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SUPPLEMENT ARTICLE

Diet quality and risk of stunting among infants and young children in low- and middle-income countries

Julia Krasevec[1] | Xiaoyi An[1] | Richard Kumapley[1] | France Bégin[2] | Edward A. Frongillo[3]

[1] Data and Analytics Section, Division of Data, Research and Policy, UNICEF, New York, New York, USA
[2] Nutrition Section, Programme Division, UNICEF, New York, New York, USA
[3] Department of Health Promotion, Education, and Behavior, University of South Carolina, Columbia, South Carolina, USA

Correspondence
Julia Krasevec, Data and Analytics Section, Division of Data, Research and Policy, UNICEF, New York, NY, USA.
Email: jkrasevec@unicef.org

Abstract
Age-appropriate complementary feeding practices are far from optimal among low- and middle-income countries with available data. The evidence on the association between feeding practices and linear growth is mixed. We sought to systematically examine the association between two indictors of dietary quality—dietary diversity and animal source food (ASF) consumption (WHO, 2008)—and stunting (length-for-age z-score) employing existing data from 39 Demographic and Health Surveys. Data on 74,548 children aged 6–23 months were pooled and multiple logistic regression models, adjusting for child, maternal, and household characteristics, employed to assess the association between dietary quality and stunting. Stratified models by child age and by World Bank country-income classifications (World Bank, 2015) were also applied. Children aged 6–23 months consuming zero food groups in the previous day had a 1.345 higher odds of being stunted when compared to the reference group (≥5 food groups); those who did not consume any ASF in the previous day had a 1.436 higher odds of being stunted compared to children consuming all three types of ASF (egg, meat, and dairy). We estimated that 2,629 cases of stunting would have been averted (12.6% of those stunted) among the population studied if all children had consumed five or more food groups. Outcomes by country-income groupings showed larger associations of diet diversity and ASF consumption for upper- and lower-middle income countries compared to low-income countries. In summary, dietary diversity and ASF consumption were associated with stunting, with associations varying by stratified groups.

KEYWORDS
animal source foods, child growth, diet diversity, infant and young child feeding, stunting, WHO feeding indicators

1 | INTRODUCTION

Age-appropriate complementary feeding (CF) practices are far from optimal in the majority of low- and middle-income countries as evidenced by low rates for minimum diet diversity, minimum meal frequency, and minimum acceptable diet in countries and regions with available data (UNICEF, 2015). Programmes to improve CF practices are capable of reducing under-five mortality, with the added potential of reducing disparities (Bhutta et al., 2013). Although evidence for the impact of CF on young child mortality is strong, the evidence on the association between feeding practices and linear growth is mixed.

A recent systematic review on the impact of CF interventions on the growth of young children showed mixed results (Lassi, Das, Zahid, Imdad, & Bhutta, 2013). The authors concluded that CF interventions, including education and/or provision of food, have the potential to improve the nutritional status of children in developing countries but that more research is needed to assess the actual impact on growth. Two older systematic reviews reported a positive relationship between CF interventions and height gain. The first showed that provision of appropriate complementary food alone and with education, as well as education alone, led to increased height gain among young children in low resource settings (Imdad, Yakoob, & Bhutta, 2011). The second reported that education about complementary feeding was enough to increase height-for-age z-scores in food secure populations when compared to controls, but that provision of supplemental food, with or without education, was needed to impact height gain among food insecure populations (Bhutta et al., 2008). Other studies have attempted to assess whether the WHO standard CF indicators of minimum diet diversity, minimum meal frequency, and/or minimum acceptable diet are related to different anthropometric outcomes and also had mixed results (Jones, Ickes, et al., 2014a, Darapheak, Takano, Kizuki, Nakamura, & Seino, 2013). In some cases, the mixed results were attributed to insufficient sample size in some of the survey populations (Jones, Ickes, et al., 2014a) and also to the limitation of having only one day of diet recall per child, which may not be representative of habitual dietary intake (Thorne-Lyman, Spiegelman, & Fawzi, 2014). Although the number and types of food groups consumed by young children has the potential to vary on any given day, suggesting that its impact on child growth might best be studied through a prospective assessment of dietary intake as assessed over multiple days, evidence exists that diets of young children in low- and middle-income countries can be monotonous (Ruel, 2003). As an abundance of cross-sectional data related to young child feeding as well as nutrition status exist in the Demographic and Health Surveys (DHS), we used them to systematically examine the association between two measures of dietary quality and stunting, but using a pooled analysis to overcome some of the limitations cited by previous studies, although still allowing for assessment of outcomes by country typology by stratifying results by the World Bank country-income classifications (World Bank, 2015). Our hypothesis was that young children with higher dietary diversity and animal source food (ASF) consumption would have lower risk of stunting.

Key messages

- Dietary diversity and consumption of different types of animal source food (ASF) were associated with stunting.
- Children aged 6–23 months consuming only one food group in the previous day had a 1.365 higher odds of being stunted when compared to the reference group (≥5 food groups); those who did not consume any ASF in the previous day had a 1.436 higher odds of being stunted compared to children consuming all three types of ASF (egg, meat, and dairy).
- We estimated that 2,629 cases of stunting would have been averted (12.6% of those stunted) among the population studied if all children had consumed five or more food groups.
- The WHO infant and young child feeding indicators were developed 8 years ago; with more available data from a variety of country settings available today, it might be timely to review these indicators.

2 | METHOD

2.1 | Data sources

This cross-sectional study aimed to assess the association between child's dietary quality and stunting employing data from DHS meeting our inclusion criteria. The DHS are nationally representative household surveys that provide data to monitor demographic, socioeconomic, health, and nutrition measures. The inclusion criteria for the surveys used in the analyses are the following: (a) dataset was available on the DHS website and allowed for generation of the seven food groups used in the dietary diversity measure (WHO, 2008); (b) child length measurements were part of the survey; (c) all controlling variables were available in the dataset; and (d) minimum of one (most recent) national level survey per country. Thirty-nine datasets from 39 countries in the 2010–2014 period met these criteria (Table 1).

2.2 | Study population and sample size

The study population comprised children aged 6–23 months in the 39 DHS meeting the inclusion criteria. As part of the DHS survey design, diet diversity data were collected from the youngest child under two years of age born to mothers aged 15 to 49 years and also living with the mother at the time of the survey. A total of 120,475 children were 6–23 months old at the time of survey from the 39 study countries, of which 111,806 were eligible for infant and young child feeding (IYCF) questions. Among these, 31,442 children, from 21 countries were not eligible for height measurements on the basis of the sampling strategy for the anthropometry module, where only a subsample were measured. There were another 5,010 children whose length-for-age z-scores (LAZs) were flagged in the DHS data files either as missing or as biologically implausible according to the WHO flags (Mei & Grummer-Strawn, 2007). These children were excluded from the analysis. We also removed 71 children whose mothers had a height of less than 130 cm, as these were considered to be implausible and likely due to measurement or recording errors. Also, 735 children with missing values for one or more covariates were not included in the analysis. The final sample size of children 6–23 months old in the pooled analysis was 74,548.

2.3 | Outcomes, exposure, and covariates

2.3.1 | Outcome: stunting

The main outcome was stunting, a measure of chronic malnutrition among young children, assessed by calculating an age and gender adjusted z-score for each child according to the WHO child growth standards (WHO, 2006) and used as a binary indicator (stunted z-score < −2; not stunted z-score ≥ −2).

2.4 | Main exposures: dietary diversity and consumption of animal source food

Dietary diversity, one of the two main exposures in this study, was assessed on the basis of the consumption of specific food items in the 24 hours prior to being surveyed. In the DHS survey, mothers provided food consumption data for their youngest child under 2 years of age using a questionnaire assessing previous day intake of a list of food items. These food items were then categorized into one of the following seven food groups as defined by WHO for diet diversity (WHO, 2008): flesh food (meat, poultry, fish,

TABLE 1 Sample size, stunting prevalence, and diet quality measures for children aged 6–23 months included in the multivariate analysis, by country

Country	Year	Stunting prevalence (weighted %)	Mean number of food groups	Mean number of animal source food groups	Sample Size
Pooled (39 countries)		28.5	2.7	1.0	74,548
Low-income countries (21 countries)		32.4	2.3	0.7	32,564
Lower-middle income (12 countries)		29.2	2.7	1.1	30,433
Upper-middle income (6 countries)		14.6	3.9	1.8	11,551
Bangladesh	2011	39.7	2.4	1.0	2,199
Burkina Faso	2010	29.6	1.4	0.4	1,977
Cameroon	2011	26.6	3.0	1.0	1,699
Colombia	2010	13.3	4.1	2.0	4,659
Comoros	2012	31.0	2.7	1.2	689
Congo (Brazzaville)	2011	23.6	2.7	1.1	1,446
Congo Democratic Republic	2013	33.6	2.3	0.6	2,386
Cote d'Ivoire	2011	25.6	1.9	0.8	1,014
Dominican Republic	2013	8.4	3.9	1.7	982
Egypt	2014	21.0	3.2	1.4	4,265
Ethiopia	2011	36.5	1.6	0.6	2,640
Gabon	2012	16.1	2.5	1.2	1,096
Gambia	2013	21.4	1.8	0.7	999
Ghana	2014	13.5	2.5	0.9	828
Guinea	2012	21.6	1.4	0.4	974
Haiti	2012	16.2	2.7	0.7	1,296
Honduras	2011	17.5	4.1	1.8	3,162
Jordan	2012	10.2	3.6	1.7	1,715
Kenya	2014	24.6	2.9	1.0	2,740
Kyrgyzstan	2012	14.5	3.1	1.4	1,263
Liberia	2013	24.6	1.8	0.6	1,067
Malawi	2010	44.4	2.8	0.6	1,470
Mozambique	2011	41.1	2.7	0.7	3,069
Namibia	2013	16.5	2.6	1.2	571
Nepal	2011	26.9	2.8	0.8	663
Niger	2012	38.1	1.7	0.4	1,307
Nigeria	2013	33.4	2.2	0.7	7,594
Pakistan	2012	42.4	2.5	1.0	771
Peru	2011	21.3	4.5	1.9	2,528
Rwanda	2010	38.9	2.7	0.4	1,155
Senegal	2010	24.7	2.4	0.9	1,093
Sierra Leone	2013	34.4	1.9	0.5	1,233
Tajikistan	2012	24.3	3.0	1.3	1,369
Tanzania	2010	40.3	2.6	0.5	2,131
Togo	2013	20.9	2.5	0.8	1,041
Uganda	2011	29.1	3.0	0.7	663
Yemen	2013	37.2	2.6	1.2	3,823
Zambia	2013	42.2	2.5	0.7	3,475
Zimbabwe	2010	27.9	2.4	0.7	1,496

and organ meat), dairy products, eggs, grains or tubers, pulses or legumes or nuts, vitamin-A-rich fruits and vegetables, and other fruits and vegetables. Dietary diversity was constructed as a categorical variable on the basis of the number of food groups the child consumed setting a minimum of zero and maximum and reference group of five or more.

In addition to dietary diversity, ASF consumption was also included as a main exposure in our study. We divided the foods in the questionnaires into three categories of ASF: (a) milk products that included infant formula, milk other than breast milk, cheese, yogurt, or other milk products; (b) eggs; and (c) meat from any animal including organ meat, poultry, fish, and shellfish. ASF consumption was constructed as a categorical variable on the basis of the number of ASF groups consumed, with a minimum of zero and maximum of three.

2.4.1 | Covariates

Covariates for child stunting were used in this analysis, covering known confounding factors at child, maternal, and household levels (Table 2). These variables were identified as risk factors for child stunting on the basis of review of determinants of undernutrition from the UNICEF conceptual framework (UNICEF, 1990) and previous studies (Corsi, Mejia-Guevara, & Subramanian, 2015) and available and related determinants in the DHS datasets. We did not control for water, sanitation, and other characteristics that were part of the construction of wealth quintiles used in analyses; models with and without these variables yielded similar results.

TABLE 2 Unadjusted stunting prevalence and mean length-for-age z-score (LAZ) for children aged 6–23 months by measure of dietary quality and child, maternal, and household covariates

Outcome variables and background characteristic	Percentage stunted (%)	Mean of LAZ	Number of cases (% of total)
Dietary diversity			
0 food group	26.5	-0.97	6,988 (9.4)
1 food group	30.5	-1.13	12,440 (16.7)
2 food groups	32.2	-1.23	16,592 (22.3)
3 food groups	29.8	-1.17	15,002 (20.1)
4 food groups	25.6	-1.02	11,021 (14.8)
5+ food groups	21.4	-0.88	12,505 (16.8)
p value	.00	.00	
Consumption of animal source food			
0 types of animal source food	32.8	-1.25	26,818 (36)
1 type of animal source food	28.6	-1.10	26,710 (35.8)
2 types of animal source food	22.7	-0.89	14,553 (19.5)
3 types of animal source food	18.5	-0.79	6,467 (8.7)
p value	.00	.00	
Child's age			
6–11 months	18.6	-0.64	26,564 (35.6)
12–17 months	29.4	-1.17	26,185 (35.1)
18–23 months	38.0	-1.53	21,799 (29.2)
p value	.00	.00	
Child's gender			
Male	31.3	-1.20	37,843 (50.8)
Female	24.8	-0.96	36,705 (49.2)
p value	.00	.00	
Breastfeeding status			
currently breastfeeding	28.7	-1.12	56,372 (75.6)
currently not breastfeeding	26.2	-0.98	18,176 (24.4)
p value	.00	.00	
Type of birth			
multiple (twin, triplet, etc)	47.9	-1.80	1,129 (1.5)
singleton	27.8	-1.07	73,419 (98.5)
p value	.00	.00	
Fever in the last 2 weeks			
No	27.6	-1.05	52,906 (71)
Yes	29.4	-1.16	21,642 (29)
p value	.00	.00	
Diarrhoea in the last 2 weeks			
No	27.7	-1.06	55,808 (74.9)
Yes	29.3	-1.18	18,740 (25.1)
p value	.00	.00	
Pneumonia in the last 2 weeks			
No	28.1	-1.08	68,501 (91.9)
Yes	27.5	-1.10	6,047 (8.1)
p value	.27	.48	
Mother's age at birth			
15–19	29.1	-1.20	7,176 (9.6)
20–24	28.1	-1.09	19,607 (26.3)
25–29	27.1	-1.03	20,561 (27.6)
30–34	27.3	-1.05	14,030 (18.8)
35–39	28.7	-1.11	8,821 (11.8)
40–44	31.9	-1.18	3,507 (4.7)
45–49	35.3	-1.35	846 (1.1)
p value	.00	.00	
Mother's height			
<145 cm	52.5	-2.06	2,270 (3.1)
145–149.9 cm	41.5	-1.68	7,694 (10.3)
150–154.9 cm	32.8	-1.35	17,496 (23.5)
155–159.9	26.4	-1.03	21,968 (29.5)
> = 160 cm	20.0	-0.68	25,120 (33.7)
p value	.00	.00	
Mother's BMI			
<18.5	37.4	-1.49	8,135 (10.9)
18.5–24.9	30.1	-1.18	46,401 (62.2)
> = 25	19.7	-0.70	20,012 (26.8)
p value	.00	.00	
Mother's education			
none	37.0	-1.41	21,369 (28.7)
primary	31.6	-1.26	24,354 (32.7)
secondary+	18.6	-0.69	28,825 (38.7)
p value	.00	.00	
Number of additional children under age 5 in the household			
0	25.0	-0.97	32,826 (44)
1 or 2	30.3	-1.17	37,887 (50.8)
3+	32.5	-1.24	3,835 (5.1)
p value	.00	.00	
Household wealth quintiles			
Quintile 1 (poorest)	35.1	-1.38	19,157 (25.7)
Quintile 2	30.4	-1.22	16,657 (22.3)
Quintile 3	27.0	-1.07	14,916 (20)
Quintile 4	24.3	-0.90	13,071 (17.5)
Quintile 5 (richest)	18.4	-0.60	10,747 (14.4)
p value	.00	.00	

Note. BMI = body mass index.

2.5 | Ethical review

We registered and obtained access to DHS data files from the DHS website. All of the DHS follow a standard protocol that have been reviewed and approved by the ICF International Institutional Review Board (IRB) to ensure compliance with the U.S. Department of Health and Human Services regulations for the protection of human subjects (United States Department of Health and Human Services, 2009). Additionally, country-specific DHS survey protocols are reviewed by the ICF IRB and typically by an IRB in the host country to ensure compliance with laws and norms of the nation. Datasets used did not contain any personal identifiers.

2.6 | Statistical analysis

Our main interest was to assess the average association of diet diversity and ASF consumption with stunting among households and individuals in all countries combined rather than the association in each individual country. Furthermore, our interest was not to examine variation among countries, although we did examine differences by country-income classification. Therefore, pooled analyses were used to increase our ability to identify associations that may not be visible in any given country due to inadequate sample size as noted in previous studies (Jones, Ickes, et al., 2014a).

The individual data files of each country were concatenated for the pooled analysis. We used two-level mixed multiple logistic regression models (i.e., with a random effect to account for variability of clusters and with country as a fixed effect to account for variability of countries) in the pooled analysis to assess the association between dietary diversity and child stunting across countries, as well as between ASF consumption and child stunting, adjusted by child, maternal, and household covariates. In the pooled analyses, we adjusted for countries effects as fixed effects and accounted for clusters as random effects because in the surveys, geographic clusters were used to take the samples (i.e., the complex survey design applied by DHS is generally a stratified two-stage cluster sampling design, with the first stage being the sampling of "enumeration areas" or clusters, drawn from census files, and the second stage being a sample of households that is drawn from a freshly updated list of households within each of the selected enumeration areas). Accounting for countries as a random effect at a third level rather than as a fixed effect yielded the same results. The analyses were carried out using the xtlogit procedure in Stata statistical software version 14 (StataCorp, 2015). The regression models using xtlogit specified the binary outcome variable (stunted) and then the variables representing diet, the list of fixed covariates, and the country fixed effects, with clusters within each survey specified as random effects. We applied stratified models for infants aged 6–11 months old and children aged 12–23 months old after testing for an interaction between dietary diversity and child's age.

Sampling weights were not used in the pooled analysis in our study because weighted and unweighted regression coefficients are both statistically inconsistent and unweighted estimates are preferable when the purpose is to examine structural relationships, as in this study, rather than population description (Deaton, 1997). We presented final models as odds ratios (ORs) with 95% confidence intervals.

Using the prevalence data in Table 2 and the ORs in Table 3, a population attributable risk calculation was done for dietary diversity in children 6–23 months of age. The calculation was made with assuming that the association between dietary diversity and stunting was causal.

3 | RESULTS

3.1 | Sample description

There were 74,548 eligible children from 39 study countries, ranging from 571 children in Namibia to 7,594 children in Nigeria. The prevalence of stunting among 6–23-month-olds varied from 8.4% in Dominican Republic to 44.4% in Malawi (Table 1). Almost all of the risk factors examined in bivariate analyses were significantly associated with child's stunting ($p < .001$, Table 2).

3.2 | Multilevel and multiple regression analysis

Several risk factors were significantly associated with child stunting in the multilevel logistic models among children 6–23 months of age, and in the age-stratified results between those aged 6–11 months versus 12–23 months.

3.2.1 | Dietary diversity

The number of food groups consumed on the previous day was associated with stunting, even after adjusted by child, maternal, and household covariates (Table 3). Children who consumed food from five or more food groups were less likely to be stunted than those who consumed fewer food groups, with a statistically significant difference even between five plus and 4 food groups. Compared to children 6–23 months of age who consumed five or more food groups within the 24-hr period before the survey, children whose diet did not include any of the food groups had a 1.345 times higher odds of being stunted (95% CI [1.233–1.468]), and children who consumed only one food group had a 1.365 times higher odds of being stunted (95% CI [1.267–1.471]); while even children who consumed four food groups had a 1.095 times higher odds of being stunted (95% CI [1.021–1.174]). A similar association between the number of food groups and stunting was also found among children 12–23 months old in the stratified models. The largest association was seen for children 6–11 months of age, where those consuming zero food groups had a 1.494 times higher odds of being stunted (95% CI [1.267–1.761]), and those who consumed only one food group had a 1.375 times higher odds of being stunted (95% CI [1.177–1.606]), when compared to children who consumed five or more food groups. Among 6–11-month-old children, there was no significant difference among those consuming two to four food groups when compared to five food groups.

A number of the child variables were significantly associated with stunting: Boys were more likely to be stunted than girls (OR 1.534; 95% CI [1.478–1.591]); Older children were more likely to be stunted than younger children (each 1-month increase in child age was associated with an increased risk in stunting); Children born as multiple births had a three-fold odds of being stunted compared to singleton born children (OR 3.055; 95% CI [2.658–3.51]). Among illnesses in the last

TABLE 3 Overall and age-stratified adjusted odds ratio of dietary diversity, child, maternal, and household covariates in relation to child stunting for children aged 6–23 months

	Stunting adjusted risk ratio (95% CI)[a]		
	6–23 months	6–11 months	12–23 months
Dietary diversity			
5+ food groups (reference)	1.0	1.0	1.0
0 food group	1.345[d] (1.233–1.468)	1.494[d] (1.267–1.761)	1.207[c] (1.072–1.359)
1 food group	1.365[d] (1.267–1.471)	1.375[d] (1.177–1.606)	1.314[d] (1.201–1.436)
2 food groups	1.259[d] (1.177–1.348)	1.130 (0.969–1.318)	1.237[d] (1.145–1.336)
3 food groups	1.187[d] (1.11-1.27)	1.045 (0.892–1.226)	1.167[d] (1.083–1.258)
4 food groups	1.095[b] (1.02–1.174)	0.880 (0.739–1.048)	1.110[c] (1.027–1.199)
Breastfeeding status			
Currently breastfeeding	1.0	1.0	1.0
Currently not breastfeeding	0.809[d] (0.770–0.851)	0.982 (0.851–1.133)	0.808[d] (0.765–0.854)
Child's age (per 1-month increase)	1.123[d] (1.118–1.128)	1.193[d] (1.166–1.220)	1.110[d] (1.103–1.118)
Child's gender			
Female	1.0	1.0	1.0
Male	1.534[d] (1.478–1.591)	1.500[d] (1.396–1.612)	1.568[d] (1.500–1.639)
Fever in the last 2 weeks			
No	1.0	1.0	1.0
Yes	1.058[b]	0.976	1.091[c]
	(1.013–1.105)	(0.897–1.063)	(1.036–1.149)
Diarrhoea in the last 2 weeks			
No	1.0	1.0	1.0
Yes	1.028	1.009	1.031
	(0.984–1.075)	(0.925–1.100)	(0.978–1.086)
Pneumonia in the last 2 weeks			
No	1.0	1.0	1.0
Yes	0.985	0.986	0.978
	(0.917–1.057)	(0.863–1.128)	(0.898–1.065)
Type of births			
Singleton	1.0	1.0	1.0
Multiple (twin, triplet, etc)	3.055[d]	4.276[d]	2.606[d]
	(2.658–3.510)	(3.335–5.483)	(2.196–3.092)
Number of additional children under age 5 in the household (per 1 more child under 5)	1.102[d]	1.074[d]	1.120[d]
	(1.080–1.124)	(1.035–1.115)	(1.093–1.147)
Mother's age			
25–29	1.0	1.0	1.0
15–19	1.142[d] (1.065–1.225)	1.182[c] (1.042–1.34)	1.123[c] (1.030–1.224)
20–24	1.052 (1.000–1.106)	1.047 (0.949–1.155)	1.057 (0.995–1.122)
30–34	1.003 (0.949–1.060)	1.134[b] (1.016–1.264)	0.963 (0.902–1.029)
35–39	1.017 (0.954–1.085)	0.980 (0.862–1.115)	1.035 (0.960–1.117)

(*Continues*)

TABLE 3 (Continued)

	Stunting adjusted risk ratio (95% CI)[a]		
	6–23 months	6–11 months	12–23 months
40–44	1.104[b] (1.009–1.209)	1.276[c] (1.063–1.530)	1.055 (0.950–1.172)
45–49	1.093 (0.926–1.290)	1.713[c] (1.225–2.396)	0.956 (0.789–1.159)
Mother's height (per 1-cm increase)	0.929 (0.925–0.932)	0.926[d] (0.920–0.932)	0.927[d] (0.924–0.931)
Mother's BMI (per 1 unit of BMI increase)	0.964[d] (0.959–0.969)	0.969[d] (0.959–0.978)	0.963[d] (0.957–0.969)
Mother's years of schooling (per 1 year of schooling increase)	0.960[d] (0.954–0.965)	0.961[d] (0.951–0.972)	0.957[d] (0.951–0.964)
Household wealth quintiles			
Quintile 5 (richest)	1.0	1.0	1.0
Quintile 1 (poorest)	1.764[d] (1.633–1.906)	1.861[d] (1.604–2.159)	1.757[d] (1.604–1.924)
Quintile 2	1.447[d] (1.342–1.559)	1.421[d] (1.228–1.644)	1.467[d] (1.343–1.602)
Quintile 3	1.293[d] (1.201–1.393)	1.285[c] (1.112–1.485)	1.296[d] (1.188–1.413)
Quintile 4	1.200[d] (1.114–1.291)	1.159[b] (1.002–1.340)	1.217[d] (1.116–1.326)
Observations	74,548	26,564	47,984

Note. BMI = body mass index; CI = confidence interval.

[a]Models were adjusted for child, maternal, and household covariates, country as fixed effects, and clusters as random effects; the coefficients for countries are not reported.

[b]$p < .05$.

[c]$p < .01$.

[d]$p < .001$.

2 weeks, children reported to have had fever exhibited a slightly higher odds of being stunted than children without fever (OR 1.058; 95% CI [1.013–1.105]), although no association was found for diarrhoea and stunting (although an association existed in the unadjusted analysis) or for pneumonia and stunting.

Maternal stature and education were also identified as protective factors for child stunting. Children born to the taller mothers (>160 cm) were less likely to be stunted than children born to shorter mothers (<145 cm). The analysis shows that each 1-cm higher maternal height was associated with lower odds of being stunted for 6–23-month-olds (OR 0.929; 95% [CI 0.925–0.932]). Similarly, children whose mothers had more years of formal education were less likely to be stunted than children whose mothers had fewer years of education.

With respect to the household variables, children from households in the poorest quintiles were more likely to be stunted than the children from the richest quintiles (OR 1.764; 95% CI [1.633–1.906]). The results also show a significant association between the number of under-5 children living in the household and child stunting. For each one additional child under 5 years of age in the household, the odds of being stunted was 1.102 times higher (95% CI [1.080–1.124]).

The population attributable risk calculation showed that 20,944 children (28.1%) in the sample were stunted. If all children had received five or more food groups, then 2,629 cases of stunting would have been averted, which is 12.6% of the stunting, reducing the prevalence of stunting to 24.6%.

3.2.2 | Consumption of animal source foods

When compared to children who consumed all three types of ASF (egg, meat, and dairy), children whose diet did not include any ASF had a 1.436 higher odds of being stunted (OR 1.436; 95% [CI 1.317–1.565]; Table 4). The association of ASF consumption and stunting was ordinal, with children who consumed only one type of ASF having a 1.282 times higher odds of being stunted (95% CI [1.179–1.392]) and children who consumed two types of ASF having a 1.156 times higher odds of being stunted (95% [CI 1.063–1.257]) when compared to children consuming all three types of ASF. When the results were broken down by age groups, only the group consuming zero ASF differed from the reference group among those 6–11 months of age. Among 12–23-month-olds, the results paralleled those for the entire 6–23 month age group described above. If all children had received three types of ASF, then 3,629 cases of stunting would have been averted, which is 17.3% of the stunting, reducing the prevalence of stunting from 28.1 to 23.2%.

3.2.3 | Dietary quality by country-income grouping

The significant association between diet diversity and child stunting remained among groupings defined by World Bank country-income classification (Table 5). The low-income countries (LICs) had fewer and weaker significant outcomes than the upper-middle income countries (UMICs) or lower-middle income countries (LMICs). Overall differences between the reference group of five plus food groups were only noted among children consuming zero, one, or two food groups in the LICs,

TABLE 4 Overall and age-stratified adjusted odds ratio of the consumption of animal source foods, child, maternal, and household covariates in relation to child stunting for children aged 6–23 months[a]

	Stunting adjusted risk ratio (95% CI)		
	6–23 months	6–11 months	12–23 months
The consumption of animal source food			
3 types of animal source food (reference)	1.0	1.0	1.0
0 types of animal source food	1.436[d] (1.317–1.565)	1.389[c] (1.131–1.705)	1.382[d] (1.253–1.523)
1 type of animal source food	1.282[d] (1.179–1.392)	1.154 (0.942–1.412)	1.226[d] (1.119–1.345)
2 types of animal source food	1.156[c] (1.063–1.257)	0.958 (0.774–1.187)	1.161[c] (1.058–1.273)
Observations	74,548	26,564	47,984

Note. CI = confidence interval.

[a]Models were adjusted for child, maternal, and household covariates, country as fixed effects and clusters as random effects as in Table 3.

[b]$p < .05$.

[c]$p < .01$.

[d]$p < .001$.

with no difference among those consuming three or four food groups. The association of dietary diversity on stunting was greater among the LMICs, with those consuming zero, one, two, or three food groups having higher odds of being stunted than the reference of five plus food groups. Among UMICs, a similar pattern emerged to that of LMICs, although the zero food group had a smaller and nonsignificant difference, which might have been due to the relatively small number of children falling into this group among this country-income classification.

With regard to ASF consumption, a similar pattern emerged between country-income grouping as for dietary diversity. Among LICs, only the children consuming no ASF had a higher risk of stunting (OR 1.191; 95% [CI 1.013–1.398]) when compared to the reference group consuming all three types of ASF (eggs, meat, and dairy). Among LMICs, those consuming zero types of ASF had a 1.420 times higher odds of being stunted (95% CI [1.245–1.621]) and those consuming only one type of ASF had a 1.263 times higher odds of being stunted (95% CI 1.114–1.430) than the reference group, but no difference was observed for those consuming two types of ASF. Among UMICs, those consuming two types of ASF had a higher odds of being stunted (OR 1.246; 95% CI [1.073–1.448]) when compared to the reference group.

4 | DISCUSSION

This study examined the association between child's dietary quality on the previous day and stunting, employing DHS data from 39 countries. Dietary diversity and ASF consumption were associated with stunting, with associations differing by country-income groups. Key findings

TABLE 5 Adjusted odds ratio of dietary diversity and animal source food consumption in relation to child stunting for children aged 6–23 months, by World Bank country-income classification[a]

	Stunting adjusted risk ratio (95% CI)		
	Low-income countries (21 countries)	Lower-middle income countries (12 countries)	Upper-middle income countries (6 countries)
Dietary diversity			
5+ food groups (reference)	1.0	1.0	1.0
0 food group	1.177[b] (1.033–1.34)	1.465[d] (1.280–1.675)	1.279 (0.929–1.761)
1 food group	1.239[d] (1.106–1.388)	1.370[d] (1.222–1.537)	1.483[c] (1.157–1.9)
2 food groups	1.129[b] (1.015–1.256)	1.272[d] (1.146–1.412)	1.307[c] (1.074–1.591)
3 food groups	1.109 (0.995–1.236)	1.123[b] (1.013–1.244)	1.253[c] (1.063–1.477)
4 food groups	0.987 (0.876–1.111)	1.095 (0.983–1.219)	1.078 (0.924–1.258)
Animal source food consumption			
3 types of animal source food (reference)	1.0	1.0	1.0
0 types of animal source food	1.191[b] (1.013–1.398)	1.420[d] (1.245–1.621)	1.253 (0.999–1.572)
1 type of animal source food	1.033 (0.881–1.212)	1.263[d] (1.114–1.430)	1.321[c] (1.115–1.564)
2 types of animal source food	0.972 (0.819–1.154)	1.097 (0.965–1.247)	1.246[c] (1.073–1.448)
Observations	32,564	30,433	11,551

Note. CI = confidence interval.

[a]Models were adjusted for child, maternal, and household covariates, country as fixed effects and clusters as random effects as in Table 3.

[b]$p < .05$.

[c]$p < .01$.

[d]$p < .001$.

were (a) diet quality was associated with lower stunting in the 39 countries studied; (b) the largest association was among the youngest group of 6–11-month-olds consuming zero food groups and may thus be more related to lack of introduction of any food groups, although a more consistent relationship between number of food groups is evident among the older group of 12–23-month-olds; (c) lower stunting exists with the consumption of three types of ASF when compared to two types of ASF; (d) a larger magnitude of association of diet diversity and ASF consumption exist for upper-middle and LMICs when compared to LICs; and (e) somewhat lower stunting exists with the consumption of five or more food groups when compared to four food groups.

The largest difference with diet diversity and stunting was among infants aged 6–11 months who had consumed zero food groups in the previous day. The only other group that was different than the reference among 6–11-month-olds was the one food group, which also was associated with higher odds of being stunted. The lack of difference of consuming two or three or four food groups among 6–11-month-olds suggests that (a) the mere introduction of solid foods is likely more important among these youngest children than is greater diversity and (b) that the measure might not be sensitive enough for this age group. Among 12–23-month-olds, each food group was associated with higher odds of stunting when compared to the reference of five plus reference group. We also found a negative association for the covariate of continued breastfeeding among children 12–23 months of age and stunting, but not among 6–11-month-olds. The lack of any association of breastfeeding on stunting among 6–11-month-olds might be because most children in this age group in the study sample (more than 90%) were breastfed and also because stunting prevalence is relatively low in this age group. For the older age group of 12–23-month-olds, reverse causality of breastfeeding and stunting is likely. The notion of reverse causality has been established in prospective cohort studies, which indicate that women with smaller children who suffer more from diseases like diarrhoea decide to continue to breastfeed and thus it is not the breastfeeding that is leading to stunting but the poor health and growth that are leading to prolonged breastfeeding (Marquis, Habicht, Lanata, Black, & Rasmussen, 1997, Simondon, Simondon, Costes, Delaunay, & Diallo, 2001).

Consumption of more types of ASF was associated with lower stunting. There are a variety of studies, which show that ASF consumption, in general, is protective against stunting (Darapheak et al., 2013, Ihab et al., 2014), or that consumption of specific types of ASF, such as meat, are protective against stunting (Darapheak et al., 2013, Ihab et al., 2014, Tang & Krebs, 2014, Tang, Sheng, Krebs, & Hambidge, 2014). We have not found published evidence, however, that consumption of multiple types of ASF might be protective when compared to fewer types of ASF. One possible explanation is that consumption of more types of ASF is a marker of other aspects of dietary quality. Alternatively, more types of ASF may be a marker of quantity of ASF intake, or as different types of ASF have different nutrient profiles, which can support linear growth in different ways, there is a biologically plausible basis to support these findings. For example, when compared to eggs and almost all meat products, dairy products have higher levels of calcium and vitamin D, which have been shown to have independent effects on stunting when compared to other nutrients (van Stuijvenberg et al., 2015, Hoppe, Molgaard, & Michaelsen, 2006). Flesh foods are high in zinc, another micronutrient essential for linear growth, but zinc is not high in most dairy products. Some supplementation trials have failed to find an effect of meat consumption on linear growth, however, which was attributed to high baseline rates of stunting (Krebs et al., 2012). A recent study in the United States that found a positive impact of meat supplementation on linear growth points to the importance of baseline nutritional status, and likely also energy sufficient diets, for meat consumption to have an impact on stunting (Tang & Krebs, 2014). Although the literature has mixed results for stunting and ASF consumption, our findings provide an impetus for further research assessing the role multiple types of ASF can play in the promotion of optimal growth and development among young children.

When assessing the findings broken down by country-income groupings in our study, we postulate that among the worst-off populations, namely, children in the LICs, other factors related to stunting, such as maternal education, maternal nutrition status, and child infection or inflammation might influence the stunting rates more than increased levels of dietary diversity are capable of doing. As noted by some authors who saw no effect on stunting with daily meat supplementation in four LICs, the baseline stunting levels (Krebs et al., 2012) and perhaps also lack of sufficient energy intake (Menon, Bamezai, Subandoro, Ayoya, & Aguayo, 2015) did not allow for this additional food to be used by the body to support additional linear growth. The differences were most pronounced among the UMICs where even consuming two types of ASF had higher odds of being stunted when compared to consuming three types of ASF. This follows the pattern of findings of a supplementation trial in the United States, where supplemental daily meat was found to significantly increase the mean LAZ among the intervention group although the mean LAZ significantly decreased among controls. The authors from this study postulated that the impact of meat consumption might be higher in high-resource settings (Krebs et al., 2012), which may explain why we saw more significant differences among UMICs, as well as LMICs, when compared to LICs. Having a diverse diet among LICs is important for many reasons, but other factors related to stunting must also be resolved among countries with the lowest level of resources.

We found a higher odds of being stunted even among the group of children consuming four food groups when compared to the reference group of five or more food groups among those aged 12–23 months and not those aged 6–11 months. The higher odds of being stunted among those who consumed four food groups when compared to those who consumed five or more food groups provides evidence to support consideration of a higher cutoff than four for the current global indicator, if at least part of the aim of the use of diet diversity data is to advocate for dietary changes to support optimal linear growth among young children. Setting a cutoff of five or more food groups ensures that at least one type of ASF (eggs, meat, or dairy) was consumed. Furthermore, ASF consumption from more than just one of the three types of ASF assessed in this study was associated with lower risk of stunting, and with a minimum of five food groups, there is a greater chance that more than one type of ASF was consumed. Another option could be to keep the cutoff of four or more food groups as it is currently established, but to require at least one ASF among the four food groups. This option may seem more feasible than reaching a minimum of five food groups and would put more emphasis on the importance of ASF in diets of infants and young children. The WHO indicators were developed using high-quality, quantified 24-hour recall data from four countries, but some limitations existed due to the limited number of datasets and sample sizes available during the development of the indicators (WHO, 2008). These findings suggest that it might be timely to review the recommended WHO IYCF indicators (WHO, 2008) now that there are more data available from a variety of country settings through the DHS and more recently, the Multiple Indicator Cluster Surveys (MICS) (Jones, Ickes, et al., 2014a).

Limitations of this study include the reporting and recall bias, which can occur in DHS and similar surveys, which rely on the mother's memory of past events (Ruel & Menon, 2002). Overall, we would expect the bias for the dietary diversity items to be low, given that the recall period in this case is the previous day. In addition, although a standard questionnaire is the basis for all DHS across all countries, the survey programme tailors the food lists to reflect food items available in each country. In general, the food categories remain the same between surveys, and variable recoding was undertaken when necessary to allow cross-country comparisons presented in this study. Nevertheless, the quality of data may have varied between countries depending on the extent and quality of the country customization of questionnaires, and we could not account for such differences. Furthermore, with only one day of recall data per child, the cross-sectional nature of this study might not reflect the usual diet of any given child in the sample. These measures are limited in assessing diet and health relationships (Jones, Mbuya, et al., 2014b); random error in the measurement of dietary quality may attenuate estimates of association (Beaton, 1994).

Given the cross-sectional design, we cannot be sure if the associations observed are causal. Three scenarios are possible: Scenario A: stunting causes poor dietary quality (e.g., stunted children are fed less because they demand food less), Scenario B where poor dietary quality causes stunting (e.g., nutrients in a variety of food are needed to support growth), or Scenario C where something else is associated with and causes both stunting and poor dietary quality (e.g., diet and stunting result from a variable not in the DHS datasets, which we could not control). We have been unable to find any publication that suggests Scenario A is likely, but it could be that stunted children are more frequently ill and consequently eat less. A review of literature on how young children are fed during common illnesses in South Asian countries suggest that complementary foods are restricted in frequency, quantity, and/or quality during illness, owing to children's anorexia (perceived or real), lack of awareness of caregivers' about the feeding needs of sick children, traditional beliefs or suboptimal counselling, and support by health workers (Paintal & Aguayo, 2016). Our analyses controlled for illnesses in the last 2 weeks, however, as collected in the DHS, including fever, diarrhoea, and pneumonia, and we also tested the model without the illness covariates and the effect sizes and significant levels were essentially unchanged. Others have reported on the difficulty of assessing illnesses through household surveys such as DHS, noting that classification errors were a potential concern, but also noted that the real association of these factors (i.e., had the assessment of illness been error free) were unlikely to be higher than results found with the reported survey data (Corsi et al., 2015). Scenario B is a strong possibility as evidence exists to support the notion that a variety of nutrients are needed to support optimal growth (van Stuijvenberg et al., 2015, Semba & Bloem, 2008). Furthermore, with the bar set at five plus food groups in this study, there is a higher chance that any child in the reference group would have had at least two types of ASF, which have key nutrients of zinc, protein, and calcium associated with linear growth and thus supports the likelihood for Scenario B. Furthermore, our results show a lower odds of being stunted when three types of ASF were consumed when compared to two types of ASF, which might provide additional support for the possibility of Scenario B given that increased types of animal source foods could increase the type of nutrients available that support linear growth. Under Scenario B, we estimated that improving dietary diversity to five or more food groups for all children 6–23 months of age would avert 12.6% of the stunting observed in the sample, which would be an important reduction on a population basis.

5 | CONCLUSIONS

Dietary diversity and consumption of different types of ASF were associated with stunting. More research is needed to understand the effects of dietary diversity as well as consumption of multiple types of ASF on stunting in different settings. Promotion of the role of ASF as part of a healthy diet, especially among infants and young children, requires continuous investment in research and utilization of information for the elaboration of appropriate guidelines and recommendations. Although most countries are already performing poorly against a standard of four plus food groups, given the findings of these analyses, there might be value in regularly reporting on additional diet diversity cutoffs as well as consumption of ASF. The recommended WHO IYCF indicators were developed 8 years ago; with more available data from a variety of country settings available today, it might be timely to review these indicators.

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CONFLICTS OF INTEREST

The authors do not have any conflicts of interest to declare.

CONTRIBUTIONS

JK conceived the study and interpreted the data. XA analysed the data and developed the tables. JK and XA wrote the initial draft of the manuscript. EF provided technical direction related to the statistical analyses and interpretation, contributed to the initial draft, and edited the manuscript. RK and FB contributed to the initial draft and edited the manuscript. All coauthors participated in the manuscript preparation and critically reviewed all sections of the text for important intellectual content.

DISCLAIMER

FB, JK, and RK are staff members of the United Nations Children's Fund. The authors alone are responsible for views expressed in this publication, and they do not necessarily reflect the policy or views of the United Nations Children's Fund.

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