiple Micronutrient Supplementation (MMS) has been identified as a vital strategy to enhance maternal health; however, achieving sustained adherence remains challenging. There is insufficient evidence on the potential of contextually appropriate behavioral interventions to improve MMS-related knowledge, attitudes, and adherence beyond routine antenatal care. Thus, this trial was designed to provide empirical evidence on whether these specific strategies could improve MMS knowledge, attitudes, and adherence among pregnant women in Ethiopia. A post-test-only cluster-randomized controlled trial was conducted from June 20, to October 20, 2024 in 29 health centers across 6 woredas in 5 Regions in Ethiopia to evaluate the effects of three behavioral interventions on MMS (knowledge, attitude, and adherence). A total of 588 pregnant women were assessed at the end-line, with 151 mothers in Treatment 1, 164 in Treatment 2, 106 in Treatment 3, and 167 in the control group. For both primary and secondary outcome variables, we employed mixed-effects logistic regression with a random intercept for the cluster to account for within-cluster correlation. The models adjusted for socio-demographic characteristics and pregnancy related profiles of participants. The mean age of participants was 25.3 years (SD ± 5), with significant differences across the four study arms ($p < 0.001$). Overall, participants demonstrated high knowledge and attitude toward MMS, whereas adherence remained suboptimal. Compared to the intervention group the control group had highest knowledge score AOR = 0.20 (95% CI 0.07–0.54, $p = 0.002$). None of the intervention groups demonstrated a statistically significant impact on attitude toward MMS uptake. The Gameboard intervention had three times effect on adherence to MMS uptake in the last three months compared with the control group (AOR = 3.32 (95% CI 1.73–6.42), $p < 0.001$). Overall knowledge and attitudes toward MMS were high across all four study groups, while the adherence remained lower. The behavioral interventions exhibited mixed effects on MMS related to knowledge, attitude and adherence. Overall, the findings suggest that behaviorally informed approaches may have potential to support MMS adherence when integrated with routine maternal health services.

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Keywords MMS · Antenatal care · Pregnant women · Random controlled trial · Ethiopia

Abbreviations

ANC	Ante natal care
CHWs	Community health workers
HCP	Healthcare professionals
HEWs	Health extension workers
ICC	Inter-cluster correlation
IFAS	Iron folic acid supplement
ITT	Intention-to-treat
LBW	Low birth weight
RCT	Randomized controlled trial
SGA	Small for gestational age

Introduction

Micronutrient deficiencies remain a major public health concern in many low- and middle-income countries, including Ethiopia[1,2]. Pregnant and lactating women are greatly susceptible to the effects of micronutrient deficiencies due to high requirements of energy, protein, vitamins, and minerals to meet the increased demands of the pregnant mother and the developing fetus[3]. However, there is a low intake of essential micronutrients among pregnant women[4], leading to potentially adverse effects on the mother and baby, including prenatal anemia, maternal and perinatal death, low birth weight (LBW), preterm birth, intra-uterine growth restriction, altered immune response, and cognitive deficits in the baby[5–8].

Globally, two out of three individuals aged 15–49 years are deficient in iron, zinc, or folate[9]. Evidence indicates that the global burden of ten maternal disorders and more than one-third of all under-five child deaths are attributable to maternal malnutrition[2,6]. Maternal iron deficiency is the most commonly known micronutrient deficiency that causes anemia, which is exacerbated by physiological changes that the mother experiences and unmet intake of essential nutrients[10]. In 2023, anemia is estimated to affect 35.5% of pregnant women aged 15–49 years globally, with the highest prevalence reported in Africa (43%)[11]. In Ethiopia, anemia continues to affect the health of numerous pregnant women. Analysis of the recent Demographic and Health Survey report indicates that 28.01% of pregnant women suffered from anemia[12]. Additionally, vitamin and mineral deficiencies have also been contributing to pregnancy complications and adverse birth outcomes[13].

MMSation (MMS) has been identified as a vital strategy to enhance maternal health and reduce adverse pregnancy outcomes. A growing body of recent research findings indicated that prenatal MMS may be more effective than iron–folic acid (IFA) supplements at reducing the risk of Small for Gestational Age (SGA) births, LBW, and preterm births[14,15]. MMS is a single tablet that contains a comprehensive range of essential micronutrients crucial for overall health, including vitamins A, D, and B12; minerals such as zinc and copper; as well as other vital elements like iodine and magnesium. Findings from recent studies show that using MMS during pregnancy helps to reduce adverse pregnancy outcomes during the second and third trimesters, including miscarriage, pre-eclampsia, anemia, preterm birth, and placental insufficiency, as well as improving the quality of breastmilk and reducing postpartum depression[16,17].

The World Health Organization (WHO) recommends MMS to be included as part of routine ANC in resource-limited settings to improve maternal micronutrient status[3,18]. The effectiveness of MMS depends on gestational age at the start of supplementation and adherence, where high adherence (≥90%) was associated with increased birthweight and lower risk of LBW and SGA, while low adherence increases the risk of stillbirth and maternal anemia[17]. However, despite its proven contribution, adherence to MMS remains suboptimal; one study found adherence of 53.9% in the 90-day intake recommendation[19]. Studies show that non-adherence to prenatal MMS is due to fear of side effects, misconceptions, trust in health professionals, perceived benefits, negative perceptions, late MMS introduction, and behavioral barriers[19,20]. Moreover, findings from the formative assessment also revealed that lack of awareness, lack of compassionate care amongst healthcare providers, stigmatization of unwed pregnancy have shown to affect MMS perception and adherence.

The study's insights have been used to inform the formulation of the social and behavior change (SBC) strategy to improve pregnant women's perceptions, attitudes, and adherence to MMS intake recommendations. In this study, different behavioral interventions were developed to testifies its effectiveness on prenatal MMS adherence, including Healthcare Professionals (HCP) Empathy Training; Educational comic booklets called the Supermom's Journey comic booklets, and the Journey to Motherhood Game Board. The behavioral interventions evaluated in this trial were selected to address potentially modifiable determinants of MMS adherence within the routine ANC settings of Ethiopia. These interventions were intended to address behavioral barriers at the individual, interpersonal, and service-delivery levels. These interventions were remained feasible for integration into routine ANC services. The interventions were selected not because they were assumed to be superior to other established adherence strategies, but because they represented feasible, contextually appropriate approaches through which different behavioral determinants of MMS use could be addressed within the Ethiopian ANC setting. Thus, this trial was designed to provide empirical evidence on whether these specific strategies could improve MMS knowledge, attitudes, and adherence among pregnant women in Ethiopia.

Methods

Patient and public involvement

Patients and members of the public were not directly involved in the formal design, conduct, reporting, or dissemination planning of this trial. However, the behavioral interventions used in the study were developed and adapted considering the local context, routine antenatal care services, and commonly identified barriers to MMSation adherence among pregnant women in Ethiopia. Conducting pretest and formative assessment helped to enhance cultural appropriateness, feasibility, and acceptability within the study setting.

Study design

A post-test only cluster-randomized controlled trial was conducted in 29 health centers across 5 Regions in Ethiopia. The approach consisted of three sequential phases; the study participants were recruited during prenatal care visits, and their baseline demographic information was collected in June 20, 2024. Finally, the endline assessment was conducted in October 20, 2024.

No baseline measurements of MMS knowledge, attitude, or adherence were collected. The primary comparison was the difference in outcomes between randomized groups at endline following the four-month intervention period under routine ANC conditions, while minimizing potential contamination and measurement-related influences associated with repeated assessment of the same behavioral constructs. Cluster randomization reduced the likelihood that intervention related changes would spread to women receiving care in other study arms. However, we recognize that without baseline outcome measurements, we cannot directly estimate within-participant change from baseline to endline.

Study setting

The study was conducted in 6 selected woredas of the 5 regions included in the study, namely Awbare Woreda of the Somali Region, Duguna Fango Woreda in South Ethiopia Region, Godere Woreda of the Gambella Region, Sire Woreda in Oromia Region, and Aleta Chuko Woreda and Bona Woreda of Sidama Region.

Eligibility criteria

The study population includes pregnant women attending ANC services at selected public health facilities during the study period.

Inclusion criteria

- Pregnant women were included if they:
  - Were attending ANC services at selected study facilities.
  - Were eligible to receive MMS supplementation according to national ANC guidelines.
  - Were willing to participate and provide informed consent.
  - Had plan to remain in the study area during the intervention period.

Exclusion criteria

- Pregnant women were excluded if they:
  - Were seriously ill or unable to communicate during data collection.
  - Had cognitive or medical conditions limiting participation.
  - Had plan to relocate from the study area during follow-up.
  - Declined to provide informed consent.

Withdrawal criteria

- Participants were withdrawn if they:
  - Voluntarily withdrawn consent.
  - Relocated outside the study area.
  - Became severely ill and unable to continue participation.
  - Delivered before the endline assessment.

Sample size

The sample size was calculated using R software, based on an assumed effect size of 0.3[21], a 95% confidence interval, and an intra-cluster correlation (ICC) of 0.01 at the clinic level in Ethiopia[21]. This calculation resulted in a planned sample size of 783 participants (with each group consisting of 216 participants, except for the HCP empathy training intervention group, which had 135 participants). Additionally, due to its function as a supplementary supply-side intervention, the Treatment 3 group was allocated to fewer clinics.

The endline sample size was smaller than at baseline due to various factors that prevented full participation. Loss to follow-up was primarily due to personal circumstances of the participants, some terminated pregnancies, moving to their mother's home for childbirth, recent deliveries, and imminent due dates, which limited some participants' availability for the endline data collection. Additionally, locating certain participants was challenging due to address discrepancies provided during their recruitment. Despite these setbacks, efforts were made to ensure the retention of at least 75.1% of the baseline sample ($n = 588$) at the endline. Except for the inclusion criteria, there was no significant difference in socio-demographic characteristics between participants who dropped out of the follow-up and those who continued.

Sampling and randomization

Health centers from separated geographical location were used as the unit of randomization and were randomly assigned to study arms to minimize contamination and spillovers across treatment arms. The geographical separation reduced the likelihood of routine interaction between participants from different study facilities. Selected facilities were randomly assigned to intervention or control arms using a computer-generated random allocation sequence prepared by an independent researcher not involved in participant recruitment or data collection. The 29 clusters in the study were randomly split across four treatment arms: Control (8), Gameboard (8), Comic Strip (8), and Healthcare Professional Empathy Training (5). The selected facilities were those which were providing MMS in the ANC service. The intervention instructions and material for each intervention were delivered to the respective treatment arms, while the Control group received no intervention.

Because of the nature of the behavioral interventions, blinding of participants and intervention providers was not feasible. However, data collectors and supervisors were trained to maintain neutrality during data collection. Statistical analysis was also conducted using coded group identifiers to minimize analytical bias.

Description of the interventions

The intervention package comprised three behaviorally informed approaches designed to address barriers associated to MMS knowledge, attitude, and adherence. The two interventions, Supermom's Journey Comic Booklet and Journey to Motherhood Gameboard were participant-directed, take-home educational interventions, whereas the HCP Empathy Training was a provider-directed intervention intended to improve the quality of interactions between healthcare professionals and pregnant women. All intervention components were implemented within the four-month intervention period.

(a) Educational comic booklet called "Supermom's Journey Comic Booklet"

Goal The comic book informs and educates pregnant women of the need to take MMS through an interesting, engaging, and illustrative story. It is designed as animated video stories, prepared in the local language, and played for the pregnant women by the field officers.

Topics It is an educational tool depicting the pregnancy journey of a single character. It contrasts the experiences of pregnant women who take MMSs (MMS) with those who do not, emphasizing the positive effects of MMS on maternal and child health outcomes.

Design features A comic book with a strong visual narrative with illustrations for easy understanding, which also includes a video version of the booklet stories for non-readers.

(b) Journey to Motherhood Game Board

Goal A game designed to tackle the persistent issues of malnutrition and anemia among expectant mothers in Ethiopia through interactive, fun, and educational games.

Topics The game covers topics such as nutrition, anemia, and maternal service. After the game instructions were delivered to them in their preferred language, any questions they had were answered.

Design features A fun game that requires players to match foods with their associated benefits and answer a specific question about the topic highlighted before.

(c) Healthcare Professionals (HCP) Empathy Training

Goal To foster empathy in patient care among health workers, especially maternal and child health (MCH) professionals and health extension workers (HEWs) through training.

Topics Effective interaction and engagement of pregnant women, implicit biases and how to minimize them, and empathy and how to develop it were among the subjects discussed.

Format One-day in-person training involving role plays, case studies, and training modules was provided by the trained trainers.

Intervention duration and follow-up

Participants were followed for four months duration to assess the effectiveness of the behavioral interventions. Follow-up activities were integrated into routine ANC visits at the selected health centers. During the four-month follow-up, participants in the intervention arms continued to receive their assigned behavioral intervention alongside standard ANC services whereas participants in the control group continued to receive only standard ANC services according to national guidelines.

The Supermom Comic Booklet and Journey to Motherhood Gameboard were take-home interventions; therefore, their intended exposure extended throughout the four-month follow-up period through participants' self-use at their home. Our study did not prescribe a fixed number of home-use frequency because the materials were designed for self-directed use. Receipt of the Comic Booklet and Gameboard was documented using an intervention delivery checklist. The HCP Empathy Training was delivered as a face-to-face one-day training, after which trained healthcare professionals applied the acquired empathy and communication skills during routine interactions with pregnant women throughout the follow-up period.

Intervention exposure and compliance monitoring

Intervention exposure was monitored primarily through documentation of intervention delivery. The research team recorded provision of the Supermom Comic Booklet and Journey to Motherhood Gameboard to participants using a standardized checklist. Because these materials were designed for self-directed use at home, the checklist documented receipt of the intervention materials rather than the frequency with which participants subsequently used them at home. No predefined participant-level compliance threshold for home use was applied. However, healthcare providers were reminding pregnant women and asking for their compliance during each ANC visit within the follow up period. The primary trial outcomes MMS knowledge, attitude, and adherence were assessed at endline after the four-month of follow-up.

Data collection

A structured interviewer-administered questionnaire consisting of five sections was developed and pre-tested based on the study objectives, relevant literature, and the content of the MMS intervention. The internal consistency of the attitude scale was assessed using Cronbach's alpha ($\alpha = 0.71$). However, since the knowledge items were treated as factual indicators rather than as a unidimensional psychometric scale, internal consistency was not assessed for knowledge items.

To maintain the quality of data and to reduce the potential bias in data collection, training of the research team field officers was done before the field data collection and continuous monitoring and supervision were conducted throughout data collection period. Data collection was conducted using Open Data Kit (ODK) data collection

technology. The survey sections included: Socio-demographics, Pregnancy-related questions, Knowledge of MMS, Attitudes towards MMS, and MMS adherence.

Outcome measures

Knowledge level The study participants' knowledge about MMS and its benefits during pregnancy was assessed using six items. Each correct response was assigned a score of "1," while incorrect responses were assigned a score of "0", resulting in a total possible knowledge score ranging from 0 to 6. Participants who scored four or more points were categorized as having good knowledge, while those scoring below four were considered to have poor knowledge.

Attitude level Respondents' attitudes toward MMS were evaluated using six Likert scale items adapted from previous studies. Each item was scored as 1 for a positive response (strongly agree and agree) and 0 for a negative (strongly disagree and disagree) or neutral response. The total attitude score ranged from 0 to 6 points. The participants who scored four or above were identified as having a positive attitude toward MMS, while those who scored three or less than three were considered to have a negative attitude.

MMS Adherence MMS Adherence was measured in two ways: (1) Primary adherence, a self-reported description of MMS Pill intake over the last 3 months, and (2) Secondary adherence, a self-reported number of pill intake days for the past week. For both of the measurements, those who reported taking every day were considered the correct answer, coded as score 1 (good adherence), and those who responded other than every day were recoded as 0 (poor).

Data analysis

We conducted a data analysis based on the endline data according to participant's original randomized study group to evaluate the effects of three behavioral interventions on MMS (knowledge, attitude, and adherence). Since the study used a post-test-only design, participants who were lost to follow-up were not included in the outcome-specific regression analyses. The number and proportion of participants lost to follow-up were reported by study arm, and the potential for attrition bias was considered in the interpretation of the findings.

Before fitting the multivariable regression models, multicollinearity among the explanatory variables was assessed before fitting the multivariable models using variance inflation factors (VIFs). All VIF values were below 5, indicating no evidence of substantial multicollinearity among the predicting variables. Socio-demographic and outcome variables differences across treatment arms were analyzed using chi-square and ANOVA tests. Multivariable mixed-effects logistic regression models were fitted separately for both primary and secondary outcome variables to estimate their association with each intervention groups, with the control group used as the reference category. The models adjusted for socio-demographic characteristics and pregnancy related profiles of participants. A random intercept for health center was included to account for the clustering of participants within health centers. Adjusted odds ratios (AORs) with 95% confidence intervals (CIs) and corresponding a p-value of < 0.05 were used to declare statistical significance.

Result

Demographic characteristics of study participants

Of the 783 participants enrolled at baseline, 588 (75.1%) were retained and completed the endline assessment, while 195 (24.9%) were lost to follow-up. Loss to follow-up was 65/216 (30%) in Treatment Arm 1, 52/216 (24%) in Treatment Arm 2, 29/135 (21.5%) in Treatment Arm 3, and 49/216 (22.7%) in the control arm. The

proportion lost to follow-up did not differ significantly across the four study arms ($p > 0.05$), suggesting that attrition was broadly comparable between groups.

At the end line, the mean age of participants was 25.3 years (SD ± 5), with significant differences across the four study arms ($p < 0.001$). More than half (54.1%) of the total participants had the primary level of education, which differed significantly across the treatment arms ($p = 0.006$), with the highest proportion of participants with no formal education observed in Treatment 3 (33%), while 16% of the participants had no formal education, of which 33% participants are in Treatment 3. Regarding husbands' level of education, slightly less than half (45.5%) had primary education, without a significant difference across the treatment arms ($p = 0.092$).

More than half of the participants (63.3%) were self-employed, with the highest score (34%) in Treatment 2 and a higher unemployment rate in Treatment 3 (40%) ($p < 0.001$). The average number of births is 1.7 (± 1.6), with a significant difference across treatment arms where Treatment 1 had the highest average 2.05 (± 1.8) number of children, while Treatment 4 had the lowest 1.3 (± 1.4). Religion was diverse, with Protestantism being the most common (74.3%), Treatment 1 having a higher proportion of Muslims (44%), and Treatment 4 having a higher proportion of Orthodox participants (41%). These differences among the study arms may lead to heterogeneous responses to the treatment. To get a clearer picture of the treatment effects, we controlled for these differences in our analysis (Table 1).

Pregnancy-related characteristics and ANC visits

The mean number of pregnancies of the study participants, including the current pregnancy, was 2.8 ± 0.06 (SD). The pregnancy of the majority (82.5%) of the participants was planned without any significant difference across the treatment arms. The primary reason to attend ANC for the majority (89.3%) of the participants was to check for their health and their baby's condition, while only a few (5.1%) of the participants visited ANC to take MMS or other supplements without a significant difference across the treatment arms. A significant number (83.1%) of the participants didn't miss their ANC schedule with no significant difference across the treatment arms ($p = 0.563$). In terms of the distance of the health facility, for most of the study participants (43%), it is very easy to get to their preferred health facility with a significant difference across the treatment arms ($p = 0.002$), where it is very difficult for the highest number (2.3%) of participants in Treatment 1 and 3.

The response distribution of participants at the time they were diagnosed with their pregnancy, whether they had ever been diagnosed with anemia, whether they had current pregnancy anemia, whether they had previously taken IFAS, and whether they had heard of MMS is presented in Table 5 (Annex).

Table 1 Socio-demographic characteristics of study participants across the treatment arms ($n = 588$).

Variables	Categories	Total *n* (%)	T1 *n*(%)	T2 *n*(%)	T3 *n*(%)	T4 *n*(%)	*P*-value
Education	No formal education	94 (16)	33 (17)	20 (21.3)	31 (33)	10 (10.6)	0.006
	Primary school	318 (54.1)	78 (24.5)	81 (25.5)	104 (32.7)	55 (17.3)	
	Secondary school	134 (22.8)	41 (22.4)	61 (35.8)	29 (19.4)	39 (22.4)	
	TVET/ Diploma	27 (4.5)	6 (22.2)	9 (33.3)	3 (11.1)	9 (33.3)	
	Degree or higher	15 (2.6)	4 (26.7)	6 (40)	3 (20)	2 (13.3)	
Employment	Unemployed	179 (30.4)	62 (34.6)	31 (17.3)	71 (39.7)	15 (8.4)	<0.001
	Casual employment	37 (6.3)	15 (40.5)	7 (18.9)	8 (21.6)	7 (18.9)	
	Self-employed	372 (63.3)	74 (19.9)	126 (33.9)	88 (23.7)	84 (22.6)	
Religion	Orthodox	34 (5.8)	5 (14.7)	10 (29.4)	5 (14.7)	14 (41.2)	<0.001
	Muslim	102 (17.4)	45 (44.1)	17 (16.7)	34 (33.3)	6 (5.9)	
	Protestant	437 (74.3)	101 (17.18)	135 (23)	117 (20)	84 (14.3)	
Age		25.3 (±4.8)	26.7 (±4.9)	25.3 (±5)	24.4 (±4.7)	24.8 (±4.4)	<0.001
Number of children		1.7 (±1.6)	2.05 (±1.8)	1.8 (±1.7)	1.7 (±1.8)	1.3 (±1.4)	0.001

Participants' MMS knowledge

After four months of intervention through different behavioral interventions, most of the participants (85%) believe that MMS could replace a balanced diet. Regarding the frequency of taking MMS, almost all participants (98%) responded that MMS should be taken once daily. Slightly more than half of the participants (95%) reported that the MMS should be taken throughout pregnancy. In relation to appropriate MMS administration, 77.7% of participants demonstrated correct knowledge, while 22.3% held an incorrect belief. Additionally, 6.6% of participants incorrectly reported that a missed MMS dose could be compensated by taking two tablets the following day. Table 6 (Annex) fully presents the responses of the participants regarding each item of the knowledge of MMS.

Binary knowledge measurement

Overall, 82.7% of participants demonstrated good knowledge about MMS. The proportion of participants with good knowledge differed across study arms (p-value < 0.001): with the highest score among the Control group (91.5%) and the lowest among Treatment 1 (71.5%), Treatment 2 (86.6%), and Treatment 3 (83.2%).

Attitude of participants toward MMS

This section evaluates how positively pregnant women feel about MMS, using a 5-point Likert scale. Most items scored above the mean value of 4.2, showing strong positive attitudes toward MMS. *MMS Supplements are good for the health of the mother and baby* (Mean = 4.65). "*Taking MMS regularly is a burden…"* had the lowest score (Mean = 3.98), indicating some resistance due to routine demands. Overall, attitudes are highly favorable, especially regarding MMS benefits.

Most of the participants (48%) agreed, and 32% strongly agreed, that every pregnant woman can be affected by anemia during pregnancy. Similarly, they agreed: taking MMS is effective in preventing anemia (94.5%), MMS is good for the health of the mother and baby (97%), and similarly for other attitude items. Table 2 presents the response distribution regarding the attitude of pregnant women toward MMS and its uptake.

Binary measurement of attitude

Nearly all of the participants (96.4%) had a positive attitude toward MMS uptake. The proportion of participants with a positive attitude differed significantly across the study arms (p-value = 0.024): the highest positive attitude (98.2%) was in Treatment 2, while the lowest positive attitude (91.5%) was in the Control group.

Table 2 Attitude toward MMS uptake among study participants (N = 588).

MMS attitude	Strongly disagree, *n* (%)	Disagree *n*(%)	Neutral *n*(%)	Agree *n*(%)	Strongly agree *n*(%)
Can any pregnant woman be affected by anemia?	7 (1.19)	42 (7.16)	14 (2.39)	277 (47.19)	247 (42.08)
MMS supplements can prevent Iron Deficiency Anemia	2 (0.34)	8 (1.36)	6 (1.02)	254 (43.27)	317 (54.0)
MMS Supplements are good for the health of the mother and baby	0 (0)	2 (0.34)	4 (0.68)	194 (33.05)	387 (65.93)
Pregnant women should consume MMS pills despite a healthy diet	8 (1.36)	12 (2.04)	4 (0.68)	234 (39.86)	329 (56.05)
Taking MMS regularly is a burden because of the daily routine	243 (41.40)	227 (38.67)	18 (3.07)	63 (10.73)	36 (6.13)

Adherence to MMS uptake

Under this section, adherence to MMS uptake and variables related to adherence to MMS were presented. More than half of the participants (55%) reported taking the MMS every day in the last seven days, while 16% of participants reported taking MMS 0 days in the last seven days. When it comes to taking MMS in the last three months, slightly less than half (48%) of the participants reported taking MMS every day as it was recommended by a healthcare provider, while 11% reported taking it occasionally and 2% rarely missing it most of the days. Most participants (55%) stated that it is very easy for them to remember to take MMS, while only a few (5%) reported that it is somewhat difficult to remember to take MMS. Similarly large number of participants (79.4%) mentioned they don't need someone to remind them; they remember to take MMS by themselves, while 18% of participants need their spouse or family member to remind them. The majority of the participants (45%) reported that they collect MMS pills every three months, while 28% didn't collect their pills regularly. Near to all of the participants (96%) mentioned that when they forget taking their pill, they skip that and continue with their regular schedule. The response distribution of the participants is presented in Table 7 (Annex).

Measurement of adherence to MMS uptake

Most of the participants (55%) were identified as having good secondary adherence (in the last 7 days) to MMS, more than the primary adherence (in the last three months), where only 47.8% had good adherence to MMS uptake. Both primary and secondary adherence to MMS had a significant difference across the treatment arms, clearly presented in Table 3.

Mixed-effects model analysis

A mixed-effects logistic regression model was fitted to examine the effect of the three behavioral interventions on adherence to MMS pill uptake among mothers (binary outcome), while accounting for the clustering effect at the health center level. An estimate of the impact of each treatment group is presented as log-odds with 95% confidence intervals (CI) compared to the reference group (control group = 4).

The Intra-cluster Correlation Coefficient (ICC) was estimated for the primary outcome variables. ICC was 0.070 for MMS knowledge, 0.053 for attitude, and 0.038 for MMS adherence, indicating low to moderate correlation among participants within the same health center.

Effect of behavioral interventions on knowledge of MMS uptake

Compared with the control group, the Journey to Motherhood Gameboard intervention demonstrated a statistically significant reduction in the knowledge of MMS (AOR = 0.14 (95% CI 0.06–0.34), $p < 0.001$). This indicates that participants in the Gameboard group had approximately 86% lower odds of the knowledge compared to the reference group (control). The Super-mom Comic Book intervention also showed a significant reduction in the knowledge of MMS compared to the reference group (AOR = 0.26 (95% CI 0.09–0.74), $p = 0.012$). This means that participants in the Comic Book group had approximately 74% lower odds of the knowledge compared with the control group. Similarly, the CHW (Community Health Workers) Empathy Training intervention

Table 3 Adherence to MMS uptake across treatment arms ($N = 588$).

Variable	Categories	Total	T1	T2	T3	T4	*P*-value
Secondary adherence (in the last seven days)	Good	323 (54.9)	50 (33.1)	103 (62.8)	68 (64.1)	99 (59.3)	<0.001
	Poor	265 (45.1)	101 (66.9)	61 (37.2)	38 (35.9)	68 (40.7)	
Primary adherence (in the last three months)	Good	281 (47.8)	69 (45.7)	79 (48.2)	69 (65)	39 (23.6)	<0.001
	Poor	307 (52.2)	82 (54.3)	85 (51.8)	37 (35)	128 (76.4)	

was associated with a significant reduction in the knowledge of the MMS pill (AOR = 0.20 (95% CI 0.07–0.54), $p = 0.002$). This shows that the CHW Empathy Training arm had approximately 80% lower odds of the knowledge compared with the control group (Fig. 1).

After adjusting for the confounding factors, compared to those who were unemployed, those involved in casual employment (AOR = 2.34; 95% of CI 0.19 to 4.48, p-value = 0.033) and self-employed (AOR = 0.87; 95% of CI 0.29 to 1.46; p-value = 0.003) are more knowledgeable about MMS pill uptake. Moreover, those who did not miss their ANC schedule had nearly twice the odds of being knowledgeable about MMS (AOR = 1.96; 95% CI 0.99 to 4.00; $p = 0.035$) compared to those who did.

Effect of behavioral interventions on attitude toward MMS uptake

None of the intervention groups demonstrated a statistically significant impact on attitude toward MMS uptake. Although not statistically significant, compared with the control group, participants in the Gameboard intervention had almost four times higher positive attitude toward MMS (AOR = 3.56 (95% CI 0.94–13.46), $p = 0.061$). The Comic Book group also showed increased odds of positive attitude toward MMS compared with the control arm (AOR = 3.13 (95% CI 0.52–18.73), $p = 0.213$). Likewise, the CHW Training group was also associated with higher odds of positive attitude toward MMS pill relative to the control group (AOR = 2.12; 95% CI 0.48–9.30; $p = 0.326$). However, the confidence interval and insignificant p-value indicate that the interventions were not significantly improved attitude toward MMS compared to control group (Fig. 2).

Effect of behavioral interventions on adherence to MMS uptake

None of the intervention groups significantly impacted both the primary and secondary MMS adherence in terms of the reported pill intake over in the last three months or seven days. The estimated log odds from a Mixed-Effects

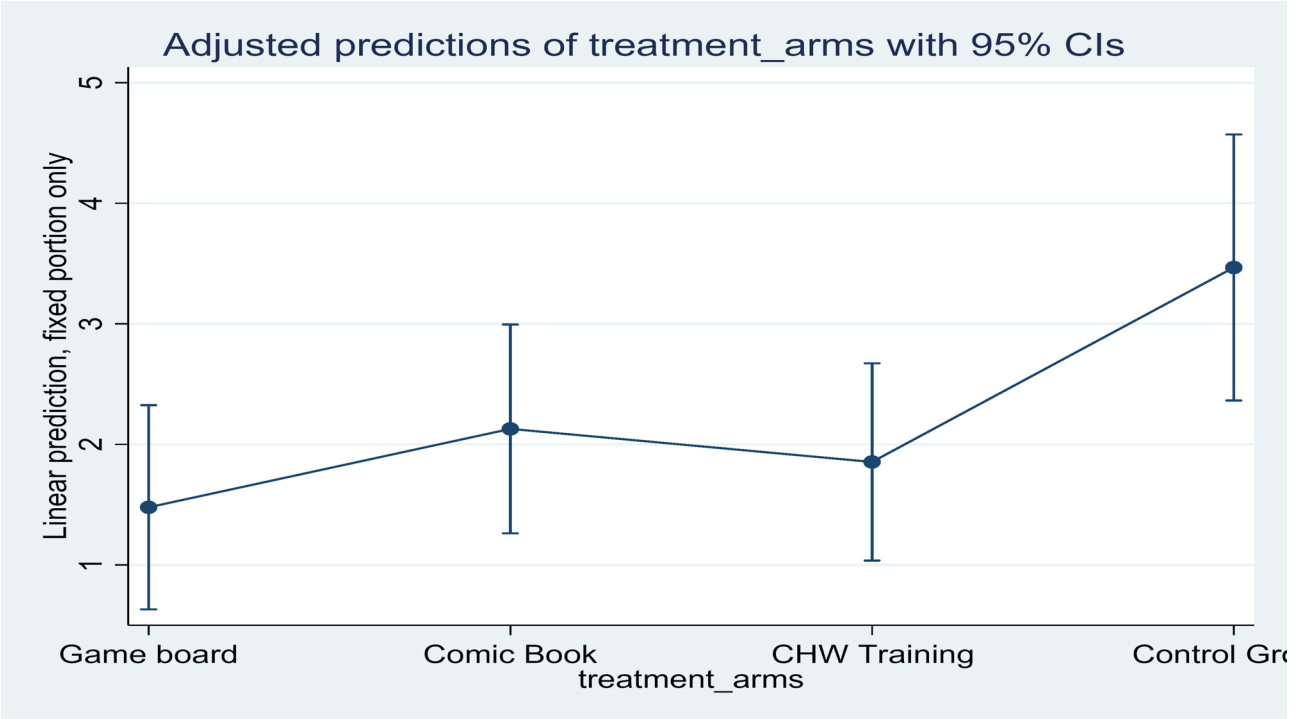


Fig. 1 Adjusted impacts of behavioral interventions on knowledge of MMS pills uptake among pregnant women in Ethiopia.

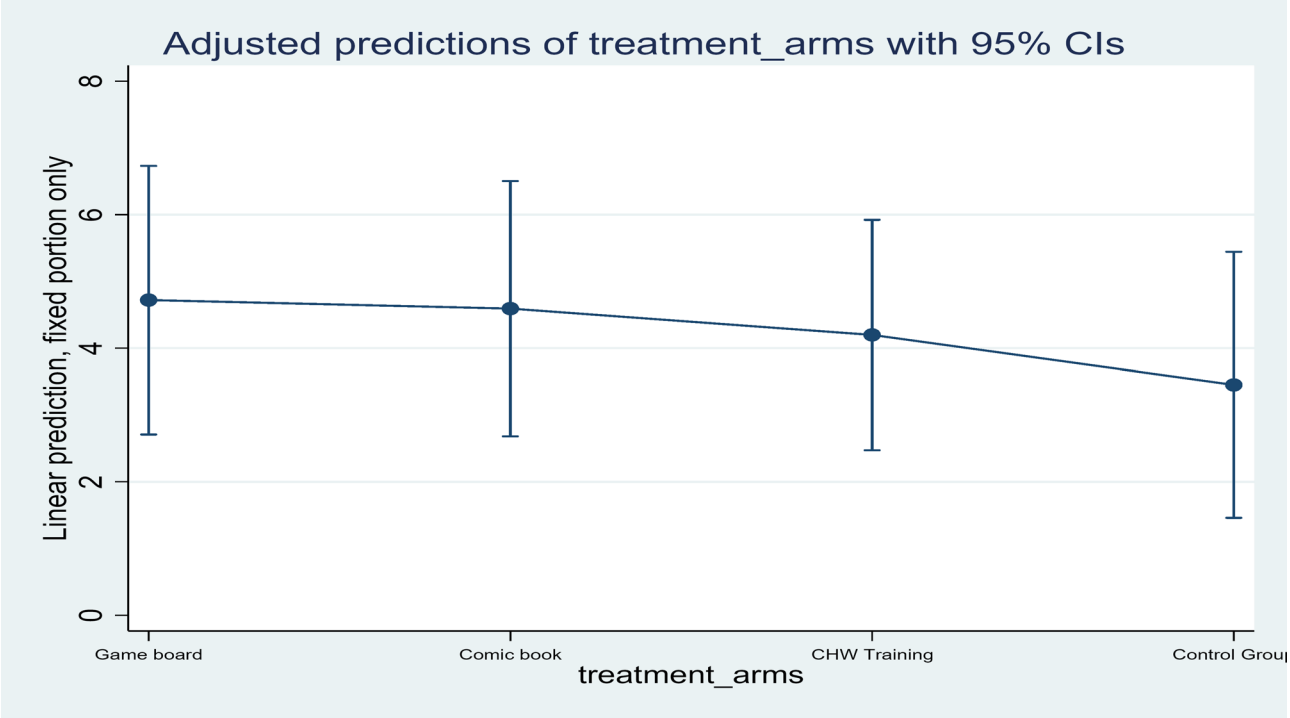


Fig. 2 Adjusted impacts of behavioral interventions on attitude toward MMS pills uptake among pregnant women in Ethiopia.

Model for the effect of three different behavioral interventions on MMS pills uptake in the last week (Fig. 3) and in the last 3 months (Fig. 4).

Compared with the control group, the Journey to Motherhood Gameboard intervention showed 60% reduction in adherence to MMS uptake in the last week (AOR = 0.40; 95% CI 0.21–0.73; $p = 0.003$). In contrast, the Supermom Comic Book intervention did not demonstrate a statistically significant effect (AOR = 1.63; 95% CI 0.88–3.00; $p = 0.122$). Similarly, the CHW Empathy Training intervention showed no statistically significant difference compared with the control arm (AOR = 0.84; 95% CI 0.41–1.70; $p = 0.622$), indicating no reliable evidence that this intervention influenced adherence to MMS in the last week.

After controlling the confounding variables, being diagnosed with anemia in current pregnancy (AOR = 0.9; 95% CI 0.40 to 1.3 0; p-value < 0.001) and increased ANC frequency (1.7; 95% CI 0.82 to 3.80; p-value = 0.026) had a positive association with adherence to MMS in the past week, whereas reported difficult distance to reach health facilities (AOR = − 1.01; 95% CI − 1.87 to − 0.14; p-value = 0.022) and difficulty to remember to take MMS pill (− 2.9; CI − 3.9 to − 1.8; p-value < 0.001)had negative association with it. The statistical output from cross-tabulation, bivariate, and multivariable analyses is presented in Table 4.

The Journey to Motherhood Gameboard intervention showed a statistically significant positive effect on adherence to MMS uptake in the last three months compared with the control group (AOR = 3.32 (95% CI 1.73–6.42), $p < 0.001$). The Super-mom Comic Book intervention also demonstrated a significant positive association (AOR = 3.35; 95% CI 1.70–6.69; $p = 0.001$), showing that participants in this group were significantly more likely to adhere to MMS uptake than those in the control group in the last three months. The CHW Empathy Training intervention was similarly associated with a significant improvement in adherence to MMS (AOR = 2.36; 95% CI 1.11–5.05; $p = 0.027$). This indicates that, relatively in the long term, the intervention group had higher odds of adherence relative to those in the control arm.

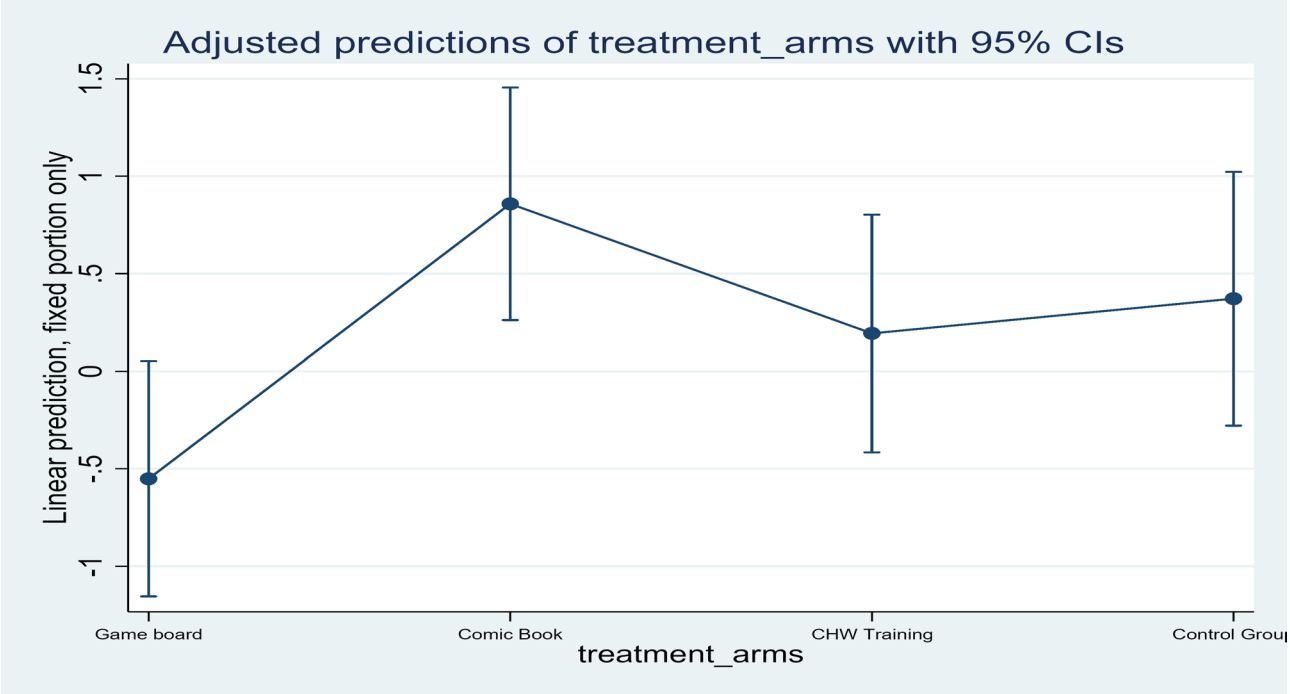


Fig. 3 Adjusted impacts of behavioral interventions on adherence to MMS within the last week.

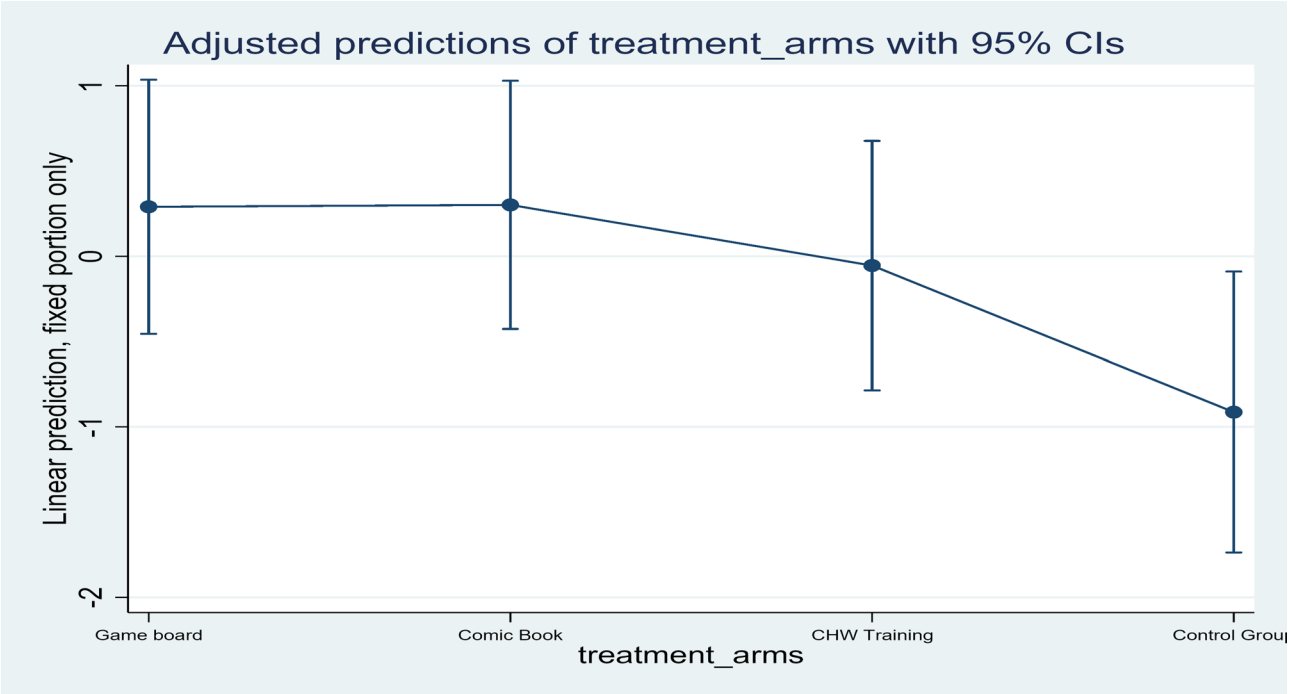


Fig. 4 Adjusted impacts of behavioral interventions on MMS pill uptake behavior in the last 3 months.

Table 4 Multivariable analysis result, factors associated with adherence to MMS uptake in the past week among pregnant women in Ethiopia, October 2024.

Variables		Adherence to MMS uptake in the past week ($n=588$)		COR	AOR (95% CI)	*P*-value
		No ($n=265$)	Yes ($n=323$)			
Age of participant	18–25	99	154	Constant	–	–
	26–35	140	154	− 0.3	− 0.3 (− 0.7, 0.1)	0.182
	>35	26	15	− 1.0	− 0.7 (− 1.5, 0.2)	0.110
Educational status	No formal education	49	45	Constant	–	–
	Primary school	144	174	0.3	− 0.4 (− 1.0, 0.3)	0.237
	Secondary school	53	81	0.5	− 0.2 (− 0.9, 0.5)	0.569
	TVET/ Diploma	10	17	0.61	− 0.1 (− 1.2, 1.0)	0.818
	Degree or higher	9	6	− 0.32	− 0.8 (− 2.2, 0.5)	0.229
Employment status	Unemployed	96	83	Constant	–	–
	Casual employment	13	24	0.8	0.9 (− 0.003, 1.8)	0.051
	Self-employed	156	216	0.5	0.4 (− 0.1, 0.9)	0.162
Pregnancy found	1–3 months	192	267	Constant	–	–
	4–6 months	73	56	− 0.6	− 0.6 (− 1.2, 0.001)	0.053
Anemia in the current pregnancy	No	154	132	Constant	–	–
	Yes	111	191	0.7***	0.9 (0.4, 1.3)	<0.001
ANC visit	1–2 times	66	44	Constant	–	–
	3–4 times	164	218	0.7	0.4 (− 0.1, 1.4)	0.106
	5–6 times	32	53	0.9	0.6 (− 0.1, 1.4)	0.106
	≥6 times	3	8	1.4	1.2 (− 0.3, 2.7)	0.129
Missed ANC	No	201	288	Constant	–	–
	Yes	64	35	− 1.0	− 0.5 (− 1.1, 0.1)	0.124
ANC frequency	NA	120	150	Constant	–	–
	Rarely	10	7	0.01	0.08 (− 0.4, 0.6)	0.739
	Sometimes	24	23	0.3	0.7 (− 0.7, 1.6)	0.108
	Most of the time	111	143	2.6***	1.7 (0.8, 3.8)	0.026
To reach the health facility	Very Easy	96	155	Constant	–	–
	Somewhat Easy	77	114	− 0.1	0.1 (− 0.3, 0.6)	0.562
	Neutral	11	9	− 0.7	0.1 (− 1.2, 1.4)	0.890
	Somewhat Difficult	38	33	− 0.6	− 0.4 (− 1.1, 0.2)	0.196
	Very Difficult	43	12	− 1.3***	− 1.3 (− 2.2, − 0.5)	0.001
Remember to take MMS (Recoded)	Easy	104	217	Constant	–	–
	Somewhat Easy	128	100	− 1.0***	− 1.4 (− 1.8, − 0.9)	<0.001
	Difficult	33	6	− 2.4***	− 2.9 (− 3.9, − 1.8)	<0.001
Knowledge of MMS	Poor	66	36	Constant	–	–
	Good	199	287	1.0	0.6 (− 0.03, 1.2)	0.061
Attitude toward MMS	Negative	14	7	Constant	–	–
	Positive	251	316	0.9	0.6 (− 0.6, 1.8)	0.347

Discussion

This study assessed the effectiveness of three behavioral interventions, Super-mom Comic Book, Journey to Motherhood Gameboard, and Community Health Workers' Empathy Training on improving knowledge, attitude, and adherence to MMS among pregnant women in Ethiopia. Unlike earlier interventions that relied mainly on counseling services during antenatal care (ANC), this study tested whether behavior-driven interventions can yield measurable improvements in maternal health outcomes and adherence behavior to supplements within a duration of four months. The findings after four months of intervention show high overall knowledge and positive attitudes toward MMS across all study groups. However, intervention effects differed, with significant variation in knowledge and adherence to MMS uptake among treatment arms.

Overall, 83% (82.7%) of pregnant women demonstrated good knowledge of MMS. This proportion is similar to that reported in previous studies in Ethiopia and similar low-resource settings, where knowledge of the MMS benefits[22]. The consistently high MMS knowledge levels across groups may be partly attributed to the integrated ANC counseling services, the relatively high proportion of women previously exposed to IFAS, and the widespread perception of anemia risk during pregnancy. Nearly all pregnant women correctly identified the recommended daily intake of MMS and duration of its intake, aligning with earlier evidence underscoring ANC counseling as a strong predictor of knowledge acquisition[3].

The knowledge observed in all intervention groups was lower relative to the control group. This does not necessarily indicate that the behavioral interventions reduced MMS knowledge. The relatively high knowledge observed in the control group may reflect exposure to routine ANC counseling and MMS services, which were available to participants across the study arms. Thus, the control condition was not equivalent to the absence of MMS-related information.

However, a notable finding was that participants in the Journey to Motherhood Gameboard arm exhibited significantly lower odds of good knowledge of MMS compared with the control group. This finding contrasts with the evidence that underscores gamified learning improves retention and comprehension in maternal health services[23]. The discrepancy may reflect effect of routine ANC counselling and MMS services provided to the control group, limited time exposure to the gameboard or low literacy among participants in this arm, considering the highest proportion of women with no formal education in this group. This suggests that an interactive game tool may require longer engagement and tailored content to low literacy audiences to achieve expected outcomes.

Attitudes toward MMS were largely positive, with almost all (96.4%) scoring within the positive attitude category. This is consistent with other findings that pregnant women generally demonstrate favorable perceptions of antenatal supplements when benefits to child health are emphasized[24]. Participants highly agreed that MMS prevents anemia during pregnancy and is beneficial for maternal and infant health outcomes. However, one of the attitude items, "taking MMS regularly is a burden," received the lowest mean score, indicating that despite positive beliefs of the supplement's benefit, daily intake may still be perceived as effortful. Similar hesitance toward routine supplement intake has been documented in antenatal supplementation programs in South Asia and sub-Saharan Africa[25]. This suggests that a positive attitude toward MMS alone may not guarantee adherence without complementary social-support mechanisms.

Adherence remained a challenge despite good knowledge and positive attitudes toward the supplement. Only 55% demonstrated adherence daily in the past week, and 47.8% maintained adherence throughout the last three months. These findings are comparable to national adherence figures for Iron Folic Acid Supplement (IFAS) in Ethiopia (40–60%)[25], suggesting that MMS's uptake behaviors indicate existing challenges in ANC micronutrient adherence. Forgetfulness was a major barrier, noted in previous studies on this area, where adherence toward supplements was improved with reminder-based interventions, including SMS, partner involvement, and social support[26].

Regarding adherence to the supplement, notable differences were observed between groups. The Gameboard and CHWs Empathy training interventions reported higher weekly adherence compared to the control arm, indicating that gamified learning and empathy training for community-level healthcare workers support MMS adherence. However, long-term adherence remained below 50% in all but one arm, suggesting that different barriers, such as pill fatigue, pill stock-outs, pregnancy discomfort, or delivery before endline assessment, may have influenced long-term adherence compared to the short-term.

Interpretation and program implications

The mismatch among the outcome variables of this study, high knowledge, positive attitudes, and lower adherence, underscores an implementation gap that can be attributed to the short duration of the intervention and uneasiness of self-managed behavioral interventions. The study suggests that educational tools alone cannot change behavior; consistent adherence requires support for habit formation, partner engagement, frequent reminders, and

follow-up reinforcement. Behavioral change takes a long time to occur compared to knowledge and attitude. Evidence shows that supplement adherence increases when behavioral intervention is paired with structured reminders, peer support, and counseling integrated into ANC workflows[27]. Behavioral tools such as the Gameboard or Comic Book may be more effective if delivered repeatedly, integrated with ANC counseling sessions, or coupled with SMS follow-ups.

The findings of this study suggest that the long-term adherence effects of behavioral interventions hold promise, particularly where literacy barriers are minimal, indicating that prolonged engagement with these educational tools positively improves adherence. Future scale-up should consider differentiated behavioral intervention strategies based on literacy status, socio-cultural contexts, and ANC attendance frequency. The limited knowledge of MMS in the Gameboard arm highlights the need to adapt the content and presentation of the tools to the literacy level of the target users.

Strengths and limitations

The strength of this study is its design, a cluster-randomized design using mixed-effects modeling to adjust for clustering effect. However, this study was a post-test-only, which limits comparisons with baseline outcome variable trajectories for the participant level effects of intervention. Although cluster randomization was used to reduce systematic differences between study arms, randomization does not necessarily ensure exact balance in all characteristics. Consequently, the observed endline differences were interpreted as between-group differences following the intervention rather than as direct evidence of change from baseline. The four-month follow-up may not allow adequate time for behavior change processes to occur. Loss to follow-up due to various factors may have underestimated the effects of behavioral interventions. Self-reported adherence may also introduce recall or social desirability bias. Future research incorporating pill count tracking mechanisms and longer follow-up duration would benefit from accurate evidence and desired effect of interventions respectively. Although geographical separation of the health centers reduced the likelihood of contamination, it could not completely eliminate the possibility of information exchange outside the health-center setting.

Conclusion

This study evaluated that the overall knowledge and attitudes toward MMS were high across the four groups, while adherence to MMS remained suboptimal, particularly long-term adherence over three months period. However, behavioral interventions exhibited mixed effects on MMS-related knowledge, attitude and adherence indicating that provision of educational tools and positive attitude alone may not be sufficient to consistently improve MMS adherence.

The study finding suggests that the sustained MMS adherence requires multifaceted support, social support, and follow-up mechanisms beyond delivering informational tools. Factors such as ANC attendance frequency, anemia diagnosis in the current pregnancy, and ease of accessing health facilities were positively associated with MMS adherence in the last seven days.

Overall, the findings suggest that behaviorally informed approaches may have potential to support MMS adherence when integrated with routine maternal health services, that move beyond information delivery to sustained habit formation through strengthening social supports, encouraging ANC visits, reducing access barriers, and integrating reminder systems to improve adherence outcomes in routine maternal health programs.

Recommendations

For Programs and Policy: behavioral intervention tools (Super Mom comic booklet, Journey Motherhood gameboard, and healthcare professionals' Empathy Training), may be considered as complementary tools with ANC counseling services rather than using those tools as stand-alone interventions. Repeated exposure to those tools during ANC sessions may enhance comprehension and retention, particularly for low-literacy populations. To counteract a common adherence barrier identified in this study, such as forgetfulness, and to improve the regular distribution of MMS to reduce missed collection, strengthening routine ANC follow-up mechanisms and introducing a reminder system like SMS at the facility level is necessary to improve long-term adherence.

For Future Research: Future research should use a longitudinal Cluster Randomized Trial (RCT) including baseline data to examine change over time and measure the intervention effect more precisely. Measure adherence using objective measures, such as pill counts, to minimize self-report bias.

Appendix

See Tables 5, 6, and 7.

Table 5 Pregnancy-related characteristics of MMS and ANC visits of the participants ($n = 588$).

Variables	Responses	Total *n*(%)	T1 *n*(%)	T2 *n*(%)	T3 *n*(%)	T4 *n*(%)	*P*-value
Self-pregnancy diagnosis	1–3 months	459 (78.06)	108 (18.37)	156 (26.53)	108 (18.37)	87 (14.8)	<0.001
	4–6 months	129 (21.9)	43 (7.3)	8 (1.4)	59 (10.0)	19 (3.2)	
Diagnosed anemia	Yes	217 (36.9)	58 (9.9)	52 (8.8)	56 (9.5)	51 (8.7)	0.035
	No	371 (63.1)	93 (15.8)	112 (19)	111 (18.9)	55 (9.4)	
Anemia in the current pregnancy	Yes	302 (51.4)	63	82	95	62	0.019
	No	286 (48.6)	88	82	72	44	
Previously taken IFAS	Yes	344 (58.5)	100	91	84	69	0.013
	No	244 (41.5)	51	73	83	37	
Frequency of ANC visit	NA	276 (46.9)	89	66	89	32	<0.001
	Rarely	11 (1.9)	1	3	4	3	
	Sometimes	47 (8)	10	15	17	5	
	Most of the time	254 (43.2)	51	80	57	66	
In terms of distance, how easy is it to reach a health facility	Very easy	251 (42.7)	78	67	68	38	0.002
	Somewhat easy	191 (32.5)	38	63	46	44	
	Neutral	20 (3.4)	7	2	11	0	
	Somewhat difficult	71 (12.1)	11	19	25	16	
	Very difficult	55 (9.4)	17 (2.3)	13	17 (2.3)	8	

Table 6 Response distribution of the participants regarding the knowledge of MMS ($n = 588$).

Items	Responses	Frequency	Percent
MMS could replace a well-balanced diet.	True	500	85.18
	False	87	14.82
How often should MMS be taken?	**Everyday**	576	98.13
	Every other day	8	1.36
	Every month	3	0.51
For how long should you take MMS?	First trimester	21	3.6
	Before Pregnancy	2	34.0
	Throughout pregnancy	558	95.06
	I don't know	6	1.02
The MMS should be swallowed as a whole tablet with any liquid?	True	457	77.7
	False	131	22.3

Table 6 Response distribution of the participants regarding the knowledge of MMS ($n=588$).

Items	Responses	Frequency	Percent
Which one is the benefit of MMS? (Multiple Response)	Reduced risk of low birth weight	422	72.1
	Reduced risk of small-for-gestational-age births	288	49.2
	Reduced risk of preterm births	216	36.9
	Reduced risk of stillbirth	170	29.1
	Reduced risk of neonatal mortality	155	26.5
A pregnant woman who forgot to take her MMS yesterday might take two today to make sure she is getting adequate nutrients.	True	39	6.64
	False	548	93.36

Table 7 Adherence to MMS uptake among the pregnant women in Ethiopia ($n=588$).

Items	Responses	Frequency	Percentages
In the past week, how many days did you take your MMSpills?	0 days	93	15.8
	1–2 days	32	5.4
	3–4 days	56	9.5
	5–6 days	84	14.3
	Every day	323	54.9
In the last three months, what best describe-syour MMS pill intakebehavior?	I took my MMS pills daily as prescribed.	281	47.8
	I missed a few days but generally took my MMS pills.	230	39.1
	I took MMS pills occasionally, missing many days.	66	11.2
	I rarely or never took my MMS pills.	11	1.9
How easy or difficult is it forYou have to remember to takeMMS pills daily?	Very easy	321	54.6
	Somewhat easy	228	38.8
	Neutral	8	1.4
	Somewhat difficult	27	4.6
	Very difficult	4	0.7
Do you take your MMS pillsAt the same time every day?	Yes, always	288	49.0
	Yes, Most of the time	229	39.0
	Sometimes	59	10.0
	Rarely	8	1.4
	Never	4	0.7
Who reminds you to takeYour MMS pills?	No one reminds me, I remind myself	443	79.4
	My healthcare Provider	5	0.9
	My spouse or family member	105	17.8
	A friend or community member	2	0.3
	I don't get reminders	9	1.6
How often do you collectYour MMS pills from thehealth center?	Every three months	266	45.2
	Every two months	106	18.0
	Once a month	17	2.9
	Every week	33	5.6
	I don't regularly collect them	166	28.2
What do you do if you forgetto take your MMS pills oneday?	I take the missed pill as soon as I remember, even if it means taking two pills in one day.	24	4.1
	I skipped the missed pill altogether and continue with my regular schedule.	564	95.9

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Author contributions T.Y.: Conceptualization, Methodology, Data curation, Formal analysis, Writing—original draft and Writing—review & editing, Visualization, Validation. E.L.: Writing—original draft and Writing—review & editing. T.E.D: Validation. H.G.K., R.S., S.C., E.K., N.G., E.A., Project administration, Resources, Supervision. D.T.M.: Writing—review

& editing, Validation. S. H.: Supervision, Formal analysis, Validation. All the authors have read and approved the final manuscript.

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Data availability All the data used in this study are kept confidential and will be available from the corresponding author upon reasonable request.

Declarations

Competing interests The authors declare no competing interests.

Ethics approval and consent to participate This study was reviewed and approved by the ethical review board of the Ethiopian Public Health Association (EPHA), an organization authorized by the Ethiopian Ministry of Health to review ethical issues and give clearance certificates. Data is used only for research purposes. Informed consent to participate in the study was obtained from all participants after explaining the objectives and procedures of the study and their right to participate or withdraw at any time during the interview. For this purpose, a one-page consent letter was attached to the cover page of each questionnaire stating the general purpose of the study and confidentiality issues, which were discussed by data collectors before proceeding to the interview. Lastly, we confirm that this study was conducted in accordance with the Declaration of Helsinki.

Consent for publication Not applicable.

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