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Short-term weight gain among preschool children in rural Burkina Faso: a prospective study

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ABSTRACT

Objectives. Nutrition has profound effects on children's health outcomes and is linked to weight gain and cognitive development. We used data from a randomized controlled trial to evaluate the prospective associations between dietary, socioeconomic, and demographic factors and short-term weight gain during the lean season in a rural area of Burkina Faso.

Design. Prospective cohort data arising from a randomized controlled trial of the effect of antibiotic distribution on child growth and intestinal microbial diversity.

Setting. Two rural communities in Nouna District, Burkina Faso.

Participants. 248 children aged 6-59 months living in the study communities were enrolled in the study.

Primary and secondary outcome measures. Anthropometric measurements, including weight and height, were obtained at baseline and one month.

Results. Of 248 children enrolled in the trial, the median weight for wasted children at baseline (WHZ < -2) was 9.78 kg (IQR 8.65 to 10.8) and the weight of non-wasted children was 12.85 kg (IQR 10.9 to 14.75). Food security was significantly associated with decreased weight gain velocity (aOR -14.1 g/kg/day, 95% CI -27.5 to -0.65, *P*=0.04).

Conclusion. In this study, experiences of household food insecurity were associated with decreased weight gain in children in rural Burkina Faso during the lean season. Understanding the relationship between food insecurity and anthropometric outcomes may help to develop policies and health programs that address both of these issues.

Trial Registration. ClinicalTrials.gov NCT03187834

Key Words. nutritional status; food insecurity; Burkina Faso

Strengths and limitations of this study

- We used prospective data collected during the lean season in rural Burkina Faso to evaluate factors associated with weight gain in preschool children.
- Data were collected during the lean season in Burkina Faso, when children are at particularly high risk of malnutrition.
- Data were collected in a standardized fashion by trained anthropometrists.
- Limitations include the relatively small sample size and low prevalence of wasting, which may limit power particularly for analyses of factors associated with wasting.

BACKGROUND

Undernutrition is implicated in 50% of child deaths every year [1]. Nutrition has profound effects on health throughout the human life course and is inextricably linked to weight gain and cognitive development during early childhood [2]. In rural settings with insufficient resources, children are at greater risk of failing to reach their full growth and development potential [2]. Several cross-sectional studies have evaluated the underlying factors that contribute to malnutrition in an attempt to improve strategies to address the prevalence of child undernutrition, focusing primarily on nutrition-related determinants of growth. These studies identified several potential modifiable risk factors for undernutrition.

Dietary diversity is critical to ensure sufficient micronutrient intake [3]. Numerous studies have linked dietary diversity to nutritional status in children [4], finding that greater diversity is associated with a greater likelihood of meeting nutrient requirements and positive health outcomes [3]. In a study using data from 11 Health and Demographic surveys, dietary diversity was significantly associated with increased height-for-age Z-score (HAZ) in 7 countries [3], indicating that dietary diversity is important for a child's long-term nutritional status.

Food insecurity is associated with lower dietary diversity and poorer child health outcomes [5]. Food insecurity has a wide range of causes, including low socioeconomic status and seasonal variation in food availability [6]. In sub-Saharan Africa and particularly in rural, agrarian areas, the dependence on rainfall and the abundance of subsistence farming create seasonal variations in food availability [7]. In the Sahel region, many experience a "lean season" during seasonal rains, typically April to August. Conversely, these populations also experience a drier post-harvest season from January through March [7]. Seasonal variation in rainfall contributes to an increase in morbidity such as malaria, diarrhea, and upper and lower respiratory infections. These diseases can impact a child's nutritional status by increasing their nutritional needs and decreasing their appetite [7]. A study conducted in Burkina Faso found that the diversity of household diets was greater throughout all seasons with higher food expenditures, greater crop production and sale and with a household head educated at the post-secondary level [8].

Although multiple cross-sectional studies have evaluated the association between dietary diversity and sociodemographic factors and nutritional status, fewer studies have examined factors influencing weight gain in young children prospectively. Understanding underlying systemic contributors to child undernutrition may help the development of future interventions to increase weight gain during seasons with high food insecurity. Here, we used data from a randomized controlled trial to evaluate the prospective associations between dietary, socioeconomic, and demographic factors to evaluate short-term weight gain during the beginning of the lean season in a rural area of Burkina Faso.

METHODS

Study Setting

This study was conducted in the Nouna Health and Demographic Surveillance Site (HDSS) in the sub-Sahelian villages of Kamadena and Dara in rural northwestern Burkina Faso. The HDSS represents roughly one-quarter of the Nouna Health District in terms of surface and population, and the population is primarily made up of cattle keeps and subsistence farmers [9]. This study was conducted from July through August 2017, during the beginning of the rainy season in Burkina Faso, which lasts from July through October. The rainy season coincides with peak malaria and malnutrition in the Sahel and sub-Sahel. This study was reviewed and approved by the Committee on Human Research at the University of California, San Francisco and the Comité Institutionnel d'Ethique at the Centre de Recherche en Santé de Nouna (CRSN). The caregiver of each child enrolled in the study provided written informed consent.

Participants & Procedures

Data for the present analysis arose from a randomized controlled trial designed to assess the effect of commonly-used childhood antibiotics on the composition of the intestinal microbiome and anthropometry [10, 11]. Children ages 6-59 months in households with two to three children at the most recent HDSS census were eligible for participation. Households were excluded if one of the children was unable to participate in the baseline assessment, due to illness or absence. If the household had two or three children, they were all enrolled and anthropometric measures were taken. Children's caregivers completed assessments at the beginning of the study. All data was collected and managed in CommCare (Dimagi, Cambridge, MA, USA).

Anthropometric Assessment

Height, weight, and mid-upper-arm circumference (MUAC) measurements were assessed at baseline and at 35 days after enrollment. Children were weighed standing if able or in the arms of a caregiver, with heavy garments and jewelry removed. Recumbent length was measured in children < 24 months of age and standing height in children > 24 months of age (Seca 874 flat floor scale, Seca GMBH & Co.). Height and weight measurements were taken three times and the median for each measure was used for analysis. Weight-for-height (WHZ) and weight-for-age (WAZ) Z-scores were calculated based on 2006 World Health Organization Child Growth Standards [12]. Change in weight, defined as the mean difference, and weight gain velocity, defined as grams per kilogram per day (g/kg/day) were also calculated. Wasting was defined as WHZ and WAZ < -2 SD, respectively.

Predictors

Age and sex were extracted from the HDSS database. Dietary diversity, food insecurity status, breastfeeding status, health care facility visits, and animal and latrine ownership were assessed at baseline by asking caregivers in their local dialect a variety of questions for each topic. Dietary diversity was evaluated using a questionnaire that asked if the child had eaten a series of 11 food groups in the past 7 days, including grains (millet, rice, sorghum), vitamin-A abundant foods (carrots, sweet potatoes, squash), greens, mangoes/papayas, other fruits, vegetables, proteins (meat, poultry, or fish), eggs, legumes, dairy products (milk, yogurt, cheese, etc.), fats (coconut milk, butter, oil etc.), sugary beverages, fortified foods, and ready to eat supplementary or therapeutic foods [4, 13]. The answers were made into a composite dietary diversity score by summing the number of food groups reported for each child by the caregiver. The possible range was 0, for children who ate none of the food groups, to 11, for children who ate foods from every food group. For each household, caregivers reported on three questions regarding food insecurity, including the number of times in the past four weeks the caregiver worried about not having enough food in the household, if a member had gone to bed hungry in the past four weeks and if a member had to eat limited amount of food because lack of resource in the previous four weeks [4, 14]. Breastfeeding status was measured by asking caregivers if the child was breastfed and if so, if the child was exclusively breastfed. Caregivers reported on the number of poultry, goats/sheep, and cows that their household owned. The total number of animals was summed. Finally, each caregiver reported whether they had visited a health facility for their child in the past 30 days and on the sanitation installation most commonly used by their household, categorized as none (open defection), latrine with slab, or latrine without slab. Finally, the child's randomization arm was included as a covariate in all models.

Sample Size

The sample size calculation was based on the primary outcome of the trial, Simpson's α diversity. A sample size of 30 children per arm was estimated to provide at least 80% power to detect a 1.5-unit difference in Simpson's α diversity based on a previous study in Niger.[15]

Statistical Methods

All statistical analyses were performed in Stata 15.1 (StataCorp, College Station, TX, USA). Descriptive statistics were calculated with medians and interquartile ranges for continuous variables and proportions for categorical variables. To assess predictors of weight gain in the one-month period, a bivariate model was built for each anthropometric outcome (WHZ, change in weight in grams, wasting status at day 35, and g/kg/day) and each baseline predictor (including age, sex, dietary diversity score, food insecurity score, latrine ownership, animal ownership, healthcare facility use, and breastfeeding status). One model was built per outcome. Linear regression analyses were performed for the continuous outcomes and a logistic regression analysis was run for the dichotomous outcome. Multivariable models were then built for each anthropometric outcome with all candidate predictor variables, including child's sex, age, baseline WHZ, food insecurity, healthcare facility usage, dietary diversity score, breastfeeding status, animal ownership, and latrine ownership. Standard errors of all regression models were adjusted for clustering at the household level.

RESULTS

For the trial, 165 households were assessed for eligibility and 41 were excluded because two children were not present in the household. The remaining 124 households were eligible for inclusion and were enrolled in the study [11]. A total of 248 children were enrolled in the study and included in the analysis. Table 1 lists baseline descriptive statistics from the analysis. From the total number of children, 49.9% were female and the median age was 37 months (IQR 23 to 49). The median baseline weight for children with WHZ < -2 was 9.78 kg (IQR 8.65 to 10.8). This weight differed substantially from the baseline weight of non-wasted children, which was 12.85 kg (IQR 10.9 to 14.75). Wasted children had a median WHZ of -2.29 (IQR -2.43 to –2.2), compared to non-wasted children with a median WHZ of -0.18 (IQR -0.91 to 0.4). Approximately 50% of caregivers with wasted children reported that they visited a health care facility in the past 30 days. The median dietary diversity score was 6 for both groups, non-wasted (IQR 4 to 7) and wasted (IQR 5 to 7). Households with a wasted child owned a median of 24.5 animals (IQR 6 to 54) while the families of non-wasted children owned a median of 13 (6 to 28). More wasted children were breastfed (35.7%) compared to non-wasted children (21.1%).

From baseline to one month, 232 non-wasted children gained a median of 320 grams (IQR 50 to 600), and weight gain velocity was 0.71 g/kg/day (IQR 0.12 to 1.37). The median WHZ at one month after baseline was -0.21 SD (IQR -1.04 to 0.36), and 5.7% of children were wasted.

Table 2 lists a series of bivariate and multivariable models depicting the association between candidate predictor variables and WHZ and wasting status one month after baseline. The only significant predictor of WHZ at one month was baseline WHZ. For wasting status at one-month, dietary diversity was associated with increased odds of wasting (aOR 3.3 per one-unit increase in dietary diversity, 95% CI 1.5 to 7.4, *P*=0.004). Children who had visited the health facility in the past month had increased odds of wasting (aOR 70.2, 95% CI 3.3 to 1499.0, *P*=0.01), and children living in households owning greater numbers of animals had reduced odds of wasting (aOR 0.93 per one additional animal owned by the household, 95% CI -0.87 to 0.10, P=0.04). However, wasting at one month was relatively uncommon (5.7%) and confidence intervals were wide. There was a non-significant decrease in animal ownership (-0.92 SD per one-unit increase in food insecurity score [CI 95% -2.22 to 0.37], p=0.16). The association between breastfeeding and the child's WHZ score was also strong with each increase in breastfeeding associated with a decrease of the child's WHZ score by a factor of -0.48 grams (95% CI -0.79 to -0.18; p=0.002). Food insecurity was not significantly associated with WHZ or wasting one month after the baseline visit.

Table 3 lists bivariate and multivariable models for the association between candidate predictor variables and weight change and weight gain velocity during the one month period. In the multivariable model, children in households with higher food insecurity scores had decreased weight gain velocity (mean difference -0.04 g/kg/day per one-unit increase in food insecurity, 95% CI -0.07 to -0.01, *P*=0.01). Dietary diversity was not significantly associated with weight gain velocity (mean difference -0.06 g/kg/day for every one-unit increase in dietary diversity score, CI 95% (-0.14 to 0.01, *P*=0.11). A higher food insecurity score was also associated with reduced change in weight (mean difference -12.5 g per one-unit increase in food insecurity score, 95% CI -23.9 to -1.1, *P*=0.03).

DISCUSSION

The purpose of the present study was to assess socioeconomic and dietary predictors of a child's short-term weight gain in a sub-Sahelian region of Burkina Faso. Food insecurity was significantly associated with decreased weight gain velocity and change in weight. These findings suggest that children in households experiencing food insecurity are at higher risk of poor weight gain, which could result in malnutrition and lead to serious consequences for their physical and mental development [16]. These results are consistent with previous literature, which shows a negative association between higher food insecurity and lower dietary diversity and child's nutritional status [3, 9]. It is important to note that our study was conducted during the lean season in the sub-Sahel. These results could be explained by the lack of nutrient dense foods available during that time period. Previous studies indicate that during the lean season, staple dishes are more often bought ready-to-eat and usually contain fewer nutrients and raw ingredients in comparison to meals made during the Sahel's post-harvest season [17]. Based on the consistent dietary diversity score of 6 between the wasted and non-wasted groups of children, it is evident that the children's diets were not completely supplemented with all necessary micronutrients.

Although the prevalence of wasting was lower than expected at one month [18], a number of variables were associated with wasting. Dietary diversity was associated with increased odds of wasting, a finding that was inconsistent with previous literature. Parents of children with malnutrition may have sought out treatment for their child, and in turn increased the child's dietary diversity in response to their malnourished state. In a previous study looking at dietary diversity and nutritional status, there was no association between wasting and dietary diversity at the baseline visit [4]. There was a strong association between health facility visits and increased odds of wasting, which possibly supports the hypothesis that parents of malnourished children were more likely to seek healthcare for their child. As health care facilities have more resources to prevent adverse events, the visiting child may have had a lower likelihood of experiencing any illness that will inhibit their growth and health. It was also observed that animal ownership was associated with decreased odds of wasting. Households with greater resources may offset malnutrition during the lean season.

This study should be considered in the context of its limitations. First, the study collected data via caregiver report, which could be subject to misclassification and bias [4]. The study villages were larger than other communities in the HDSS and only households with two or more children were included in the trial [4]. Thus, the results from this study may not be applicable to children from smaller households or smaller communities. This study was conducted over a span of only 35 days. Although the focus was to evaluate short-term weight gain in children, a longer time period would may reflect more accurate weight change. Future studies could evaluate weight changes over an entire lean season to understand the total effect of the lean season on nutrition outcomes. These findings may not be generalizable outside of regions with similar seasonal variation in food availability. Children included in this analysis were participating in a trial of antibiotics on the intestinal microbiome. Antibiotics may disrupt the pediatric microbiome and affect weight gain outcomes.[15, 19] However, all predictors were measured at baseline prior to randomization and we do not anticipate that they were different across randomization arms, and treatment was included as a covariate in models. Given that antibiotic use in this study was higher than would be anticipated outside of a trial of antibiotics [20], generalizability may be limited in settings where antibiotic use is very low.

In this study, we demonstrated that experiences of household food insecurity are associated with decreased weight gain in children in rural Burkina Faso during the lean season.

Children are particularly vulnerable to adverse nutrition outcomes during this period, and this study suggests that interventions that address food insecurity may be effective for reducing the incidence of malnutrition during the lean season. Understanding the relationship between food insecurity and anthropometric outcomes is crucial to developing policies and health programs to address these issues. Given that the determinants of weight gain may differ in different seasons, it is important for these policies to consider the seasonal variation of crops in agrarian communities and target interventions during the months where childhood malnutrition is most prevalent.

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Conflicts of Interest. None to report.

Author Contributions. EGD: formulate research question, data analysis, writing the article. AS: formulating research question, designing study, implementation of study, critical review of article. LO: designing study, implementation of study, critical review of article. CD: designing study, implementation of study, critical review of article. CT: designing study, implementation of study, critical review of article. PZ: designing study, implementation of study, data analysis, critical review of article. TB: formulating research question, designing study, critical review of article. KSO: data analysis, critical review of article. EL: designing study, implementation of study, critical review of article. JDK: formulate research question, designing study, implementation of study, critical review of article. CEO: formulate research question, designing study, implementation of study, data analysis, writing article.

Table 1: Baseline descriptive statistics of the study (N=246)

	Not Wasted (MUAC or WHZ > -2) N= 232	Wasted (MUAC or WHZ < -2) N= 14	Overall
Age, months, median (IQR)	37.5 (25 to 50)	37 (23 to 46)	37 (23 to 49)
Female sex, N (%)	115 (49.6%)	7 (50.0%)	122 (49.6%)
Male sex, N (%)	117 (50.4%)	7 (50.0%)	124 (50.4%)
Weight, kg, median (IQR)	12.85 (10.9 to 14.75)	9.775 (8.65 to 10.8)	12.6 (10.75 to 14.6)
WHZ, median (IQR)	-0.18 (-0.91 to 0.4)	-2.29 (-2.43 to -2.2)	-0.21 (-1.04 to 0.36)
Number of times went to bed hungry due to not enough food, last 35 days, median (IQR)	0 (0 to 0)	0 (0 to 3)	0 (0 to 0)
Had limited food	50 (21.6%)	5 (35.7%)	55 (22.4%)
Went to bed hungry, last 35 days, N (%)	28 (12.1%)	2 (14.9%)	30 (12.2%)
Visited healthcare facility in past 30 days, N (%)	32 (14.2%)	7 (50.0%)	39 (16.3%)
Dietary diversity score, median (IQR)	6 (4 to 7)	6 (5 to 7)	6 (4 to 7)
Breastfeeding status, N (%)	49 (21.1%)	5 (35.7%)	54 (22.0%)
Number of animals owned by household, median (IQR)	13 (6 to 28)	24.5 (6 to 54)	13 (6 to 29.5)
Household latrine ownership, N (%)			
Bush	82 (35.3%)	3 (21.4%)	85 (34.6%)
Slab	70 (30.2%)	7 (50.0%)	77 (31.3%)
	80 (34.5%)	4 (28.5%)	84 (34.4%)

No Slab			
Change in weight, median (IQR)	350 (50 to 600)	185 (-50 to 500)	310 (50 to 600)
Grams per kilogram per day, median (IQR)	0.71 (0.12 to 1.36)	0.61 (-0.14 to 1.44)	0.70 (0.12 to 1.37)

Table 2: Weight for Height Z Score and Wasting Status at Day 35

	Weight for Height Z-score				Wasted at Day 35			
	Bivariate		Multivariable		Bivariate		Multivariable	
	Effect Size (95% CI)	P-value	Effect Size (95% CI)	P-value	OR (95% CI)	P-value	aOR (95% CI)	P-value
Age	0.011 (0.003 to 0.020)	0.01	0.004 (-0.005 to 0.012)	0.43	0.97 (0.93 to 1.01)	0.12	0.96 (0.87 to 1.1)	0.50
Sex	-0.17 (-0.43 to 0.10)	0.22	0.02 (-0.16 to 0.21)	0.80	0.98 (0.33 to 2.92)	0.98	0.27 (0.02 to 3.3)	0.31
Dietary diversity	0.02 (-0.053 to 0.098)	.56	0.02 (-0.038 to 0.07)	0.55	1.2 (0.99 to 1.55)	0.07	1.6 (0.92 to 2.8)	.10
Food insecurity	-0.02 (-0.041 to 0.01)	0.16	-0.01 (-0.021 to 0.009)	0.40	1.1 (0.98 to 1.13)	0.18	1.3 (1.1 to 1.5)	.01
Breastfeeding	-0.48 (-0.79 to -0.18)	.002	-0.06 (-0.36 to 0.24)	0.68	2.1 (0.66 to 6.53)	0.21	0.20 (0.01 to 3.6)	0.28
Health facility visit	-0.45 (-0.82 to -0.071)	0.02	-0.17 (-0.43 to 0.08)	0.18	6.1 (1.98 to 18.54)	0.002	2.9 (0.6 to 15.6)	0.21
WHZ, Baseline	0.62 (0.46 to 0.77)	<0.001	0.58 (0.42 to 0.74)	<0.001	0.08 (0.028 to 0.24)	<0.001	0.04 (0.01 to 0.12)	<0.001
Animals	-0.002 (-0.007 to 0.003)	0.39	-0.0007 (-0.003 to 0.002)	0.59	1.01 (1.00 to 1.02)	0.01	0.99 (0.95 to 1.04)	0.80
Latrine								
None								
No slab	0.032 (-.29 to 0.36)	0.85	-0.02 (-0.26 to 0.22)	0.87	1.4 (0.30 to 6.1)	0.68	1.5 (0.08 to 26.4)	0.79

Slab	0.15 (-0.17 to 0.48)	0.35	0.21 (-0.02 to 0.46)	0.08	2.7 (0.70 to 10.6)	0.15	11.7 (0.36 to 377.4)	0.17

Table 3: Change in Weight and Weight gain velocity (g/kg/day)

	Change in Weight				Weight gain velocity (g/kg/day)			
	Bivariate		Multivariable		Bivariate		Multivariable	
	Effect Size (95% CI)	P-value	Effect Size (95% CI)	P-value	OR (95% CI)	P-value	aOR (95% CI)	P-value
Age	2.4 (-5.30 to 10.11)	.52	-0.23 (-7.3 to 6.9)	.95	-0.005 (-0.024 to 0.013)	0.57	-0.009 (-0.03 to 0.01)	0.27
Sex	32.8 (-81.97 to 147.51)	0.54	1.8 (-119.2 to 122.8)	0.98	0.14 (-0.18 to 0.45)	0.39	0.01 (-0.33 to 0.35)	0.95
Dietary diversity	-12.7 (-44.93 to 19.58)	0.44	-20.6 (-55.7 to 14.5)	0.25	-0.06 (-0.13 to .021)	0.16	-0.06 (-0.14 to 0.01)	0.11
Food insecurity	-12.5 (-23.87 to -1.12)	0.03	-15.0 (-27.2 to -2.9)	0.02	-0.03 (-0.06 to -.005)	0.02	-0.04 (-0.07 to -0.01)	0.01
Breastfeeding	-157.1 (-454.15 to 139.99)	0.300	-294.3 (-658.7 to 70.1)	0.11	-0.06 (-0.79 to 0.68)	0.88	-0.62 (-1.5 to 0.23)	0.15
Health facility visit	-30.7 (-216.12 to 154.79)	0.74	-41.6 (-252.7 to 169.4)	.70	-0.04 (-0.49 to 0.41)	0.86	-0.15 (-0.64 to 0.35)	0.55
WHZ, Baseline	137.0 (-239.47 to -34.45)	0.01	-172.7 (-308.7 to -36.7)	0.01	-0.44 (-0.71 to -.16)	0.002	-0.50 (-0.87 to -0.14)	0.01
Animals	-0.92 (-2.22 to 0.37)	0.16	-1.6 (-3.1 to -0.13)	0.03	-0.002 (-0.006 to .001)	0.19	-0.004 (-0.01 to .0002)	0.06

Latrine								
None								
No slab	-22.5 (-189.5 to 144.5)	0.80	72.5 (-108.3 to 253.3)	0.43	-0.10 (-0.54 to .34)	0.65	0.10 (-0.31 to 0.52)	0.62
Slab	65.5 (-74.4 to 205.4)	0.36	124.5 (-31.3 to 280.3)	0.12	0.07 (-0.32 to .45)	0.74	0.16 (-0.21 to 0.53)	0.39

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STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	6
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	n/a
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7
Bias	9	Describe any efforts to address potential sources of bias	8
Study size	10	Explain how the study size was arrived at	8
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	n/a
		(*c*) Explain how missing data were addressed	n/a
		(*d*) If applicable, explain how loss to follow-up was addressed	n/a
		(*e*) Describe any sensitivity analyses	n/a
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	8-9
		(b) Give reasons for non-participation at each stage	8-9
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8-9
		(b) Indicate number of participants with missing data for each variable of interest	n/a
		(c) Summarise follow-up time (eg, average and total amount)	8-9
Outcome data	15*	Report numbers of outcome events or summary measures over time	9
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	9
		(*b*) Report category boundaries when continuous variables were categorized	n/a
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	n/a
Discussion			
Key results	18	Summarise key results with reference to study objectives	10-11
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11-12
Generalisability	21	Discuss the generalisability (external validity) of the study results	12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	13

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Short-term weight gain among preschool children in rural Burkina Faso: a secondary analysis of a randomized controlled trial

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Keywords:	nutritional status, food insecurity, Burkina Faso, Nutrition < TROPICAL MEDICINE

Short-term weight gain among preschool children in rural Burkina Faso: a secondary analysis of a randomized controlled trial

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ABSTRACT

Objectives. Nutrition has profound effects on children's health outcomes and is linked to weight gain and cognitive development. We used data from a randomized controlled trial to evaluate the prospective associations between dietary, socioeconomic, and demographic factors and short-term weight gain during the lean season in a rural area of Burkina Faso.

Design. Prospective cohort data arising from a randomized controlled trial of the effect of antibiotic distribution on child growth and intestinal microbial diversity.

Setting. Two rural communities in Nouna District, Burkina Faso.

Participants. 246 children aged 6-59 months living in the study communities were enrolled in the study.

Primary and secondary outcome measures. Anthropometric measurements, including weight and height, were obtained at baseline and one month.

Results. Of 246 children, the median weight for wasted children at baseline (WHZ < -2) was 9.78 kg (IQR 8.65 to 10.8) and the weight of non-wasted children was 12.85 kg (IQR 10.9 to 14.75). Food insecurity was significantly associated with decreased weight gain velocity (mean difference -0.03 g/kg/day, 95% CI -0.06 to -0.006, *P*=0.04).

Conclusion. Experiences of household food insecurity before the beginning of the lean season were associated with decreased weight gain in children in rural Burkina Faso during the lean season, although the mean difference was small. Understanding the relationship between timing of food insecurity and anthropometric outcomes may help to develop policies and health programs that address both of these issues.

Trial Registration. ClinicalTrials.gov NCT03187834

Key Words. nutritional status; food insecurity; Burkina Faso

Strengths and limitations of this study

- We used prospective data collected during the lean season in rural Burkina Faso to evaluate factors associated with weight gain in preschool children.
- Data were collected during the lean season in Burkina Faso, when children are at particularly high risk of malnutrition.
- Data were collected in a standardized fashion by trained anthropometrists.
- Limitations include the relatively small sample size and low prevalence of wasting, which may limit power particularly for analyses of factors associated with wasting.

BACKGROUND

Undernutrition is implicated in 50% of child deaths every year [1]. Nutrition has profound effects on health throughout the human life course and is inextricably linked to weight gain and cognitive development during early childhood [2]. In rural settings with insufficient resources, children are at greater risk of failing to reach their full growth and development potential [2]. Several cross-sectional studies have evaluated the underlying factors that contribute to malnutrition in an attempt to improve strategies to address the prevalence of child undernutrition, focusing primarily on nutrition-related determinants of growth. These studies identified several potential modifiable risk factors for undernutrition.

Dietary diversity is critical to ensure sufficient micronutrient intake [3]. Numerous studies have linked dietary diversity to nutritional status in children [4], finding that greater diversity is associated with a greater likelihood of meeting nutrient requirements and positive health outcomes [3]. In a study using data from 11 Health and Demographic surveys, dietary diversity was significantly associated with increased height-for-age Z-score (HAZ) in 7 countries [3], indicating that dietary diversity is important for a child's long-term nutritional status.

Food insecurity is associated with lower dietary diversity and poorer child health outcomes [5]. Food insecurity has a wide range of causes, including low socioeconomic status and seasonal variation in food availability [6]. In sub-Saharan Africa and particularly in rural, agrarian areas, the dependence on rainfall and the abundance of subsistence farming create seasonal variations in food availability [7]. In the Sahel region, many experience a "lean season" during seasonal rains, typically April to August. Conversely, these populations also experience a drier post-harvest season from January through March [7]. Seasonal variation in rainfall contributes to an increase in morbidity such as malaria, diarrhea, and upper and lower respiratory infections. These diseases can impact a child's nutritional status by increasing their nutritional needs and decreasing their appetite [7]. A study conducted in Burkina Faso found that the diversity of household diets was greater throughout all seasons with higher food expenditures, greater crop production and sale and with a household head educated at the post-secondary level [8].

Although multiple cross-sectional studies have evaluated the association between dietary diversity and sociodemographic factors and nutritional status, fewer studies have examined factors influencing weight gain in young children prospectively. Cross-sectional studies are limited by inability to determine temporality, and potential predictors may be influenced by outcomes of interest. Here, we used data from a randomized controlled trial to evaluate the prospective associations between dietary, socioeconomic, and demographic factors to identify possible modifiable risk factors for short-term weight gain during the beginning of the lean season in a rural area of Burkina Faso.

METHODS

Study Setting

This study was conducted in the Nouna Health and Demographic Surveillance Site (HDSS) in the sub-Sahelian villages of Kamadena and Dara in rural northwestern Burkina Faso. The HDSS represents roughly one-quarter of the Nouna Health District in terms of surface and population, and the population is primarily made up of cattle keeps and subsistence farmers [9]. This study was conducted from July through August 2017, during the beginning of the rainy season in Burkina Faso, which lasts from July through October. The rainy season coincides with peak malaria and malnutrition in the Sahel and sub-Sahel. This study was reviewed and approved by the Committee on Human Research at the University of California, San Francisco (Protocol 17-22036) and the Comité Institutionnel d'Ethique at the Centre de Recherche en Santé de Nouna (CRSN; Protocol 2017-05-/CIE/CRSN). The caregiver of each child enrolled in the study provided written informed consent.

Participants & Procedures

Data for the present analysis arose from a randomized controlled trial designed to assess the effect of commonly-used childhood antibiotics on the composition of the intestinal microbiome and anthropometry [10, 11]. In the parent trial, children ages 6-59 months in households with two to three children at the most recent HDSS census were eligible for participation. Households were excluded if one of the children was unable to participate in the baseline assessment, due to illness or absence. If the household had two or three children, they were all enrolled and anthropometric measures were taken. Children's caregivers completed assessments at the beginning of the study. After the baseline assessment, children were randomized in a 1:1:1:1 fashion to a 5-day course of placebo, amoxicillin, azithromycin, or cotrimoxazole [10]. All treatments were directly observed by study staff and administered as pediatric oral suspension. Children were followed for 35 days from enrollment for anthropometric outcomes [11]. All data was collected and managed in CommCare (Dimagi, Cambridge, MA, USA).

Anthropometric Assessment

Height, weight, and mid-upper-arm circumference (MUAC) measurements were assessed at baseline and at 35 days after enrollment. Children were weighed standing if able or in the arms of a caregiver, with heavy garments and jewelry removed. Recumbent length was measured in children < 24 months of age and standing height in children > 24 months of age (Seca 874 flat floor scale, Seca GMBH & Co.). Height and weight measurements were taken three times and the median for each measure was used for analysis. The median of the three measurements was used to avoid undue influence of outlying or implausible values. MUAC was measured a single time. Weight-for-height (WHZ) and weight-for-age (WAZ) Z-scores were calculated based on 2006 World Health Organization Child Growth Standards [12]. Change in weight, defined as the mean difference, and weight gain velocity, defined as grams per kilogram per day (g/kg/day) were also calculated. Wasting and underweight were defined as WHZ and WAZ < -2 SD, respectively.

Predictors

Age and sex were extracted from the HDSS database. Dietary diversity, food insecurity status, breastfeeding status, health care facility visits, and animal and latrine ownership were assessed at baseline by asking caregivers in their local dialect a variety of questions for each topic. Breastfeeding status was determined by asking the caregiver if the child was currently breastfeeding, and if so if the child was exclusively breastfeeding. Dietary diversity was evaluated using a questionnaire that asked if the child had eaten a series of 11 food groups in the past 7 days, including grains (millet, rice, sorghum), vitamin-A abundant foods (carrots, sweet potatoes, squash), greens, mangoes/papayas, other fruits, vegetables, proteins (meat, poultry, or fish), eggs, legumes, dairy products (milk, yogurt, cheese, etc.), fats (coconut milk, butter, oil etc.), sugary beverages, fortified foods, and ready to eat supplementary or therapeutic foods [4, 13]. The answers were made into a composite dietary diversity score by categorizing the food groups into 7 unique food groups, including starch, vitamin A-rich foods, other fruits and vegetables, animal protein (e.g., meat, eggs, poultry, fish), legumes, dairy, and fat (e.g., oil, butter, other fat).[3] We then summed the number of food groups reported for each child by the caregiver. The possible range was 0, for children who ate none of the food groups, to 11, for children who ate foods from every food group. For each household, caregivers reported on three questions regarding food insecurity, including the number of times in the past four weeks the caregiver worried about not having enough food in the household, if a member had gone to bed hungry in the past four weeks and if a member had to eat limited amount of food because lack of resource in the previous four weeks [4, 14]. Breastfeeding status was measured by asking caregivers if the child was breastfed and if so, if the child was exclusively breastfed. Caregivers reported on the number of poultry, goats/sheep, and cows that their household owned. The total number of animals was summed. Finally, each caregiver reported whether they had visited a health facility for their child in the past 30 days and on the sanitation installation most commonly used by their household, categorized as none (open defection), latrine with slab, or latrine without slab. Finally, the child's randomization arm was included as a covariate in all models.

Sample Size

The sample size calculation was based on the primary outcome of the trial, Simpson's α diversity. A sample size of 30 children per arm was estimated to provide at least 80% power to detect a 1.5-unit difference in Simpson's α diversity based on a previous study in Niger.[15]

Statistical Methods

Descriptive statistics were calculated with medians and interquartile ranges for continuous variables and proportions for categorical variables. To assess predictors of weight gain in the one-month period, a bivariate model was built for each anthropometric outcome (WHZ, WAZ, change in weight in grams, wasting and underweight status at day 35, and g/kg/day) and each baseline predictor (including age, sex, dietary diversity score, food insecurity score, latrine ownership, animal ownership, healthcare facility use, and breastfeeding status). One model was built per outcome. Linear regression analyses were performed for the continuous outcomes and a logistic regression analysis was run for the dichotomous outcome. Multivariable models were then built for each anthropometric outcome with all candidate predictor variables, including child's sex, age, baseline WHZ, food insecurity, healthcare facility usage, dietary diversity score, breastfeeding status, animal ownership, and latrine ownership. Standard errors of all regression models were adjusted for clustering at the household level. Children with implausible weight changes between baseline and one-month measurements (gained or lost more than 2 kg) were assumed to be data entry errors (for example, the wrong child was measured), and were excluded from analyses. All analyses were performed in Stata 15.1 (StataCorp, College Station, TX, USA).

Patient and Public Involvement

This study recruited a population-based sample of the general population, and thus no patients were involved in the study. Leaders of the study communities were involved in informing residents about the study, recruiting children and families to participate, and facilitating follow-up visits.

RESULTS

For the trial, 165 households were assessed for eligibility and 41 were excluded because two children were not present in the household. The remaining 124 households were eligible for inclusion and were enrolled in the study [11]. A total of 248 children were enrolled in the study, of whom 233 had eligible anthropometric measurements at baseline and four weeks after treatment. Table 1 lists baseline descriptive statistics from the analysis. From the total number of children, 49.6% were female and the median age was 37 months (IQR 23 to 49). The mean baseline weight for children with WHZ < -2 was 9.7 kg (SD 1.3) compared to non-wasted 12.8 kg (SD 2.8) in non-wasted children. Approximately 50% of caregivers with wasted children reported that they visited a health care facility in the past 30 days. The median dietary diversity score was 6 for both groups, non-wasted (IQR 4 to 7) and wasted (IQR 5 to 7). Households with a wasted child owned a median of 24.5 animals (IQR 6 to 54) while the families of non-wasted children owned a median of 13 (6 to 28). More wasted children were breastfed (35.7%) compared to non-wasted children (21.1%).

From baseline to one month, 219 non-wasted children gained a mean of 334 grams (SD 485), and weight gain velocity was 0.82 g/kg/day (SD 1.2). The median WHZ at one month after baseline was -0.37 SD (SD 0.98), and 6.0% of children were wasted. Caregivers of five children reported that their child received antibiotics outside of the study treatment during the course of the study.

Table 2 lists a series of bivariate and multivariable models depicting the association between candidate predictor variables and WHZ and wasting status one month after baseline. The only significant predictor of WHZ at one month was baseline WHZ. In a bivariate model, children who had visited the health facility in the past month had increased odds of wasting (aOR

5.66, 95% CI 1.85 to 17.3, *P*=0.001), and children living in households owning greater numbers of animals had increased odds of wasting (aOR 1.01 per one additional animal owned by the household, 95% CI 1.00 to 1.02, P=0.005). However, wasting at one month was relatively uncommon and confidence intervals were wide, and animal ownership was not significant in the multivariable models. There was a non-significant increase in risk of wasting in children living in households with higher levels of food insecurity (aOR 1.32, 95% CI 1.00 to 1.74, *P*=0.05). No other variables were statistically significantly associated with WHZ or wasting four weeks after baseline.

Table 3 lists bivariate and multivariable models for the association between candidate predictor variables and weight change and weight gain velocity during the one-month period. In the multivariable model, children in households with higher food insecurity scores had decreased weight gain velocity (mean difference -0.03 g/kg/day per one-unit increase in food insecurity, 95% CI -0.06 to -0.006, *P*=0.04). Dietary diversity was not significantly associated with weight gain velocity (mean difference -0.05 g/kg/day for every one-unit increase in dietary diversity score, CI 95% (-0.16 to 0.05, *P*=0.29). A higher food insecurity score was also associated with reduced change in weight (mean difference -12.2 g per one-unit increase in food insecurity score, 95% CI -24.3 to -0.03, *P*=0.049).

Table 4 lists bivariate and multivariable models for the association between candidate predictor variables and WAZ and underweight four weeks after baseline. Age was significantly associated with WAZ in the multivariable model (mean difference -0.005 SD per one-month increase in age, 95% CI -0.009 to -0.0008, *P*=0.02). No other candidate predictors were statistically significantly associated with WAZ or underweight.

DISCUSSION

The purpose of the present study was to assess socioeconomic and dietary predictors of a child's short-term weight gain in a sub-Sahelian region of Burkina Faso to identify potential modifiable risk factors at the beginning of the lean season that may lead to better nutritional outcomes for preschool children. Food insecurity was the only independent predictor significantly associated with decreased weight gain velocity and change in weight. Food insecurity was measured over the 30-day period prior to the baseline assessment, which happened at the beginning of the lean season. These findings suggest that children in households experiencing food insecurity before the lean season are at higher risk of poor weight gain, which could result in malnutrition and lead to serious consequences for their physical and cognitive development [16]. These results are consistent with previous literature, which shows a negative association between higher food insecurity and lower dietary diversity with a child's nutritional status [3, 9]. These results could be explained by the lack of nutrient dense foods available during and before the lean season, as food insecurity before the lean season is likely predictive of food insecurity during the lean season. Previous studies indicate that during the lean season, staple dishes are more often bought ready-to-eat and usually contain fewer nutrients and raw ingredients in comparison to meals made during the Sahel's post-harvest season [17]. The results of this study suggest that food insecurity, above and beyond other potential risk factors, is an important potentially modifiable risk factor for adverse nutritional outcomes. These findings underscore the importance of prioritizing policies related to improving food security in areas with seasonal malnutrition, as experiences of food insecurity immediately before the beginning of the lean season may predispose children to worse outcomes during the course of the lean season. Interventions addressing food insecurity prior to the lean season, not only during the lean season, may help improve outcomes for children during this vulnerable time.

The prevalence of wasting and underweight were lower than expected at one month [18], limiting statistical power to detect risk factors for both conditions. Children who had visited a health facility had increased odds of wasting and reduced WHZ at day 35, although this was not statistically significant in multivariable models. This is likely reflective of parents seeking care for malnourished children, and reduced weight gain was likely related to sick children gaining less weight.

This study should be considered in the context of its limitations. First, the study collected data via caregiver report, which could be subject to misclassification and bias [4]. The study villages were larger than other communities in the HDSS and only households with two or more children were included in the trial.[4] Thus, the results from this study may not be generalizable to children from smaller households or smaller communities. These findings also may not be generalizable outside of regions with similar seasonal variation in food availability. This study was conducted over a span of only 35 days. Although the focus was to evaluate short-term weight gain in children, a longer time period may reflect more accurate weight change, and longer-term data would be useful to understand modifiable risk factors for nutritional outcomes. Future studies could evaluate weight changes over an entire lean season to understand the total effect of the lean season on nutrition outcomes. Children included in this analysis were participating in a trial of antibiotics on the intestinal microbiome. Antibiotics may disrupt the pediatric microbiome and affect weight gain outcomes [15, 19]. However, all predictors were measured at baseline prior to randomization and we do not anticipate that they were different across randomization arms, and treatment arm was included as a covariate in models. Few children were given antibiotics outside of the study treatment during the course of the study. Such antibiotic use may be influenced by baseline characteristics and could potentially be a mediator of any effect of baseline characteristics on nutritional outcomes. Given that antibiotic use in this study area was higher than would be anticipated outside of a trial of antibiotics [20], generalizability may be limited in settings where antibiotic use is very low. Finally, the sample size of this study was limited. Larger prospective studies would have greater power to identify potential risk factors for low weight gain.

In this study, we demonstrated that experiences of household food insecurity prior to the lean season are associated with decreased weight gain in children in rural Burkina Faso during the lean season. Children are particularly vulnerable to adverse nutrition outcomes during this period, and this study suggests that interventions that address food insecurity may be effective for reducing the incidence of malnutrition during the lean season. Given that the determinants of weight gain may differ in different seasons, such policies should consider the seasonal variation of crops in agrarian communities and target interventions during the months prior to the vulnerable season when malnutrition may develop.

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Conflicts of Interest. None to report.

Author Contributions. EGD: formulate research question, data analysis, writing the article. AS: formulating research question, designing study, implementation of study, critical review of article. LO: designing study, implementation of study, critical review of article. CD: designing study, implementation of study, critical review of article. CT: designing study, implementation of study, critical review of article. PZ: designing study, implementation of study, data analysis, critical review of article. TB: formulating research question, designing study, critical review of article. KSO: data analysis, critical review of article. EL: designing study, implementation of study, critical review of article. JDK: formulate research question, designing study, implementation of study, critical review of article. CEO: formulate research question, designing study, implementation of study, data analysis, writing article.

Data Availability. No additional data available.

Table 1: Baseline descriptive statistics of the study (N=246)

	Not Wasted (MUAC or WHZ > -2) N= 232	Wasted (MUAC or WHZ < -2) N= 14	Overall N=246
Age, months, median (IQR)	37.5 (25 to 50)	37 (23 to 46)	37 (23 to 49)
Female sex, N (%)	115 (49.6%)	7 (50.0%)	122 (49.6%)
Male sex, N (%)	117 (50.4%)	7 (50.0%)	124 (50.4%)
Weight, kg, mean (SD)	12.8 (2.8)	9.7 (1.3)	12.7 (2.8)
Height, cm, mean (SD)	90.9 (10.1)	85.3 (6.9)	90.6 (10.0)
WHZ, mean (SD)	-0.31 (1.09)	-2.3 (0.50)	-0.42 (1.16)
WAZ, mean (SD)	-0.85 (0.99)	-2.41 (0.80)	-0.94 (1.04)
HAZ, mean (SD)	-1.13 (1.48)	-1.56 (1.16)	-1.16 (1.46)
MUAC, mean (SD)	15.2 (1.10)	13.7 (0.72)	15.2 (1.14)
Number of times went to bed hungry due to not enough food, last 35 days, median (IQR)	0 (0 to 0)	0 (0 to 3)	0 (0 to 0)
Had limited food	50 (21.6%)	5 (35.7%)	55 (22.4%)
Went to bed hungry, last 35 days, N (%)	28 (12.1%)	2 (14.9%)	30 (12.2%)
Visited healthcare facility in past 30 days, N (%)	32 (14.2%)	7 (50.0%)	39 (16.3%)

Dietary diversity score, median (IQR)	6 (4 to 7)	6 (5 to 7)	6 (4 to 7)
Any breastfeeding, N (%)	49 (21.1%)	5 (35.7%)	54 (22.0%)
Number of animals owned by household, median (IQR)	13 (6 to 28)	24.5 (6 to 54)	13 (6 to 29.5)
Household latrine ownership, N (%)			
Bush	82 (35.3%)	3 (21.4%)	85 (34.6%)
Slab	70 (30.2%)	7 (50.0%)	77 (31.3%)
No Slab	80 (34.5%)	4 (28.5%)	84 (34.4%)
Change in weight, median (IQR)	350 (50 to 600)	185 (-50 to 500)	310 (50 to 600)
Grams per kilogram per day, median (IQR)	0.71 (0.12 to 1.36)	0.61 (-0.14 to 1.44)	0.70 (0.12 to 1.37)
Underweight at day 35, N (%)	14 (6.0%)	8 (57.1%)	22 (8.9%)

Table 2: Bivariate and multivariable models of weight-for-height Z-score and wasting at day 35

	Weight for Height Z-score				Wasted at Day 35			
	Bivariate		Multivariable		Bivariate		Multivariable	
	Effect Size (95% CI)	P-value	Effect Size (95% CI)	P-value	OR (95% CI)	P-value	aOR (95% CI)	P-value
Age	0.01 (0.001 to 0.02)	0.03	0.003 (-0.01 to 0.004)	0.45	0.97 (0.93 to 1.01)	0.12	0.99 (0.87 to 1.13)	0.90
Sex	-0.19 (-0.45 to 0.07)	0.14	0.03 (-0.10 to 0.16)	0.63	0.97 (0.33 to 2.89)	0.96	0.18 (0.001 to 28.4)	0.51
Dietary diversity[1]	0.005 (-0.09 to 0.10)	0.91	-0.03 (-0.07 to 0.02)	0.24	1.48 (1.00 to 2.18)	0.05	3.00 (0.69 to 13.1)	0.14
Food insecurity[2]	-0.02 (-0.04 to 0.009)	0.21	-0.01 (-0.02 to 0.003)	0.12	1.05 (0.97 to 1.12)	0.21	1.32 (1.00 to 1.74)	0.05
Breastfeeding	-0.43 (-0.74 to -0.13)	0.006	-0.06 (-0.31 to 0.19)	0.63	1.98 (0.63 to 6.23)	0.24	0.07 (0.003 to 1.34)	0.08
Health facility visit	-0.41 (-0.78 to 0.04)	0.03	-0.06 (-0.28 to 0.15)	0.55	5.66 (1.85 to 17.3)	0.001	10.2 (1.08 to 97.0)	0.04
WHZ, Baseline	0.68 (0.59 to 0.77)	<0.001	0.81 (0.72 to 0.89)	<0.001	0.16 (0.08 to 0.33)	<0.001	0.005 (0.0003 to 0.07)	<0.001
Animals	-0.003 (-0.008 to 0.002)	0.28	-0.002 (-0.004 to 0.0003)	0.09	1.01 (1.00 to 1.02)	0.005	0.98 (0.95 to 1.02)	0.41
Latrine								
None								
No slab	0.02 (-0.32 to 0.36)	0.91	0.01(-0.16 to 0.19)	0.89	1.37 (0.30 to 6.14)	0.68	2.05 (0.05 to 81.3)	0.70
Slab	0.012 (-0.20 to 0.44)	0.45	0.09 (-0.09 to 0.26)	0.35	2.73 (0.70 to 10.6)	0.15	16.1 (0.12 to 2220.7)	0.27

Abbreviations: CI, confidence interval; OR, odds ratio, WHZ, weight-for-height Z-score; [1]Operationalized as a composite score of 7 food groups eaten over the past 7 days; [2]Operationalized as a composite score of three questions related to frequency of food insecurity over the past four weeks.

Table 3: Bivariate and multivariable predictors of change in weight and weight gain velocity at day 35

	Change in Weight (grams)				Weight gain velocity (g/kg/day)			
	Bivariate		Multivariable		Bivariate		Multivariable	
	Effect Size (95% CI)	P-value	Effect Size (95% CI)	P-value	Effect Size (95% CI)	P-value	Effect Size (95% CI)	P-value
Age	-1.8 (-5.4 to 1.8)	0.33	-1.69 (-8.3 to 5.0)	0.62	-0.005 (-0.024 to 0.013)	0.57	-0.01 (-0.03 to 0.003)	0.12
Sex	12.8 (-100.3 to 125.8)	0.82	13.0 (-114.2 to 140.1)	0.84	0.14 (-0.18 to 0.45)	0.39	0.13 (-0.17 to 0.42)	0.39
Dietary diversity	-18.3 (-62.5 to 25.9)	0.42	-11.1 (-57.6 to 35.4)	0.64	-0.06 (-0.17 to 0.05)	0.29	-0.05 (-0.16 to 0.05)	0.29
Food insecurity	-11.8 (-23.1 to -0.57)	0.04	-12.2 (-24.3 to -0.03)	0.049	-0.03 (-0.06 to -0.005)	0.02	-0.03 (-0.06 to -0.006)	0.04
Breastfeeding	-6.46 (-123.4 to 110.4)	0.91	-133.8 (-329.2 to 61.6)	0.18	-0.06 (-0.79 to 0.68)	0.88	-0.28 (-0.80 to 0.25)	0.30
Health facility visit	-20.0 (-205.2 to 165.3)	0.83	-64.7 (-286.9 to 157.4)	0.57	-0.04 (-0.49 to 0.41)	0.86	-0.20 (-0.70 to 0.30)	0.44
WHZ	-82.3 (-139.2 to -25.5)	0.005	-125.4 (-212.5 to -38.4)	0.005	-0.44 (-0.71 to -0.16)	0.002	-0.37 (-0.60 to -0.15)	0.001
Animals	-0.77 (-2.02 to 0.49)	0.23	-1.45 (-2.9 to -0.002)	0.05	-0.002 (-0.006 to .001)	0.19	-0.003 (-0.007 to 0.0008)	0.12

Latrine								
None								
No slab	4.0 (-160.8 to 168.8)	0.96	42.0 (-132.6 to 216.7)	0.64	-0.10 (-0.54 to .34)	0.65	0.12 (-0.30 to 0.54)	0.56
Slab	92.0 (-45.3 to 229.3)	0.19	95.4 (-56.4 to 247.1)	0.22	0.07 (-0.32 to .45)	0.74	0.20 (-0.16 to 0.55)	0.27

Abbreviations: CI, confidence interval; OR, odds ratio, WHZ, weight-for-height Z-score; [1]Operationalized as a composite score of 7 food groups eaten over the past 7 days; [2]Operationalized as a composite score of three questions related to frequency of food insecurity over the past four weeks.

Table 4: Bivariate and multivariable predictors of weight-for-age Z-score and underweight at day 35

	Weight-for-Age Z-score				Underweight			
	Bivariate		Multivariable		Bivariate		Multivariable	
	Effect Size (95% CI)	P-value	Effect Size (95% CI)	P-value	OR (95% CI)	P-value	aOR (95% CI)	P-value
Age	-0.004 (-0.01 to 0.005)	0.38	-0.005 (-0.009 to -0.0008)	0.02	0.98 (0.94 to 1.01)	0.14	0.97 (0.93 to 1.02)	0.32
Sex	-0.12 (-0.38 to 0.14)	0.36	0.03 (-0.05 to 0.12)	0.44	0.88 (0.35 to 2.16)	0.77	0.93 (0.32 to 2.65)	0.89
Dietary diversity	0.02 (-0.07 to 0.11)	0.65	-0.01 (-0.05 to 0.02)	0.36	0.93 (0.72 to 1.20)	0.56	0.89 (0.68 to 1.17)	0.40
Food insecurity	-0.01 (-0.04 to 0.01)	0.27	-0.008 (-0.02 to 0.0006)	0.07	0.99 (0.92 to 1.06)	0.81	1.03 (0.95 to 1.11)	0.52
Breastfeeding	-0.008 (-0.33 to 0.31)	0.96	-0.06 (-0.21 to 0.10)	0.49	1.80 (0.68 to 4.78)	0.24	0.71 (0.15 to 3.35)	0.66
Health facility visit	-0.23 (-0.56 to 0.10)	0.17	-0.04 (-0.17 to 0.10)	0.60	1.15 (0.37 to 3.61)	0.81	0.63 (0.16 to 2.46)	0.51
WAZ, Baseline	0.93 (0.88 to 0.98)	<0.001	0.92 (0.87 to 0.98)	<0.001	0.004 (0.0004 to 0.06)	<0.001	n/a[3]	
Animals	-0.004 (-0.008 to -0.00001)	0.05	-0.001 (-0.002 to 0.00003)	0.06	1.01 (0.00 to 1.02)	0.01	1.01 (1.00 to 1.02)	0.09
Latrine								
None								
No slab	0.05 (-0.29 to 0.38)	0.78	0.03 (-0.09 to 0.14)	0.64	2.97 (0.94 to 9.35)	0.06	2.16 (0.63 to 7.41)	0.22
Slab	0.15 (-0.19 to 0.48)	0.38	0.05 (-0.05 to 0.15)	0.33	1.92 (0.56 to 6.57)	0.30	1.89 (0.51 to 7.10)	0.34

Abbreviations: CI, confidence interval; OR, odds ratio, WAZ, weight-for-age Z-score; [1]Operationalized as a composite score of 7 food groups eaten over the past 7 days; [2]Operationalized as a composite score of three questions related to frequency of food insecurity over the past four weeks; [3]Not included in model due to near perfect prediction of the outcome.

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STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	**Item #**	**Recommendation**	**Reported on page #**
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	6
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	n/a
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7
Bias	9	Describe any efforts to address potential sources of bias	8
Study size	10	Explain how the study size was arrived at	8
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	n/a
		(*c*) Explain how missing data were addressed	n/a
		(*d*) If applicable, explain how loss to follow-up was addressed	n/a
		(*e*) Describe any sensitivity analyses	n/a
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	8-9
		(b) Give reasons for non-participation at each stage	8-9
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8-9
		(b) Indicate number of participants with missing data for each variable of interest	n/a
		(c) Summarise follow-up time (eg, average and total amount)	8-9
Outcome data	15*	Report numbers of outcome events or summary measures over time	9
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	9
		(*b*) Report category boundaries when continuous variables were categorized	n/a
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	n/a
Discussion			
Key results	18	Summarise key results with reference to study objectives	10-11
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11-12
Generalisability	21	Discuss the generalisability (external validity) of the study results	12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	13

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.