ORIGINAL ARTICLE

Maternal & Child Nutrition WILEY

Low dietary diversity is associated with linear growth faltering and subsequent adverse child developmental outcomes in rural Democratic Republic of the Congo (REDUCE program)

Christine Marie George[1] | Nicole Coglianese[2] | Sarah Bauler[2] | Jamie Perin[1] | Jennifer Kuhl[1] | Camille Williams[1] | Yunhee Kang[1] | Elizabeth D. Thomas[1] | Ruthly François[1] | Angela Ng[1] | Amani S. Presence[2] | Bisimwa R. Jean Claude[2] | Fahmida Tofail[3] | Patrick Mirindi[2] | Lucien B. Cirhuza[2]

[1]Department of International Health, Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland, USA

[2]Health Division, Food for the Hungry, Phoenix, Arizona, USA

[3]Nutrition Division, International Centre for Diarrhoeal Disease Research, Dhaka, Bangladesh

Correspondence

Christine Marie George, Associate Professor, Department of International Health, Program in Global Disease Epidemiology and Control, Johns Hopkins Bloomberg School of Public Health, 615 N. Wolfe St, Room E5535, Baltimore, MD 21205-2103, USA.
Email: cmgeorge@jhu.edu

Abstract

The objective of this study was to investigate the association between dietary diversity, child growth and child developmental outcomes. This was a prospective cohort study. Developmental outcomes were assessed by communication, fine motor, gross motor, personal social, problem solving and combined developmental scores measured by the Extended Ages and Stages Questionnaire (EASQ) at a 6-month follow-up visit. Height and weight were measured at baseline and a 6-month follow-up. Baseline minimum dietary diversity (MDD) for children 6–23 months old was defined by consumption of five or more of the following food groups: (1) breast milk; (2) grains, roots and tubers; (3) legumes and nuts; (4) dairy products; (5) flesh foods; (6) eggs; (7) vitamin A-rich fruits and vegetables and (8) other fruits and vegetables. Participants were 117 children 6–23 months of age. Linear growth faltering was defined as a significant decline ($p < 0.05$) in length-for-age Z-scores (LAZ) between baseline and follow-up. Regression models were performed. The study was conducted in rural eastern Democratic Republic of the Congo (DRC). MDD was positively associated with change in LAZ (coefficient: 0.87 [95% confidence interval [CI]: 0.33, 1.40]), and a reduced odds of stunting (LAZ < −2) (odds ratio: 0.21 [95% CI: 0.07, 0.61]). MDD was also associated with a significantly higher combined EASQ-Z-scores (coefficient: 0.34 [95% CI: 0.003, 0.68], higher communication EASQ-Z-scores [0.50 {95% CI: 0.14, 0.85}], and higher personal social EASQ-Z-scores [0.46 {95% CI: 0.11, 0.82}]). This study provides further evidence demonstrating the need for interventions to improve dietary diversity among young children.

KEYWORDS

child developmental outcomes, child growth, Democratic Republic of the Congo, dietary diversity, prospective cohort study

1 | INTRODUCTION

One hundred forty-nine million children under 5 years of age are estimated to be stunted globally (WHO, 2021b). Furthermore, 250 million young children in low- and middle-income countries (LMICs) are at risk of not achieving their developmental potential (Black et al., 2017). The first 2 years of life are a critical window for child development when adequate nutrient intake is essential, as the brain is rapidly developing (Prado & Dewey, 2014). If young children do not have adequate nutrient intake, this can result in impaired growth and adverse child cognitive development outcomes (Berkman et al., 2002; Prado & Dewey, 2014; Walker et al., 2007).

Previous studies have found an association between dietary diversity and stunting (Kim et al., 2017; Krasevec et al., 2017). The minimum dietary diversity (MDD) score, which is defined by children having five out of eight dietary diversity food groups in the past 24 h, for children 6–23 months is a population-level indicator used by the World Health Organization (WHO) to assess child dietary quality and adoption of adequate feeding practices (WHO, 2021a). This indicator is 1 of 17 indicators to assess infant and young child feeding (IYCF) practices at the population level. Child MDD was found to be positively associated with mean dietary micronutrient adequacy, and is, therefore, a helpful tool for assessing infant and young child diet quality and appropriate complementary feeding practices (USAID, 2006). A previous study conducted using Demographic and Health Surveys (DHS) from Afghanistan, Bangladesh, India, Nepal and Pakistan found that low MDD was associated with a higher risk of stunting as measured by height-for-age (Kim et al., 2017). Consistent with this finding, studies using DHS data from 21 countries in Africa, Asia, the Americas and Europe, found that MDD was associated with higher length attainment (Jones, Ickes, et al., 2014; Marriott et al., 2012; Onyango et al., 2014). Studies in Ethiopia, China and Sri Lanka found that MDD was associated with higher length-for-age Z-scores (LAZ) (Kuche et al., 2020; Perkins et al., 2018; Wang et al., 2017). In Bangladesh, MDD was associated with a reduced risk of stunting, underweight and wasting (Sheikh et al., 2020; Zongrone, Winskell, & Menon, 2012). In Zambia, MDD was associated with higher LAZ and weight-for-height/length Z-scores (WHLZ) (Mallard et al., 2014).

There is also growing evidence in LMICs on the association between child dietary diversity and child developmental outcomes. In Nepal, MDD was associated with subsequent higher child developmental outcomes using the Ages and Stages questionnaire (Thorne-Lyman et al., 2019). In a prospective cohort study conducted in Ghana, Malawi and Burkina Faso, child dietary diversity was associated with higher language and motor scores using the Developmental Milestones Checklist-II, Kilifi Developmental Inventory and MacArthur-Bates Communicative Development Inventory (Prado et al., 2017). In India, a cross-sectional study found an association between child dietary diversity and gross and fine motor skills and mental development using the Developmental Milestones Checklist II (Larson et al., 2017). These recent studies build on previous studies that focused on animal sources of protein and child developmental outcomes, rather than dietary diversity (Hulett et al., 2014; Murphy & Allen, 2003; Whaley et al., 2003). Two studies in Kenya found animal source foods (ASF) were associated with improved academic performance (Hulett et al., 2014; Whaley et al., 2003).

The Reducing Enteropathy, Undernutrition, and Contamination in the Environment (REDUCE) study focuses on identifying risk factors that are significant contributors to morbidity for young children in the Democratic Republic of the Congo (DRC), and on developing and evaluating scalable interventions to reduce these pathways. In this prospective cohort study, we sought to expand on the current evidence base by investigating the association between child dietary diversity, child growth and child developmental outcomes in rural DRC. There are no previous studies investigating the association between dietary diversity and child developmental outcomes in DRC. We hypothesized that low or poor dietary diversity would be associated with impaired growth and adverse child developmental outcomes among young children in rural DRC.

2 | METHODS

2.1 | Study design

This prospective cohort study of 117 children 6–23 months of age was conducted in Walungu Territory of South Kivu in eastern DRC. The sample size was based on the number of study participants who could be enrolled between June 2018 and January 2019. To be eligible for the study, households had to have a child <2 years, and plan to reside in the same residence for the next 6 months. There were no other exclusion criteria. A national ID card or birth certificate was used to calculate child age, when this was not available in the household this information was obtained in the nearest community health clinic where child health records are kept. A 6-month follow-up was conducted in households between December 2018 and August 2019. All children with at least 5 months of surveillance data from baseline to follow-up that had baseline dietary diversity data and baseline and follow-up anthropometric data were included in the analysis. Research assistants obtained socioeconomic status information from households at baseline on household educational level, housing type and the number of the individuals in the household.

Key messages

- Dietary diversity was low among young children in our study setting in rural eastern Democratic Republic of the Congo.
- Low dietary diversity was associated with linear growth faltering and lower child developmental outcomes.
- This study provides further evidence demonstrating the need for interventions to improve dietary diversity among young children to improve child health.

2.2 | Child growth measurements

Research assistants with training in standardized anthropometry measured the child's weight once and height/length three times at baseline and a 6-month follow-up. Length was measured for children 0–23 months. These measurements were used to calculate Z-scores according to the WHO child growth standards (de Onis & Onyango, 2008). LAZ, weight-for-age Z-scores (WAZ) and WHLZ were calculated. Two standard deviations (SD) below the WHO growth standard was defined as stunting (<−2 LAZ), underweight (<2 WAZ) and wasting (<−2 WHLZ). Biologically implausible data defined as child growth Z-scores < −6 were excluded from statistical analysis (WHO, 2006).

2.3 | Child developmental assessments

Communication, gross motor, fine motor, problem-solving and personal social skills were assessed for children 6–23 months of age using the Extended Ages and Stages Questionnaire (EASQ) at the 6-month follow-up. This questionnaire is a combination of direct tests of young children and parental reports, which was adapted for use in LMICs (Fernald et al., 2012; Tofail et al., 2018). Direct tests of young children included drawings, naming items in a picture book, stacking blocks and kicking a ball. Previous use of this tool in Bangladesh and in Kenya has shown results consistent with other measures of child development such as the WHO child development module, which also has direct assessments and parental reports of whether children can perform certain actions such as standing with support (Wijnhoven et al., 2004). The EASQ domains for the tests were in 2-month age bands up until 24 months, then in 3-month age bands from 25 to 36 months, and 6-month age bands thereafter. Respondents could respond 'yes', 'sometimes' or 'no' for items. The EASQ questionnaire was reviewed by the study psychologist, translated and back-translated and piloted according to previously published methods (Fernald et al., 2009). The EASQ was piloted in a subset of 50 households before being administered for the cohort study, and households were read questions and asked to explain the meaning of the statements as a form of cognitive interviewing. Eighteen testers (university graduates) received a 10-day extensive hands-on training on how to administer the EASQ. The standardized EASQ Z-scores were constructed for each domain and all domains combined based on the mean and standard deviation in each age band.

2.4 | Dietary diversity assessment

For the MDD assessment, research assistants conducted a 24-h dietary recall through a structured interview, which recorded the number of food groups consumed at baseline for children 6–23 months of age, according to previously published methods (WHO, 2021a). The following eight food groups were included in this assessment: (1) breast milk; (2) grains, roots and tubers and plantains (e.g., manioc, cassava, white potatoes, plantains or foods made with roots, including root-based porridge); (3) pulses (beans, peas and lentils), nuts and seeds; (4) dairy products (milk, infant formula, yogurt and cheese); (5) flesh foods (meat, fish, poultry and organ meats); (6) eggs; (7) vitamin A-rich fruits and vegetables and (8) other fruits and vegetables. The criterion for MDD, as recommended by WHO, is the consumption of foods from five or more food groups within the previous 24 h.

2.5 | Statistical analysis

Our objective was to determine the relationship between child dietary diversity, growth and developmental outcomes in rural DRC. Linear growth faltering (continuous variable) was defined as a significant decline ($p < 0.05$) in LAZ between baseline and the 6-month follow-up. Growth faltering (continuous variable) was also assessed for the change in WHLZ and WAZ between baseline and the 6-month follow-up. To assess the association between dietary diversity measured using MDD (binary variable of five or more food groups), child growth (continuous variable: change in LAZ, WHLZ and WAZ), and child developmental outcomes (continuous variable), linear regression models were fit using generalized estimating equations (GEE) to account for clustering at the household level and to approximate 95% confidence intervals (CIs). Child growth and developmental outcomes (combined, communication, fine motor, gross motor, problem solving and personal social Z-scores) were modeled separately. To assess the association between MDD and binary child growth outcomes (stunting, wasting and underweight), logistic regression models were fit using GEE to account for clustering at the household level and to approximate 95% CIs. The predictor was MDD. Models were adjusted for household educational level (binary variable of any formal education), number of individuals in the household (continuous variable) and household wall type [mud wall type (most common) or other] based on a previously published study for a similar setting on child growth to control for potential confounding (Dusingizimana et al., 2021). A significant finding was defined as a $p < 0.05$. Analyses were performed in SAS software (version 9.4). Fidelity to the protocol was maintained to minimize performance bias, and the study team prepared a data analysis plan before analyzing study data to minimize reporting bias.

3 | RESULTS

One hundred twenty-six children 6–23 months of age during the study surveillance period had baseline dietary diversity assessments and baseline anthropometric measurements available. Ninety-three percent (117/126) of these children had follow-up anthropometric measurements and were included in this analysis. There was a 7% (9/126) lost to follow-up; there were no significant baseline differences in anthropometric measurements between those with follow-up data and those without follow-up data ($p > 0.05$). The median age for children was 12 months [SD: 3 (range: 6–19)] (Table 1). Fifty-five percent (64/117) of children were female. Sixty-eight percent (80/117) of children had a household member with formal education. The median number of individuals in the household was six individuals

[SD: 2 (2–17)]. Sixty-three percent (72/114) of children lived in households with mud walls, 9% (10/114) wood walls, 6% (7/114) concrete walls, 4% (5/114) brick walls and 4% (5/114) wood and mud walls. Forty-five percent (53/117) of children were stunted, 3% (3/117) were wasted and 10% (12/117) were underweight. For the MDD food groups, 97% (114/117) of children consumed breast milk, 92% (108/117) grains, roots and tubers, 20% (23/117) legumes and nuts, 9% (11/117) dairy products, 59% (69/117) flesh foods, 6% (7/117) eggs, 75% (88/117) vitamin A-rich fruits and vegetables and 18% (21/117) other fruits and vegetables. Twenty-six percent of children (30/117) consumed five or more MDD food groups. Sixty-four percent of children (75/117) consumed ASF (eggs, dairy and flesh foods) in the past 24 h and 70% (82/117) of children consumed any source of protein (eggs, dairy, flesh foods, nuts and legumes).

All regression models were adjusted for household wall type, number of household members and household educational level. Regression models were also adjusted for baseline anthropometric Z-score when the predictor was a follow-up anthropometric measure. For child growth outcomes, MDD was positively associated with change in LAZ (coefficient: 0.87 [95% CI: 0.33, 1.40, $p = 0.002$]), and associated with a reduced odds of stunting (odds ratio: 0.21 [95% CI: 0.07, 0.61, $p = 0.004$]) (Table 2). For child developmental outcomes, MDD was associated with a significantly higher combined EASQ Z-score (coefficient: 0.34 [95% CI: 0.003, 0.68, $p = 0.048$]), higher communication EASQ Z-scores (0.50 [95% CI: 0.14, 0.85, $p = 0.006$]) and higher personal social EASQ Z-scores (0.46 [95% CI: 0.11, 0.82, $p = 0.011$]) (Table 3).

4 | DISCUSSION

In this prospective cohort study conducted in eastern DRC, we investigated the association between child dietary diversity, growth and developmental outcomes. Only a quarter of children achieved

TABLE 1 Baseline demographic characteristics among children 6-23 months in rural Democratic Republic of the Congo

	%	n	N
Children 6-23 months			117
Baseline age (months)			
Median ±SD (Min–Max)	12 ± 3 (6-19)		
Gender			
Female	55%	64	117
Household member with any formal education	68%	80	117
Number of individuals in the household			
Median ±SD (Min–Max)	6 ± 2 (2–17)		114
Household wall type			
Mud	63%	72	114
Wood	9%	10	114
Concrete	6%	7	114
Brick	4%	5	114
Wood and Mud	4%	5	114
Other	13%	15	114
Baseline growth measurements			
Stunted (LAZ < −2)	45%	53	117
Wasted (WHLZ < −2)	3%	3	117
Underweight (WAZ < −2)	10%	12	117
Minimum dietary diversity food groups			
Group 1: Breast milk	97%	114	117
Group 2: Grains, roots and tubers	92%	108	117
Group 3: Legumes and nuts	20%	23	117
Group 4: Dairy products	9%	11	117
Group 5: Flesh foods	59%	69	117
Group 6: Eggs	6%	7	117
Group 7: Vitamin A-rich fruits and vegetables	75%	88	117
Group 8: Other fruits and vegetables	18%	21	117
Minimum dietary diversity (≥5 Food Groups)	26%	30	117

Note: n represents the number of children with the individual or household level characteristics.

Abbreviations: LAZ, length-for-age Z-score; SD, standard deviation; WAZ, weight-for-age Z-score; WHLZ, weight-for-height/length Z-score.

TABLE 2 Association between minimum dietary diversity and child growth in a cohort study in rural Democratic Republic of the Congo (N = 117)

Outcome	Baseline minimum dietary diversity[a] (≥5 Food Groups) Coefficient/odds ratio (95% CI)*			p value
Children 6-23 months				
Change in height-for-age Z-score[b]	**0.87**	**0.33**	**1.40**	**0.002**
Change in weight-for-age Z-score[b]	0.26	−0.07	0.59	0.124
Change in weight-for-height/length for age Z-score[b]	0.21	−0.70	0.28	0.407
Follow-up stunting	**0.21**	**0.07**	**0.61**	**0.004**
Follow-up underweight	0.80	0.23	2.82	0.723
Follow-up wasting[c]	---	---	---	---

Abbreviation: CI, confidence interval. *Models are adjusted for household wall type, number of household members, household educational level and baseline anthropometric Z-score (where the outcome was a follow-up anthropometric measure).

[a]Minimum dietary diversity score ranges from 0 to 8 food groups, with the standard cutoff to define minimum dietary diversity being five or more food groups. Bold indicates a significant finding ($p < 0.05$).

[b]Change is from baseline to the 6-month follow-up.

[c]Only three children were wasted.

TABLE 3 Association between minimum dietary diversity and Extended Ages and Stages Questionnaire Z-scores in a cohort study in rural Democratic Republic of the Congo (N = 117)

Outcome at 6-month follow-up	Baseline minimum dietary diversity[a] (≥5 Food Groups) Coefficient (95% CI)*			p value
Children 6-23 months				
Combined EASQ Z-score	**0.34**	**0.003**	**0.68**	**0.048**
Communication EASQ Z-score	**0.50**	**0.14**	**0.85**	**0.006**
Gross Motor EASQ Z-score	0.31	−0.02	0.64	0.065
Fine Motor EASQ Z-score	−0.05	−0.45	0.35	0.802
Problem solving EASQ Z-score	0.17	−0.20	0.54	0.362
Personal social EASQ Z-score	**0.46**	**0.11**	**0.82**	**0.011**

Abbreviation: CI, confidence interval; EASQ, Extended Ages and Stages Questionnaire. *Models are adjusted for household wall type, number of household members, household educational level, and baseline anthropometric Z-score (where the outcome was a follow-up anthropometric measure).
[a]Minimum dietary diversity score ranges from 0 to 8 food groups, with the standard cutoff to define high dietary diversity being five or more food groups. Bold indicates a significant finding ($p < 0.05$).

MDD. Low dietary diversity was associated with linear growth faltering, stunting and reduced developmental outcomes overall and in the personal social and communication domains. These findings demonstrate the importance of dietary diversity in early life on child development. This study provides further evidence demonstrating the need for interventions to improve dietary diversity among young children to improve child health.

Dietary diversity was low in our study setting in eastern DRC (26%) with MDD. Additionally, in our cohort, 30% of children did not consume an protein source within the past 24 h. Country-level DHS data from DRC found that 17% of children 6–23 months of age achieved MDD, even lower than the 26% in our study area (Heidkamp et al., 2020). A recently published study from South Kivu, DRC found that 21% of children 6–23 months in rural areas achieved MDD, and 45% of children in urban areas (Kambale et al., 2021). This is the only other published study on MDD from South, Kivu, DRC, and is similar to the findings from our study.

In our cohort study, dietary diversity was associated with child growth. This finding is consistent with previous studies in Africa, Asia, the Americas and Europe that have found this same association (Jones, Ickes, et al., 2014; Kim et al., 2017; Marriott et al., 2012; Onyango et al., 2014). The first 2 years of life are when children are most susceptible to linear growth faltering, when adequate nutrient intake is essential (de Onis & Onyango, 2008). Stunting has been associated with a higher risk for mortality (McDonald et al., 2013; Olofin et al., 2013). Therefore, interventions are needed to reduce stunting for susceptible pediatric populations during the first 2 years of life.

Low dietary diversity was found to be associated with subsequent developmental outcomes. Only two other prospective cohort studies have investigated the association between children's diet and subsequent developmental outcomes (Prado et al., 2017; Thorne-Lyman et al., 2019). These studies conducted in Nepal, Ghana, Malawi and Burkina Faso also found that low dietary diversity was associated with adverse child developmental outcomes. These

findings further highlight that adequate nutrient intake is crucial as the brain is rapidly developing to ensure positive cognitive development outcomes in young children (Larson et al., 2017; Prado et al., 2017; Thorne-Lyman et al., 2019). Future studies are needed on the impact of interventions targeting dietary diversity on child developmental outcomes.

Intervention approaches are needed to increase dietary diversity in DRC. In Kenya, the Baby-Friendly Community Initiative was implemented in rural areas to promote breastfeeding and complementary feeding. The randomized controlled trial of this intervention showed that it was effective in significantly increasing MDD among young children (Maingi et al., 2018). In Malawi, farm production diversity was found to be significantly associated with child MDD (Jones, Shrinivas, et al., 2014). This is consistent with findings from Ethiopia that found that household production of fruits and vegetables was associated with child MDD (Kuche et al., 2020). A recently published intervention study in Katanga, DRC found that small quantity lipid-based nutrient supplements increased gross motor and communication ASQ domains (Addo et al., 2020), however, no improvement in dietary diversity was observed (Locks et al., 2019). Lipid-based nutrient supplements can be a costly and challenging programmatic approach to sustain over time at scale, and may disrupt existing positive child feeding practices (e.g., local diverse diet) (Dewey & Arimond, 2012; Flax et al., 2010). Therefore, increasing diversity in food production in our rural study setting in eastern DRC could serve as a potential complementary approach to increase child dietary diversity over time.

This study has some limitations. First, our cohort study only followed children for 6 months, therefore we cannot determine the longer-term impacts of child growth on child developmental outcomes. This was also an exploratory study, and so we did not pre-specify the power to find an association between child growth and MDD. Second, our analysis focused on dietary diversity and not quantity. Future studies should consider including dietary diversity and minimum meal frequency at multiple timepoints. Third, we relied

on EASQ outcomes from a single point and therefore cannot determine trends over time. Future studies should collect EASQ outcomes at multiple time points over the study period. Fourth, due to time constraints, we were limited in the number or socioeconomic status variables collected, future studies should consider including a household wealth index. Finally, our small sample size. Larger sample sizes (>200) should be used in future studies.

This study has strengths. First, we collected anthropometric data at baseline and the 6-month follow-up, which allowed us to assess linear growth faltering. Second, we collected EASQ data at the 6-month follow-up, building upon previous cross-sectional studies and allowing us to investigate the impact of dietary diversity on subsequent child developmental outcomes. Finally, we conducted multiple direct and indirect tests to evaluate child developmental outcomes using a tool that was previously adapted to LMICs (Tofail et al., 2018).

In conclusion, this prospective cohort study has shown that inadequate dietary diversity is associated with linear growth faltering and reduced child developmental outcomes among children residing in rural DRC. These findings indicate the need for effective interventions to improve dietary diversity for this susceptible pediatric population. Formative research including community engagement is needed to identify the best promogramtic approaches to increase child dietary diversity in our study setting in rural eastern DRC.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

ETHICS STATEMENT

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving research study participants were approved by the research ethical review committee of the University of Kinshasa (Protocol 043-2017), and the Johns Hopkins Bloomberg School of Public Health (Protocol 8057). Written informed consent was obtained from all participants.

AUTHOR CONTRIBUTIONS

Christine Marie George formulated the research question, designed study, and carried out the analysis and wrote the paper. Nicole Coglianese and Sarah Bauler supported the design of the study and critically reviewed the manuscript. Jamie Perin supported the design of the study, analysis of study data and critically reviewed the manuscript. Jennifer Kuhl, Camille Williams, Yunhee Kang, Elizabeth D. Thomas, Ruthly François, Angela Ng, Amani Sanvura Presence, Bisimwa Rusanga Jean Claude, Patrick Mirindi, Lucien Bisimwa Cirhuza supported the study design, data collection, data cleaning and critically reviewed the manuscript. Fahmida Tofail designed the Extended Ages and Stages assessment, and was the psychologist overseeing the study activities, and critically reviewed the manuscript. All authors meet journal guidelines for authorship.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ORCID

Christine Marie George http://orcid.org/0000-0001-9219-0953
Yunhee Kang http://orcid.org/0000-0002-8184-9166

REFERENCES

Addo, O. Y., Tripp, K., Nanama, S., Albert, B., Sandalinas, F., Nanema, A., Jefferds, M. E., Whitehead, R. D. Jr., Garg, A., Kupka, R., & Locks, L. M. (2020). An integrated infant and young child feeding and small-quantity lipid-based nutrient supplementation program is associated with improved gross motor and communication scores of children 6–18 months in the Democratic Republic of Congo. *Journal of Pediatrics*, *222*, 154–163. https://doi.org/10.1016/j.jpeds.2020.01.023

Berkman, D. S., Lescano, A. G., Gilman, R. H., Lopez, S. L., & Black, M. M. (2002). Effects of stunting, diarrhoeal disease, and parasitic infection during infancy on cognition in late childhood: A follow-up study. *Lancet*, *359*(9306), 564–571. https://doi.org/10.1016/s0140-6736(02)07744-9

Black, M. M., Walker, S. P., Fernald, L., Andersen, C. T., DiGirolamo, A. M., Lu, C., Mccoy, D. C., Shawar, Y. R., Shiffman, J., Devercelli, A. E., Wodon, Q. T., Vargas-Barón, E., Grantham-McGregor, S., & Lancet Early Childhood Development Series Steering Committee. (2017). Advancing early childhood development: From science to scale 1: Early childhood development coming of age: Science through the life course. *Lancet*, *389*(10064), 77–90.

de Onis, M., & Onyango, A. W. (2008). WHO child growth standards. *Lancet*, *371*(9608), 204–204.

Dewey, K. G., & Arimond, M. (2012). Lipid-based nutrient supplements: How can they combat child malnutrition? *PLOS Medicine*, *9*(9), e1001314. https://doi.org/10.1371/journal.pmed.1001314

Dusingizimana, T., Weber, J. L., Ramilan, T., Iversen, P. O., & Brough, L. (2021). An empirical study of factors associated with height-for-age Z-scores of children aged 6-23 months in northwest Rwanda: The role of care practices related to child feeding and health. *British Journal of Nutrition*, *126*(8), 1203–1214. https://doi.org/10.1017/s0007114520004961

Fernald, L. C., Kariger, P., Engle, P., & Raikes, A. (2009). *Examining early child development in low-income countries: A toolkit for the assessment of children in the first five years of life*. World Bank.

Fernald, L. C., Kariger, P., Hidrobo, M., & Gertler, P. J. (2012). Socioeconomic gradients in child development in very young children: Evidence from India, Indonesia, Peru, and Senegal. *Proceedings of the National Academy of Sciences*, 109(suppl 2), 17273–17280.

Flax, V. L., Phuka, J., Cheung, Y. B., Ashorn, U., Maleta, K., & Ashorn, P. (2010). Feeding patterns and behaviors during home supplementation of underweight Malawian children with lipid-based nutrient supplements or corn-soy blend. *Appetite*, 54(3), 504–511. https://doi.org/10.1016/j.appet.2010.02.003

Heidkamp, R. A., Kang, Y., Chimanya, K., Garg, A., Matji, J., Nyawo, M., Craig, H., & Lyman, A. (2020). Implications of updating the minimum dietary diversity for children indicator for tracking progress in the Eastern and Southern Africa Region. *Current Developments in Nutrition*, 4(9), nzaa141. https://doi.org/10.1093/cdn/nzaa141

Hulett, J. L., Weiss, R. E., Bwibo, N. O., Galal, O. M., Drorbaugh, N., & Neumann, C. G. (2014). Animal source foods have a positive impact on the primary school test scores of Kenyan school children in a cluster-randomised, controlled feeding intervention trial. *British Journal of Nutrition*, 111(5), 875–886. https://doi.org/10.1017/s0007114513003310

Jones, A. D., Ickes, S. B., Smith, L. E., Mbuya, M. N., Chasekwa, B., Heidkamp, R. A., Menon, P., & Stoltzfus, R. J. (2014). World Health Organization infant and young child feeding indicators and their associations with child anthropometry: A synthesis of recent findings. *Maternal & Child Nutrition*, 10(1), 1–17. https://doi.org/10.1111/mcn.12070

Jones, A. D., Shrinivas, A., & Bezner-Kerr, R. (2014). Farm production diversity is associated with greater household dietary diversity in Malawi: Findings from nationally representative data. *Food Policy*, 46, 1–12.

Kambale, R. M., Ngaboyeka, G. A., Kasengi, J. B., Niyitegeka, S., Cinkenye, B. R., Baruti, A., & Mutuga (2021). Minimum acceptable diet among children aged 6–23 months in South Kivu, Democratic Republic of Congo: A community-based cross-sectional study. *BMC Pediatrics*, 21(1), 239. https://doi.org/10.1186/s12887-021-02713-0

Kim, R., Mejía-Guevara, I., Corsi, D. J., Aguayo, V. M., & Subramanian, S. V. (2017). Relative importance of 13 correlates of child stunting in South Asia: Insights from nationally representative data from Afghanistan, Bangladesh, India, Nepal, and Pakistan. *Social Science and Medicine*, 187, 144–154. https://doi.org/10.1016/j.socscimed.2017.06.017

Krasevec, J., An, X., Kumapley, R., Bégin, F., & Frongillo, E. A. (2017). Diet quality and risk of stunting among infants and young children in low- and middle-income countries. *Maternal & Child Nutrition*, 13(suppl 2), e12430. https://doi.org/10.1111/mcn.12430

Kuche, D., Moss, C., Eshetu, S., Ayana, G., Salasibew, M., Dangour, A. D., & Allen, E. (2020). Factors associated with dietary diversity and length-for-age Z-score in rural Ethiopian children aged 6–23 months: A novel approach to the analysis of baseline data from the sustainable undernutrition reduction in ethiopia evaluation. *Maternal & Child Nutrition*, 16(1), e12852. https://doi.org/10.1111/mcn.12852

Larson, L. M., Young, M. F., Ramakrishnan, U., Webb Girard, A., Verma, P., Chaudhuri, I., & Srikantiah, S. (2017). A cross-sectional survey in Rural Bihar, India, indicates that nutritional status, diet, and stimulation are associated with motor and mental development in young children. *Journal of Nutrition*, 147(8), 1578–1585. https://doi.org/10.3945/jn.117.251231

Locks, L. M., Nanama, S., Addo, O. Y., Albert, B., Sandalinas, F., Nanema, A., Whitehead, R D. Jr., Kupka, R., Jefferds, M. E., & Tripp, K. (2019). An integrated infant and young child feeding and small-quantity lipid-based nutrient supplementation programme in the Democratic Republic of Congo is associated with improvements in breastfeeding and handwashing behaviours but not dietary diversity. *Maternal & Child Nutrition*, 15(3), e12784. https://doi.org/10.1111/mcn.12784

Maingi, M., Kimiywe, J., & Iron-Segev, S. (2018). Effectiveness of Baby Friendly Community Initiative (BFCI) on complementary feeding in Koibatek, Kenya: A randomized control study. *BMC Public Health*, 18(1), 600. https://doi.org/10.1186/s12889-018-5519-1

Mallard, S. R., Houghton, L. A., Filteau, S., Mullen, A., Nieuwelink, J., Chisenga, M., & Siame, J. (2014). Dietary diversity at 6 months of age is associated with subsequent growth and mediates the effect of maternal education on infant growth in urban Zambia. *Journal of Nutrition*, 144(11), 1818–1825. https://doi.org/10.3945/jn.114.199547

Marriott, B. P., White, A., Hadden, L., Davies, J. C., & Wallingford, J. C. (2012). World Health Organization (WHO) infant and young child feeding indicators: Associations with growth measures in 14 low-income countries, *Maternal & Child Nutrition*, 8(3)354–370. https://doi.org/10.1111/j.1740-8709.2011.00380.x

McDonald, C. M., Olofin, I., Flaxman, S., Fawzi, W. W., Spiegelman, D., Caulfield, L. E., Black, R. E., Danaei, G., & Nutrition Impact Model, S. (2013). The effect of multiple anthropometric deficits on child mortality: Meta-analysis of individual data in 10 prospective studies from developing countries. *American Journal of Clinical Nutrition*, 97(4), 896–901. https://doi.org/10.3945/ajcn.112.047639

Murphy, S. P., & Allen, L. H. (2003). Nutritional importance of animal source foods. *The Journal of Nutrition*, 133(11), 3932S–3935S.

Olofin, I., McDonald, C. M., Ezzati, M., Flaxman, S., Black, R. E., Fawzi, W. W., Caulfield, L. E., & Nutrition Impact Model Study (anthropometry cohort pooling) (2013). Associations of suboptimal growth with all-cause and cause-specific mortality in children under five years: A pooled analysis of ten prospective studies. *PLOS One*, 8(5), e64636. https://doi.org/10.1371/journal.pone.0064636

Onyango, A. W., Borghi, E., de Onis, M., Casanovas Mdel, C., & Garza, C. (2014). Complementary feeding and attained linear growth among 6-23-month-old children. *Public Health Nutrition*, 17(9), 1975–1983. https://doi.org/10.1017/s1368980013002401

Perkins, J. M., Jayatissa, R., & Subramanian, S. V. (2018). Dietary diversity and anthropometric status and failure among infants and young children in Sri Lanka. *Nutrition*, 55–56, 76–83. https://doi.org/10.1016/j.nut.2018.03.049

Prado, E. L., Abbeddou, S., Adu-Afarwuah, S., Arimond, M., Ashorn, P., Ashorn, U., Bendabenda, J., Hess, S. Y., Kortekangas, E., Lartey, A., Maleta, K., Oaks, B. M., Ocansey, E., Okronipa, H., Ouédraogo, J. B., Pulakka, A., Somé, J. W., Stewart, C. P., Stewart, R. C., ... Dewey, K. G. (2017). Predictors and pathways of language and motor development in four prospective cohorts of young children in Ghana, Malawi, and Burkina Faso. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, 58(11), 1264–1275. https://doi.org/10.1111/jcpp.12751

Prado, E. L., & Dewey, K. G. (2014). Nutrition and brain development in early life. *Nutrition Reviews*, 72(4), 267–284. https://doi.org/10.1111/nure.12102

Sheikh, N., Akram, R., Ali, N., Haque, S. R., Tisha, S., Mahumud, R. A., & Sarker, A. R. (2020). Infant and young child feeding practice, dietary diversity, associated predictors, and child health outcomes in Bangladesh. *Journal of Child Health Care*, 24(2), 260–273. https://doi.org/10.1177/1367493519852486

Thorne-Lyman, A. L., Shrestha, M., Fawzi, W. W., Pasqualino, M., Strand, T. A., Kvestad, I., Hysing, M., Lohani, M., & Miller, L. C. (2019). Dietary diversity and child development in the far West of Nepal: A cohort study. *Nutrients*, 11(8). https://doi.org/10.3390/nu11081799

Tofail, F., Fernald, L. C., Das, K. K., Rahman, M., Ahmed, T., Jannat, K. K., Unicomb, L., Ashraf, S., Winch, P. J., Kariger, P., Stewart, C. P.,

Colford J. M. Jr., & Luby, S. P. (2018). Effect of water quality, sanitation, hand washing, and nutritional interventions on child development in rural Bangladesh (WASH Benefits Bangladesh): A cluster-randomised controlled trial. *The Lancet Child & Adolescent Health*, 2(4), 255–268. https://doi.org/10.1016/s2352-4642(18)30031-2

USAID. (2006). Developing and validating simple indicators of dietary quality and energy intake of infants and young children in developing countries: Summary of findings from analysis of 10 data sets. https://www.fantaproject.org/sites/default/files/resources/IYCF_Datasets_Summary_2006.pdf

Walker, S. P., Chang, S. M., Powell, C. A., Simonoff, E., & Grantham-McGregor, S. M. (2007). Early childhood stunting is associated with poor psychological functioning in late adolescence and effects are reduced by psychosocial stimulation. *Journal of Nutrition*, 137(11), 2464–2469.

Wang, A., Scherpbier, R. W., Huang, X., Guo, S., Yang, Y., Josephs-Spaulding, J., Ma, C., & Wang, Y. (2017). The dietary diversity and stunting prevalence in minority children under 3 years old: A cross-sectional study in forty-two counties of Western China. *British Journal of Nutrition*, 118(10), 840–848. https://doi.org/10.1017/s0007114517002720

Whaley, S. E., Sigman, M., Neumann, C., Bwibo, N., Guthrie, D., Weiss, R. E., & Alber, S. (2003). The impact of dietary intervention on the cognitive development of Kenyan school children. *Journal of Nutrition*, 133(suppl 2), 3965s–3971s. https://doi.org/10.1093/jn/133.11.3965S

WHO. (2006). *WHO child growth standards: length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age: methods and development*: World Health Organization.

WHO. (2021a). Indicators for assessing infant and young child feeding practices: Definitions and measurement methods.

WHO. (2021b). *Levels and trends in child malnutrition*. UNICEF.

Wijnhoven, T. M., de Onis, M., Onyango, A. W., Wang, T., Bjoerneboe, G. E., Bhandari, N., & Lartey, A. (2004). Assessment of gross motor development in the WHO Multicentre Growth Reference Study. *Food and Nutrition Bulletin*, 25(suppl 1), S37–S45. https://doi.org/10.1177/15648265040251s105

Zongrone, A., Winskell, K., & Menon, P. (2012). Infant and young child feeding practices and child undernutrition in Bangladesh: Insights from nationally representative data. *Public Health Nutrition*, 15(9), 1697–1704. https://doi.org/10.1017/s1368980012001073