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Meat and milk intakes and toddler growth: a comparison feeding intervention of animal-source foods in rural Kenya

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Abstract

Objective: To examine the effects of animal-source foods on toddler growth.
Design: A 5-month comparison feeding intervention study with one of three millet-based porridges randomized to eighteen feeding stations serving 303 children aged 11–40 months. Feeding stations served plain millet porridge (Plain group), porridge with milk (Milk group) or porridge with beef (Meat group). Anthropometry, morbidity and food intake were measured at baseline and regular intervals. Longitudinal mixed models were used to analyse growth.
Setting: Embu, Kenya.
Subjects: Two hundred and seventy-four children were included in final analyses.
Results: Linear growth was significantly greater for the Milk group than the Meat group ($P = 0{\cdot}0025$). Slope of growth of mid-arm muscle area of the Plain group was significantly greater than in the Meat group ($P = 0{\cdot}0046$), while the Milk group's mid-upper arm circumference growth rate was significantly greater than the Meat group's ($P = 0{\cdot}0418$). The Milk and Plain groups' measures did not differ.
Conclusions: Milk and meat porridges did not have a significantly greater effect on growth than plain porridge in this undernourished population. Linear growth was influenced by more than energy intakes, as the Plain group's total body weight-adjusted energy intakes were significantly greater than the Meat group's, although linear growth did not differ. Energy intakes may be more important for growth in arm muscle. The diverse age distribution in the study makes interpretation difficult. A longer study period, larger sample size and more focused age group would improve clarity of the results.

Keywords
Milk
Meat
Growth
Undernutrition
Kenya

In East Africa, among children under 5 years of age, nearly 45 % are stunted and over 30 % are underweight[1]. Multiple contributing factors include poverty, inadequate dietary quality and quantity, poor child feeding practices, high illness burdens and high prevalence of low birth weight in poor communities. In poor communities in East Africa, diets are largely plant-based and intakes of animal-source foods (ASF), such as meat and milk, are limited[2,3]. These bulky diets have low energy density. Because of limited gastric capacity, toddlers are unable to consume sufficient quantities of food at a single meal to supply the needed nutrient quantity and quality. During the critical stage when complementary foods contribute increasingly to total daily intakes, energy-dense and micronutrient-rich ASF may contribute to the demands of rapid growth and development, as well as combating the increasing burden of infectious disease[4–6].

Previous observational studies have shown associations between ASF and child growth[7–14]. However, a causal relationship cannot be established as it is difficult to distinguish the effects of diets on growth from a number of other intervening variables (socio-economic status (SES), education, infection). An earlier 2-year long randomized controlled feeding intervention trial of ASF on growth and cognitive function in Kenyan schoolchildren showed a causal relationship between meat consumption and improved cognitive function, school performance and physical activity[15], and increased mid-arm muscle area[8]. As growth rates in young children are relatively greater than in school-aged children, we hypothesized that ASF would increase toddler growth in a shorter period of time than seen in the aforementioned study, hence accounting for the shorter duration (5 months) of the present study. While the present study was designed

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to compare the effects of milk and meat consumption on multiple outcomes, the current paper focuses only on the associations between ASF consumption and growth.

Materials and methods

Study area

The study was conducted in Embu District, Eastern Province, Kenya on the south-east slopes of Mt Kenya where the elevation ranges from 1200 to 1460 m above sea level – the same location of the Child Nutrition Project (CNP)[3,8,15]. The community comprises mainly subsistence farmers who cultivate maize, beans and a variety of greens. Most households have small numbers of goats, chickens and cows. A few households cultivate cash crops such as coffee, cotton and tobacco. Dietary diversity is limited, with little or no consumption of ASF among young children[10]. With few exceptions, community members are Kiembu speakers of the Embu tribe.

Study sample and design

Toddlers (aged 11–40 months) were recruited from the same sampling frame as the CNP schoolchildren (a 2-year study), with 125 households represented in both studies. If there were no toddlers in the CNP households, toddlers were recruited from the next closest home. Toddlers were assigned to the closest of eighteen temporary feeding stations, within 15 min of home. Feeding stations were randomized to one of three types of feeding interventions. The study has a hierarchical design with individual children's observations nested within feeding stations and feeding stations nested within feeding groups. Sample characteristics are found in Table 1. Due to strong community sentiment, there was no non-supplemented control group. Therefore, the present study is a comparison of three types of supplementary feeding interventions. The three intervention foods were as follows.

1. Milk porridge: whole ultra-heat-treated (UHT) milk added to a millet-based porridge.
2. Meat porridge: minced beef added to a millet-based porridge.
3. Plain porridge: millet-based porridge containing additional sugar, millet and Blueband brand margarine.

All three porridges were isoenergetic (1130 kJ (270 kcal)/serving). Nutrient composition, porridge recipes and serving size information can be found in Table 2. Porridge recipes were taste-tested in a pilot by local toddlers and adults and deemed acceptable.

Porridge was cooked in a centralized cooking facility overnight, and individually measured quantities were delivered each morning to each feeding station in separate containers labelled for each child. The cooks preparing the porridge were trained in weighing, measuring, preparing recipes with boiled water and safe food handling practices, and were inspected regularly by the local Public Health Officer. Participants were fed one serving/d, 5 d/week for 5 months, excluding holidays. Servings were available any time between 07.00 and 11.00 hours. Supervised by a research assistant, caregivers fed children and leftovers were measured and recorded. When porridge samples were analysed for nutrient content during the study to ensure that they were isoenergetic, the meat and milk porridges contained less energy than the plain porridge. Additional sugar and margarine were added to the meat and milk recipes to make all porridges isoenergetic. More ground meat was added to the second version of the porridge because during the fine grinding of the meat, a layer of fat was found sticking to the side

Table 1 Baseline child, maternal and household characteristics among feeding groups in Kenyan toddlers

	Meat group (*n* 81)		Milk group (*n* 97)		Plain group (*n* 96)	
	Mean or %	SE	Mean or %	SE	Mean or %	SE
Age at baseline (months)	25·7	0·87	25·2	0·79	25·4	0·79
Daily baseline household energy intake (kJ/kg body weight)	453	16·8	458	15·3	479	15·4
Maternal height (cm)	156	0·8	157	0·7	156	0·7
Household socio-economic score (range = 31–120)	66	2·1	63	1·9	62	1·9
% girls	57		52		50	
% breast-feeding at baseline	54		57		57	
% mild morbidity at baseline	56		56		61	
% severe morbidity at baseline	21		31		22	
Baseline height (cm)	81·6	0·39	82·1	0·33	81·9	0·34
Baseline HAZ	−1·49	0·115	−1·39	0·098	−1·45	0·099
Baseline MUAC (cm)	14·7	0·12	14·7	0·10	14·7	0·10
Baseline MAMA (mm^2)	1137	16·5	1147	14·9	1129	14·9
Baseline MAFA (mm^2)	589	17·7	581	16·1	596	16·2
Baseline HC (cm)	47·6	0·15	47·5	0·13	47·6	0·13
Baseline weight (kg)	10·8	0·13	11·0	0·12	10·9	0·12
Baseline WAZ	−1·28	0·100	−1·15	0·090	−1·24	0·090
Baseline WHZ	−0·43	0·085	−0·37	0·078	−0·52	0·078

HAZ, height-for-age *Z*-score; MUAC, mid-upper arm circumference; MAMA, mid-arm muscle area; MAFA, mid-arm fat area; HC, head circumference; WAZ, weight-for-age *Z*-score; WHZ, weight-for-height *Z*-score.
None of the characteristics were statistically significantly different among the porridges ($P < 0·05$).

Table 2 Nutrient composition of study porridges per serving†,‡

	Meat porridge (370 g)	Milk porridge (360 g)	Plain porridge (400 g)
Energy (kJ)	1079	1068	1109
Protein (g)	13·0	5·9	3·4
Fat (g)	7·2	8·4	5·7
Ca (mg)	85·7	223·1	140·4
P (mg)	171·6	197·7	144·6
Fe (mg)	1·57	0·95	1·39
Available Fe§ (mg)	0·27	0·05	0·07
Zn (mg)	2·16	0·85	0·61
Available basal Zn (mg)	0·75	0·13	0·06
Mg (mg)	18·3	21·5	13·8
Cu (mg)	0·19	0·15	0·25
Mn (mg)	1·7	1·7	2·8
Vitamin A (μg)	70·0	124·5	90·7
Vitamin D (mg)	0	0	0
Vitamin E (mg)	0·31	0·26	0·40
Vitamin C (mg)	0	1·2	0
Niacin (mg)	1·65	0·36	0·41
Thiamin (mg)	0·12	0·13	0·14
Vitamin B_6 (mg)	0·21	0·14	0·12
Riboflavin (mg)	0·11	0·25	0·07
Folate (μg)	5·8	10·3	5·1
Vitamin B_{12} (μg)	0·82	0·49	0
Pantothenic acid (mg)	0·29	0·54	0·19

†Milk porridge recipe for first 4 months of study: 20·2 g unfermented millet, 10·1 g fermented millet, 12·2 g sugar, 4 g margarine, 121·4 g milk; Meat porridge recipe for first 4 months of study: 20·3 g unfermented millet, 10·1 g fermented millet, 13·1 g sugar, 4·8 g margarine, 48·7 g minced beef; Plain porridge recipe for first 4 months of study: 33·9 g unfermented millet, 17·1 g fermented millet, 13·8 g sugar, 6·2 g margarine.
‡Milk porridge recipe for second half of study: 20·2 g unfermented millet, 10·1 g fermented millet, 14·2 g sugar, 6 g margarine, 121·4 g milk; Meat porridge recipe for second half of study: 20·3 g unfermented millet, 10·1 g fermented millet, 16·1 g sugar, 8·8 g margarine, 53·7 g minced beef; Plain porridge recipe for second half of study: 33·9 g unfermented millet, 17·1 g fermented millet, 13·8 g sugar, 6·2 g margarine.
§Available Fe and available basal Zn are calculated based on Murphy *et al.*[29].

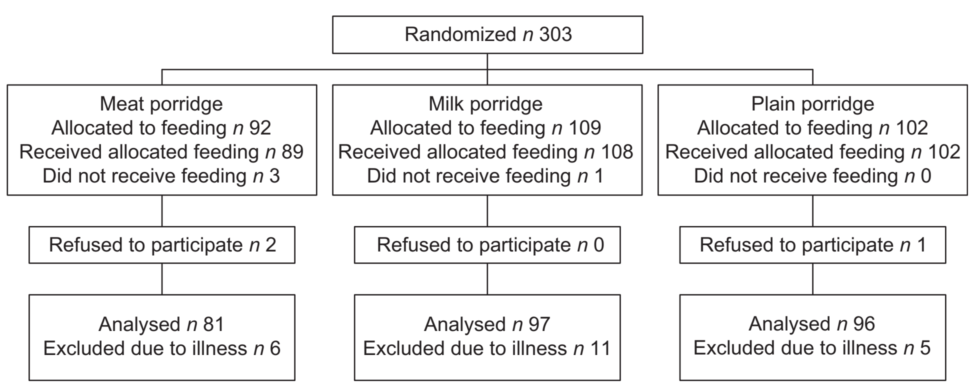

Fig. 1 Flowchart showing profile of sample in the feeding study

of the blender bowl, resulting in a greater amount of waste than originally calculated. This change took effect 4 months after the beginning of the study; thus the first cohort of children consumed the second version of the porridge for 1 month, while the second cohort consumed the second version of the porridge for the duration of their participation.

Of 303 children initially randomized to a feeding group, a final sample size of 274 children was analysed: ninety-six children in the Plain group, eighty-one in the Meat group and ninety-seven in the Milk group (Fig. 1). Of the children omitted from analyses, seven withdrew and twenty-two were excluded for health reasons: one child was reported to be HIV-positive by the caregiver; one had Down's syndrome; one had congenital heart disease; and nineteen children were diagnosed with clinical rickets and were given high doses of vitamin D and Ca. Due to sample size considerations, two groups of children were enrolled with start dates 4 months apart; 246 children were enrolled in the first group with 229 remaining for analyses, and fifty-seven were enrolled in the second group with forty-five remaining for analyses. Regardless of start date, all children were supplemented for the same time period. There were no differences between the first and second groups for baseline anthropometric measures or baseline household energy intakes, although dietary patterns may have changed given the seasonal shift in food availability. The second group of children had a significantly higher score for SES (as described below) than the first group. The change in the study porridge recipe as noted above was made when the second group began the trial.

Data collection and quality control

Anthropometry, food intake and socio-economic data were collected by trained enumerators who were employed in the previous 2-year intervention study by the same research team. To ensure quality control, supervisors retrained enumerators for each component of the study and enumerators collected repeated measures to ensure accuracy. During routine data collection quality control procedures, there was a high degree of agreement between data collected by supervisors and enumerators. Methodology for anthropometry, food intake and SES were the same as those used for prior CNP studies[3].

Anthropometry

Height, weight, mid-upper arm circumference (MUAC), triceps skinfold thickness (TSF) and head circumference (HC) were measured according to established methods[16,17] at baseline and every other month thereafter, for a total of four measures. Maternal height was obtained once. Length for the children and height for the mothers were measured to the nearest 0·1 cm using a locally made wooden measuring board with a fixed head board and sliding foot board. The child's weight was assessed using a Salter scale with a Teflon spring and recorded to the nearest 0·1 kg. If a child was upset, the child was weighed together with the mother and the mother's weight was subtracted. MUAC was measured with a Teflon insertion tape using standard methods. HC was also measured with a thin insertion tape to the nearest 0·1 cm. TSF was measured in three replicates at the same site as MUAC with a Lange calliper (Cambridge Scientific Industries, Cambridge, MD, USA) to the nearest 0·5 mm and the three measures were averaged. Each child was measured by two enumerators and the values were averaged. If the difference between the means of the two enumerators' measurements was greater than preset differences (0·5 cm for height, 0·1 kg for weight, 0·2 cm for HC, 2 mm for TSF and 0·2 cm for MUAC), then the enumerators each obtained a second set of measurements and the mean of the second set of measures was used in analyses. Mid-upper arm muscle area (MAMA) and mid-upper arm fat area (MAFA) were calculated using MUAC and TSF values[18]. Equipment was calibrated at the beginning of the study and routinely throughout data collection.

Dietary assessment

Each toddler's usual daily intake was estimated using a quantitative 24 h recall administered to the mother at baseline (mean of 2 d of intake) followed by four additional recalls collected at regular intervals in the following 5 months. Energy intakes are reported in kJ/kg body weight. The mother was asked to estimate all foods the child ate in the previous 24 h using pre-calibrated common household measures. Recipes, ingredient quantities and the final volume of mixed dishes were also recorded, which enabled estimation of the child's consumption of each ingredient in the mixed dishes. The amount of the intervention study porridge consumed was obtained from feeding records.

Frequency of breast milk intake per 24 h was recorded. Quantities of breast milk consumed were estimated on the basis of a previous study which obtained weighed 24 h intakes of breast milk by Kenyan toddlers in the adjacent district of Machakos[19]. In the Machakos study, total 24 h human milk intakes were measured by test-weighing children before and after breast-feeding, and mean amounts consumed per feeding were calculated for different age groups, corresponding to the age groups in our study. To estimate the quantity of human milk consumed by a child in the present study, the age-specific amount per feeding in the Machakos study was multiplied by the frequency of feeding reported in the current study.

Food intake was converted into nutrients using nutrient composition data from the WorldFood Dietary Assessment System version 2·0 (University of California, Berkeley, CA, USA), based on actual nutrient analysis of some Embu ingredients and mixed dishes as well as selected published nutrient data (US Department of Agriculture (USDA))[20]. The food composition database was updated as described previously[21]. Human milk nutrient composition was obtained from the USDA Nutrient Database for Standard Reference[22].

Total nutrient intake was calculated combining household intake and intervention feeding. Total household nutrient intake for each child was derived by the total number of days in the study multiplied by the mean daily intake of each nutrient (the mean of four 24 h recalls administered after baseline).

Clinical and morbidity assessments

A physician examined each child at baseline and the study's conclusion. Children were screened for malaria using the Rapid Antigen Dip Stick test[23] and for anaemia using a Hemocue haemoglobinometer (HemoCue AB, Angelholm, Sweden). If the child was positive for malaria and/or other acute illness needing further evaluation and treatment, s/he was referred to the health centre. Children with Hb $\leq$7 g/dl were treated with Fe for 30 d; if no response, they were referred for further care. Children treated for malaria and/or anaemia were included in the analyses unless excluded for other health reasons listed earlier. After baseline stool examination for ova and parasites, all of the toddlers were dewormed with mebendazole before and after the study.

Morbidity information was collected at baseline and every other month. Mothers were asked to recall signs and symptoms the children experienced on the day of the home visit and during the preceding week. The questionnaire used was the same as those developed for the previous study of schoolchildren in Embu[3,8]. However, criteria for morbidity severity were modified slightly to reflect the differences in illness patterns between school-aged children and toddlers. Mild morbidity and severe morbidity were used as covariates in the anthropometric analyses.

Socio-economic status

Household SES was evaluated at baseline using the CNP study questionnaire[3]. Variables were weighted and summarized to create an SES score used as a covariate in analyses. This questionnaire was validated against the local chief's ratings of SES, and there was significant agreement with an earlier study[4].

Statistical analyses

Means and their standard errors were calculated for all study porridge feeding compliance and complete household and study porridge food intake measures including individual nutrient intakes, baseline anthropometry measures, SES, child age and maternal height. Significance for testing covariates in the models and comparisons between groups was defined as $P < 0{\cdot}05$.

Longitudinal models were fit to the anthropometric outcomes using SAS PROC MIXED (SAS statistical software package version 8; SAS Institute, Cary, NC, USA), which estimated a population intercept and slope for each feeding group (fixed effects) for each anthropometric outcome. The core model included fixed-effect covariates for gender, baseline age, time and the age-by-time interaction. As toddlers ranging in age from 11 months to 40 months have different growth rates, we included the age-by-time interaction in the core model. We used a random-effects model with subject-specific intercepts and slopes to account for the correlation among longitudinal measures for each child.

No significant differences were found in children's anthropometry at baseline after testing feeding station as a random effect in the model, thus feeding station was removed from the model.

Each covariate and covariate-by-time interaction was added separately to the core model to estimate its effects. Those that were significant were included in the core model to create the final model. Covariates included SES, baseline toddler household dietary intake (mean of two 24 h recall visits), morbidity (mild and severe), number of children aged <5 years per household (illness exposure), post-baseline toddler household dietary intake (mean of four 24 h recalls), breast-feeding and total energy intake (intervention porridge energy intake plus average post-baseline toddler household intake). Maternal height was included in the analyses for height.

Human subjects protection assurance

The University of California, Los Angeles Office for Protection of Research Subjects, the University of Nairobi School of Medicine Ethics Committee and the Office of the President, Government of Kenya approved this research protocol before the study began. Parents gave informed verbal assent for their children's participation in the study, and community permission was granted through community-wide meetings with investigators before the study began.

Results

Baseline findings

Age groups were equally represented among feeding groups. Two per cent of children were <12 months of age, 84 % aged 12–36 months and 14 % above 36 months. Toddler baseline characteristics did not differ significantly by feeding group (Table 1).

Baseline findings from the group as a whole indicate that severe morbidity and mild morbidity affected 25 % and 58 % of children, respectively.

Over 90 % of children below 24 months of age were still breast-feeding, while only 48 % of children aged 24–30 months and ~11 % of children over 36 months were breast-feeding. At baseline, 80 % of children consumed animal milk from household sources, primarily as an ingredient in mixed dishes and tea. Among these children, 116 (SD 126·9) g of milk was consumed daily while the median daily milk intake was 76 g. Mean baseline vitamin A intake among study children was 507 μg.

Study compliance

Over 70 % of children from each feeding group had a total of four anthropometry visits, with missing data distributed equally among feeding groups. All 274 children, regardless of feeding attendance or completeness of anthropometry records, were included in the final analyses. Baseline intakes in kJ/kg body weight, baseline anthropometry and SES did not differ between children who completed all anthropometry visits and those who did not.

Intakes by group assignment

Feeding compliance measures are shown in Table 3. There were no statistically significant differences in the number of days children were present at the feeding stations. Over the duration of the study, the Plain group consumed a greater total number of porridge servings* than the Meat group ($P = 0{\cdot}0016$), although there were no differences between the number of servings consumed between the Plain and Milk groups or the Milk and Meat groups (Table 3). Moreover, the Plain porridge group consumed significantly more energy, i.e. mean daily kJ of study porridge per kg of body weight, than the Milk and the Meat groups ($P < 0{\cdot}0013$). Energy densities of the porridges were: 2·77 kJ/g porridge

* The number of porridge servings consumed is the total grams of porridge actually consumed throughout the study, divided by the daily gram amount served. For example, if a child consumed 20 000 g of plain porridge throughout the study, the number of porridge servings consumed is 50 (20 000 g divided by 400 g/serving).

Table 3 Intakes by study group in Kenyan toddlers

	Meat group (n 81)		Milk group (n 97)		Plain group (n 96)	
	Mean	SE	Mean	SE	Mean	SE
Daily energy intake from study porridge (kJ/kg body weight)	89^{b}	1·8	90^{b}	1·7	98^{a}	1·7
Daily total energy intake (household intake+study porridge) (kJ/kg body weight)†	466^{b}	12·5	$493^{a,b}$	11·4	508^{a}	11·4
Number of study porridge servings consumed‡	64^{b}	2·5	$70^{a,b}$	2·2	76^{a}	2·3
Number of days child present at feeding station	72^{a}	2·5	74^{a}	2·2	78^{a}	2·2

a,bMean values within a row with unlike superscript letters were significantly different ($P<0·05$).
†Mean daily total energy intake (kJ) is based on the average of four 24 h recalls of household intakes recorded over the course of the study plus the porridge intake as recorded from the feeding station records.
‡Porridge servings consumed are calculated by summing the daily total grams of porridge served minus leftovers for the duration of the study, divided by the sum of total grams of porridge served for the duration of the study. Therefore, if a child consumed half a serving each day during the study, the total number of porridge servings consumed would equal half the number of total portions served during the study.

Table 4 Growth slope estimates for each anthropometric outcome by feeding group in Kenyan toddlers

	Meat group		Milk group		Plain group	
Anthropometric outcome	Mean	SE	Mean	SE	Mean	SE
Height (cm)	$5·5^{b,*}$	0·82	$6·0^{a,*}$	0·82	$5·8^{a,b,*}$	0·82
HAZ	$0·15^{b}$	0·321	$0·32^{a,*}$	0·309	$0·25^{a,b,*}$	0·304
MUAC (cm)	$-0·08^{b}$	0·392	$0·09^{a}$	0·384	$0·08^{a,b}$	0·391
MAMA (mm^2)	$31·2^{b}$	54·69	$58·6^{a,b,*}$	52·31	$73·6^{a,*}$	52·23
MAFA (mm^2)	$-63·9^{a,*}$	74·04	$-61·0^{a,*}$	72·77	$-75·8^{a,*}$	74·28
HC (cm)	$1·53^{a,*}$	0·227	$1·58^{a,*}$	0·219	$1·53^{a,*}$	0·220
Weight (kg)	$0·80^{a,*}$	0·348	$0·87^{a,*}$	0·341	$0·92^{a,*}$	0·347
WAZ	$-0·25^{a,*}$	0·264	$-0·21^{a,*}$	0·258	$-0·15^{a}$	0·263
WHZ	$-0·41^{a,*}$	0·348	$-0·49^{a,*}$	0·341	$-0·37^{a,*}$	0·349

HAZ, height-for-age Z score; MUAC, mid-upper arm circumference; MAMA, mid-upper arm muscle area; MAFA, mid-upper arm fat area; HC, head circumference; WAZ, weight-for-age Z-score, WHZ, weight-for-height Z-score.
Values are estimates with their standard errors of the total amount of growth calculated by the end of 5 months. The estimates are expressed in the units listed for each anthropometric outcome and are calculated from the growth measured in the 5 months of the study. For instance, children in the Meat group grew an average of 5·5 cm in height by the end of the study.
a,bEstimates within a row with unlike superscript letters were significantly different ($P<0·05$).
*Indicates a significant difference from zero ($P<0·05$).

for the Plain porridge, 2·92 kJ/g porridge for Meat porridge and 2·97 kJ/g porridge for Milk porridge. While there were no differences among the feeding groups for daily energy intakes from only household sources, there were differences in total intakes (combined household and study porridge intakes). The Meat group consumed significantly less daily mean kJ of total intake (household plus study porridge) per kg of body weight than the Plain group ($P=0·036$). When comparing baseline total intakes (household intakes only) with total intakes (household plus study porridge) during the study, the Plain and Milk groups showed an increase in total daily intake in kJ per kg of body weight during the study, while the Meat group's intakes did not change.

Anthropometric findings

Growth over the study period for each outcome can be seen in Table 4. For the whole sample, 22 % of study children were underweight, 26 % of children were stunted and 4 % of children were wasted.

Height

Linear growth was significantly greater for the Milk group compared with the Meat group ($P=0·0025$). There were no significant differences between Plain and Milk or Plain and Meat groups.

Mid-upper arm measures

Rate of MUAC growth was significantly greater in the Milk compared with the Meat group ($P=0·0418$) while that in the Plain group was borderline significantly greater than in the Meat group ($P=0·0519$). Rates of MUAC growth did not differ between the Milk and Plain groups. The MAFA growth rate did not differ among feeding groups; however, it was negative and significantly different from zero for all groups. For MAMA, the Plain group had a greater slope of growth than the Meat group ($P=0·0046$), while the Milk group had only a borderline significantly greater growth rate than the Meat group ($P=0·068$). The Milk and Plain groups did not differ significantly from each other for MAMA growth rate.

Baseline animal milk intakes were positively associated with greater baseline height, weight, HC and MAMA ($P<0·05$), although there was no effect of household milk intakes over time on the growth rate for any of these outcomes. Maternal height was positively associated with toddler baseline height ($P<0·05$). SES was positively associated ($P<0·05$) with baseline height, weight, MAMA and MUAC.

Baseline energy intakes and growth rates during the study were consistent with observing catch-up growth. Total baseline energy intakes were significantly negatively associated with all baseline anthropometric measures ($P < 0{\cdot}05$). For example, after age adjustment, children with higher baseline energy intakes weighed less at baseline than children with lower baseline energy intakes – indicating that lighter children were consuming more energy which enabled catch-up growth. The slope estimates for energy intake were significantly positively associated with increases in MUAC, MAFA and weight over time ($P < 0{\cdot}05$), which would be expected as these measures are rapidly responsive to changes in energy intakes. For example, children may have reduced intakes during illness, increased consumption during recovery, and weight gains exceeded pre-illness rates of growth to catch up. This was consistent with the significant negative correlation between slopes and intercepts of MUAC and MAMA ($P < 0{\cdot}05$).

Discussion

Compared with the Meat group, the Milk and Plain groups had better growth rates for height and MAMA, respectively. If energy intakes were completely responsible for the differences in linear growth among groups, we would expect the Plain group to have had a significantly greater slope of growth than the Meat group, but it did not. However, energy intakes may be important for increasing muscle mass in this undernourished population. As the study participants spanned the ages of 11 to 40 months, there was considerable variability among stages of development, physiological needs and activity levels. Thus, greater resolution on the relationship between energy intakes and muscle mass is limited with these data, as compared with other studies. As energy intakes do not account for the differences we observed in linear growth, we examined factors beyond energy intakes to explain our findings.

Baseline animal milk intake from household sources was significantly positively associated with both baseline height and MAMA in all study children, even after controlling for SES and other covariates. This trend of milk associated with linear growth is consistent with observational reports in the literature[7,11], a controlled study that examined possible underlying mechanisms for this in school-age boys[24], and the controlled study among a subset of children in the Milk group of the schooler study conducted in the same community[8,25]. Among the schoolers, only Milk group children less than 6 years of age or who were stunted (Z-score <-2) had a greater linear growth rate than the Meat or Control groups[8,25]. Among this subset of schoolers, there was no significant difference in linear growth between the Milk and Plain groups[8,25]. When comparing the arm muscle findings of the toddler study with the schoolers, the differences in total energy intakes among treatment groups, age distribution and stage of growth of study participants makes comparison inappropriate. Ca, Mn and P, particularly found in milk, are associated with bone growth, and the Ca content of the Plain and Milk porridges was higher than that of the Meat porridge. As children in all three feeding groups consumed inadequate amounts of Ca at baseline compared with the daily recommended level of 800 mg/d for children ages 1–3 years[26], we analysed the effect of total Ca intakes, combined from both household intakes and study porridge, on growth. Total Ca intakes were not significantly associated with growth rate for height, MUAC or MAMA. The present study was not designed to focus on this, thus it would be necessary to directly examine the role of Ca intakes on bone growth, the relationship to arm circumference and calculations of MAMA in undernourished populations. As rickets from Ca deficiency has been noted in other African populations[27], and nineteen study children were diagnosed with clinical rickets, this question merits further investigation.

The present study indicates that energy intakes are important for toddler growth; however, the role of meat is less certain. Difficulties with the Meat porridge preparation and the lower total energy intakes of the Meat group make it difficult to draw conclusions about the potential of meat porridges on toddler growth. As the meat porridge was well liked during community taste-tests, the meat porridge, with its much greater protein content, may have provided greater satiety leading to the Meat group's lower energy intakes. Studies have shown that protein increases satiety[28]. As the study progressed, fewer children consumed porridge at home in the mornings. The Meat group's total energy intakes per kg body weight were constant between baseline and follow-up, while the other two groups increased their total daily household intakes. It appears the study porridge replaced household porridge and other breakfast foods, although to varying degrees among study groups. The Plain and Milk groups consumed more food at other meals than the Meat group. As food preparation changes could affect other household children, researchers should consider ways to reduce unintended consequences of feeding study participation through continued community consultation.

A longer study period or larger sample size may have improved our ability to distinguish significant differences in growth among groups. As growth, activity, development and illness are significantly different among children in the 11–40 months age range, a more homogeneous sample of children with respect to age would improve interpretation of study findings and how diet quality relates to various stages of child growth.

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