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An Integrated Microcredit, Entrepreneurial Training, and Nutrition Education Intervention Is Associated with Better Growth Among Preschool-Aged Children in Rural Ghana[1–3]

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Abstract

Background: Poor diet quality is a determinant of the high prevalence rates of malnutrition in Ghana. There is little evidence on the effectiveness of a multisector intervention to improve children's diets and nutritional status.

Objective: The project tested whether participation in an entrepreneurial and nutrition education intervention with microcredit was associated with the nutritional status of children 2–5 y of age.

Methods: A quasi-experimental 16-mo intervention was conducted with microcredit loans and weekly sessions of nutrition and entrepreneurship education for 179 women with children 2–5 y of age [intervention group (IG)]. Nonparticipating women and their children from the same villages (nonparticipant, $n = 142$) and from similar neighboring villages (comparison, $n = 287$) were enrolled. Repeated measures linear regression models were used first to examine children's weight-for-age (WAZ), height-for-age (HAZ), and body mass index–for-age (BAZ) *z* scores at baseline and at 4 follow-up time points ~4 mo apart. Time, intervention status, time-by-intervention interaction terms, region of residence, household wealth rank, household head occupation, number of children <5 y of age, and child sex and age were included.

Results: There was a significant interaction between the IG and time for BAZ ($P = 0.02$) with significant Bonferroni-corrected pairwise comparisons between the IG and comparison group (CG) at 8 mo (difference of 0.36 ± 0.09 *z* score, $P < 0.0001$). The WAZ group difference was significant between 4 and 16 mo ($P = 0.01$ for interaction) and peaked at 8–12 mo (differences of ~0.28 *z*). The HAZ of children in the IG was significantly higher than that in the CG, reaching a 0.19 *z* difference at 16 mo ($P < 0.05$). When the fixed effects models were fitted in sensitivity analyses, some group anthropometric differences were of lower magnitude but remained significant.

Conclusion: An integrated package of microcredit and education may improve nutritional outcomes of children living in poor, rural communities. *J Nutr* 2015;145:335–43.

Keywords: animal source foods, diet, growth, nutrition education, preschool children

Introduction

Consumption of energy- and nutrient-poor foods is a primary cause of childhood malnutrition, which contributes to ~45% of child deaths in low-resource communities (1, 2). In Ghana, children's diets consist primarily of cereals and roots with little or no animal source foods (ASFs)[13], an important source of energy, macro-, and micronutrients. The 2008 National Demographic and Health Survey reported that 35% of children 6–23 mo of age consumed no ASFs in the 24 h preceding the survey (3). When children do consume ASFs, it is usually in small quantities. Harding and colleagues (4) reported that rural preschool children in the middle-belt region of Ghana consumed a mean of 30 g/d of ASFs,

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[13]Abbreviations used: ASF, animal source food; BAZ, BMI-for-age *z* score; CG, comparison group; ENAM, Enhancing Child Nutrition through Animal Source Food Management; HAZ, height-for-age *z* score; IG, intervention group; IGA, income-generation activity; WAZ, weight-for-age *z* score.

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primarily as fish. In some settings, the amount of ASFs can be miniscule; preschool lunches in one community in rural Ghana provided only 1.5 g of fish powder per child per day (5). Low availability, accessibility, and knowledge of the importance of ASFs are major contributing factors to a lack of intake among many communities (6, 7). Consistent with these dietary reports are stunting and wasting prevalence rates among Ghanaian children <5 y of age that remain high at 28% and 9%, respectively (3).

An inverse relation between animal source food (ASF) intake and risk of stunting was reported in a nationally representative sample of Cambodian children <5 y of age (8). Similarly, some growth benefits of ASFs were reported by a trial among Kenyan school-aged children who were randomly assigned to the control group or to receive a snack of githeri (a maize, beans, and greens dish) enriched with up to 80-g minced meat, 250-mL milk, or an equivalent energy supplement (9). After 3 mo, the meat and milk groups had significant increases in vitamin B-12, vitamin A, and calcium intakes than the control group; the milk group also had an increase in riboflavin intake, whereas the meat group had increased available iron, zinc, and energy intakes. All 3 supplemented groups had higher weight gain than the control group over the 2-y study (10). In addition, the meat group doubled the rate of increase of midupper arm muscle area (an indicator for lean body mass); younger and stunted children in the milk group had the highest rate of height gain. In this setting, ASFs contributed to the difference in growth in these children who normally had an inadequate quantity and quality of diet.

Maternal nutrition knowledge (11) and socioeconomic status (12) were also positively associated with child nutritional status; however, a review of interventions that have addressed these factors separately demonstrated inconsistent results (13). Nutrition education that emphasized ASFs was effective at improving child nutritional status among households that could afford these products (14). However, in Lesotho, increased maternal nutrition knowledge was positively associated with child nutritional status only among wealthier households (15). Interventions aimed at improving the diet and nutritional status of young children may need to simultaneously increase caregivers' nutrition knowledge and their financial capacity to purchase nutritious foods.

Integrated interventions involving microcredit and nutrition education may improve women's income, control over household resources, and nutrition knowledge, thereby indirectly improving children's diet and their nutritional status (16, 17). However, Freedom from Hunger's evaluations on the impact on child nutritional status of their Credit with Education integrated programs targeted toward women in Bolivia and Ghana were mixed (17).

The Enhancing Child Nutrition through Animal Source Food Management (ENAM) Study tested an entrepreneurial and nutrition education intervention with microcredit to increase consumption of ASFs and improve the diet and nutritional status of children 2–5 y of age. This article presents the effect of the integrated intervention on children's growth. It was hypothesized that children of caregivers who received the integrated intervention would show improved indicators of nutritional status than children whose caregivers did not receive the intervention.

Methods

The intervention and data collection methods have been described in detail elsewhere (18). They are summarized here.

Study sites. Two communities within each of 3 agro-ecologic zones (Coastal Savannah, Savannah-Forest Transitional, and Guinea Savannah) were chosen based on ASF availability and use representative of the zone, presence of livestock activities, and logistic accessibility of the communities. These 6 communities were assigned to be intervention sites. A nearby community with similar economic status and principal livelihoods was selected as a matched comparison for each intervention community, giving a total of 12 study communities.

Study design and sample selection. This study used a quasi-experimental longitudinal design to follow caregivers and their 2–5-y-old children for ~16 mo. A caregiver was defined as the person who lived with and had primary responsibility (caring and feeding) for the child. Caregivers in the intervention communities self-selected to participate in the intervention group (IG) and received microcredit and education activities. Caregivers who lived in an intervention community but did not receive microcredit were considered as nonparticipants. These caregivers may have been exposed to the open-air educational meetings. Finally, the study enrolled a comparison group (CG) that included caregivers who lived in matched nearby communities but did not participate in any microcredit or educational activities. Both nonparticipants and comparison participants were selected from community census lists to match the distribution of household wealth ranking of intervention participants.

Intervention. A participatory process was first completed to develop a problem model for constraints on ASF availability, accessibility, and utilization in Ghana. An integrated intervention for caregivers with children 2–5 y of age was then developed that included support for viable income-generation activities (IGAs) (microcredit, technical training, and entrepreneurial education) and nutrition education. Eligible caregivers self-selected to form solidarity groups of 3–5 members, and all solidarity groups in a community joined together to form a credit and savings association. The study period included four 16-wk loan cycles with mandatory weekly meetings. A maximum loan of $50 was established for the first loan cycle, after which solidarity group members acted as loan appraisers and mutual guarantors, with appraisals based on meeting attendance, loan repayment, and savings.

The education was delivered weekly. Nutrition education (use of ASFs, diet diversity, feeding frequency, responsive feeding, and hygiene) was included in the first cycle. Entrepreneurial education (marketing, customer care, record keeping, costing, pricing, financial literacy) was included in the second cycle. During cycles 3 and 4, nutrition and entrepreneurial education sessions alternated on a weekly basis. Additional activities, such as food demonstrations, also took place throughout the study to reinforce the educational messages.

Data collection. Data were collected for baseline between April and July 2006. A second wave of enrollment occurred during the first follow-up survey because 45 additional women requested to join the intervention (24 nonparticipant and 26 comparison women were added for comparison). Follow-up data were collected at 4 time points (3 for the second wave of enrollment) approximately every 4 mo, through December 2007.

A household was defined as a group of people who ate together from the same pot on a regular basis, and its head was defined as the person who made the major decisions. Household information included type of living arrangement, age, education, and occupation of members, and food consumption. Household wealth rank was determined by peers within each community, as has been described elsewhere (18). Household food security was measured with a 10-item pretested tool that was adapted from the USDA Household Food Security Core Module to emphasize ASF consumption as the indicator of diet quality (19). Caregiver information included age, education, occupation, relationship to household members, place of origin, ethnicity, marital status and living arrangement, weekly income, and weekly food expenditures.

Child weight was measured with a digital scale (model BWB-800; Tanita Corp.) to the nearest 0.1 kg and height was measured with a vertical stadiometer (Shorr Board; Irwin Shorr) to the nearest 1 mm. All measurements were taken in duplicate by the same trained staff at each time point using standard methodology (20); the mean value was used.

Frequency of children's ASF consumption in the past week was obtained using a list of 10 ASF categories [livestock meats, organ meats and offal, bush meats (wild game), whole fish, fish powder, shellfish, snails, poultry, eggs, and milk and milk products].

Statistical analysis. Weight-for-age z score (WAZ), height-for-age z score (HAZ), and BMI-for-age z score (BAZ) were computed with use of WHO Anthro (version 3.2.2; 2011) for children ≤60 mo of age and WHO AnthroPlus (version 2007) for children >60 mo of age. Weight-for-height z score was not included in this analysis because a number of children were >60 mo of age at the last visit. Height, weight, and their corresponding indices were checked for outliers and inconsistencies over time; questionable data points were verified with the original data forms and any data entry errors were corrected. No biologically implausible values were found according to WHO Anthro cutoffs; a few data points [18 out of 2461 weights (<1%) and 21 out of 2458 heights (<1%)] were dropped out of the final data set because *1*) the change in WAZ or HAZ between 2 follow-up points was >3 SDs, or *2*) it was obvious from the longitudinal pattern of growth for both weight and height data that a different child had been measured by mistake.

A child ASF diversity score was created by summing all the ASF categories consumed at least once in the past week (range: 0–10) (21). In addition, an ASF frequency score was calculated based on the sum of the frequency (0, 1, 2–4, 5–7, ≥8/wk) that each of the 10 ASF categories were consumed in the last week, with the lowest number in each range used in the final score (range: 0–80). Positive responses to the 8 dichotomous food security questions were summed to give a total food security score that was used to categorize households as food secure (0 positive responses), mild food insecurity (1–3 positive responses), moderate food insecurity (4–6 positive responses), or severe food insecurity (7–8 positive responses) (22).

Bivariate tests between anthropometric outcomes of interest and explanatory variables were performed with use of an independent Student's t test, ANOVA, or Kruskal-Wallis nonparametric test for continuous variables, and Pearson's chi-square or Fisher's exact test for categorical variables. Repeated measures general linear mixed models were created with use of SAS statistical software (version 9.3; PROC MIXED) to examine anthropometric indicator outcomes (WAZ, HAZ, BAZ) at each of the 5 data collection time points [baseline (time point 1) and follow-ups 1 through 4: follow-up 1 = time point 2, ~4 mo after baseline; follow-up 2 = time point 3, ~8 mo after baseline; follow-up 3 = time point 4, ~12 mo after baseline; follow-up 4 = time point 5, ~16 mo after baseline] and measure the associations with time-varying and time-invariant variables. In this initial analysis, the data collection point variable ("time point") was used as a 5-level nominal categorical variable [with use of the CLASS statement to define the subgroup combinations with baseline (time point 1) as the reference level] and reflected both time and the educational activities that differed by cycle. Factors were included in the models if baseline comparisons showed them to be different between study groups, if $P < 0.25$ for the bivariate relation with the outcome, or if they were considered to be important to child growth based on previous research (e.g., household wealth and maternal education). All independent time-invariant variables were included as baseline values, and the household study number was included as a random effects variable, nested within these nonrepeated categorical variables in the models. Backward elimination was performed, and variables were kept in the models if $P < 0.10$. Time point, group, time point–by–group interaction, region of residence, household wealth rank, household head occupation, number of children <5 y of age with caregiver, child sex, and child age were included in all models. The interaction term (time point by group) tested the group difference in the pattern of change in growth indicators across the project period (23). Residuals and random effects were plotted to ensure normal distribution. Least square means or β coefficients and SEs were calculated for each variable, with Bonferroni's method of adjustment used to consider all meaningful pairwise comparisons between the least square means related to the intervention (i.e., group comparisons at each time point). Statistically significant results were accepted at $P < 0.05$ except for Bonferroni-adjusted pairwise comparisons for the interaction for which $P < 0.0033$ was used.

Next, to further examine the relation between time point and anthropometric indices, orthogonal contrasts were constructed to assess whether any of the models would be better fit with quadratic, cubic, and quartic terms (quartic would be equivalent to the above 5-level nominal categorical model) when time was used as an ordered categorical variable (1–5). For models where this was the case (WAZ and HAZ), a second general linear mixed model analysis was carried out (PROC MIXED with a RANDOM statement for participant). Backward elimination was performed and higher order interaction terms were kept if $P < 0.05$; all corresponding lower order interaction terms remained in the model. Predicted vs. observed values were plotted to evaluate the various models.

Finally, a third set of analyses assessed the robustness of the findings. Given the nonrandomized study design and the potential for bias because of unmeasured group differences, sensitivity analyses were carried out to examine the within-subject variation. Individual fixed effects general linear regression models (with use of PROC MIXED in SAS with household ID as a random variable) for HAZ, WAZ, and BAZ were run. All time-invariant covariates were dropped from the model, and cluster-robust SEs were calculated with use of group membership as cluster. Time point was included first as a categorical and then an ordinal variable, and interaction and higher order time terms were included to match the final models that were run in PROC MIXED. The final choice of models was consistent with both the mixed and fixed effects approaches.

The study was approved by the institutional review boards at the Noguchi Memorial Institute for Medical Research (University of Ghana, Legon), Iowa State University, and McGill University. Written informed consent was obtained from all participating caregivers and permission was granted by community chiefs and other local leaders during community entry.

Results

The study enrolled 179 households for the integrated intervention activities (IG, **Figure 1**). In addition, 142 households were enrolled as nonparticipating comparisons from the same villages (nonparticipant group) and 287 households as external comparisons from neighboring villages (CG).

Household and caregiver characteristics at baseline. Overall, 61% (n = 369) of households were considered of low wealth rank within their communities (**Table 1**). Almost all (91%, n = 555) of households reported having some level of food insecurity; the severity of food insecurity tended to be higher among the comparison households (P = 0.08). Households had an mean of 7 members with fewer than 2 children <5 y of age; almost half were extended families. The majority (70%, n = 428) of household heads were the caregiver's husband who worked primarily in farming, fishing, or animal rearing for sale. Almost half (48%, n = 292) of the household heads had some formal education.

Most caregivers (88%, n = 537) were the child's biological mother. There were a few group differences among caregivers (Table 1). Compared with the other groups, those in the nonparticipant group were more likely to be migrants from the north ($P < 0.001$), whereas the IG caregivers were more likely to be traders with higher weekly incomes ($P < 0.001$). One-third of all caregivers (33%, n = 164) reported having an ASF-related IGA at baseline.

Child characteristics at baseline. Study children in IG households were younger than those in nonparticipant or comparison households, and they had a higher baseline BAZ than CG children (Table 1). Overall, 13% of children were underweight, 28% stunted, and 2% thin. Child ASF diversity score (mean ± SD) was 4.8 ± 2.2 across all children. The only between-group differences in dietary patterns that reached

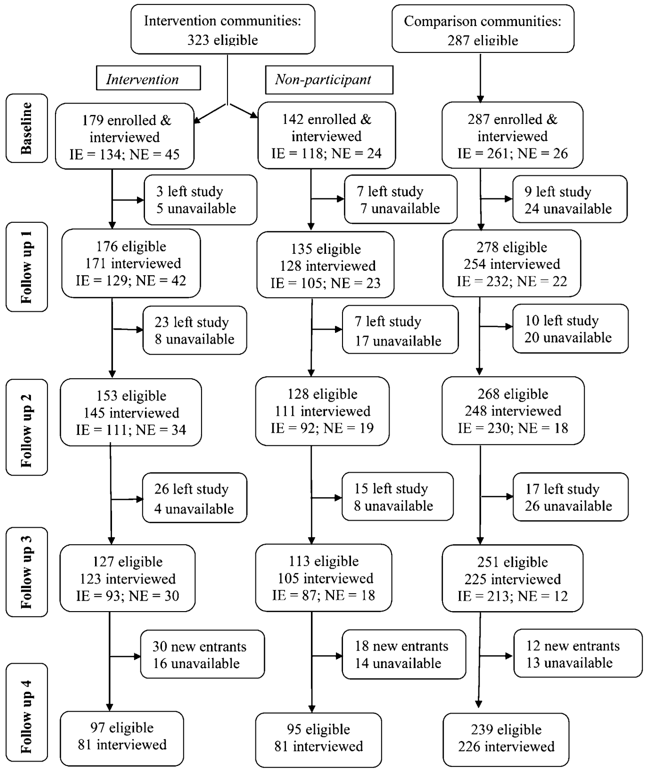

FIGURE 1 Participant flow chart for rural Ghanaian children in the IG, NP, and CG groups, from baseline through follow-up 4. CG, comparison; IG, intervention; IE, initial entrant; NE, new entrant; NP, nonparticipant; Unavailable, not found on that follow-up visit but remained in the study.

significance was for the ASF frequency score; the mean frequency among IG children was ~20% higher than CG children (<0.001). Fish was the most common ASF reported in all 3 agro-ecologic zones.

Group differences in anthropometric outcomes. Time point as a nominal categorical variable reflected both the concept of time and educational activities that were carried out in that cycle. In this first analysis, there was a statistically significant interaction between time point and IG for BAZ ($P = 0.02$), and tended toward significance for WAZ ($P = 0.09$), indicating the change in these outcomes differed over time points among study groups [**Table 2** as an ordered categorical variable (1–5)]. Meaningful pairwise comparisons between least square means ± SEs were found in both BAZ (difference of 0.36 ± 0.09 z score, $P < 0.0001$) and WAZ (difference of 0.32 ± 0.09 z score, $P < 0.001$) between children from IG households and those from CG households at the second follow-up time point (~8 mo after initiation of the intervention).

Using time point as an ordered variable to capture only the passage of time did not change the final model for BAZ. A quartic interaction term for time point × group was significant, demonstrating that the BAZ was best described by its unique 5 time point categories as described above; this model was kept as the final model for BAZ (**Figure 2**, **Table 3**). The WAZ model was improved by the inclusion of a quadratic term for time point and its corresponding interaction term with group ($P < 0.05$). The group difference was significant between 4 and 16 mo ($P = 0.01$ for interaction) and peaked at 8–12 mo (with least square means differences of 0.28 z). In contrast, a linear equation with the time point × group interaction was the best fit for HAZ ($P = 0.04$). In this model, HAZ among children in the IG was significantly higher than that of the CG, reaching a 0.19 z difference at 16 mo ($P < 0.05$).

Sensitivity analysis with fixed effects. When the fixed effects models were fitted, all previously noted relations remained significant, however, some of the group differences in children's anthropometric indicators were reduced (Table 3). Using time point as a nominal categorical variable for the BAZ fixed effects model, the IG had a BAZ that was significantly higher than that of the CG (CG) at 8 mo ($P < 0.001$). With a quadratic model and time point as an ordered categorical variable, WAZ in the IG was 0.25 z above the CG at 8 mo $\{[\text{intercept} + \beta(\text{time point}) \times 3 + \beta(\text{time point}^2) \times 9 + \beta(\text{time point} \times \text{intervention}) \times 3 + \beta(\text{time point}^2 \times \text{intervention}) \times 9] - [\text{intercept} + \beta(\text{time point}) \times 3 + \beta(\text{time point}^2) \times 9] = [-1.023 + (-0.007 \times 3) + (-0.001 \times 9) + (0.148 \times 3) + (-0.022 \times 9)] - [-1.023 + (-0.007 \times 3) + (-0.001 \times 9)]\}$ and was 0.24 z above the CG at 12 mo $\{[-1.023 + (-0.007 \times 4) + (-0.001 \times 16) + (0.148 \times 4) + (-0.022 \times 16)] - [-1.023 + (-0.007 \times 4) + (-0.001 \times 16)]\}$, interaction terms: $P < 0.05$. Finally, the linear model (with time point as an ordered categorical variable) for HAZ confirmed a significantly higher HAZ among the IG children than the CG, reaching a difference of 0.11 z $\{[\text{intercept} + \beta(\text{time point}) \times 5 + \beta(\text{time point} \times \text{intervention}) \times 5] - [\text{intercept} + \beta(\text{time point}) \times 5] = [-1.446 + (0.034 \times 5) + (0.022 \times 5)] - [-1.446 + (0.034 \times 5)]\}$ at the end of the study ($P = 0.03$).

Other associations. Other factors were associated with children's nutrition indicators in the initial model. Child age at baseline was negatively associated with BAZ and WAZ (β ± SE: −0.010 ± 0.003 and −0.009 ± 0.003; $P < 0.01$ for both). The number of children <5 y of age being cared for by the caregiver was negatively associated with HAZ (β ± SE: −0.222 ± 0.058; $P < 0.001$) and WAZ (β ± SE: −0.110 ± 0.046; $P = 0.02$). Boys had a higher BAZ than girls (least square mean: −0.14 ± 0.07 vs. −0.28 ± 0.07; $P = 0.03$) but lower HAZ (least square mean: −1.52 ± 0.09 vs. −1.24 ± 0.10; $P = 0.003$). Finally, living in the Savannah Forest Transitional compared to the Guinea Savannah zone was associated with a lower HAZ (least square mean: −1.53 ± 0.10 vs. −1.24 ± 0.11; $P = 0.03$).

Discussion

This study demonstrated that an integrated intervention approach that combined entrepreneurial and nutrition education with access to microcredit loans was positively associated with indictors of nutritional status among preschool-aged children living in rural poverty. The quasi-experimental design of the study limits our ability to make causal inferences. The caregivers self-selected to participate and despite efforts to choose a similar CG, there were differences between the study groups at baseline, including children's nutritional indicators. We assumed that the initial mixed models included those baseline child and household correlates that were needed to adequately address group differences to obtain unbiased estimates of nutritional indicators at each time point. The focus was not on whether the baseline value predicted change but whether the patterns across time points differed among the groups (23). The mixed model results were supported by the fixed effects sensitivity analyses that controlled for the same correlates but tested the within-subject variation (time point and time point × group interaction terms), eliminating concern about unmeasured between-group

TABLE 1 Baseline household, caregiver, and child characteristics in rural Ghana for intervention, nonparticipant, and comparison groups[1]

	Intervention group (n = 179)	Nonparticipant group (n = 142)	Comparison group (n = 287)	P^2
Household				
Low wealth ranking	55.3 (99)	62.7 (89)	63.1 (181)	0.51
Extended family	48.6 (87)	54.9 (78)	40.8 (117)	0.02
Family size, n	7.0 ± 2.9	6.9 ± 2.6	6.6 ± 2.7	0.18
Children <5 y of age in family, n	1.7 ± 1.0	1.6 ± 0.9	1.5 ± 0.9	0.08
Food security status				0.08
Food secure	8.5 (15)	11.7 (16)	7.8 (22)	—
Mild food insecurity	26.1 (46)	21.2 (29)	17.1 (48)	—
Moderate food insecurity	40.3 (71)	37.2 (51)	38.1 (107)	—
High food insecurity	25.0 (44)	29.9 (41)	37.0 (104)	—
Household head				
Primary occupation[3]				0.08
Farming/fishing/animal rearing	60.9 (109)	71.6 (101)	72.5 (208)	—
Trading/wage earning	33.0 (59)	24.1 (34)	24.4 (70)	—
Unemployed	6.2 (11)	4.3 (6)	3.1 (9)	—
Any formal education	50.3 (90)	38.7 (55)	51.2 (147)	0.03
Caregiver				
Age, y	32.9 ± 9.0	32.2 ± 8.8	33.2 ± 8.9	0.56
Any formal education	49.7 (89)	43.7 (62)	48.8 (140)	0.51
Migrant	53.1 (95)	68.3 (97)	47.0 (135)	<0.001
Ethnicity				<0.001
Akan	47.5 (85)	31.7 (45)	48.1 (138)	—
Northern ethnicity	50.3 (90)	65.5 (93)	45.0 (129)	—
Other	2.2 (4)	2.2 (4)	7.0 (20)	—
Marital status				0.16
Unmarried	13.4 (24)	16.9 (24)	10.5 (30)	—
Married (only wife)	70.4 (126)	66.9 (95)	69.9 (192)	—
Married (multiple wives)	16.2 (29)	16.2 (23)	22.6 (65)	—
Main occupation				<0.001
Farming/animal rearing for sale	21.2 (38)	35.2 (50)	64.2 (158)	—
Trading/earning salary	76.5 (137)	55.6 (79)	38.3 (110)	—
Unemployed	2.2 (4)	9.2 (13)	6.6 (19)	—
Total earnings/wk, GH¢	6.0 (0, 12.0)[a]	3.5 (0, 10.5)[b]	3.0 (0, 11.0)[b]	<0.001
Children <5 y supervised, n	1.0 (1.0, 5.0)[a]	1.0 (0[4], 6.0)[a,b]	1.0 (1.0, 5.0)[b]	0.04
Child				
Sex, F	43.0 (77)	54.2 (77)	49.1 (141)	0.13
Age, mo	38.8 ± 10.4[b]	43.1 ± 11.3[a]	43.6 ± 12.2[a]	<0.001
WAZ	−0.84 ± 0.96	−0.95 ± 0.97	−1.06 ± 0.97	0.05
HAZ	−1.32 ± 1.38	−1.34 ± 1.15	−1.43 ± 1.21	0.62
BAZ	0.02 ± 0.88[a]	−0.15 ± 1.06[a,b]	−0.21 ± 0.91[b]	0.04
Underweight (<−2 SD WAZ)	8.9 (16)	12.9 (18)	16.1 (46)	0.09
Stunted (<−2 SD HAZ)	27.9 (50)	29.8 (42)	27.4 (78)	0.87
Thinness (<−2 SD BAZ)	0.6 (1)	2.9 (4)	2.8 (8)	0.21
ASF diversity score[5]	5.1 ± 2.0[a]	4.6 ± 2.2[a]	4.7 ± 2.2[a]	0.04
ASF frequency score[6]	15.2 ± 7.1[a]	14.0 ± 7.7[a,b]	12.7 ± 7.0[b]	0.001

[1] Values are % (n), means ± SDs, or median (minimum, maximum). ASF, animal source food; BAZ, BMI-for-age z score; GH¢, Ghana New Cedi; HAZ, height-for-age z score; WAZ, weight-for-age z score.
[2] Chi-square test, ANOVA, or Kruskal-Wallis test was used to examine group differences. Labeled means in a row without a common letter differ significantly (a > b).
[3] n = 608 except for household head's occupation (n = 607); WAZ, HAZ, underweight, stunting (n = 605); and BAZ, thinness (n = 603).
[4] One child was >5.0 y of age at enrollment and had no younger siblings.
[5] Summative score for livestock meats, organ meats and offal, bush meats, whole fish, fish powder, shellfish, snails, poultry, eggs, and milk and milk products consumed the past week.
[6] Summative score of frequency for the ASFs consumed the past week.

differences that could bias estimates. Both analysis approaches produced similar, although not identical, results. There was a small, continual drop in mean WAZ in the CG, whereas the IG demonstrated an improvement midstudy (8–12 mo) with a decrease at the end. The largest group difference for BAZ was also at 8 mo in both analyses. This second follow-up time point corresponded to the months of January to March, the start of the hungry season. Although the severity of seasonal stress on

TABLE 2 Adjusted least square means for interaction term (group × time point) from the repeated measures general linear mixed models for height-for-age, weight-for-age, and BMI-for-age of rural Ghanaian children, by intervention, nonparticipant, and comparison groups[1]

	Intervention group	Nonparticipant group	Comparison group
HAZ			
Baseline	−1.41 ± 0.11	−1.41 ± 0.12	−1.53 ± 0.10
Follow-up 1	−1.43 ± 0.11	−1.44 ± 0.12	−1.57 ± 0.10
Follow-up 2	−1.32 ± 0.11	−1.29 ± 0.12	−1.45 ± 0.10
Follow-up 3	−1.24 ± 0.11	−1.28 ± 0.12	−1.45 ± 0.10
Follow-up 4	−1.22 ± 0.11	−1.21 ± 0.12	−1.41 ± 0.10
WAZ			
Baseline	−0.95 ± 0.09	−1.04 ± 0.10	−1.15 ± 0.08
Follow-up 1	−0.88 ± 0.09	−1.00 ± 0.10	−1.11 ± 0.09
Follow-up 2	−0.88 ± 0.09[2]	−1.00 ± 0.10	−1.20 ± 0.08
Follow-up 3	−0.90 ± 0.09	−1.03 ± 0.10	−1.15 ± 0.08
Follow-up 4	−0.95 ± 0.10	−1.10 ± 0.10	−1.20 ± 0.08
BAZ			
Baseline	−0.06 ± 0.08	−0.19 ± 0.09	−0.22 ± 0.07
Follow-up 1	0.08 ± 0.08	−0.10 ± 0.09	−0.14 ± 0.08
Follow-up 2	−0.03 ± 0.08[2]	−0.22 ± 0.09	−0.39 ± 0.08
Follow-up 3	−0.14 ± 0.09	−0.30 ± 0.10	−0.32 ± 0.08
Follow-up 4	−0.22 ± 0.09	−0.48 ± 0.10	−0.41 ± 0.08

[1] Values are means ± SEs; the model used a nominal categorical variable for time point. Five time points: HAZ (*n* = 605, 545, 491, 441, 376), WAZ (*n* = 605, 545, 493, 441, 377), and BAZ (*n* = 605, 545, 490, 440, 375). Adjusted for group, time point, zone, household wealth rank, household head occupation, child age and sex, and number of children <5 y of age with caregiver. BAZ, BMI-for-age *z* score; HAZ, height-for-age *z* score; WAZ, weight-for-age *z* score.
[2] Represents a significant pairwise difference from the comparison group, $P < 0.001$.

nutritional status decreased in Ghana in the last decades, it was still present (24). Our results suggested that families in the IG may have been more able than the CG to protect their children during the hungry season. The nonparticipant group fell in-between the groups, which may reflect their exposure to education but not loans.

Previous integrated economic and health interventions have demonstrated improvements in child nutrition indicators. In Bangladesh, women's involvement in the BRAC Rural Development Program included credit and savings, income generation, functional education, skill and human development training, promotion of safe water, sanitation, health, and nutrition education, and diverse health services (16). Over a 3-y period, the decrease in an indicator of severe malnutrition (midupper arm circumference <125 mm) among 1518 children 6–72 mo of age was >4-fold greater in the member households (23% to 14%) than nonmember households (23% to 21%) ($P < 0.01$). Length/height measurements were not reported. This large intervention effect may reflect the more severe nutritional situation of their participants, the wider range and duration of programs including basic health services, and the larger sample size compared to the ENAM Study.

The Freedom from Hunger Credit with Education program has demonstrated varying results (17). MkNelly and Watson (17) reported differences for both HAZ (0.5 *z* score) and WAZ (0.4 *z* score) change from baseline to endline between participant and comparison children 12–24 mo of age in Ghana but not among children 11–26 mo of age in Bolivia (*P* values not provided). The Bolivian intervention may not have shown a positive effect on child nutritional status because of *1*) incon-

TABLE 3 Comparison of the parameter estimates for intervention, nonparticipant, and comparison groups and time point in repeated measures mixed effects and fixed effect linear regression models for height-for-age, weight-for-age, and BMI-for-age of rural Ghanaian children[1]

	Mixed effects model			Fixed effects model		
Parameter	β	SE	*P* value	β	SE	*P* value
HAZ						
Intercept	−1.552	0.306	<0.0001	−1.446	0.048	<0.0001
Time point (*n*)	0.035	0.006	<0.0001	0.034	0.005	<0.0001
Intervention	0.092	0.114	0.42	—	—	—
Nonparticipant	0.094	0.121	0.44	—	—	—
Comparison	0	—	—	—	—	—
Time point × intervention	0.020	0.010	0.039	0.022	0.010	0.024
Time point × nonparticipant	0.020	0.010	0.053	0.020	0.010	0.049
Time point × comparison	0	—	—	0	—	—
WAZ						
Intercept	−0.893	0.242	0.0002	−1.023	0.045	<0.001
Time point (*n*)	0.001	0.029	0.99	−0.007	0.027	0.798
Time point^2 (*n*)	−0.002	0.005	0.62	−0.001	0.005	0.770
Intervention	0.089	0.106	0.40	—	—	—
Nonparticipant	0.019	0.113	0.87	—	—	—
Comparison	0	—	—	—	—	—
Time point × intervention	0.117	0.049	0.017	0.148	0.041	<0.001
Time point × nonparticipant	0.101	0.054	0.061	0.097	0.045	0.030
Time point × comparison	0	—	—	0	—	—
Time point^2 × intervention	−0.017	0.008	0.037	−0.022	0.007	0.002
Time point^2 × nonparticipant	−0.017	0.009	0.056	−0.017	0.007	0.031
Time point^2 × comparison	0	—	—	0	—	—
BAZ						
Intercept	0.086	0.221	0.70	−0.129	0.037	<0.001
Time point 5	−0.184	0.041	<0.0001	−0.202	0.038	<0.001
Time point 4	−0.094	0.041	0.021	−0.111	0.038	0.003
Time point 3	−0.164	0.039	<0.0001	−0.180	0.037	<0.001
Time point 2	0.084	0.035	0.015	0.066	0.036	0.066
Time point 1	0	—	—	—	—	—
Participant	0.161	0.087	0.065	—	—	—
Nonparticipant	0.030	0.092	0.79	—	—	—
Control	0	—	—	—	—	—
Time point 5 × intervention	0.022	0.075	0.77	0.064	0.069	0.353
Time point 5 × nonparticipant	−0.101	0.078	0.20	−0.104	0.071	0.142
Time point 5 × comparison	0	—	—	0	—	—
Time point 4 × intervention	0.019	0.068	0.77	0.066	0.061	0.283
Time point 4 × nonparticipant	−0.013	0.073	0.86	−0.003	0.066	0.970
Time point 4 × comparison	0	—	—	0	—	—
Time point 3 × intervention	0.198	0.063	0.002	0.242	0.058	<0.001
Time point 3 × nonparticipant	0.133	0.070	0.057	0.142	0.064	0.027
Time point 3 × comparison	0	—	—	0	—	—
Time point 2 × intervention	0.056	0.055	0.31	0.105	0.056	0.058
Time point 2 × nonparticipant	0.006	0.061	0.92	0.011	0.061	0.863
Time point 2 × comparison	0	—	—	0	—	—
Time point 1 × intervention	0	—	—	—	—	—
Time point 1 × nonparticipant	0	—	—	—	—	—
Time point 1 × comparison	0	—	—	—	—	—

[1] Repeated measures linear regression mixed models: HAZ (*n* = 2457), WAZ (*n* = 2460), and BAZ (*n* = 2452), also adjusted for zone, household wealth rank, household head occupation, child age and sex, and number of children <5 y of age with caregiver. Fixed effects linear regression models: HAZ (*n* = 2461), WAZ (*n* = 2464), and BAZ (*n* = 2456). Time point was used as an ordinal categorical variable for HAZ and WAZ and nominal categorical variable for BAZ. BAZ, BMI-for-age *z* score; HAZ, height-for-age *z* score; WAZ, weight-for-age *z* score.

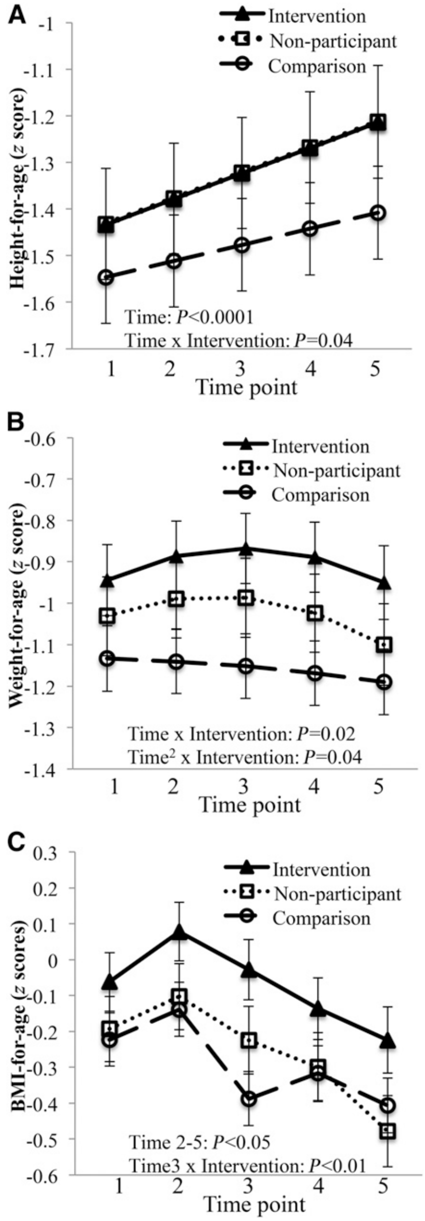

FIGURE 2 Rural Ghanaian children's anthropometric indicators at baseline (time point 1) and 4 follow-up time points (~4 mo apart), by study groups (IG, NP, and CG groups). Data shown are least square means and SEs from repeated measures linear regression mixed models adjusted for group, time point, region, household wealth, household head's primary occupation, number of children <5 y of age, and child sex and age for (A) HAZ (n = 605–377), (B) WAZ (n = 605–378), and (C) BAZ (n = 603–376). Time was used as an ordinal variable for HAZ and WAZ and a nominal categorical variable for BAZ. BAZ, BMI-for-age z score; CG, comparison group; HAZ, height-for-age z score; IG, intervention group; NP, nonparticipant; WAZ, weight-for-age z score.

sistent quality in the education intervention, *2*) the use of loan strategies that promoted better nutritional outcomes in the longer- rather than shorter-term, and *3*) use of household-run rather than woman-run enterprises, which may have limited caregivers' access to additional money for improving diet quality. The researchers categorized the quality of the education intervention as "worst," "average," and "best." There was a significant difference between the worst and average education groups for mean change in WAZ ($P < 0.05$). Improvement in the quality and consistency of the education component may have increased the effectiveness of the intervention.

The small differences found in HAZ in the present study may be explained by the short project duration and the older age of the children (>24 mo). The linear growth difference observed in the Freedom from Hunger trial in Ghana was among a younger age range of children (12–24 mo) and over a longer time period for the intervention (3 y) (17). The difference in these studies may be expected because interventions that target the first 1000 d have the greatest impact (2). However, attention is also needed for preschool-aged children who may fall between government programs for growth monitoring of infants and feeding programs for school-aged children. Recent studies show recuperation from stunting can occur at this age (25).

Contrary to previous literature (26), caregiver education was not associated with nutrition anthropometric indicators in this study. This may be due to the low level of education attainment that did not equate with adequate literacy. In addition, researchers have suggested that at least secondary education is needed to improve child nutrition (27). Besides formal education, practical nutrition knowledge is important to improving a child's nutritional status. Appoh and Krekling (11) compared 55 well-nourished and 55 undernourished Ghanaian children and found that maternal nutrition knowledge was associated with child nutritional status, whereas the limited maternal education was not, confirming our results.

Variation in the exposure and duration of education may have played a role in the present study. A randomized controlled trial conducted in Pucallpa, Peru, investigated the effect of incorporating a health intervention with monthly microcredit meetings over an 8-mo period (28). Although loan groups exposed to the intervention possessed greater knowledge about child health than those who were not exposed, no differences were found between groups for child health status or anthropometric indicators. The authors suggested that low intensity (monthly) and low quality of the educational sessions by loan officers may have decreased the intervention's effectiveness.

The ENAM intervention was delivered by experienced program leaders on a weekly basis, which has been shown to be more effective than monthly education sessions (29). The sessions included diverse topics that were reviewed over the cycles. However, individual attendance ranged from 60% to 86% (unpublished data) and only 60% of caregivers attended all 4 cycles. This would have affected the amount of information some caregivers obtained, how often the information was reinforced, and consequently, how well they were able to implement their entrepreneurial and dietary-related activities. Finally, the education sessions were delivered to microcredit groups rather than at the individual level and may not have addressed the specific needs of individual caregivers.

Study limitations. Although the power of the intervention by time point interaction term for the first mixed model analysis was reasonable for BAZ (0.89) and WAZ (0.79), it was low for HAZ (0.55), limiting our ability to detect any group difference in height in that analysis. Power at the end of the third and fourth cycles was reduced by loss-to-follow-up, decreasing our ability in this analysis to detect BAZ and WAZ differences at the end of the intervention. The loss-to-follow-up for the IG was primarily related to women who stopped receiving loans or who joined after the first cycle and therefore could only participate for a maximum of 4 cycles. For the other 2 groups, loss was primarily related to out-migration. The follow-up rates at 12 mo (third cycle) were 69% (IG), 83% (nonparticipant group), and 91% (CG). In contrast, the fixed effects model for BAZ (also a categorical model) had substantially smaller SEs than the mixed model and was able to detect group differences throughout the study. Finally, the large SDs for height-related outcomes most likely indicate inaccurate age assessments that would have decreased our power (20). Assessment of children's age was extremely challenging because child birth cards or health record booklets were often not available or were incomplete.

Conclusions. Publications from the ENAM Study demonstrating higher IGA profits, more ASF purchases, and more consumption of ASFs among children in the intervention groups than the CGs lend support to the interpretation that the anthropometric differences were related to the intervention itself (30). However, the observed group differences were modest. A 0.3–z score difference in WAZ for an average weight female child would be a little over 500 g, a difference consistent with other similar integrated interventions, including the Freedom from Hunger Study in Ghana (17). This is an indication of the complexity of undernutrition and the myriad of factors that must be considered when looking for effective solutions (31). This study suggests that integrated nutrition education interventions with microcredit may have modest benefits for the nutritional status of children 2–5 y of age. Future studies need to consider a longer intervention timeframe and address additional determinants of child undernutrition.

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