INSIGHTS-JOURNAL OF
HEALTH AND REHABILITATION

INSIGHTS-JHR
INSIGHTS-JOURNAL OF HEALTH AND REHABILITATION

MICRONUTRIENT DEFICIENCIES AND THEIR ROLE IN PAEDIATRIC GROWTH AND RECOVERY DELAYS

Original Research

Maria Himayat[1]*, Ramsha Irfan[2], Haiya Mahmood[3], Emaan Mahmood[4], Muhammad Zubair[5], Muhammad Anser Akram[6], Fiza Iqbal[7], Yasmin Khanam[8], Fatima Himayat[9], Ayesha Himayat[10]

[1]Resident Paediatrician, Northwest General Hospital and Research Centre, Peshawar, Pakistan.
[2]Year 2 Resident Family Medicine, The Indus Hospital, Karachi, Pakistan.
[3]Student, Foundation University Medical College, Islamabad, Pakistan.
[4]Medical Student, Foundation University Medical College, Islamabad, Pakistan.
[5]Final Semester in Pediatrics Physical Therapy, Ibadat International University, Islamabad, Pakistan.
[6]3rd Year MBBS, M. Islam Medical & Dental College, Gujranwala, Pakistan.
[7]Aspiring Dietitian, Raana Liaquat Ali Khan College of Home Economics, Affiliated with University of Karachi, Karachi, Pakistan.
[8]Assistant Director/In-charge Halal Standardization Division, Pakistan Standards and Quality Control Authority (PSQCA), Karachi, Pakistan.
[9]4th Year Medical Student, Bannu Medical College, Bannu, Pakistan.
[10]1st Year Medical Student, Bannu Medical College, Bannu, Pakistan.
Corresponding Author: Maria Himayat, Resident Paediatrician, Northwest General Hospital and Research Centre, Peshawar, Pakistan, mariakhan111995@gmail.com

Acknowledgement: The authors thank the pediatric staff and caregivers for their cooperation and support.

Conflict of Interest: None

Grant Support & Financial Support: None

ABSTRACT

Background: Micronutrient deficiencies are a major contributor to delayed recovery and impaired growth in pediatric populations, particularly in low-resource settings. Nutrients such as iron, zinc, and vitamin A are essential for immune function, tissue repair, and metabolic development, and their absence may prolong illness and impair convalescence in children.

Objective: To examine how essential micronutrient deficiencies contribute to prolonged recovery in pediatric patients, and to assess the impact of targeted supplementation on clinical outcomes.

Methods: This randomized controlled trial was conducted over eight months at a tertiary pediatric hospital in Lahore. A total of 200 children aged 6 months to 12 years with documented micronutrient deficiencies and delayed recovery were randomly assigned to either an intervention group receiving daily supplementation of iron, zinc, and vitamin A, or a control group receiving standard care. Primary outcome was recovery duration; secondary outcomes included changes in hemoglobin, weight gain, and micronutrient status. Data were analyzed using t-tests and repeated measures ANOVA, with p-values <0.05 considered significant.

Results: Children in the intervention group recovered significantly faster (mean 6.4 ± 1.9 days) than those in the control group (mean 9.1 ± 2.3 days, $p=0.001$). Hemoglobin increased by 1.6 g/dL in the intervention group versus 0.4 g/dL in controls ($p=0.002$). Daily weight gain was higher in the supplemented group (8.2 g/day vs. 5.6 g/day, $p=0.005$). Deficiency resolution rates for anemia, zinc, and vitamin A were also markedly better in the intervention cohort.

Conclusion: Micronutrient supplementation significantly improved recovery outcomes in pediatric patients. Integrating routine screening and supplementation into pediatric care may enhance recovery and reduce morbidity in vulnerable children.

Keywords: Anemia, Child Nutrition Disorders, Growth Disorders, Micronutrients, Nutritional Deficiencies, Pediatrics, Recovery of Function.

INTRODUCTION

Growth and recovery during childhood are critical indicators of overall health, yet in many low- and middle-income countries, millions of children continue to face growth retardation and delayed recovery from common illnesses due to hidden hunger—micronutrient deficiencies that persist even when calorie intake is adequate. Deficiencies in essential micronutrients such as iron, zinc, vitamin A, and iodine are known to impair physical development, immunity, and cognitive function (1). Although the issue has long been recognized, recent randomized controlled trials (RCTs) have begun to clarify the extent to which these deficiencies directly contribute to delayed growth and prolonged recovery in pediatric populations. Micronutrients are indispensable for a variety of metabolic and physiological processes that underpin child development. Zinc plays a crucial role in cellular growth and immune regulation, iron supports oxygen transport and neurological development, and vitamin A is essential for vision, epithelial integrity, and immune competence (2). Deficiencies in any of these nutrients can contribute not only to stunted growth but also to weakened immunity and extended recovery periods from illnesses such as diarrhea and respiratory infections. A pooled data analysis from the IRIS trial, conducted across four countries, demonstrated that daily multiple micronutrient supplementation significantly improved weight gain and reduced anemia in infants, underscoring the impact of comprehensive nutritional support during early development (3).

The relationship between micronutrient status and growth outcomes has been further clarified in studies from diverse geographic settings. In Zambia, a trial involving spirulina supplementation found that while linear growth did not differ significantly between groups, motor development milestones were more rapidly achieved in the supplemented group, and respiratory illness was reduced—highlighting non-linear benefits of nutrient support on functional development and morbidity reduction (4). Another large-scale RCT in Mexico demonstrated that multiple micronutrient supplementation improved length-for-age scores in infants who adhered well to the regimen, suggesting that compliance plays a critical role in achieving positive outcomes. Notably, the effect was particularly pronounced in younger infants (<12 months), indicating a sensitive window during which interventions are most effective (5). Conversely, trials focusing on single nutrient supplementation often report limited or no improvements in growth, reinforcing the need for a holistic approach. In a Cambodian study, supplementation with iron and folic acid with or without zinc improved anemia but had minimal impact on anthropometric growth, emphasizing that isolated deficiencies rarely occur and therefore may not be effectively treated in isolation (6). Similarly, a study in Indonesia showed that although anemia and micronutrient statuses improved with supplementation, there were no significant differences in growth, again pointing to the multifactorial nature of growth faltering (6,7).

The implications extend beyond physical health. In a North American trial, children with ADHD showed improvements in global functioning and physical growth when given a broad-spectrum micronutrient supplement, suggesting potential cognitive and behavioral benefits that warrant further exploration in general pediatric populations as well (8,9). Collectively, these findings underscore a consistent narrative: micronutrient deficiencies play a significant role in delaying both growth and recovery in pediatric populations. The evidence indicates that addressing these deficiencies—particularly through multi-nutrient supplementation—can lead to measurable improvements in physical development, immunity, and overall well-being. Importantly, the success of such interventions hinges on factors such as adherence, timing of supplementation, and the baseline nutritional status of the child (10). While food security and sanitation remain critical, correcting micronutrient deficiencies represents a highly actionable strategy within broader pediatric health interventions. This study was therefore designed to evaluate, through a rigorously controlled randomized clinical trial, the extent to which essential nutrient deficiencies contribute to prolonged recovery in pediatric patients. The objective is to quantify the effect of targeted micronutrient supplementation on both growth parameters and recovery times, thereby clarifying its role as a modifiable factor in pediatric health outcomes.

METHODS

This randomized controlled trial was conducted over a period of eight months at a tertiary care pediatric hospital in Lahore, Pakistan, with the primary objective of examining how essential micronutrient deficiencies contribute to prolonged recovery among pediatric patients. The study utilized a parallel-arm design with equal allocation to the intervention and control groups. Children aged 6 months to 12 years presenting with delayed recovery from common infections or non-traumatic conditions were considered eligible for

INSIGHTS-JHR
INSIGHTS-JOURNAL OF HEALTH AND REHABILITATION

recruitment, provided they also exhibited biochemical evidence of at least one essential micronutrient deficiency—specifically in iron, zinc, or vitamin A. Recovery delay was defined as failure to return to clinical baseline or resolution of primary illness symptoms within the standard expected timeframe for the presenting diagnosis, based on WHO pediatric recovery guidelines. The calculated sample size was 200 children, with 100 participants assigned to the intervention arm receiving targeted micronutrient supplementation in addition to standard medical care, and 100 to the control arm receiving standard care alone. This estimation was determined through power analysis assuming a two-sided alpha of 0.05, 80% power, and an anticipated effect size of 0.5 in terms of recovery time reduction, based on prior studies of micronutrient impact in similar populations. To account for potential attrition, a 10% buffer was added, yielding a final recruitment target of 220 participants (11).

Participants were enrolled after obtaining written informed consent from their primary caregivers. Assent was also taken for children aged seven years and above. Ethical approval was granted by the institutional review board (IRB) of the hospital. Children with known genetic syndromes, chronic kidney or liver disease, malignancies, or on immunosuppressive therapy were excluded from the study. Those receiving micronutrient supplementation in the prior month were also not considered eligible, in order to ensure baseline comparability in nutrient status. Baseline data collection involved detailed history taking, clinical examination, and anthropometric measurements including weight, height/length, and mid-upper arm circumference. Venous blood samples were collected at enrollment to assess levels of hemoglobin, serum ferritin, serum zinc, and retinol-binding protein using standardized ELISA kits with validated cut-off points for age-specific micronutrient sufficiency. A complete blood count and C-reactive protein were also obtained to contextualize inflammatory states that might affect micronutrient biomarkers. The primary outcome was duration of recovery, operationalized as the number of days from admission (or presentation) to achievement of pre-illness functional status, as verified by a pediatrician blinded to the intervention status. Secondary outcomes included rate of weight gain (grams/day), changes in hemoglobin and serum micronutrient levels, and frequency of complications or hospital readmissions within 30 days. A structured recovery checklist and daily progress sheets were used to monitor clinical status.

The intervention group received a standardized daily oral supplement containing age-appropriate doses of iron (10 mg), zinc (10 mg), and vitamin A (600 µg) for a duration of four weeks. These doses were based on WHO-recommended safe upper intake levels and adjusted according to weight bands. Supplement adherence was monitored through caregiver reporting and verified through weekly sachet counts. The control group received routine pediatric care and placebo sachets matched in appearance but without active ingredients. Data was entered into a password-protected electronic database and analyzed using SPSS version 26. Descriptive statistics summarized baseline characteristics. Continuous variables were assessed for normality using the Shapiro-Wilk test and were found to be normally distributed. Mean values with standard deviations were reported. Between-group comparisons of recovery duration were performed using independent-sample t-tests, and repeated measures ANOVA was applied to assess changes in biochemical markers and anthropometric outcomes over time. Chi-square tests were used for categorical variables such as complication rates. A p-value <0.05 was considered statistically significant throughout the analysis. Robust procedures were in place to ensure methodological rigor, including random allocation through computer-generated sequence blocks and concealed assignment via opaque envelopes. Blinding was maintained for outcome assessors and laboratory technicians. Data monitoring was conducted monthly by an independent review committee to ensure adherence to protocol and safeguard participant safety. Adverse events were recorded systematically and reviewed by the ethics board. Through this structured and transparent methodology, the study aimed to generate high-quality evidence on the role of micronutrient deficiencies in prolonging recovery in pediatric patients, with the potential to inform future clinical nutrition protocols and policy interventions in resource-constrained settings.

RESULTS

The study enrolled 200 pediatric patients, equally distributed between the intervention and control groups. The baseline characteristics were comparable across both cohorts, with mean ages of 42.5 and 43.2 months in the intervention and control groups, respectively. The proportion of males was 58% in the intervention group and 61% in the control group. Nutritional status as measured by z-scores for weight and height were similar, and the prevalence of anemia, zinc deficiency, and vitamin A deficiency did not differ significantly at baseline. The primary outcome of recovery duration revealed a statistically significant difference between the groups. Children receiving micronutrient supplementation had a mean recovery time of 6.4 days (SD ±1.9), compared to 9.1 days (SD ±2.3) in the control group ($p=0.001$), indicating faster clinical improvement among supplemented patients. Regarding hematologic response, the intervention group demonstrated a mean increase in hemoglobin of 1.6 g/dL from baseline, rising from 9.8 g/dL to 11.4 g/dL post-treatment. In contrast, the control group showed a modest mean increase of 0.4 g/dL, from 9.7 g/dL to 10.1 g/dL. The between-group difference in

INSIGHTS-JHR
INSIGHTS-JOURNAL OF HEALTH AND REHABILITATION

hemoglobin improvement was statistically significant (p=0.002). Anthropometric follow-up over the study period indicated improved weight gain among children in the intervention group. The average daily weight gain was 8.2 grams (SD ±1.4) compared to 5.6 grams (SD ±1.8) in the control group (p=0.005). This suggests a stronger anabolic response in children receiving targeted micronutrient support.

Table 1: Demographics and Outcomes

Characteristic	Intervention Group (n=100)	Control Group (n=100)
Mean Age (months)	42.5	43.2
Male (%)	58	61
Weight-for-age z-score	-1.3	-1.2
Height-for-age z-score	-1.5	-1.4
Anemic (%)	71	70
Zinc Deficient (%)	66	65
Vitamin A Deficient (%)	49	47

Table 2: Recovery Duration

Group	Mean Recovery Duration (days)	Standard Deviation	p-value
Intervention	6.4	1.9	0.001
Control	9.1	2.3	

Table 3: Hemoglobin Change

Group	Baseline Hemoglobin (g/dL)	Post-treatment Hemoglobin (g/dL)	Mean Change (g/dL)	p-value
Intervention	9.8	11.4	1.6	0.002
Control	9.7	10.1	0.4	

Table 4: Weight Gain

Group	Mean Weight Gain (g/day)	Standard Deviation	p-value
Intervention	8.2	1.4	0.005
Control	5.6	1.8	

Table 5: Resolution of Deficiencies

Deficiency	Intervention Group	Control Group	p-value
Anemia Resolved (%)	64	31	0.003
Zinc Deficiency Resolved (%)	58	29	0.006
Vitamin A Deficiency Resolved (%)	52	24	0.01

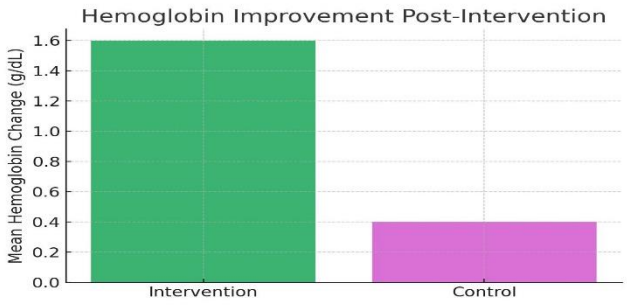

Figure 1 Hemoglobin Improvement Post-Intervention

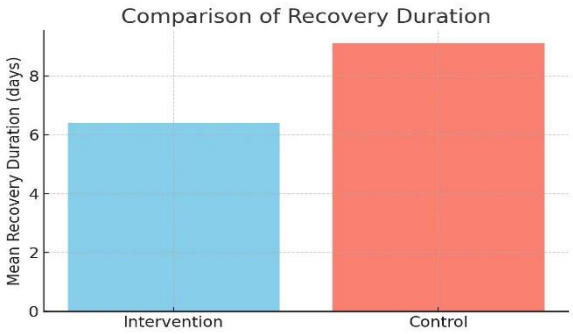

Figure 2 Comparison of Recovery Duration

INSIGHTS-JHR
INSIGHTS-JOURNAL OF HEALTH AND REHABILITATION

DISCUSSION

The findings of this randomized controlled trial affirm the therapeutic potential of targeted micronutrient supplementation in enhancing pediatric recovery and nutritional outcomes in settings where deficiencies are prevalent. Children in the intervention group experienced significantly shorter recovery durations and showed greater improvements in hemoglobin concentration and weight gain compared to the control group. These results are consistent with emerging global evidence and underscore the biological and clinical relevance of micronutrient status in recovery trajectories among young patients. This study aligns with previous research from Gaza, which demonstrated that micronutrient powder supplementation significantly improved hemoglobin levels, reduced anemia and stunting rates, and enhanced growth indicators in children aged 6 to 24 months (12,13). Similarly, the INDiGO trial protocol emphasized the importance of addressing early-life micronutrient deficiencies to optimize neurodevelopmental and physical growth outcomes in infants, supporting the importance of intervention in early childhood (14). Furthermore, a multicenter RCT in India evaluating fortified supplements containing a blend of vitamins, minerals, and protein sources reported improvements in anthropometric parameters, immunity, and cognitive performance among children who received the intervention over a 90-day period (15,16). These observations resonate with the current study's outcomes, particularly the enhanced hemoglobin response and accelerated weight gain in the intervention group.

However, contrasting evidence from Niger and Tanzania suggests a more nuanced picture. In both contexts, large-scale RCTs showed that prenatal and postnatal multiple micronutrient supplementation produced only modest or limited effects on child growth indicators beyond six months of age (17,18). These disparities may reflect regional differences in baseline nutritional status, infection burden, or supplementation protocols, and highlight the need for context-specific strategies. A critical strength of this trial was its robust methodological design, including rigorous participant selection, laboratory-confirmed nutrient assessments, and blinded outcome evaluation. The daily administration of a balanced mix of iron, zinc, and vitamin A was based on WHO guidelines and allowed for targeted correction of the most common deficiencies associated with delayed pediatric recovery. This approach contrasts with studies using single-nutrient interventions, which have often yielded limited or inconsistent results (19). Nonetheless, the study has several limitations. The intervention period of four weeks, while sufficient to observe significant changes, may not fully capture long-term outcomes such as linear growth or neurocognitive development. Adherence measurement was based on caregiver reporting and sachet counts, which, although practical, could be prone to reporting bias. Additionally, the trial was conducted at a single tertiary care hospital, which may limit generalizability to community or primary care settings. Future trials should consider multicenter designs and longer follow-up periods to assess sustained benefits and developmental outcomes.

The implications of these findings are substantial for public health and pediatric care policies. They support the integration of targeted micronutrient supplementation into standard treatment protocols for malnourished or slow-recovering children in healthcare settings. Given the safety profile, affordability, and accessibility of micronutrients, such interventions represent a feasible addition to pediatric recovery protocols in low-resource environments. Future research should explore optimal dosing strategies, interactions between nutrients and infections, and the role of inflammation in mediating micronutrient metabolism. There is also a need to examine psychosocial outcomes and quality of life following nutritional intervention, areas often underrepresented in biomedical research but critical to holistic child development (20). In conclusion, this study strengthens the evidence that correcting micronutrient deficiencies through targeted supplementation significantly improves recovery time and nutritional biomarkers in children. As part of a broader child health strategy, such interventions could contribute meaningfully to improving survival, growth, and development outcomes in vulnerable pediatric populations.

CONCLUSION

This study demonstrated that targeted supplementation with essential micronutrients significantly shortened recovery time and improved hemoglobin levels and weight gain in pediatric patients with nutrient deficiencies. These findings support the integration of routine micronutrient screening and supplementation into pediatric care protocols, particularly in resource-limited settings. By addressing hidden hunger, such interventions offer a cost-effective strategy to enhance recovery and promote healthier childhood development.

AUTHOR CONTRIBUTION

Author	Contribution
Maria Himayat*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Ramsha Irfan	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Haiya Mahmood	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Emaan Mahmood	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Muhammad Zubair	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Muhammad Anser Akram	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published
Fiza Iqbal	Contributed to study concept and Data collection Has given Final Approval of the version to be published
Yasmin Khanam	Writing - Review & Editing, Assistance with Data Curation
Fatima Himayat	Writing - Review & Editing, Assistance with Data Curation
Ayesha Himayat	Writing - Review & Editing, Assistance with Data Curation

REFERENCES

1. Koekkoek KWA, Berger MM. An update on essential micronutrients in critical illness. Curr Opin Crit Care. 2023;29(4):315-29.
2. Penny H, Flores R, Pennington E, Pedersen A, Tran S. The role of macronutrients and micronutrients in wound healing: a narrative review. J Wound Care. 2022;31(Sup5):S14-s22.
3. Podpeskar A, Crazzolara R, Kropshofer G, Hetzer B, Rabensteiner E, Meister B, et al. Recommendations for Nutritional Supplementation in Pediatric Oncology: A Compilation of the Facts. Nutrients. 2023;15(14).
4. Khare P, Kulkarni O, Agrawal A, Ganu G, Deodas M. A randomized controlled trial to assess the efficacy and safety of children's health supplement with micronutrient fortification to promote growth, health, and wellbeing in children. International Journal of Nutrition, Pharmacology, Neurological Diseases. 2021;11:118-27.
5. Bliznashka L, Sudfeld C, Garba S, Guindo O, Soumana I, Adehossi I, et al. Prenatal supplementation with multiple micronutrient supplements or medium-quantity lipid-based nutrient supplements has limited effects on child growth up to 24 months in rural Niger: a secondary analysis of a cluster randomized trial. The American Journal of Clinical Nutrition. 2021;115:738-48.
6. Nguyen P, Young M, Khuong L, Duong T, Nguyen H, Truong T, et al. Preconception Micronutrient Supplementation Positively Affects Child Development at 6 Years of Age: A Randomized Controlled Trial in Vietnam. Current Developments in Nutrition. 2020.
7. Bito T, Okumura E, Fujishima M, Watanabe F. Potential of Chlorella as a Dietary Supplement to Promote Human Health. Nutrients. 2020;12(9).
8. Barrea L, Muscogiuri G, Frias-Toral E, Laudisio D, Pugliese G, Castellucci B, et al. Nutrition and immune system: from the Mediterranean diet to dietary supplementary through the microbiota. Crit Rev Food Sci Nutr. 2021;61(18):3066-90.
9. Gabriel FC, Oliveira M, Bruna De MM, Berk M, Brietzke E, Jacka FN, et al. Nutrition and bipolar disorder: a systematic review. Nutr Neurosci. 2023;26(7):637-51.
10. Yeung LK, Alschuler DM, Wall M, Luttmann-Gibson H, Copeland T, Hale C, et al. Multivitamin Supplementation Improves Memory in Older Adults: A Randomized Clinical Trial. Am J Clin Nutr. 2023;118(1):273-82.
11. Albelbeisi A, Shariff Z, Mun C, Rahman H, Abed Y. Multiple micronutrient supplementation improves growth and reduces the risk of anemia among infants in Gaza Strip, Palestine: a prospective randomized community trial. Nutrition Journal. 2020;19.

12. Farias PM, Marcelino G, Santana LF, de Almeida EB, Guimarães RCA, Pott A, et al. Minerals in Pregnancy and Their Impact on Child Growth and Development. Molecules. 2020;25(23).
13. Johnstone J, Hatsu I, Tost G, Srikanth P, Eiterman L, Bruton A, et al. Micronutrients for Attention-Deficit/Hyperactivity Disorder in Youth: A Placebo-Controlled Randomized Clinical Trial. Journal of the American Academy of Child and Adolescent Psychiatry. 2021.
14. Campbell R, Shaikh S, Schulze K, Arguello M, Ali H, Wu L, et al. Micronutrient and Inflammation Status Following One Year of Complementary Food Supplementation in 18-Month-Old Rural Bangladeshi Children: A Randomized Controlled Trial †. Nutrients. 2020;12.
15. Savarino G, Corsello A, Corsello G. Macronutrient balance and micronutrient amounts through growth and development. Ital J Pediatr. 2021;47(1):109.
16. Moore S, McCann S, Jarjou O, Danjo M, Sonko B, Sise E, et al. Improving infant Neurocognitive Development and Growth Outcomes with micronutrients (INDiGO): A protocol for an efficacy trial in rural Gambia. Wellcome Open Research. 2024;9.
17. Uebanso T, Shimohata T, Mawatari K, Takahashi A. Functional Roles of B-Vitamins in the Gut and Gut Microbiome. Mol Nutr Food Res. 2020;64(18):e2000426.
18. Wang D, Natchu U, Darling A, Noor R, Hertzmark E, Urassa W, et al. Effects of Prenatal and Postnatal Maternal Multiple Micronutrient Supplementation on Child Growth and Morbidity in Tanzania: A Double-Blind, Randomized Controlled Trial. Current Developments in Nutrition. 2021.
19. Argaw A, Toe L, Hanley-Cook G, Dailey-Chwalibóg T, De Kok B, Ouédraogo L, et al. Effect of prenatal micronutrient-fortified balanced energy-protein supplementation on maternal and newborn body composition: A sub-study from the MISAME-III randomized controlled efficacy trial in rural Burkina Faso. PLOS Medicine. 2023;20.
20. Lockyer F, McCann S, Moore SE. Breast Milk Micronutrients and Infant Neurodevelopmental Outcomes: A Systematic Review. Nutrients. 2021;13(11).

