Complementary Feeding Interventions Have a Small but Significant Impact on Linear and Ponderal Growth of Children in Low- and Middle-Income Countries: A Systematic Review and Meta-Analysis

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Abstract

Background: World Health Assembly member states have committed to ambitious global targets for reductions in stunting and wasting by 2025. Improving complementary diets of children aged 6–23 mo is a recommended approach for reducing stunting in children <5 y old. Less is known about the potential of these interventions to prevent wasting.

Objective: The aim of this article was to review and synthesize the current literature for the impact of complementary feeding interventions on linear [length-for-age *z* score (LAZ)] and ponderal [weight-for-length *z* score (WLZ)] growth of children aged 6–23 mo, with the specific goal of updating intervention-outcome linkages in the Lives Saved Tool (LiST).

Methods: We started our review with studies included in the previous LiST review and searched for articles published since January 2012. We identified longitudinal trials that compared children aged 6–23 mo who received 1 of 2 types of complementary feeding interventions (nutrition education or counseling alone or complementary food supplementation with or without nutrition education or counseling) with a no-intervention control. We assessed study quality and generated pooled estimates of LAZ and WLZ change, as well as length and weight gain, for each category of intervention.

Results: Interventions that provided nutrition education or counseling had a small but significant impact on linear growth in food-secure populations [LAZ standardized mean difference (SMD): 0.11; 95% CI: 0.01, 0.22] but not on ponderal growth. Complementary food supplementation interventions with or without nutrition education also had a small, significant effect in food-insecure settings on both LAZ (SMD: 0.08; 95% CI: 0.04, 0.13) and WLZ (SMD: 0.05; 95% CI: 0.01, 0.08).

Conclusions: Nutrition education and complementary feeding interventions both had a small but significant impact on linear growth, and complementary feeding interventions also had an impact on ponderal growth of children aged 6–23 mo in low- and middle-income countries. The updated LiST model will support nutrition program planning and evaluation efforts by allowing users to model changes in intervention coverage on both stunting and wasting. *J Nutr* 2017;147 (Suppl):2169S–78S.

Keywords: complementary feeding, Lives Saved Tool, stunting, wasting, food security

Introduction

In 2012, World Health Assembly member states committed to reducing the number of stunted [length-for-age *z* score (LAZ) <−2 SDs] children by 40% and the prevalence of wasting [weight-for-length *z* score (WLZ) <−2 SDs] to <5% globally by the year 2025 (1). There are an estimated 162 million stunted children <5 y of age globally (2). In the highest-burden countries, 1 in 5 children <5 y of age is wasted (3). Stunting is associated with negative physical and cognitive outcomes during early childhood as well as poor school performance, reduced economic productivity, and increased risk of noncommunicable diseases into adulthood (4). Severely wasted children (weight-for-height <−3 SDs) are 11 times more likely to die compared with a normal child; the risk of mortality is also elevated for mild (−2 SDs < weight-for-height < −1 SD) and moderate (−3 SDs < weight-for-height < −2 SDs) wasting, which are more prevalent conditions (5).

Poor dietary intake is a proximal cause of child undernutrition (4). The window of 6–23 mo of age is a time of accelerated growth and the period of highest risk for growth faltering among children in low- and middle-income countries (LMICs). Nutrient requirements are high in this age group and can no longer be met

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through breast milk alone. However, children are not yet developmentally ready to consume the family diet. Complementary feeding refers to the timely introduction and provision of developmentally appropriate, nutrient-dense foods in addition to breast milk (6). Caregiver education or counseling about appropriate complementary feeding practices (e.g., offering diversity of nutrient-dense food, safe and developmentally appropriate food preparation, age-appropriate frequency of feeding, continued breastfeeding) is an effective strategy for improving child intake and reducing growth faltering in settings where households have sufficient resources to put the recommendations into practice (6). In food-insecure settings, improving growth outcomes in children aged 6–23 mo often requires the direct provision of foods, including fortified foods and lipid-based nutrient supplements (7).

The Lives Saved Tool (LiST) is a multicausal model that relates changes in intervention coverage to changes in stunting, wasting, and mortality risk in children <5 y in LMICs. LiST can be used to identify context-appropriate interventions to improve nutrition and child survival outcomes and set more informed intervention scale-up targets at national or subnational levels. A linkage between complementary feeding interventions and stunting was added to LiST to support the 2008 *Lancet* series on undernutrition (8). The Child Health Epidemiology Reference Group (CHERG) produced an updated review of the effectiveness of complementary feeding interventions on stunting in 2013, also for LiST (7).

The evidence base for complementary feeding interventions has continued to expand. In particular, there is growing recognition of the potential for these interventions to prevent moderate and severe wasting (also referred to as acute malnutrition) (9). A 2015 Cochrane review on the provision of supplementary foods included both LAZ and WLZ outcomes; however, it captured a wider range of ages (6–59 mo) and contexts (both high- and low-income) than required for LiST (10). The aim of this article was to produce updated pooled estimates by using controlled trials of the impact of 2 types of complementary feeding interventions (nutrition education or counseling alone, provision of food or nutrition supplements with or without nutrition education) on changes in LAZ and WLZ among children aged 6–23 mo in LMICs.

Methods

We carried out an updated systematic review and meta-analyses guided by the process outlined by the CHERG (11) and consistent with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) (12). Our outcomes of interest for LiST are the absolute mean difference (MD) between intervention and control groups in change in LAZ and WLZ from baseline to endline (difference-in-differences). For comparability to previous reviews, we also report the standardized MD (SMD) for *z* score outcomes and absolute and standardized differences in length (centimeters) and weight (kilograms) gain as available.

Inclusion and exclusion criteria. We included intervention studies with no-intervention control groups [randomized controlled trials, controlled before-and-after studies (CBAs)] from both research and programmatic contexts in LMICs. We define a "no intervention" control as no intervention above and beyond routine government health services, which may include some form of nutrition counseling from providers. We did not restrict our search by language. Our inclusion age range was 6–23 mo, although some studies included a slightly wider age range. The minimum intervention duration was 6 mo.

For studies involving the provision of food or a specially formulated supplement, we included studies that used blanket supplementation strategies to reach all children in the intervention group, as well as those that enrolled children on the basis of mild or moderate underweight criteria. We excluded any studies that reported selectively enrolled children with severe stunting, wasting, or underweight (*z* score <-3 SDs).

We also excluded studies that did not report ≥1 of our primary outcomes of interest (LAZ, WLZ) or if information provided was not sufficient to calculate difference-in-differences for these outcomes. Consistent with CHERG guidance, we excluded studies with a sample size of <50 children/arm, those with a cross-sectional design, or those that reported extreme estimates without adequate justification (11). **Supplemental Table 1** summarizes the study and intervention design for each study that met the inclusion criteria.

Search strategy. We started our search with the articles included in an earlier systematic review prepared for LiST (7) and then searched PubMed (https://www.ncbi.nlm.nih.gov/pubmed/), Cochrane Library (http://www.cochranelibrary.com/), Google Scholar (https://scholar.google.com/), WHO International Clinical Trials Registry Platform (http://www.who.int/ictrp/en/), and EMBASE (https://www.elsevier.com/solutions/embase-biomedical-research) to capture additional studies published from October 2012 onward, the date the previous review ended. Search strings are included in the **Supplemental Methods**.

Data abstraction and quality assessment. We abstracted data onto a standardized form, including study design, randomization methods, blinding, allocation concealment, loss to follow-up, and adjustment for clustering, if appropriate. Other study characteristics, including study population, context, outcomes, sample size, duration, and other intervention details, were also abstracted. Studies were further classified by food security status on the basis of site-specific context provided by the authors. In studies with multiple intervention arms, we included each arm separately.

Grading of the quality of evidence was conducted following the CHERG systematic review guidelines (11). Randomized controlled trials were given an initial score of "high" and CBA studies were "low." Depending on the strengths and limitations of the study design and methods, each study was assigned a grade of "high," "moderate," "low," or "very low." Studies with a "very low" grade were excluded from all analyses. We conducted the meta-analyses with and without the "low" quality studies. For the meta-analyses, pooled outcomes were graded according to the quality of studies that contributed to them.

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Supplemental Tables 1 and 2, Supplemental Methods, and Supplemental Figures 1–5 are available from the "Online Supporting Material" link in the online posting of the article and from the same link in the online table of contents at http://jn.nutrition.org.

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Abbreviations used: CBA, controlled before-and-after study; CHERG, Child Health Epidemiology Reference Group; LAZ, length-for-age *z* score; LiST, Lives Saved Tool; LMIC, low- and middle-income country; MD, mean difference; NCHS, National Center for Health Statistics; SMD, standardized mean difference; WLZ, weight-for-length *z* score.

Quantitative data synthesis. All of the analyses were conducted with STATA version 14.0 with the use of the *metan* command, version 3.04 (StataCorp) (13). We report pooled effect sizes as weighted MDs with 95% CIs. We also report pooled effect sizes as SMDs to allow us to combine trials that reported z scores by using different growth references.

If the study reported an effect size as difference-in-differences, we used these values. For studies that instead reported baseline and follow-up values, we calculated the difference-in-differences for the outcomes of interest. To calculate SDs, we used the formula presented in the Cochrane Handbook, taking the square root of the sum of the squared SD values at each time point (14). Crude estimates were used where available; for cluster study designs, we used cluster-adjusted values when provided.

Studies published before 2006 generally report z scores on the basis of the CDC National Center for Health Statistics (NCHS) growth reference (15), whereas after 2006, studies began to use the WHO 2006 growth standard (16). It is not possible to directly convert between z score values calculated with the different references (17). However, for those studies that used the NCHS reference to calculate z scores but reported length in centimeters (means and SDs or 95% CIs) at baseline and endline for each study arm, we estimated the WHO 2006-standardized LAZ by using WHO Anthro software version 3.2.2 (18). Because LAZ is age- and sex-specific, we assumed all children were the mean age reported and assumed an equal proportion of girls and boys. We were unable to apply this NCHS-to-WHO estimation method to WLZ scores, because that would require the weight and length measurements in individual children. Instead, we report pooled MDs for the 2 references separately and the combined estimate as the SMD.

For all of the analyses, we assessed heterogeneity by performing a chi-square test and by calculating the I^2 statistic. Given the high level of heterogeneity, especially in the pooled analyses, we used random-effects models. This model adds a normally distributed error term to the observed effect size, on the basis of the sample size and effect size of each study, in order to assume the true effect size is also normally distributed. Fixed-effects models were used where heterogeneity was low.

We classified studies as being in "food secure" or "food insecure" contexts with the use of 2 different approaches. Our primary approach was to interpret the baseline population characteristics and the narrative description provided by the authors for each study. Key factors signifying food security included explicit mention of food security status of the population, or access or availability to foods. Poverty status was a proxy for those studies that did not report information on food security or availability. Our secondary approach was to use national World Bank data as done in previous reviews (7, 19). We classified countries on the basis of income status (2015), defining "low" and "lower-middle" income countries as having low food security and "upper-middle" countries as having high food security (20). We compared the findings from the 2 approaches in a sensitivity analysis.

Results

Trial flow. Our overall search yielded 858 studies from 2012 onward, of which we initially considered 33 on the basis of the contents of the abstract (**Figure 1**). Of these, 26 were excluded altogether. Five were removed due to lack of or incompatible outcomes of interest per our methods (21–25), 12 lacked a no-intervention control arm (26–37), and 2 were cross-sectional in design (38, 39). Two were removed for unexplained extreme values for ≥1 outcome (40, 41). Two had an inadequate sample size (42, 43). One study followed a wide age range and did not report disaggregate data (44), and another did not have enough information to calculate the difference-in-differences estimates (45).

Eleven studies included in previous reviews were removed for ≥1 of the following reasons: lack of outcomes of interest or complete information on outcomes at baseline and follow-up (46, 47), lack of a no-intervention control arm (48, 49), an inadequate sample size (50–53), or inability to convert length values to WHO growth standards (54). One was removed for

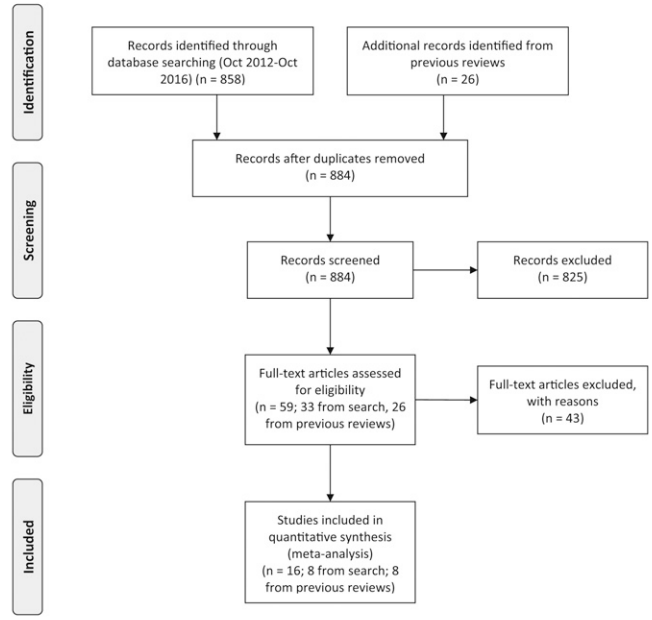

FIGURE 1 PRISMA flow chart. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

unexplained extreme outcome values (55), 1 due to a duration period <6 mo (56), and 1 due to a high attrition rate in anthropometric outcomes (57).

After in-depth review, we included 8 new studies (58–65) and 8 from previous reviews (66–73), for a total of 16 studies that matched our inclusion criteria. Nine of these studies contributed to the analysis of nutrition education only and 8 to the analysis of provision of food or nutritional supplementation with or without education. One study included both nutrition education only and the provision of food or nutritional supplement arms, compared with a control, and so contributed to both analyses (66).

Quality of evidence. The quality of evidence was also determined for each study and outcome by using the CHERG criteria. For nutrition education only, there were 3 studies with high-quality evidence (70, 71, 73), 5 with moderate-quality evidence (62, 63, 66, 67, 72), and 1 study with low-quality evidence (64) (**Supplemental Table 2**). For the provision of food or supplement, there were 4 studies with high-quality (60, 61, 70, 73), 3 with moderate-quality (58, 59, 66), and 3 with low-quality (65, 68, 69) evidence.

Pooled estimates of effect. **Tables 1** and **2** summarize the pooled estimates by complementary feeding intervention type. Absolute differences (MDs) are calculated for studies where difference-in-difference outcomes were reported by using the WHO growth standard or were able to be estimated on the basis of length gain by using the approach described above. SMDs are used to combine all available studies meeting the inclusion criteria, regardless of growth reference used. SMDs should be interpreted as the relative magnitude of effect in the intervention compared with the control. An SMD of 0.2 is considered a small effect, 0.5 a medium effect, and 0.8 a large effect (75).

Nutrition education or counseling alone. Nutrition education had a small effect on LAZ in food-secure settings, as defined by the authors [MD: 0.22; 95% CI: 0.08, 0.37 (4 studies); SMD: 0.11; 95% CI: 0.01, 0.22 (5 studies)] (**Figure 2**), but no effect in

TABLE 1 Summary of findings for pooled analyses of provision of nutrition education only in children aged 6–23 mo in LMICs[1]

	Quality assessment			Summary of findings			
Outcome of interest [reference(s)]	Design	Limitations	Consistency	Intervention, *n*	Control, *n*	MD[2] (95% CI)	SMD[3] (95% CI)
Length gain (cm): moderate outcome-specific quality							
7 studies Food-secure (62–64,[4] 70, 71) Food-insecure (66, 67)	RCT	Fixed-effects model (random effects used for food-secure SMD due to heterogeneity)	5 studies suggest benefit	Overall: 1361 Food-secure: 829 Food-insecure: 532	Overall: 1140 Food-secure: 653 Food-insecure: 487	Overall: 0.37 (0.10, 0.64) Food-secure: 0.46 (0.14, 0.77) Food-insecure: 0.12 (−0.40, 0.64)	Overall: 0.09 (0.02, 0.16) Food-secure: 0.12 (0.01, 0.24) Food-insecure: 0.03 (−0.09, 0.15)
Weight gain (kg): moderate outcome-specific quality							
7 studies Food-secure (62–64,[4] 70, 71) Food-insecure (66, 67)	RCT	Random effects model used due to heterogeneity	4 studies suggest benefit	Overall: 1361 Food-secure: 829 Food-insecure: 532	Overall: 1140 Food-secure: 653 Food-insecure: 487	Overall: 0.06 (−0.05, 0.18) Food-secure: 0.11 (−0.05, 0.26) Food-insecure: −0.02 (−0.15, 0.11)	Overall: 0.05 (−0.04, 0.14) Food-secure: 0.08 (−0.04, 0.20) Food-insecure: −0.00 (−0.12, 0.12)
LAZ: moderate outcome-specific quality							
6 studies reporting WHO growth standards Food-secure (62–64, 71) Food-insecure (66, 67)	RCT	Random-effects model used due to heterogeneity (fixed-effects used for WHO MD)	5 studies suggest benefit in WHO MD; 6 studies suggest benefit in SMD	WHO growth standards: Overall: 1143 Food-secure: 859 Food-insecure: 284	WHO growth standards: Overall: 934 Food-secure: 675 Food-insecure: 259	WHO growth standards: Overall: 0.13 (0.01, 0.24) Food-secure: 0.22 (0.08, 0.37) Food-insecure: −0.05 (−0.24, 0.15)	WHO and NCHS combined: Overall: 0.06 (−0.02, 0.14) Food-secure: 0.11 (0.01, 0.22) Food-insecure: −0.01 (−0.10, 0.08)
3 studies reporting NCHS growth reference Food-secure (70) Food-insecure (72, 73)				NCHS growth reference: Overall: 650 Food-secure: 218 Food-insecure: 432	NCHS growth reference: Overall: 630 Food-secure: 206 Food-insecure: 424	NCHS growth reference: Overall: −0.01 (−0.14, 0.12) Food-secure: −0.04 (−0.21, 0.13) Food-insecure: 0.03 (−0.17, 0.23)	
WLZ: low outcome-specific quality							
1 study reporting WHO growth standards (64) Food-secure (64) Food-insecure: N/A	RCT	Fixed-effects model	One study suggests benefit in WHO MD; 3 studies suggest benefit in SMD	WHO growth standards: Overall: 248 Food-secure: 248 Food-insecure: N/A	WHO growth standards: Overall: 228 Food-secure: 228 Food-insecure: N/A	WHO growth standards: Overall: 0.21 (−0.06, 0.48) Food-secure: 0.21 (−0.06, 0.48) Food-insecure: N/A	WHO and NCHS combined: Overall: 0.09 (−0.04, 0.21) Food-secure: 0.15 (−0.04, 0.34) Food-insecure: 0.09 (−0.21, 0.39)
3 studies reporting NCHS growth reference Food-secure (70) Food-insecure (72, 73)				NCHS growth reference: Overall: 650 Food-secure: 218 Food-insecure: 432	NCHS growth reference: Overall: 630 Food-secure: 206 Food-insecure: 424	NCHS growth reference: Overall: 0.10 (−0.14, 0.35) Food-secure: 0.09 (−0.18, 0.36) Food-insecure: 0.14 (−0.32, 0.60)	

[1] Generalizability of all outcomes is to food-insecure populations; control sample sizes only included once for multiple treatment arms per study. LAZ, length-for-age *z* score; LMIC, low- and middle-income country; MD, mean difference; N/A, not applicable; NCHS, National Center for Health Statistics; RCT, randomized controlled trial; SMD, standardized mean difference; WLZ, weight-for-length *z* score.

[2] Absolute (weighted) MDs only include estimates from studies that reported *z* scores with the use of WHO growth standards (16) or values able to be converted to WHO growth standards.

[3] SMDs (weighted) include estimates that used WHO growth standards and the NCHS growth reference (15) as originally reported.

[4] Shi et al. (74) values were used for Zhang et al. (64) for length and weight for the same study.

TABLE 2 Summary of findings for pooled analyses of the provision of food or nutritional supplement (with or without nutrition education) in children aged 6–23 mo in LMICs[1]

Outcome of interest [reference(s)]	Quality assessment: Design	Quality assessment: Limitations	Quality assessment: Consistency	Summary of findings: Intervention, *n*	Summary of findings: Control, *n*	Summary of findings: MD[2] (95% CI)	Summary of findings: SMD[3] (95% CI)
Length gain (cm): Moderate outcome-specific quality							
5 studies (58, 60, 61, 66, 69)	RCT and non-RCT	Random-effects model was used due to heterogeneity	4 studies suggest benefit	6885	2427	0.29 (0.10, 0.47)	0.09 (0.05, 0.14)
Weight gain (kg): Moderate outcome-specific quality							
5 studies (58, 60, 61, 66, 69)	RCT and non-RCT	Random-effects model was used due to heterogeneity	4 studies suggest benefit	6885	2427	0.10 (0.03, 0.17)	0.09 (0.04, 0.15)
LAZ: moderate outcome-specific quality							
7 studies reporting WHO growth standards (58–61, 65, 66, 69) 2 studies reporting NCHS growth reference (68, 69)	RCT and non-RCT	Random-effects model was used due to heterogeneity	4 studies suggest benefit in WHO MD; 5 studies suggest benefit in SMD	WHO growth standards: 7151 NCHS growth reference: 202	WHO growth standards: 2699 NCHS growth reference: 199	WHO growth standards: 0.10 (0.03, 0.17) NCHS growth reference: −0.03 (−0.31, 0.25)	WHO and NCHS combined: 0.08 (0.04, 0.13)[4]
WLZ: moderate outcome-specific quality							
4 studies reporting WHO growth standards (58, 60, 61, 65) 2 studies reporting NCHS growth reference (68, 69)	RCT and non-RCT	Random-effects model was used due to heterogeneity (fixed-effects model was used for WHO)	3 studies suggest benefit in WHO MD; 4 studies suggest benefit in SMD	WHO growth standards: 6783 NCHS growth reference: 205	WHO growth standards: 2339 NCHS growth reference: 199	WHO growth standards: 0.07 (0.03, 0.12) NCHS growth reference: −0.06 (−0.28, 0.15)	WHO and NCHS combined: 0.05 (0.01, 0.08)

[1] Generalizability of all outcomes is to food-insecure populations; control sample sizes were only included once for multiple treatment arms per study. LAZ, length-for-age *z* score; LMIC, low- and middle-income country; MD, mean difference; NCHS, National Center for Health Statistics; RCT, randomized controlled trial; SMD, standardized mean difference; WLZ, weight-for-length *z* score.
[2] Absolute (weighted) MDs only include estimates from studies that reported *z* scores with the use of WHO growth standards (16) or values able to be converted to WHO growth standards.
[3] SMDs (weighted) include estimates that used WHO growth standards and the NCHS growth reference (15) as originally reported.
[4] For SMD analysis of LAZ, only the NCHS reference estimate was used for Santos et al. (69).

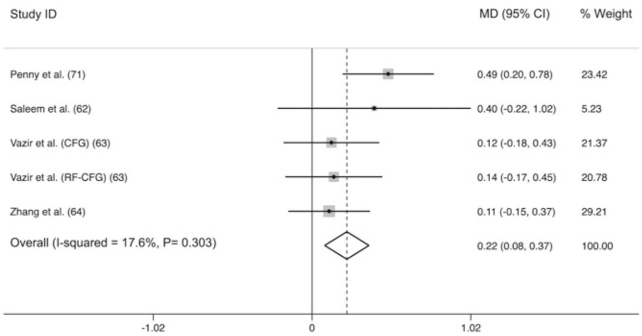

FIGURE 2 Forest plot for the effect of nutrition education only on LAZ (WHO growth standard) (16) in children aged 6–23 mo: food-secure populations. CFG, complementary feeding education–only group; ID, identifier; LAZ, length-for-age *z* score; MD, mean difference; RF-CFG, complementary plus responsive feeding education and play group.

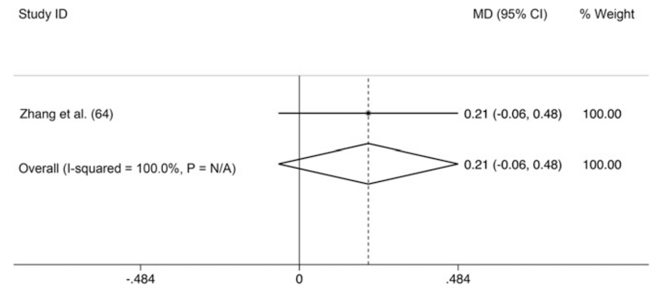

FIGURE 4 Forest plot for the effect of nutrition education only on WLZ (WHO growth standard) (16) in children aged 6–23 mo in LMICs. ID, identifier; LMIC, low- and middle-income country; MD, mean difference; N/A, not applicable; WLZ, weight-for-length *z* score.

food-insecure settings [MD: −0.05; 95% CI: −0.24, 0.15 (2 studies); SMD: −0.01; 95% CI: −0.10, 0.08 (4 studies)] (**Figure 3**). When food-secure and -insecure populations were combined, the effect of nutrition education or counseling alone on LAZ persisted in the MD, but not when standardized [MD: 0.13; 95% CI: 0.01, 0.24 (6 studies); SMD: 0.06; 95% CI: −0.02, 0.14 (9 studies)] (Table 1, **Supplemental Figure 1**).

Fewer studies reported outcomes on WLZ. There was no significant effect in one study that reported outcomes with the use of WHO growth standards (MD: 0.21; 95% CI: −0.06, 0.48) (**Figure 4**) and no significant effect when that result was pooled with 3 additional studies by using the NCHS reference [SMD: 0.09; 95% CI: −0.04, 0.21 (4 studies)] (**Figure 5**). Subgroup analysis by food security status did not yield significant results.

Overall estimates of length gain were significant for the nutrition education studies (MD: 0.37; 95% CI: 0.10, 0.64; SMD: 0.09; 95% CI: 0.02, 0.16), but this was only evident in food-secure settings with subgroup analysis, similar to the pattern observed with LAZ. There was no significant impact on weight gain (Table 1, **Supplemental Figures 2** and **3**).

Provision of food or nutritional supplement with or without nutrition education. All 8 studies of interventions that provided food or nutritional supplementation, with or without education, were from food-insecure settings. The absolute effect on LAZ from more recent studies that used WHO growth standards was significant [MD: 0.10; 95% CI: 0.03, 0.17 (7 studies)] (**Figure 6**) but was not for older studies that reported LAZ with the use of the NCHS reference [MD: −0.03; 95% CI: −0.31, 0.25 (2 studies)] (Table 2). Pooling results from all studies regardless of reference, there was a small but significant impact of interventions on LAZ [SMD: 0.08; 95% CI: 0.04, 0.13 (8 studies)].

The impact on WLZ followed a pattern similar to that of LAZ. Pooling results from all studies regardless of growth reference, there was a small but significant impact of interventions on WLZ for interventions [SMD: 0.05; 95% CI: 0.01, 0.08 (6 studies)] (Table 2). The absolute effect on WLZ from more recent studies that used the WHO growth standard was also small but significant [MD: 0.07; 95% CI: 0.03, 0.12 (4 studies)] (**Figure 7**) but was not for older studies that used the NCHS reference [MD: −0.06; 95% CI: −0.28, 0.15 (2 studies)] (Table 2). Pooled estimates of weight and length gain were significant (**Supplemental Figures 4** and **5**).

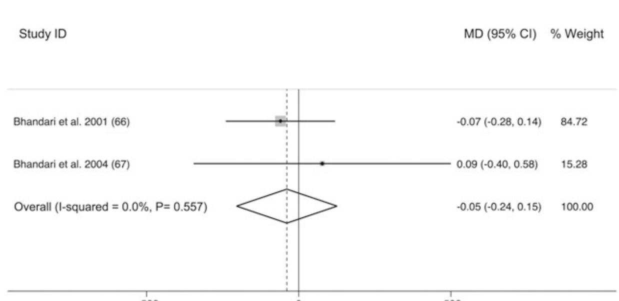

FIGURE 3 Forest plot for the effect of nutrition education only on LAZ (WHO growth standard) (16) in children aged 6–23 mo in LMICs: food-insecure populations. ID, identifier; LAZ, length-for-age *z* score; LMIC, low- and middle-income country; MD, mean difference.

Sensitivity analyses. Two of 9 studies were defined as "lower-middle" income according to the World Bank classification, yet were conducted in food-secure settings as reported by the authors (61, 62). We found that moving these 2 studies to food-insecure did not change the conclusion about the impact of education-only in food-secure settings only (data not shown). We also conducted sensitivity analyses that examined only high- and moderate-quality studies, which did not differ from the overall analysis that included low-quality CBAs (data not shown).

Discussion

According to our analysis, complementary feeding interventions have small but significant impacts on linear and ponderal growth among children aged 6–23 mo in LMICs, whereas nutrition education interventions had an impact on linear growth only. Consistent with previous reviews, nutrition education improved linear growth in food-secure contexts, whereas the impact of interventions that provided food or nutritional supplements (with or without nutrition education) on linear growth was limited to studies in food-insecure settings (7, 8, 19). The lack of impact of education-only interventions in food-insecure contexts is consistent with the rationale that food-insecure families would lack the resources to implement recommendations. It is plausible that food supplementation would affect the risk of growth faltering in food-secure settings, but we lack evidence to support this.

The effect sizes on WLZ are generally smaller than on LAZ. According to our pooled analysis, nutrition education–only interventions in food-secure settings do not affect WLZ, whereas interventions that provide food or nutritional supplements in

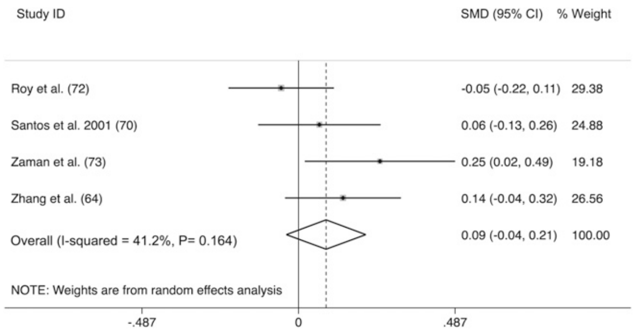

FIGURE 5 Forest plot for the effect of nutrition education only on WLZ (pooled WHO growth standard and NCHS reference) (15, 16) in children aged 6–23 mo in LMICs. Weights are from random-effects analysis. ID, identifier; LMIC, low- and middle-income country; NCHS, National Center for Health Statistics; SMD, standardized mean difference; WLZ, weight-for-length *z* score.

food-insecure settings do have a small but significant impact (76). Because country-level data may not necessarily reflect the true food security status of the study population, we chose narrative descriptions as our primary method of assigning food security status to individual studies. Although this method was not standardized, we saw no meaningful difference in estimates when we applied the more standardized approach based on World Bank country classifications. However, these results should be interpreted cautiously because there are a small number of studies overall, particularly for nutrition education only.

Generalizing effect sizes for such diverse interventions and populations is a challenge. Nutrition education–only interventions ranged from training of health care workers to deliver messages during clinic visits or at health centers (70, 72) to home visits for counseling on complementary feeding (66, 67, 70, 71, 73) and responsive feeding (63). Food or nutritional supplement interventions also included a range of delivery platforms and varied in the supplement type, including ready-to-use therapeutic foods (58), local cereal and protein blends (58, 61, 66, 69), insect meal (65), and small-quantity lipid-based nutrient supplements (59, 60).

The limitation in the number and types of studies was compounded by the fact that outcomes reported in the studies were not consistent and comparable. The older studies (pre-2008)

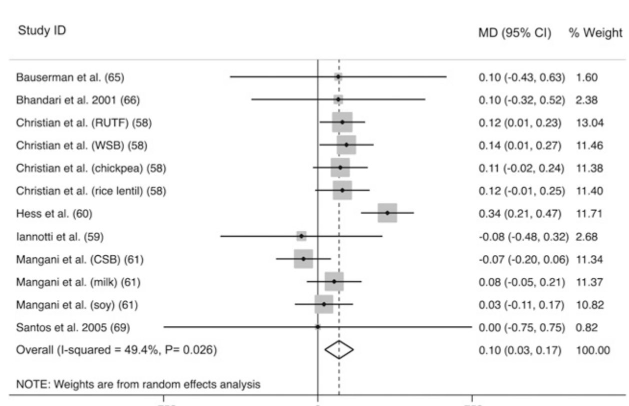

FIGURE 6 Forest plot for the provision of food or nutritional supplement (with or without nutrition education) on LAZ (WHO growth standard) (16) in children aged 6–23 mo in LMICs. Weights are from random-effects analysis. CSB, corn-soy blend; ID, identifier; LAZ, length-for-age *z* score; LMIC, low- and middle-income country; MD, mean difference; RUTF, ready-to-use therapeutic food; WSB, wheat-soy blend.

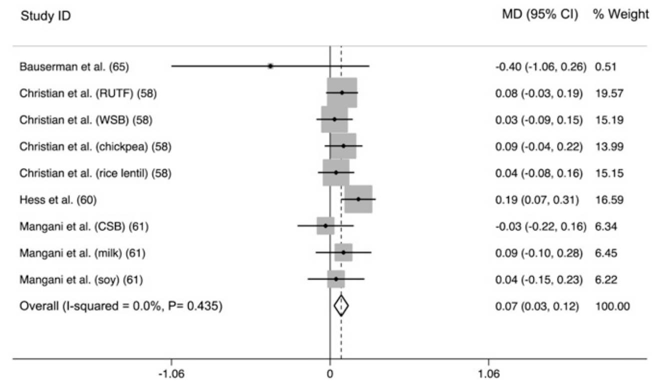

FIGURE 7 Forest plot for the provision of food or nutritional supplement (with or without nutrition education) on WLZ (WHO growth standard) (16) in children aged 6–23 mo in LMICs. CSB, corn-soy blend; ID, identifier; LMIC, low- and middle-income country; MD, mean difference; RUTF, ready-to-use therapeutic food; WLZ, weight-for-length *z* score; WSB, wheat-soy blend.

tended to exclude WLZ outcomes, which could signal a bias against reporting null results. Reporting bias could also be a factor that influences the types of studies available (e.g., studies of nutrition education only with null findings may not have been published). Those earlier studies that did report both LAZ and WLZ were subject to the shift in growth reference.

Ideally, we would have a sufficient number and diversity of studies available to estimate effects for meaningful subtypes of interventions (e.g., provision of high-energy supplements compared with small-quantity lipid-based nutrient supplements). This may be possible as the evidence base continues to grow, particularly for "new" interventions such as small-quantity lipid-based nutrient supplements and existing interventions such as micronutrient powders, which were not included in the current analysis. We also acknowledge that we limited our definition of complementary feeding interventions to "nutrition-specific" approaches that are delivered through the health system or community health workers. This is consistent with LiST, but a more comprehensive review that also includes "nutrition-sensitive" strategies to improve complementary diets, including home gardens and cash transfer programs, is called for. We reinforce previous calls for researchers to present growth outcomes completely and consistently to allow for global comparisons (77).

In the interim, these more generalized estimates are useful for supporting evidence-based decision making by policymakers and program planners. The small but significant effects estimated in our review are consistent with evidence from programmatic contexts. The relatively small contribution of a single-intervention strategy to improved growth outcomes should not dissuade countries from implementing it. The nutrition community has accepted that there is no "silver bullet" strategy for combating child malnutrition in LMICs; alternatively, improvements depend on the combined impacts of multiple nutrition-specific and nutrition-sensitive interventions.

The primary aim of this review was to estimate the absolute effect size for complementary feeding interventions on LAZ and WLZ to support modeling in LiST. For input into LiST, the pooled *z* score effect size estimates must be translated into ORs for stunting or wasting across 4 categories: food-secure individuals who receive nutrition education or counseling, food-secure individuals who receive no intervention, food-insecure individuals who receive food or nutritional supplements, and

TABLE 3 Summary of effect size and inputs for complementary feeding interventions in LiST: new ORs compared with those used before the updated review[1]

	Effect size, MD (95% CI)	Updated OR	Previous OR
Stunting			
Food-secure with nutrition education or counseling only	LAZ: 0.22 (0.08, 0.37)	1.00	1.00
Food-secure with no intervention	LAZ: 0.22 (0.08, 0.37)	1.30	1.43
Food-insecure with supplementation (with or without education)	LAZ: 0.10 (0.03, 0.17)	1.74	1.60
Food-insecure with no intervention	LAZ: 0.10 (0.03, 0.17)	1.95	2.39
Wasting			
Food-secure with nutrition education or counseling only	N/A (insufficient evidence)	1.00	N/A
Food-secure with no intervention	N/A (insufficient evidence)	1.00	N/A
Food-insecure with supplementation (with or without education)	WLZ: 0.07 (0.03, 0.12)	1.50	N/A
Food-insecure with no intervention	WLZ: 0.07 (0.03, 0.12)	1.64	N/A

[1] LAZ, length-for-age *z* score; LiST, Lives Saved Tool; MD, mean difference; N/A, not applicable; WLZ, weight-for-length *z* score.

food-insecure individuals who receive no intervention. The OR for children who receive the intervention compared with no intervention for each intervention subtype is calculated on the basis of the formula provided in the Cochrane Handbook for combining continuous and dichotomous outcomes with the use of the absolute effect size estimate from our meta-analysis and the mean SD for LAZ or WLZ in the population (14). On the basis of an analysis of the most recent nationally representative household surveys from 70 LMICs, we assumed the mean SD in the population for LAZ is 1.6 and for WLZ is 1.4. We assumed the relative odds for food-insecure populations without interventions compared with food-secure populations without interventions are 1.5 higher for stunting and 1.64 for wasting. **Table 3** summarizes the LiST inputs and compares these with previous estimates.

In conclusion, complementary feeding interventions contribute to small but significant gains in both linear and ponderal growth among children 6–23 mo of age in LMICs. Nutrition education interventions also had a significant impact on linear growth. As the evidence base continues to grow, we hope to strengthen estimates for impacts of nutrition education interventions on wasting and to distinguish subtypes of interventions that are meaningful for policymakers and program planners in LMICs. These should include interventions that aim to improve child feeding through nutrition-sensitive strategies, including agriculture and cash transfer programs.

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