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Maternal Dietary Habits and Prenatal Micronutrient Supplementation Patterns as Joint Predictors of Continuous Infant Birth Metrics in Western Kenya

Damaris Okiri
Jaramogi Oginga Odinga University of Science and Technology
Shehu Awandu
Jaramogi Oginga Odinga University of Science and Technology
Johana Nyagaya
Jaramogi Oginga Odinga University of Science and Technology
Wyclife Nicholus
Jaramogi Oginga Odinga University of Science and Technology
Vincent Amollo
Jaramogi Oginga Odinga University of Science and Technology
George Ayodo
gayodo@jooust.ac.ke
Jaramogi Oginga Odinga University of Science and Technology

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Abstract

Background

Optimal prenatal conditions are vital for positive clinical delivery metrics, yet the comparative relationships of specific maternal behaviors with infant metrics remain heavily debated. This study evaluated how maternal age, dietary habits, and prenatal micronutrient supplement patterns concurrently predict infant birth weight and gestational age at delivery.

Methods

A descriptive, quantitative, cross-sectional design was utilized with a cohort of *N* = 234 maternal-infant pairs at Siaya County Referral Hospital in Western Kenya. Baseline characteristics included maternal age, fruit and vegetable intake frequency, and micronutrient supplement utilization patterns (never used, used one type, or used multiple types). Data were analyzed using multi-factor Multivariate Analysis of Variance (MANOVA), multivariable linear regressions, Pearson Chi-Square tests, and multivariable logistic regression.

Results

Full-term gestations reached 90.6% (n = 212) and normal birth weights reached 90.2% (n = 211). The omnibus MANOVA demonstrated that maternal supplementation pattern was the only factor significantly associated with joint infant outcomes (p = .006), showing independent associations with birth weight (p = .001) and gestational age (p = .029). Complete absence of supplementation was linked to the highest proportion of low birth weight (38.5%) and preterm delivery (30.8%). Use of a single formulation was associated with the lowest proportions of low birth weight (4.7%) and preterm delivery (5.8%), whereas multiple-type use showed numerically higher proportions (10.2% and 8.6%); this contrast was not formally tested. Finally, preterm birth was heavily clustered with low birth weight, showing a 54.64-fold increase in the crude odds of restricted infant mass (p < .001, 95% CI: 16.0–187.0).

Conclusion

Prenatal micronutrient supplement patterns were associated with infant birth weight and gestational age in this single-center cross-sectional study. Single-formulation use was associated with the lowest observed proportions of preterm birth and low birth weight. These exploratory findings require confirmation in prospective studies with verified dosing before informing supplementation guidance.

1. INTRODUCTION

The prenatal environment functions as a critical determinant of lifelong metabolic, structural, and physiological health for the developing fetus [1]. Among the myriad of maternal influences during gestation, nutritional status and micronutrient adequacy stand out as prominent, modifiable levers of infant health [2]. While macroeconomic and public health interventions have historically focused on caloric or macronutrient

deficiencies, modern perinatology increasingly emphasizes the importance of maternal micronutrient sufficiency [3]. Essential vitamins and minerals serve as vital cofactors in cellular signaling, motility, proliferation, differentiation, and apoptosis, the processes that regulate tissue growth and organogenesis throughout gestation [4].[5]

Beyond isolated vitamin use, broader maternal characteristics such as maternal age and baseline dietary habits represent foundational biological determinants of the intrauterine environment. Maternal age groups often dictate systemic vascular elasticity and uterine blood flow capacity, where adolescent and advanced maternal ages introduce distinct physiological stressors that can restrict early placental growth. Furthermore, regular dietary frequency – specifically the consistent intake of local fruits and vegetables – serves as the primary baseline matrix for dietary fiber, antioxidants, and macronutrient absorption. These dietary components may act alongside micronutrient supplementation in relation to maternal systemic inflammation and gestational duration.

Preterm delivery and low birth weight are not merely short-term clinical challenges but represent the leading contributors to neonatal morbidity, prolonged intensive care, and long-term neurodevelopmental delay [6]. Globally, a substantial proportion of newborns are born with restricted mass, accounting for the vast majority of annual neonatal mortalities worldwide [7]. Global disease burden analyses confirm that neonatal disorders account for the overwhelming majority of disability-adjusted life years attributable to the combined burden of preterm birth and low birth weight, with this burden falling disproportionately on low socio-demographic regions [8]. Consequently, quantifying how maternal age, specific dietary habits, and targeted supplement regimens relate to these dual continuous birth metrics is of great clinical importance.

Despite widespread consensus regarding the importance of maternal nutrition, public health guidance remains fragmented concerning the optimal structure of prenatal supplementation [9]. Large-scale systematic reviews and meta-analyses demonstrate that multiple micronutrient supplementation reliably relates to a reduced risk of restricted newborn mass compared to standard iron-folic acid regimens [10, 11]. However, its specific relationship with extending gestational duration remains inconsistent across global trials. Because of this ambiguity, where supplementation shows a robust association with birth weight but an inconsistent association with gestational age, the World Health Organization issued a conditional recommendation for multiple micronutrient protocols, calling for targeted investigations to resolve these conflicting trends [12].[13, 14]

However, public health research frequently evaluates maternal characteristics, basic dietary intake, and targeted supplement regimens in separate analytical silos. This methodological fragmentation fails to capture how these maternal factors concurrently shape interconnected birth parameters, potentially obscuring non-linear interactions where the use of multiple supplement types may introduce competitive biochemical interference. [15] To bridge this analytical gap, this quantitative investigation utilizes a multivariate (MANOVA) and multivariable regression framework to achieve several targeted objectives. First, we establish a comprehensive baseline profile tracking maternal age, dietary intake, and birth outcomes at a regional referral hub. Second, we evaluate the joint continuous vector of infant birth weight and gestational age to isolate the concurrent predictive value of maternal age, dietary frequency, and supplement complexity. Finally, we map the categorical risks of low birth weight and preterm delivery across distinct supplement behaviors to define the precise clinical intersection linked with neonatal morbidity in Western Kenya.

2. METHODOLOGY

2.1 Study Design and Setting

This study utilized a quantitative cross-sectional research design to examine the associations between maternal baseline factors and subsequent infant clinical birth outcomes. Predictive and baseline elements were evaluated without clinical manipulation, allowing for a realistic assessment of maternal nutritional behaviors and spontaneous birth parameters within a naturalistic healthcare environment.

The study was conducted at Siaya County Referral Hospital, a public facility in Kenya with an approximate capacity of 420 beds [16]. Serving a high-density catchment area of over 2,530 square kilometers, the hospital supports a population of nearly one million people, which is predominantly female [17]. This high-volume, demographically diverse maternal and neonatal caseload provides a representative cohort for evaluating localized dietary behaviors and clinical supplement utilization patterns.

2.2 Target Population and Eligibility Criteria

The target population for this research comprised maternal-infant pairs transitioning through post-delivery care who delivered at the Siaya County Referral Hospital during the data collection period spanning the calendar years of 2024 and 2025. These participants were reached and recruited while they were actively attending routine follow-up clinic visits at the facility.

To meet the inclusion criteria, participants were required to be postnatal mothers who were at least 18 years of age, had completed tracking records detailing prenatal dietary and supplement histories, and had delivered a singleton live infant with documented post-birth metrics. Conversely, specific exclusion criteria were applied to protect the precision of the models. Women outside the defined reproductive age window were excluded to prevent extreme values from skewing the variance in the models. Furthermore, pregnancies complicated by severe pre-existing maternal metabolic disorders or those with missing or unverifiable clinical antenatal records were excluded from evaluation. In strict compliance with research ethics, any postnatal women who declined to provide voluntary informed consent were also excluded from participation.

2.3 Sample Size and Sampling Framework

The targeted sample size was originally determined using Cochran's sampling framework for known, finite populations:

$$n_0 = \frac{[Z^2 \cdot p(1-p)]}{e^2} = \frac{[1.96^2 \cdot 0.5(1-0.5)]}{0.05^2} = 384$$

Where:

- Z is the standard normal deviation at a 95% confidence interval (1.96).
- p is the estimated proportion of an attribute present in the population, set at a conservative maximum variability threshold of 0.5 to maximize the required sample size.
- e is the acceptable margin of error (0.05).

According to institutional records from the hospital delivery register, approximately 700 cases of low birth weight and preterm deliveries were documented. Applying the Finite Population Correction (FPC):

$$n = \frac{no}{1 + \frac{(n\square - 1)}{N}} = \frac{384}{1 + \frac{(384 - 1)}{700}} = 248.2 \approx 248 \text{ mothers}$$

Adding a 10% contingency buffer (248 × 1.1) resulted in a target of 273 mothers. Following data cleaning, the exclusion of incomplete entries, and the removal of clinical outliers, the final analytical sample size resulted in exactly 234 maternal-infant pairs.

A simple random sampling technique was utilized to select the participants from the hospital's delivery register. The 700 eligible records identified from the log served as the complete sampling frame. Each eligible maternal record was assigned a unique, sequential identification number. Computer software was then applied to assign an automated random decimal value to each entry. The entire dataset was subsequently sorted in ascending order based on these random values to select the participants. This automated process ensured that every eligible record within the sampling frame maintained an equal and non-zero probability of selection, thereby reducing the risk of selection bias. Mothers corresponding to the selected records were approached during their postnatal follow-up clinic visits, and those who provided written informed consent were enrolled in the study.

2.4 Target Variables and Measurements

The data framework integrated both continuous and categorical measurements to allow for comprehensive multivariable modeling. Maternal predictor variables included maternal age group, which was classified categorically for distribution mapping into distinct cohorts spanning 18 to 24 years, 25 to 34 years, 35 to 44 years, and 45 to 54 years, and was also utilized continuously during multivariable modeling.

Micronutrient supplement use was grouped ordinally based on utilization complexity, categorizing participants as Never Used (zero routine prenatal supplements documented), Used One Type (use of exactly one standard public-facility prescription regimen, primarily standard Iron-Folic Acid Supplementation [IFAS]), or Used Multiple Types (simultaneous or sequential consumption of multiple distinct brands or uncoordinated over-the-counter mineral combinations purchased from private chemists). Because detailed data regarding absolute mineral dosages, compliance rates, and precise gestational age at initiation were unavailable, these broad categories serve as observational proxies for supplement patterns.

Maternal dietary intake frequency of fruits and vegetables was stratified into two distinct categories representing frequent intake, defined as daily or more frequent consumption, or infrequent intake, defined as occasional or zero consumption.

Dependent clinical birth outcomes comprised birth weight and gestational age. Birth weight was collected as a continuous metric measured in grams and was also grouped categorically for clinical threshold testing into a favorable outcome, defined as equal to or greater than 2,500 grams representing normal birth weight, or an adverse outcome, defined as less than 2,500 grams representing low birth weight. Gestational age was measured continuously in weeks of gestation and was categorized clinically into a favorable outcome, representing a full-term delivery at 37 weeks of gestation or more, or an adverse outcome, representing a preterm delivery at fewer than 37 weeks of gestation. In the primary analysis, both metrics are modeled as a

joint continuous dependent vector to capture covariance. In the categorical risk analysis, gestational status is treated as an upstream predictor associated with the binary outcome of low birth weight.

2.5 Validity and Reliability

Content validity was established through peer and expert review protocols to ensure the data collection instruments accurately captured the intended constructs. The draft questionnaire was systematically reviewed by university supervisors and seasoned clinical experts in maternal health. These experts evaluated whether the items covered the required public health domains, specifically focusing on maternal behavioral predictors and neonatal outcomes. Based on their feedback, ambiguous questions were restructured for clarity and cultural appropriateness before final field data collection commenced.

Tool reliability was assessed via a formal pretest at Bondo Sub-County Hospital, which shares demographic and clinical infrastructure with the primary study site. The pretest was administered to 27 mothers (approximately ten percent of the initial target sample). The pretest allowed the researcher to identify layout errors and confirm instrument consistency. Internal consistency was assessed using Cronbach's alpha, which yielded a coefficient of 0.85, exceeding the recommended threshold of 0.70 and indicating good reliability.

2.6 Data Analysis

Data analysis was performed using SPSS version 26.0. Descriptive analysis such as mean, standard deviation, frequencies, and percentages was used to summarize participants' characteristics. A multi-factor multivariate analysis of variance (MANOVA) was performed to examine the simultaneous associations of maternal age, micronutrient supplement use, and fruit and vegetable intake frequency with the continuous joint birth outcomes of birth weight and gestational age. This approach evaluates the factors in a mutually adjusted framework, controlling each predictor for the presence of the others. Pillai's Trace was used as the primary multivariate test statistic because of its robustness to violations of multivariate assumptions.

Where the multivariate test was statistically significant, follow-up univariate analyses of variance (ANOVA) were conducted for each outcome, with Bonferroni adjustment applied to control for multiple comparisons. To adjust for mutual confounding and report precise effect estimates, multivariable linear regression models were constructed for each continuous outcome, reporting standardized beta coefficients (β) and 95% confidence intervals. Pearson's chi-square test was used to examine associations between categorical variables. Multivariable logistic regression was then applied to evaluate the odds of low birth weight across supplement classes, using the Never Used cohort as the reference category to calculate crude Odds Ratios (cOR) and adjusted Odds Ratios (aOR) controlling for maternal age and diet. Finally, a binary logistic regression model quantified the specific risk association between preterm delivery (exposure) and low birth weight (outcome). Statistical significance was set at $p < 0.05$.

2.7 Ethical Considerations

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Scientific and ethical clearance was officially obtained from the Jaramogi Oginga Odinga University of Science and Technology Institutional Ethical Review Committee. Research authorization was granted by the National Commission for Science, Technology and Innovation (NACOSTI), and administrative consent was secured from

the Siaya County Health Department. The study posed minimal risk to participants, utilizing non-invasive questionnaires and extracting existing metrics with no collection of blood or biological tissues.

Interviews were conducted in private hospital rooms to ensure strict confidentiality. Written informed consent was obtained from all participants prior to enrollment, and individuals were explicitly informed of their right to skip questions or withdraw at any point without penalty. Data were fully anonymized by omitting personal identifiers, including names and inpatient numbers, from the final analytical dataset. Furthermore, no monetary inducements were provided to the participants, ensuring completely voluntary and unbiased participation.

3. RESULTS

3.1 Cohort Descriptive Characteristics and Distribution of Birth Metrics

The finalized analytical dataset comprised exactly N = 234 maternal-infant pairs after data cleaning, clinical outlier exclusion, and removal of incomplete entries. Descriptive evaluation of the continuous neonatal metrics demonstrated a mean infant birth weight of 3,120 grams (SD = 410g) and a mean gestational age at delivery of 38.4 weeks (SD = 1.6 weeks).

When evaluated against standard clinical thresholds, the categorical burden of neonatal complications was mapped:

- Birth Weight: 90.2% (n = 211) of infants achieved normal birth weight (≥ 2,500g), while 9.8% (n = 23) presented with low birth weight (< 2,500g).
- Gestational Age: 90.6% (n = 212) of deliveries were full-term (≥ 37 weeks), while 9.4% (n = 22) were classified as preterm deliveries (< 37 weeks).

Maternal profiles showed a mean age of 26.4 years (SD = 4.8 years), with the 25–34 age bracket representing the largest cohort (46.2%, n = 108). Dietary profiles indicated that 62.4% (n = 146) maintained frequent fruit and vegetable intake, whereas 37.6% (n = 88) reported infrequent consumption. Regarding prenatal micronutrient clinical behaviors, 59.0% (n = 138) utilized exactly one formulation, 29.9% (n = 70) utilized multiple types, and 11.1% (n = 26) never used supplements.

Table 1
Maternal and clinical characteristics of study participants

Maternal and Infant Parameters	Category / Metric	Frequency (n)	Percentage (%)	Mean ± SD
Maternal Age Group	18–24 Years	94	40.2%	Continuous: 26.4 ± 4.8 Years
	25–34 Years	108	46.2%	
	35–44 Years	28	12.0%	
	45–54 Years	4	1.7%	
Supplementation Patterns	Never Used	26	11.1%	
	Used One Type	138	59.0%	
	Used Multiple Types	70	29.9%	
Dietary Intake Frequency	Frequent (Daily+)	146	62.4%	
	Infrequent (Occasional/Zero)	88	37.6%	
Infant Birth Weight	Normal Birth Weight (≥ 2,500g)	211	90.2%	3,120 ± 410 grams
	Low Birth Weight (< 2,500g)	23	9.8%	
Gestational Age	Full-Term Delivery (≥ 37 weeks)	212	90.6%	38.4 ± 1.6 weeks
	Preterm Delivery (< 37 weeks)	22	9.4%	

3.2 Association of Maternal Age, Diet, and Supplementation Patterns with Joint Neonatal Outcomes

The multi-factor MANOVA model demonstrated that maternal supplementation pattern was the only factor significantly associated with the combined dependent neonatal vector (Pillai's Trace = 0.062, F = 3.64, p = .006). No statistically significant multivariate associations were observed for maternal age (Pillai's Trace = 0.027, p = .385) or fruit and vegetable intake frequency (Pillai's Trace = 0.028, p = .358).

Follow-up univariate ANOVAs confirmed that maternal micronutrient supplement patterns showed significant main associations with birth weight (F(2, 228) = 7.06, p = .001) and gestational age (F(2, 228) = 3.60, p = .029). In contrast, maternal age showed no significant main association with birth weight (F(3, 228) = 1.06, p = .365) or gestational age (F(3, 228) = 1.17, p = .320). Similarly, fruit and vegetable intake frequency was not significantly associated with birth weight (F(1, 228) = 1.76, p = .156) or gestational age (F(1, 228) = 1.37, p = .252).

Table 2
Association of maternal age and dietary metrics with neonatal outcomes

Predictive Factor	Multivariate Pillai's Trace	P-value	Univariate Dependent Variable	Degrees of Freedom (df)	Sum of Squares	Mean Square	F-value	P-value
Maternal Age	0.027	0.385	Birth Weight	3, 228	0.405	0.135	1.06	0.365
			Gestational Age	3, 228	0.403	0.134	1.17	0.320
Micronutrient Use	0.062	0.006*	Birth Weight	2, 228	1.703	0.851	7.06	0.001*
			Gestational Age	2, 228	0.807	0.404	3.60	0.029*
Dietary Intake	0.028	0.358	Birth Weight	1, 228	0.663	0.663	1.76	0.156
			Gestational Age	1, 228	0.470	0.470	1.37	0.252
Residuals (Error)	—	—	Birth Weight	228	29.168	0.127	—	—
			Gestational Age	228	26.336	0.115	—	—

*Statistically significant at $p < 0.05$

In the follow-up multivariable linear regressions adjusting for maternal age and diet, single supplement use remained significantly associated with higher birth weight (β = 0.24, 95% CI: [0.08, 0.40], p = .003) and higher gestational duration (β = 0.19, 95% CI: [0.03, 0.35], p = .021) relative to non-use. Estimates for multiple-formulation use were smaller and not statistically significant (birth weight: β = 0.14, 95% CI: [− 0.03, 0.31], p = .112; gestational age: β = 0.08, 95% CI: [− 0.09, 0.25], p = .341; Table 3).

Table 3
Multivariable linear regression estimates for supplementation pattern

Outcome	Supplement pattern (vs. Never Used)	β	95% CI	p-value
Birth weight	One type	0.24	0.08 to 0.40	= .003
Gestational age	One type	0.19	0.03 to 0.35	= .021
Birth weight	Multiple types	0.14	−0.03 to 0.31	= .112
Gestational age	Multiple types	0.08	−0.09 to 0.25	= .341

Note: Standardized β from multivariable linear regression adjusted for maternal age and dietary intake. Reference category: Never Used. Confidence intervals for the multiple-type estimates were derived from the reported β coefficients and p-values (t distribution, 228 df).

3.3 Categorical Risks Associated with Micronutrient Exposure and Gestational Status

Bivariate cross-tabulations demonstrated that maternal supplementation history was significantly associated with both birth weight ($\chi^2(2) = 20.01$, $p < .001$) and gestational outcome ($\chi^2(2) = 12.33$, $p = .002$). Relative to the Never Used reference group, mothers utilizing exactly one formulation demonstrated significantly lower odds of low birth weight (aOR = 0.08, 95% CI: [0.02, 0.31], p < .001). Mothers who used multiple supplement types also had lower odds of low birth weight than never-users (aOR = 0.18, 95% CI: [0.04, 0.77], p = .021). The proportion with low birth weight was numerically higher among multiple-type users (10.2%) than single-type users (4.7%), but this contrast was not formally tested.

Furthermore, categorical analysis confirmed that gestational status was strongly associated with newborn birth weight ($\chi^2(1) = 90.80$, $p < .001$). Infants delivered preterm (< 37 weeks) presented with a 54.64-fold increase in the crude odds of low birth weight (cOR = 54.64, 95% CI: 16.0–187.0, p < .001) compared to those delivered at full term.

Table 4
Association between maternal supplement patterns, gestational status, and infant birth weight

Variable Predictor	Normal Birth Weight (n, %)	Low Birth Weight (n, %)	Preterm Delivery (n, %)	Full-Term Delivery (n, %)	χ^2 (df)	Crude OR (95% CI)	Adjusted OR (95% CI)**
Micronutrient Use							
Never Used	16 (61.5%)	10 (38.5%)	8 (30.8%)	18 (69.2%)	20.01 (2) 12.33 (2)	REF	REF
Used One Type	132 (95.3%)	6 (4.7%)	8 (5.8%)	130 (94.2%)		0.08 (0.02, 0.31)	0.08 (0.02, 0.31)
Used Multiple Types	63 (89.8%)	7 (10.2%)	6 (8.6%)	64 (91.4%)		0.18 (0.04, 0.76)	0.18 (0.04, 0.77)
Gestational Status							
Full-Term	204 (96.2%)	8 (3.8%)	—	—	90.80 (1)	REF	—
Preterm	7 (31.8%)	15 (68.2%)	—	—		54.64 (16.0–187.0)	—

Note: χ^2 (df) 20.01 (2) tests supplementation against birth weight, 12.33 (2) tests supplementation against gestational age, and 90.80 (1) tests gestational status against birth weight. Crude and adjusted odds ratios refer to low birth weight, with Never Used (supplementation) and Full-Term (gestational status) as reference categories. Preterm and full-term percentages are row percentages within each supplementation group (n = 26, 138 and 70; N = 234). **Adjusted for maternal age and dietary intake.

4. DISCUSSION

4.1 Interpretation of Findings

The analysis identified an observational association between maternal prenatal supplementation patterns and infant birth metrics. Mothers who reported using a single targeted formulation had the lowest observed rates of adverse birth endpoints within this cohort. Biologically, this pattern could be compatible with a hypothesised competitive saturation model of maternal-fetal mineral transport [18]. Standard public health prenatal supplements supply essential baseline nutrients, such as iron and folic acid, which are involved in supporting early placental villous development and normal trophoblast invasion. [19]

Conversely, the numerically higher proportion of low birth weight among mothers using more than one supplement type than among single-type users, a contrast not formally tested here, is hypothesis-generating and may reflect competitive intestinal absorption pathways, although this study did not measure absorption, dose or serum micronutrient status. Divalent minerals like iron, zinc, calcium, and copper utilize shared

mucosal transporters, primarily divalent metal transporter 1 (DMT1) [20]. When high, uncoordinated doses are concurrently introduced through multiple product types, competitive inhibition may restrict individual mineral bioavailability. In the local context of Siaya County, this pathway competition could hypothetically be further complicated by regional consumption of phytate-dense [21] local staple flours, which bind divalent cations in the gastrointestinal tract (phytate intake was not measured in this study). [22] [23] [24] This uncoordinated over-the-counter tracking must be clearly distinguished [25] from scientifically integrated Multiple Micronutrient Supplementation (MMS) capsules, which are carefully [26] balanced to avoid transport saturation. [27] [28]

In Western Kenya, this structural clustering may also be considered in the context of regional comorbidities described in the literature, none of which were measured in this study. Gestational malaria, hookworm infestation, and chronic maternal anemia have been described as a syndemic linked to chronic placental inflammation, vascular dysfunction, and intense nutrient depletion [29, 30]. When *Plasmodium falciparum* parasites sequester in the maternal placental vascular space, they are reported to trigger an infiltration of inflammatory cells [31]. This leukocyte accumulation can disrupt normal blood flow and affect the architecture of the placental villi. At the same time, hookworm infestations in the gut can cause blood loss, while maternal iron-deficiency anemia can restrict oxygen delivery to developing tissues. Together, these hypothesised upstream infections have been associated with accelerated preterm labor in other settings, possibly by triggering an early, stress-induced activation of the maternal-fetal hypothalamic-pituitary-adrenal (HPA) axis [32]. [33]Clinically, the clustering of preterm delivery and low birth weight may reflect shared upstream origins, although malaria, helminth infection, anaemia, parity and socioeconomic status were not measured in this study and remain hypotheses for future investigation. Integrated strategies [34] combining malaria chemoprevention, deworming and prenatal supplement counselling merit evaluation in future studies.

4.2 Limitations

This study is subject to several methodological considerations. First, while the single-center sample captures critical regional data, it may constrain immediate generalizability to broader populations. Second, the heavy clustering of positive clinical outcomes led to unevenly distributed subgroups, which limits the statistical power to explore subtle secondary interactions. Findings should therefore be interpreted cautiously. Finally, the analysis relied on self-reported formulation categories and binary dietary stratification rather than verified dosages, leaving vulnerability to recall bias and residual socioeconomic confounding. Because detailed data regarding absolute mineral dosages, compliance rates, and precise gestational age at initiation were unavailable, these broad categories serve as observational proxies for supplement patterns. The observational design precludes causal inference, and malaria, helminth infection, anaemia, parity and socioeconomic status were not measured. Future multi-center longitudinal studies incorporating objective serum micronutrient assays and precise dosage tracking will be valuable to build upon these foundational findings.

5. CONCLUSION

In this single-center cross-sectional study, prenatal micronutrient supplementation patterns were associated with neonatal birth weight and gestational age. In the multi-factor model, supplementation pattern was the only factor significantly associated with the joint birth outcomes, whereas maternal age and fruit and vegetable intake frequency were not significantly associated in this cohort. Use of a single formulation was associated with the lowest observed proportions of preterm delivery and low birth weight. Multiple-type use showed

numerically less favourable proportions, a contrast that was not formally tested and that may be consistent with competitive mineral absorption, a hypothesis this study could not examine. These exploratory findings should be confirmed in prospective studies with verified dosing before they inform prenatal supplementation guidance in the region.

Declarations

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Competing interests

The authors have no relevant financial or non-financial interests to disclose.

Ethical Approval

Scientific and ethical clearance for this study was officially reviewed and granted by the Jaramogi Oginga Odinga University of Science and Technology Institutional Ethical Review Committee. Research authorization was licensed by the National Commission for Science, Technology and Innovation (NACOSTI), and operational administrative clearance was approved by the Siaya County Health Department.

Consent to Participate

Prior to enrollment and data extraction, formal, written informed consent was voluntarily obtained from all individual postnatal mothers participating in this study. All participants were fully briefed on their right to skip questions or withdraw at any point without penalty.

Consent to Publish

Not applicable. The manuscript contains completely anonymized aggregate data and does not include any individual participant clinical images, personal identifiers, or identifiable case reports.

Availability of data and materials

The anonymised dataset and SPSS syntax supporting the findings of this study are available from the corresponding author on reasonable request, subject to institutional ethics and data-protection requirements.

Authors' contributions

DO, SA and GA contributed to conceptualization, study design, methodology, fieldwork supervision, and drafting. DO, SA, JN, WN, VA, and GA contributed to data cleaning, statistical modelling, validation, table and figure preparation, and critical manuscript revision. All authors reviewed and approved the final manuscript.

References

1. McMillen IC, Robinson JS. Developmental origins of the metabolic syndrome: prediction, plasticity, and programming. Physiol Rev. 2005;85:571–633. https://doi.org/10.1152/physrev.00053.2003.
2. Rajendram R, Preedy VR, Patel VB, editors. Diet, Nutrition, and Fetal Programming. Cham: Springer International Publishing; 2017. https://doi.org/10.1007/978-3-319-60289-9.
3. Thayer ZM, Rutherford J, Kuzawa CW. The Maternal Nutritional Buffering Model: an evolutionary framework for pregnancy nutritional intervention. Evol Med Public Health. 2020;2020:14–27. https://doi.org/10.1093/emph/eoz037.
4. Widasari L, Chalid MT, Jafar N, Thaha AR, Dirpan A. The role of multimicronutrients on improving better pregnancy outcomes: A literature review. Multifaceted Rev J Field Pharm. 2020.
5. Miller EM. The reproductive ecology of iron in women. Am J Phys Anthropol. 2016;159 Suppl 61:S172-195. https://doi.org/10.1002/ajpa.22907.
6. Johnson S, Marlow N. Early and long-term outcome of infants born extremely preterm. Arch Dis Child. 2017;102:97–102. https://doi.org/10.1136/archdischild-2015-309581.
7. Lawn JE, Blencowe H, Oza S, You D, Lee ACC, Waiswa P, et al. Every Newborn: progress, priorities, and potential beyond survival. Lancet. 2014;384:189–205. https://doi.org/10.1016/S0140-6736(14)60496-7.
8. Liu T, Xu Y, Gong Y, Zheng J, Chen Z. The global burden of disease attributable to preterm birth and low birth weight in 204 countries and territories from 1990 to 2019: An analysis of the Global Burden of Disease Study. J Glob Health. 2024;14:04109. https://doi.org/10.7189/jogh.14.04109.
9. Adams JB, Kirby JK, Sorensen JC, Pollard EL, Audhya T. Evidence based recommendations for an optimal prenatal supplement for women in the US: vitamins and related nutrients. Matern Health Neonatol Perinatol. 2022;8:4. https://doi.org/10.1186/s40748-022-00139-9.
10. Tam E, Keats EC, Rind F, Das JK, Bhutta AZA. Micronutrient Supplementation and Fortification Interventions on Health and Development Outcomes among Children Under-Five in Low- and Middle-Income Countries: A Systematic Review and Meta-Analysis. Nutrients. 2020;12:289. https://doi.org/10.3390/nu12020289.
11. Hodgins S, Tielsch J, Rankin K, Robinson A, Kearns A, Caglia J. A New Look at Care in Pregnancy: Simple, Effective Interventions for Neglected Populations. PLOS ONE. 2016;11:e0160562. https://doi.org/10.1371/journal.pone.0160562.
12. WHO. Composition of a multi-micronutrient supplement to be used in pilot programmes among pregnant women in developing countries: report of a UNICEF, World Health Organization (WHO) and United Nations University workshop. 1999. https://www.who.int/publications/i/item/composition-of-a-multi-micronutrient-supplement-to-be-used-in-pilot-programmes-among-pregnant-women-in-developing-countries--report-of-a-united-nations-children-s-fund-(-unicef)---world-health-organization-(-who)--and-united-nations-university-workshop. Accessed 14 July 2026.

13. Taylor RMJ, Moore JA, Griffiths AR, Cousins AL, Young HA. Unveiling Dietary Complexity: A Scoping Review and Reporting Guidance for Network Analysis in Dietary Pattern Research. Nutrients. 2025;17:3261. https://doi.org/10.3390/nu17203261.
14. Vinther JL, Cadman T, Avraam D, Ekstrøm CT, Sørensen TIA, Elhakeem A, et al. Gestational age at birth and body size from infancy through adolescence: An individual participant data meta-analysis on 253,810 singletons in 16 birth cohort studies. PLoS Med. 2023;20:e1004036. https://doi.org/10.1371/journal.pmed.1004036.
15. Dong S, Liu Q, Yu S, Wang Y, Yang Y, Zhou R, et al. Association between micronutrient supplementation and age-related diseases: a meta-analysis of randomized controlled trial studies. Food Sci Hum Wellness. 2026;15:9250641. https://doi.org/10.26599/FSHW.2025.9250641.
16. SCRH SCR. Siaya County Referral Hospital (SCRH). Siaya County Referral Hospital. 2026. https://www.siayacrh.com/. Accessed 14 July 2026.
17. KNBS. Kenya National Bureau of Statistics (KNBS). (2019). 2019 Kenya Population and Housing Census, Volume II: Distribution of Population by Administrative Units, Table 2.3. 2019.
18. Yoon M, Nong A, Clewell HJ, Taylor MD, Dorman DC, Andersen ME. Evaluating placental transfer and tissue concentrations of manganese in the pregnant rat and fetuses after inhalation exposures with a PBPK model. Toxicol Sci Off J Soc Toxicol. 2009;112:44–58. https://doi.org/10.1093/toxsci/kfp198.
19. Wu G, Imhoff-Kunsch B, Girard AW. Biological mechanisms for nutritional regulation of maternal health and fetal development. Paediatr Perinat Epidemiol. 2012;26 Suppl 1:4–26. https://doi.org/10.1111/j.1365-3016.2012.01291.x.
20. Mims MP, Prchal JT. Divalent metal transporter 1. Hematology. 2005;10:339–45. https://doi.org/10.1080/10245330500093419.
21. Chesang J, Oluoch D, Aila P, Wanyonyi R, Mise D, Nindo P, et al. ASSESSING CASSAVA MARKETING, POLICY FRAMEWORK, AND VALUE CHAINS IN WESTERN KENYA. 2026;Vol. 14:page 2.
22. Asfaw M, Urga kelbessa, Tassew G, Weledesemayat G. Development-and-nutritional-assessment-of-complementary-foods-from-fermented-cereals-and-soybean. 2020;2:14.
23. Dako-Gyeke P, Aikins M, Aryeetey R, McCough L, Adongo PB. The influence of socio-cultural interpretations of pregnancy threats on health-seeking behavior among pregnant women in urban Accra, Ghana. BMC Pregnancy Childbirth. 2013;13:211. https://doi.org/10.1186/1471-2393-13-211.
24. Kamau MW, Mirie W, Kimani ST. Maternal knowledge on iron and folic acid supplementation and associated factors among pregnant women in a rural County in Kenya. Int J Afr Nurs Sci. 2019;10:74–80. https://doi.org/10.1016/j.ijans.2019.01.005.
25. Zand N, Christides T, Loughrill E. Dietary intake of minerals. In: Handbook of Mineral Elements in Food. John Wiley & Sons, Ltd; 2015. p. 23–39. https://doi.org/10.1002/9781118654316.ch2.
26. Mukherjee R, Gupta Bansal P, Lyngdoh T, Medhi B, Sharma KA, Prashanth T, et al. Recommendations for India-specific multiple micronutrient supplement through expert consultation. Indian J Med Res. 2024;159:547–56. https://doi.org/10.25259/IJMR_318_24.
27. Möllers LS, Yousuf EI, Hamatschek C, Morrison KM, Hermanussen M, Fusch C, et al. Metabolic-endocrine disruption due to preterm birth impacts growth, body composition, and neonatal outcome. Pediatr Res. 2022;91:1350–60. https://doi.org/10.1038/s41390-021-01566-8.

28. Casler L. Maternal deprivation: a critical review of the literature. Monogr Soc Res Child Dev. 1961;26(2):1–64.
29. Masai RJ. Geo-helminth infections: Neglected helminthiases among pregnant women attending antenatal care at Nandi-Hills Sub-County Hospital, Nandi County, Kenya. PAN Afr Sci J. 2024. https://doi.org/10.47787/pasj.v3i02.20.
30. Singer M. Development, coinfection, and the syndemics of pregnancy in Sub-Saharan Africa. Infect Dis Poverty. 2013;2:26. https://doi.org/10.1186/2049-9957-2-26.
31. Sharma L, Shukla G. Placental Malaria: A New Insight into the Pathophysiology. Front Med. 2017;4. https://doi.org/10.3389/fmed.2017.00117.
32. Wadhwa PD, Culhane JF, Rauh V, Barve SS, Hogan V, Sandman CA, et al. Stress, infection and preterm birth: a biobehavioural perspective. Paediatr Perinat Epidemiol. 2001;15 Suppl 2:17–29. https://doi.org/10.1046/j.1365-3016.2001.00005.x.
33. Hunter PJ, Awoyemi T, Ayede AI, Chico RM, David AL, Dewey KG, et al. Biological and pathological mechanisms leading to the birth of a small vulnerable newborn. Lancet. 2023;401:1720–32. https://doi.org/10.1016/S0140-6736(23)00573-1.
34. Larcher A, Belladelli F, Cei F, Re C, Rowe I, Montorsi F, et al. Centralization of care for rare genetic syndromes associated with cancer: improving outcomes and advancing research on VHL disease. Nat Rev Urol. 2024;21:565–71. https://doi.org/10.1038/s41585-024-00874-y.