



Meat Supplementation Improves Growth, Cognitive, and Behavioral Outcomes in Kenyan Children^{1,2}

Charlotte G. Neumann,^{3*} Suzanne P. Murphy,⁴ Connie Gewa,⁵ Monika Grillenberger,⁶ and Nimrod O. Bwibo⁷

³Departments of Community Health Sciences and Pediatrics, Schools of Public Health and Medicine, University of California, Los Angeles, CA 90095; ⁴Cancer Research Center of Hawaii, University of Hawaii at Manoa, Honolulu, HI 96813; ⁵Department of Community Health Sciences, School of Public Health, University of California, Los Angeles, CA 90095; ⁶Wageningen University, Wageningen 6700 EV, The Netherlands; and ⁷Department of Pediatrics, Faculty of Medicine, University of Nairobi, Nairobi 00100, Kenya

Abstract

A randomized, controlled school feeding study was conducted in rural Embu District, Kenya to test for a causal link between animal-source food intake and changes in micronutrient nutrition and growth, cognitive, and behavioral outcomes. Twelve primary schools were randomly assigned to 1 of 4 groups. Children in Standard I classes received the local plant-based dish *githeri* as a midmorning school snack supplemented with meat, milk, or fat added to equalize energy content in all feedings. The Control children received no feedings but participated in data collection. Main outcome measures assessed at baseline and longitudinally were 24-h food intake recall, anthropometry, cognitive function, physical activity, and behaviors during school free play. For cognitive function, the Meat group showed the steepest rate of increase on Raven's Progressive Matrices scores and in zone-wide school end-term total and arithmetic test scores. The Plain *githeri* and Meat groups performed better over time than the Milk and Control groups ($P < 0.02$ – 0.03) on arithmetic tests. The Meat group showed the greatest increase in percentage time in high levels of physical activity and in initiative and leadership behaviors compared with all other groups. For growth, in the Milk group only younger and stunted children showed a greater rate of gain in height. The Meat group showed near doubling of upper midarm muscle area, and the Milk group a smaller degree of increase. This is the first randomized, controlled feeding study to examine the effect of meat- vs. milk- vs. plant-based snacks on functional outcomes in children. J. Nutr. 137: 1119–1123, 2007.

Introduction

Multiple micronutrient deficiencies are widespread in the developing world (1), frequently coexisting with protein-energy malnutrition, particularly in sub-Saharan Africa and Southeast Asia. These are linked to poverty, poor diet quality, little or no intake of animal-source foods (ASF),⁸ and a high burden of infection. The ubiquitous plant-based diets, with their high

phytate and fiber content, decrease iron, zinc, and calcium bioavailability and lack vitamin B-12 (2). Diets tend to be of low energy density, and protein of poor quality.

Findings from the 3-country Nutrition Collaborative Research Support Program (NCRSP) study in Egypt, Kenya, and Mexico during the mid 1980s stimulated the study reported here. The NCRSP longitudinal observational study of "energy intake and human function" found positive associations between meat intake and physical growth, cognitive function, school performance, physical activity, and social behaviors, particularly in the Kenya study (3). Findings persisted even after statistically controlling for a number of important covariates. Because these observational findings did not establish causation of the impact of ASF on outcomes, there was a cogent need to carry out a randomized controlled intervention study to test for cause-and-effect relationships. This article presents a summary of the main cognitive, behavioral, and growth portions of the study, "Role of Animal Source Foods to Improve Diet Quality and Growth and Development in Kenyan School Children." Project methods and specific features of findings have been published earlier (4–9).

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* To whom correspondence should be addressed. E-mail: cneumann@mednet.ucla.edu.

⁸ Abbreviations used: ASF, animal-source foods; MAMA, midarm muscle area; PA, physical activity; RPM, Raven's Progressive Matrices; TSF, triceps skinfold.

Materials and Methods

Kenya study area

The area covered $\sim 60 \text{ km}^2$ in a drought-prone area with serious food shortages every 3–5 y. *Falciparum* malaria is endemic. Maize, beans, sorghum, and millet to a lesser extent are grown as the main food crops by smallholder, subsistence farmers. Modest amounts of coffee, cotton, and tobacco are raised as cash crops by some farmers. Households own several goats and chickens, but few own cows. Although animal flesh is rarely eaten, households do consume modest amounts of milk and few eggs. There is some seasonal consumption of worms, termites, and other forms of ASF (4).

Design

A controlled feeding intervention study was designed with schools randomized to 3 feeding groups and a Control group that received no feeding. The design is described in greater detail in previous publications (4,6,9). Feeding assignment was the same for each school and classroom within each school. Each treatment group was comprised of 3 schools with children aged 6–14 y (median 7.4 y). The study continued over 7 3-mo school terms (2.25 y). Feedings were provided only during the days that schools were officially open. No feedings were given during school holidays.

Twelve schools, based on their size and accessibility for daily food delivery, were randomly assigned to each of the 4 conditions, with 3 schools per condition. The total sample size of Standard I children for Cohort I was 525, and Cohort II was 375 children. Cohort II was enrolled exactly 1 y after Cohort I because of a prolonged teacher strike and severe drought during the early months of the Cohort I Study. Cohort II students were recruited from the same schools and the same feeding assignment (replicate study) as Cohort I.

Feeding intervention. Children received midmorning “snacks” every day they attended school. The Control group participated in all measurements but did not receive an intervention feeding. Each Control family received a milk goat at the end of data collection, a gift of the parent's choice. The snacks for all 3 intervention groups were based on *githeri*, a local dish composed of maize, beans, and greens. For the Meat group, finely ground beef (Farmer's Choice, Nairobi, Kenya) with 10–12% fat was added to *githeri*. The Milk group was given a glass of Ultra Heat Treated whole cow's milk in addition to the basic *githeri*. The Plain *Githeri* (Energy) group received *githeri* with extra oil (Kimbo, Unilever, East African Industries, Nairobi, Kenya) added to equalize the energy content of the 3 snacks. [The fat was used in all 3 types of feeding, but most was added in the Plain *Githeri* group. It was found to be fortified with retinol (37 $\mu\text{g/g}$) but was not initially labeled.] Ingredients were increased by $\sim 25\%$ after 1 y as children increased in size. Feedings were designed to offer $\sim 20\%$ of required daily energy intake. Preparation and nutrient composition of the snacks have been described by Murphy et al. (10). Snacks furnished $\sim 250 \text{ kcal}$ ($\sim 1060 \text{ kJ}$) per day.

Hypotheses

Hypotheses addressed in this article are that children supplemented with ASF would show the steepest increase in rate of physical growth, the greatest rate of increase of test scores over time on measures of cognitive function, and spend a greater percentage of time in high levels of physical activity (PA) than those children receiving the plant-based supplement and the Control group. It was further hypothesized that Meat and Milk supplementation would not show equivalent impacts because of their different nutrient compositions. Compared with the Milk group, the Meat group would show greater gains in cognitive testing and end-term school examination test scores and spend a greater percentage of time in high levels of PA. Compared with the Meat group, the Milk group would show a greater rate of increase of linear growth.

Measures and procedures

Data were collected using longitudinal, repeated measures for each child. Baseline and subsequent data points were collected at varying intervals depending on the type of parameter. Details are found in a previous publication (4). Morbidity and biochemical micronutrient blood concentrations were obtained but are not included in this article.

Cognitive measures. Cognitive status was assessed using a variety of tests at baseline, once per term in y 1, and in alternate terms in y 2. These tests were extensively used in the same Embu population and age groups by well-trained and experienced staff from the original NCRSP study. The Raven's Progressive Matrices (RPM) measures fluid intelligence, abstract reasoning, problem solving, perceptual awareness, and reasoning by analogy (11). Arithmetic skills were assessed by an adaptation of the WISC-R Arithmetic Scale, which measures crystallized intelligence: arithmetic concepts and basic quantitative skills. The Verbal Meaning Test, designed in East Africa, uses pictures of familiar objects and people and is used to measure receptive language and vocabulary. Digit Span measures recall of number sequences. Zonal-wide multitest scores are given at the end of each term and were collected on each child. The score is based on the percentage of correct answers. Eight subjects are covered and scored separately. Total scores and arithmetic scores were obtained from the schools for each child several weeks after the examinations were scored. Protocols used for cognitive testing have been described in detail by Whaley et al. (6).

Observational methods for activity levels and behaviors. Schoolyard behaviors were observed during unstructured play to obtain estimates of child activity and social interactions. Strictly defined criteria for behaviors and activity levels were used in training the staff (12). Timed observations were used (30 s for observation and 30 s for recording) with a total of 30 min per child per session required. These measures were used extensively in the former NCRSP and were carried out by the former staff once a term (3). Reliability and validity for these measures have been demonstrated, and the mean intraclass correlation was 0.95 (9).

Anthropometry. Weight, mid-upper-arm circumference, triceps skinfold thickness (TSF), and subscapular skinfold thickness were measured every month in y 1 and every other month in y 2, and height every 4 mo. Protocols and methods are described in detail in previous publications (7,13). Mid-upper-arm muscle area (MAMA), an indicator of lean body mass (14), was calculated from TSF and mid-upper-arm circumference (15). The EpiInfo2000 program (version 1.0.5; CDC, Atlanta, GA), using CDC/WHO 1977/1985 reference data for height and weight by gender and age (16), was used to transform height and weight measurements into Z-scores used for descriptive purposes.

Human subjects protection assurance

Approval was obtained from the UCLA Human Subject Protection Committee, the Ethics Committee of the University of Nairobi School of Medicine, and the Office of the President before the study commenced. Verbal informed consent by parents, assent by children, and community permissions were also obtained.

Statistical methods

This study has a nested or hierarchical design (17): schools within feeding groups and children within schools. The primary goal of data analyses was to compare rates of change across children and feeding groups. The SAS program for Windows 8e (SAS Institute) was used with SAS PROC MIXED to compute estimates and standard errors for 2 types of parameters: 1) fixed effects (feeding group, baseline age, gender, school), including the mean intercepts and slopes for the 4 groups, and 2) random effects (morbidity, anthropometry, and food intake), including the intercepts and slopes of the individual children and school effects (18). Validity of the models was confirmed using standard statistical methods.

Results

Baseline findings

No statistically significant differences were seen among intervention groups and the control group for most baseline variables. However, the Meat group had the highest prevalence of severe vitamin B-12 deficiency at baseline compared with other groups. Anemia (hemoglobin $< 11.5 \text{ g/dL}$) was found in 48.9% overall, with moderate/severe anemia ($\text{Hg} < 7\text{--}9.9 \text{ g/dL}$)

in 12% of children as a whole. *Falciparum* malaria was diagnosed in 31% of children using a rapid dipstick assay test (19). Stunting (defined as -2 Z-scores below the median) and underweight (defined as -2 Z-scores below median) were present in 19.4 and 30.4% of children, respectively. On average, TSF were generally below percentile 5, and MAMA was in percentile 5–10 (15).

Baseline food intake data revealed total energy intake was slightly below recommended intakes for moderately active children weighing 20 kg (mean baseline weight), which is ~ -1.1 Z-scores for weight-for-age for sexes combined (14,20). Total protein intake was adequate, but little to no ASF protein (mean 3.1 ± 4.1 g/d) was consumed. Fat intake was 12% of energy intake, considered to be low. Multiple micronutrient deficiencies were documented (iron, zinc, calcium, vitamins A and B-12, and riboflavin). Fiber and phytate intakes were high, $43.8 (\pm 18.0)$ g/d and $3361 (\pm 1402)$ mg/d, respectively (10,21).

Findings from the intervention study

Cognitive and school performance. The steepest rate of increase on RPM test scores was observed in the Meat group. The Milk group showed the lowest rate of increase in RPM test scores, significantly below all other groups. On arithmetic tests, both the Plain *githeri* (Energy) and Meat groups performed significantly better over time than the Milk and Control groups ($P < 0.02$ – 0.03) (Fig. 1). No significant differences were seen in scores on tests of verbal meaning and digit span. For school performance, as measured by end-of-term test scores, the greatest percentage increase in zonal end-term total test scores was observed in the Meat group, with the greatest percentage increase in arithmetic subtest scores also seen in the Meat group, both statistically significant increases (Fig. 2) (6).

PA and behaviors during free play. Over time the highest percentage of time spent in high levels of PA during free play was seen in the Meat group (Fig. 3 a). The Meat group also showed the greatest decrease in percentage time spent in low levels of PA. The Meat group, compared with all other groups, showed the greatest increase in percentage time in leadership (Fig. 3 b) and the greatest increase in percentage time in initiative behavior (Fig. 3 c). Children in the Plain *githeri* plus oil (Energy) group were also more active and displayed more initiative and leadership behaviors than those in the Milk and Control groups,

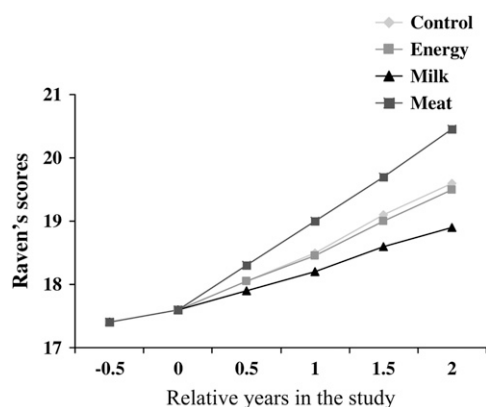


Figure 1 Raven's scores over time by intervention feeding group. From Neumann et al. (28). Reproduced with permission of author, who holds copyright.

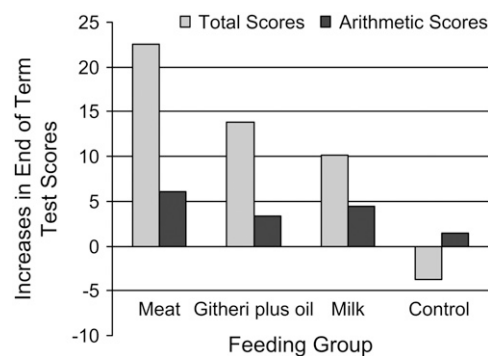


Figure 2 Increases in end-of-term test scores over time by feeding groups (Cohort II), adjusted for baseline age, gender, and height.

although not nearly as much as for the Meat group. The Milk group performed the most poorly of the 3 intervention groups.

Anthropometry. All feeding groups showed a greater rate of weight gain than the Control group. For the Milk group, only younger children (≤ 6 y) and stunted children (< -2 Z-scores) showed a greater rate of gain in height than the other children in the Milk group. None of the other groups showed any significant rate of gain in height. The Meat group showed the steepest rate of increase, near doubling, of MAMA (indicative of lean body mass) (Fig. 4), and the Milk group showed the next greatest improvement. A significant positive association was found between MAMA and percentage time spent in high levels of PA in the Meat group.

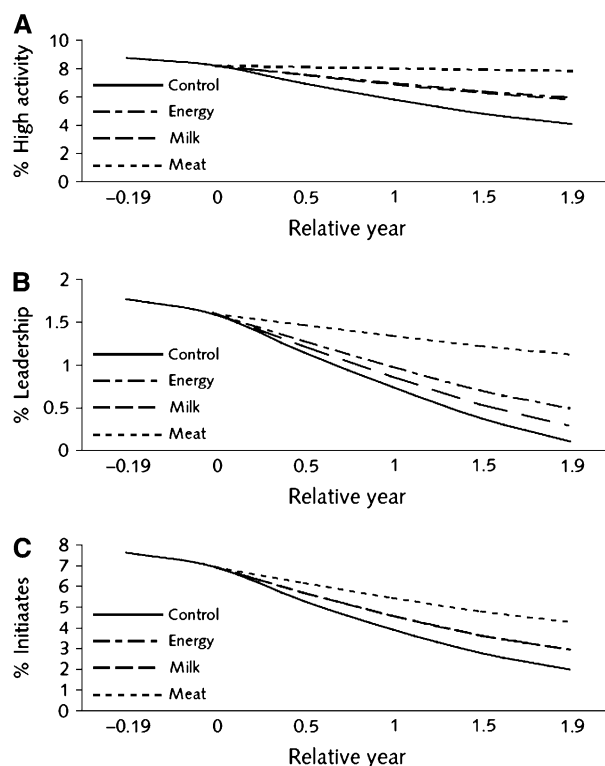


Figure 3 Behaviors during free play. From Sigman et al. (9). Reprinted with permission from the *UNU Food and Nutrition Bulletin*. (a) Percentage time spent in high activity over time by intervention feeding group. (b) Percentage time spent in leadership behavior over time by intervention feeding group. (c) Percentage time spent in initiative behavior over time by intervention feeding group.

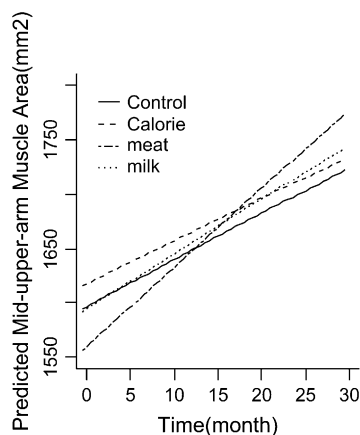


Figure 4 Predicted MAMA by relative time in study (Cohorts I and II). Calorie refers to the Plain *githeri* (Energy) group.

Discussion

This is the first randomized, controlled feeding intervention study with meat supplementation to show a causal set of positive relationships between meat and milk intake and important functional outcomes in children: improved cognitive performance; increased high levels of PA; increased initiative and leadership behaviors; and increased MAMA. Milk supplementation resulted in improved linear growth in younger and already stunted children. Compared with the Control group, all supplemented groups improved overall weight gain, suggesting a chronic energy deficit and inadequate energy intake for any catch-up growth. The improved cognitive performance and increased PA and leadership and initiative behaviors in the Meat group may be linked to greater intake of Vitamin B-12 and more available iron and zinc as a result of the presence of meat, which increases iron and zinc absorption from fiber and phytate-rich plant staples (2,22). Meat, through its intrinsic micronutrient content and other constituents and high-quality protein, may facilitate specific mechanisms, such as speed of information processing, that are involved in learning tasks such as problem-solving capacity, that are reflected in the significant increase in RPM scores in the Meat group. The Milk group performed the poorest on the RPM testing. A possible explanation is that milk, with its high casein and calcium content, impedes iron absorption—iron is intimately involved with cognitive function (6). The increase in MAMA in the Meat group may be because of the intake of zinc and complete protein, which both promote protein synthesis (23–25), and iron and protein, which are essential to myoglobin synthesis in striated muscle (7,26).

Food-based approaches, we believe, can offer more protection and sustainability than single- or multimicronutrient nonfood supplements. Putting “meat on the table” requires a supply of small animals within the production capabilities of smallholder farmers and families. Extension workers need to provide technical support and nutrition education to women in household animal production and in the preparation, preservation, and feeding of such ASF, particularly meat, to children and young women. School feeding programs that provide energy and high-quality protein and micronutrients are needed to promote improved learning and school performance. Such programs should be considered a major educational input and can also serve to educate children about good nutrition. Investments in children that enhance their ability to grow and develop cogni-

tively and remain in good health are essential to their future development, the workforce, and the nation (27).

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