Milk Powder Added to a School Meal Increases Cognitive Test Scores in Ghanaian Children

Reginald Lee, Lauren Singh, Danielle van Liefde, Meghan Callaghan-Gillespie, Matilda Steiner-Asiedu, Kwesi Saalia, Carly Edwards, Anja Serena, Tamara Hershey, and Mark J Manary

Abstract

Background: The inclusion of milk in school feeding is accepted as good nutritional practice, but specific benefits remain uncertain.

Objective: The objective was to determine whether consumption of 8.8 g milk protein/d given as milk powder with a multiple micronutrient–enriched porridge resulted in greater increases in linear growth and Cambridge Neuropsychological Test Automated Battery (CANTAB) scores in Ghanaian schoolchildren when compared with 1 of 3 control groups.

Methods: A randomized, double-blind, placebo-controlled clinical trial in healthy children aged 6–9 y was conducted comparing 8.8 g milk protein/d with 4.4 g milk protein/d or 4.4 g milk protein + 4.4 g rice protein/d (isonitrogenous, half of the protein from milk and half from rice) or a non-nitrogenous placebo. Primary outcomes were changes in length after 9 mo and CANTAB scores after 4.5 mo; secondary outcomes were body-composition measures. Supplements were added to porridge each school day and consumed for 9 mo. Anthropometric and body-composition measures and CANTAB tests were completed upon enrollment and after 4.5 and 9 mo. Group results were compared by using ANCOVA for anthropometric measures and the Kruskal-Wallis test for CANTAB scores.

Results: Children receiving 8.8 g milk protein/d showed greater increases on percentage correct in Pattern Recognition Memory (mean ± SD: 5.5% ± 16.8%; P < 0.05) and Intra/Extradimensional Set Shift completed stages compared with all other food groups (0.6 ± 2.3; P < 0.05). No differences were seen in linear growth between the groups. The children receiving either 4.4 or 8.8 g milk protein/d had a higher fat-free body mass index than those who received no milk, with an effect size of 0.34 kg/m².

Conclusion: Among schoolchildren, the consumption of 8.8 g milk protein/d improved executive cognitive function compared with other supplements and led to the accretion of more lean body mass, but not more linear growth. This trial was registered at www.clinicaltrials.gov as NCT02757508.

Keywords: school feeding, milk, Ghana, cognition, linear growth, CANTAB

Introduction

School feeding programs to address childhood malnutrition in developing countries are commonplace. The World Food Program provides school meals to ~20 million children every year. Consistent positive associations are seen between school feeding and micronutrient status, school attendance, and energy intake, but the impact of school meals on children’s physical growth and cognitive performance is less certain (1, 2).

Animal-source foods provide high-quality macro- and micronutrients and improve linear growth, micronutrient status, and cognitive performance in young children (3, 4). These foods make up <5–10% of total energy intake in most African countries. When fed a school meal with meat for 6 mo, rural Kenyan schoolchildren showed greater improvements in cognitive testing and nearly doubled their midupper arm muscle area when compared with controls (5). Cow milk is a source of high-quality protein, vitamins, minerals, PUFAs, insulin-like growth factors, and bioactive peptides, all of which have been shown to be beneficial to childhood growth and overall health (6). There is considerable evidence that cow milk stimulates weight gain and linear growth when given as a school food, especially in populations with poor nutritional status (7–10).

Several school feeding studies utilizing milk and measuring intellectual performance have been conducted worldwide (11). Typically, these studies have used tests of reading, language, and mathematics competency. Milk intervention groups have shown superiority in approximately one-third of these studies. This has led to uncertainty as to whether including the milk in school feeding improves cognition.
This study tested the hypotheses that Ghanaian schoolchildren receiving a micronutrient supplement with 8.8 g milk protein/d (Milk8; equivalent to 1 glass of milk) would have superior linear growth and performance on standardized tests of cognition than children receiving 4.4 g milk protein/d (Milk4), 4.4 g milk protein + 4.4 g rice protein/d (Milk/Rice), or a micronutrient supplement control group.

Methods

Participants and setting. Eligible children were aged 6–9 y, otherwise healthy, and enrolled in Primary 1–or Kindergarten 2–level classes at 1 of 13 schools in the Atebubu district within the Brong Ahafo region of Ghana. Exclusion criteria included severe acute malnutrition, milk allergy, or a chronic debilitating disease. In the Brong Ahafo region the mortality rate for children <5 y old is 87 deaths/1000 births. In 2010, the Atebubu district had a population of ~106,000 people and an average household size of 5.1. The main crops consumed in this population were maize, cassava, plantains, yams, rice, and tomatoes (12).

Study design. This was a prospective, randomized, double-blinded, controlled clinical trial in which children received 1 of 4 daily dietary supplements mixed into porridge before the start of the school day for an entire academic year, ~9 mo of school. This duration was chosen because it would allow ample time for the intervention to affect the primary outcomes, cognition and linear growth, as has been shown in previous studies (5, 6, 11). Three of the supplements included protein—Milk8, Milk4 (skimmed-milk powder, Arla Foods Amba), Milk/Rice (RemyProN80+, Beneo) with the addition of micronutrients (DSM)—whereas the control group received only the micronutrients. The protein amounts were chosen because Milk8 corresponds to 1 glass of milk/d; Milk/Rice was isonitrogenous with Milk8, but half of the protein was of plant origin; and Milk4 provided half as much protein as did Milk8 and allowed us to test for a dose-response.

The primary outcomes were as follows: change in linear growth measured as height-for-age z score (HAZ) and change in performance on a set of standardized cognitive tests. The sample size was revised to 1000 children when the participation period was extended from 4.5 to 9 mo. This change was made to allow for increases in HAZ to be more readily detected, because these increases would correspond to greater changes in height (centimeters). This sample size provided an 80% chance of detecting a significant difference at the 5% level in an increase in HAZ from 0 in the control group to 0.13 in the protein intervention groups, with 233 subjects required in each group (13). Cognitive testing data are not normally distributed, which precluded us from estimating a sample size for this outcome.

All of the study participants were randomly assigned to the Milk8, Milk4, Milk/Rice, or the control groups by using a random-number list that prospectively assigned numbers to 1 of 4 colors in blocks of 8. Each eligible child was given a number that corresponded to a color and shape that were coded to each of the 4 study supplements. Each supplement powder was provided in a foil package labeled with a unique color and shape. All of the research nurses and field investigators were blinded to the supplement groups. Although the allocated supplement group was not revealed to the study participants, their caregivers, or study assistants serving the food, the 4 supplements differed slightly in appearance and texture.

Informed consent was obtained individually after the headmaster agreed to allow the study to be conducted at his school. Large group meetings were held with all parents and children who were in the Primary 1 and Kindergarten 2 classes. The child’s participation was described in the local language, and ample time was allowed for complete discussion. At the conclusion of the meeting, each parent who expressed interest provided consent individually, both verbally and with a written document. All of the children indicated their assent verbally. The trial was registered at clinicaltrials.gov as NCT02757508, and ethical approval was obtained from the Noguchi Memorial Institute for Medical Research Institutional Review Board, Accra, Ghana, and the Human Research Protection Office at Washington University in St. Louis, Missouri.

Study foods. The 3 intervention supplements included Milk8, Milk4, and Milk/Rice, each with 0.2 g multiple micronutrient powder. The control supplement consisted of 0.2 g multiple micronutrient powder blended in a small amount of sucrose. Daily servings of Milk8 and Milk/Rice provided 15–16 g carbohydrates and ~100 kcal, whereas Milk4 provided 7 g carbohydrate and 48 kcal and the control provided 2.5 g carbohydrate and 10 kcal (Supplemental Table 1 (14)). Overall, these powders provided no more than 5% of the daily energy requirement and 8% of the daily protein requirement. All of the supplements were served with 300 g of porridge at school every morning. The porridge ingredients included broken rice or maize flour, water, sugar, and salt and provided ~150 kcal of energy and 3 g protein. Because the children at all 13 schools received the same rice or maize porridge, the nutrients and antinutrients (compounds that may interfere with nutrient absorption) from the porridge were similar in all groups. Study assistants monitored feedings to ensure participants consumed the entirety of their porridge and were prepared to intervene in the case of any observed sharing or adverse events such as an allergic reaction to the supplements. The multiple micronutrient powder cost ~$0.008/d, and the milk powder cost $0.05/d.

Subject participation. Participants received their morning porridge in bowls colored yellow, blue, green, or red in coordination with the 4 supplements. Children would gather into groups according to their assigned colored bowls, and a trained study assistant served them the porridge with a standardized scoop of the corresponding powder. To ensure that each participant received the assigned supplement throughout the study, assistants verified the powder dispensed with a list of each child’s name and color. Attendance was recorded each morning when the child received his or her bowl of porridge.

Upon enrollment at baseline, study assistants measured weight, height, and midupper arm circumference, as previously described (15). Body composition was determined by using an RJL Systems Quantum IV Bioelectrical Impedance Analyzer, as recommended by the manufacturer (16). The same procedures were used for follow-up measurements taken after 4.5 and 9 mo. Fat-free mass, lean dry mass, total body water, fat, fat mass index, and fat-free mass index (FFMI) were calculated with the use of recommended equations from RJL Systems (17–19). Fat mass index and FFMI were used as normalized measures of body composition because of the variation in heights of the study population (20).

Upon enrollment, cognitive tests created by Cambridge Cognition were administered, and follow-up testing occurred after 4.5 and 9 mo of participation. Five different tests were administered consecutively on a Windows tablet with the use of CANTAB (Cambridge Neuropsychological Test Automated Battery) Research Suite software from the Cambridge Neuropsychological Test Automated Battery. The tests were language-independent and used touchscreen technology to deliver noninvasive, objective cognitive assessment. Trained research assistants administered the test in a quiet section of the school after meals were completed, and no technical knowledge or prior familiarity with computers was necessary for the participants. Before formal testing, the children participated in a prescribed exercise to familiarize themselves
FIGURE 1  Study flow diagram of Ghanaian schoolchildren aged 6–9 y in the school feeding study. *Excluded for missing 4.5 and 9 mo of testing. A, anthropometric measurements; C, cognitive testing; EMB, excluded for missing baseline; Milk4, 4.4 g milk protein/d; Milk8, 8.8 g milk protein/d; Milk/Rice, 4.4 g milk protein + 4.4 g rice protein/d.

with the operation of the tablet, and the research assistant verified their understanding before testing. All test images were geometric shapes without any cultural connotations. The following tests were used to examine visual memory pattern, recognition memory, comprehension, rule acquisition, and attention set shifting: Motor Screening Task (MOT), Paired-Associated Learning (PAL), Pattern Recognition Memory (PRM), Big/Little Circle (BLC), and Intra/Extradimensional Set Shift (IED), respectively. Among these 5 test types, 13 different scores were collected for analysis, distributed as follows: MOT (2), PAL (5), PRM (2), BLC (1), and IED (3).

Information on socioeconomic characteristics and household food security and FFQs were completed for 20% of the participants enrolled in the study; the guardian of every fifth enrollee was asked to participate. Surveys were conducted at initial parent meetings where local research assistants sat with the parent and completed the survey together. Data describing the demographic and socioeconomic status of the child’s household were collected. In order to characterize a family’s consumption of dairy and animal-source foods, an FFQ assessing intakes of 30 local foods and beverages was administered.

Statistical analyses. All of the analyses were undertaken blinded to food-group assignment. Data were double-entered into a Microsoft Access database, and discrepant values corrected by reviewing the original data collection cards. Characteristics and outcomes were tabulated. Data were analyzed by using SPSS Statistics software (version 25.0; IBM Corp.). Anthropometric z scores were calculated by using the WHO Anthroplus version 1.0.4, based on the 2006 WHO Child Growth Standards (21). Study participants with data from any 4.5- or 9-mo outcome were included in the analyses.

For the CANTAB data, differences in performance from enrollment to 4.5 mo were used as the primary outcome. The CANTAB cognitive test scores were continuous outcomes but were not normally distributed; therefore, nonparametric tests were used to compare differences between the food groups. Kruskal-Wallis chi-square tests were performed with protein supplement groups as the independent variable and change in CANTAB scores as the dependent variable. The Mann-Whitney U test was used for CANTAB data pairwise comparisons. The nonparametric Jonckheere-Terpstra test was used to assess the trend of the natural order between the supplement groups. Because there were 13 comparisons made with CANTAB scores, the Benjamini-Hochberg procedure to correct for the multiple comparisons was conducted, setting the false discovery rate at 10%.

The changes from enrollment to 9 mo were calculated for anthropometric z scores and body-composition measurements. Changes in anthropometric and body-composition outcomes by supplement group were compared by using a univariate ANCOVA, with the anthropometric measure upon enrollment used as a covariate.

Bivariate analyses were conducted to evaluate linearity and reliability of the changes observed in the primary outcomes at 4.5 and 9 mo. The Pearson product-moment correlation was calculated to assess the
consistency of the change in anthropometric measures between enrollment and 4.5 mo and enrollment and 9 mo. Similarly, Spearman correlation coefficient was calculated to explore associations between the change in cognitive performance after 4.5 and 9 mo. Significance was set at $P < 0.05$; all statistical tests were 2-sided.

### Results

The study was conducted from March 2016 until July 2017, during which 1041 children were enrolled, and of whom 939 had HAZ outcomes and 883 had CANTAB outcomes (Figure 1). Upon enrollment, there were no differences seen in anthropometric measures or cognition between the 4 supplement groups (Tables 1 and 2, Supplemental Table 2).

The household and dietary survey showed that more than half of the children had access to clean water (91 of 159; 57%), such as a borehole or a public pipe, and 81 of 159 (51%) disposed of their stools in a contained area. Milk consumption was reported to be ~1 time/wk, whereas meat was consumed typically every other day. Only 1 guardian reported having a computer in the house (Table 1). Of the 883 children who completed the CANTAB testing, school attendance was 115 ± 15 d (mean ± SD) out of a total of 134 potential school days.

For all of the participants, the change in HAZ between enrollment and 9 mo was 0.02 $z$ scores, and there were no differences between the 4 supplement groups ($P = 0.47$; Figure 2, Supplemental Table 3). The food groups who received milk protein had lower decreases in FFMI from enrollment to 9 mo than did controls (0.00 ± 0.64, $-0.03 ± 0.64$, $-0.07 ± 0.64$, and $-0.19 ± 0.68$ kg/m² in the Milk8, Milk4, Milk/Rice, and control groups, respectively; $P = 0.01$). A direct correlation was seen between the change in anthropometric measures from enrollment to 4.5 mo and from enrollment to 9 mo for all children ($r > 0.52$, $P < 0.001$ for all comparisons; Supplemental Table 4).

Within the CANTAB variables, the Milk8 group showed greater improvements in the PRM and IED tests of CANTAB from enrollment to 4.5 mo than did all other supplement groups (Figures 3 and 4). Children receiving the Milk8 supplement showed greater improvement for PRM percentage correct than did those receiving Milk4, Milk/Rice, or control supplements (Supplemental Table 5; $P < 0.007$). Similarly, children receiving the Milk8 supplement showed superior improvement on all 3 IED tests, stages completed, errors, and total errors, when compared with those receiving Milk4, Milk/Rice, or control supplements (Figure 3, Supplemental Table 5; $P < 0.05$ for all comparisons).

### Table 1: Characteristics of Ghanaian schoolchildren receiving protein and micronutrient supplements

<table>
<thead>
<tr>
<th>Demographic and anthropometric characteristics</th>
<th>Milk8</th>
<th>Milk4</th>
<th>Milk/Rice</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>$n$</td>
<td>236</td>
<td>234</td>
<td>232</td>
<td>237</td>
</tr>
<tr>
<td>Age, y</td>
<td>112 (47)</td>
<td>117 (50)</td>
<td>105 (45)</td>
<td>116 (49)</td>
</tr>
<tr>
<td>Weight-for-age $z$ score</td>
<td>−0.9 ± 1.0</td>
<td>−1.0 ± 0.9</td>
<td>−1.0 ± 1.0</td>
<td>−1.0 ± 1.0</td>
</tr>
<tr>
<td>Height-for-age $z$ score</td>
<td>−0.8 ± 1.3</td>
<td>−0.8 ± 1.1</td>
<td>−0.9 ± 1.1</td>
<td>−0.8 ± 1.2</td>
</tr>
<tr>
<td>MUAC, cm</td>
<td>16.9 ± 1.3</td>
<td>16.8 ± 1.2</td>
<td>16.9 ± 1.3</td>
<td>17.0 ± 1.3</td>
</tr>
<tr>
<td>Body fat, %</td>
<td>14.9 ± 5.8</td>
<td>14.3 ± 5.5</td>
<td>14.8 ± 5.8</td>
<td>14.7 ± 5.5</td>
</tr>
<tr>
<td>Fat-free mass index, kg/m²</td>
<td>12.6 ± 1.0</td>
<td>12.6 ± 1.1</td>
<td>12.6 ± 1.0</td>
<td>12.7 ± 1.0</td>
</tr>
<tr>
<td>Fat mass index, kg/m²</td>
<td>2.2 ± 1.0</td>
<td>2.1 ± 0.9</td>
<td>2.2 ± 1.0</td>
<td>2.2 ± 0.9</td>
</tr>
<tr>
<td>Lean dry mass, %</td>
<td>22.8 ± 3.9</td>
<td>22.9 ± 3.3</td>
<td>23.0 ± 3.8</td>
<td>22.8 ± 3.5</td>
</tr>
</tbody>
</table>

1 Values are means ± SDs or n (%).
2 Household and dietary characteristics surveyed on a subset of the study population. Mid-upper arm circumference (MUAC).
3 MUAC, mid-upper arm circumference.

### Table 2: Cognitive testing results of Ghanaian schoolchildren aged 6–9 y upon enrollment in the school feeding study

<table>
<thead>
<tr>
<th>Cognitive test</th>
<th>Milk8 (n = 220)</th>
<th>Milk4 (n = 221)</th>
<th>Milk/Rice (n = 215)</th>
<th>Control (n = 227)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRM percent correct, %</td>
<td>57 ± 14</td>
<td>54 (46, 67)</td>
<td>58 ± 16</td>
<td>54 (46, 71)</td>
</tr>
<tr>
<td>PRM mean correct latency, ms</td>
<td>3528 ± 1754</td>
<td>3123 (2401, 4054)</td>
<td>3263 ± 2131</td>
<td>2875 (2350, 3603)</td>
</tr>
<tr>
<td>IED Pre-ED shift errors, errors</td>
<td>15.3 ± 13.4</td>
<td>11 (7,18)</td>
<td>13 ± 9.2</td>
<td>10 (7,16)</td>
</tr>
<tr>
<td>IED stages complete, stages</td>
<td>7.2 ± 0.0</td>
<td>7 (7,8)</td>
<td>7.4 ± 2.1</td>
<td>8 (7,9)</td>
</tr>
<tr>
<td>IED total errors, errors</td>
<td>37 ± 15</td>
<td>36 (28,45)</td>
<td>34 ± 14</td>
<td>35 (25,42)</td>
</tr>
</tbody>
</table>

1 The cognitive tests are part of the Cambridge Neurophysiological Test Automated Battery. IED, Intra/Extradimensional Set Shift; Milk4, 4 g milk protein/d; Milk8, 8.8 g milk protein/d; Milk/Rice, 4.4 g milk protein + 4.4 g rice protein/d; Pre-ED, Pre-Extradimensional; PRM, pattern recognition memory.
2 Derived by using Kruskal-Wallis test.
FIGURE 2 Changes in HAZ (A), WAZ (B), and FFMI (C) among Ghanaian schoolchildren aged 6–9 y receiving varying amounts of milk protein as a supplement for 9 mo. The numbers of observations were 223, 223, 213, and 226 for the Milk8, Milk4, Milk/Rice, and control groups, respectively. Boxes span the IQR (25th–75th percentiles); the middle line represents the median and crosses indicate the mean.

*Mean differs from control, $P < 0.05$ (ANCOVA). FFMI, fat-free mass index; HAZ, height-for-age $z$ score; Milk4, 4.4 g milk protein/d; Milk8, 8.8 g milk protein/d; Milk/Rice, 4.4 g milk protein + 4.4 g rice protein/d; WAZ, weight-for-age $z$ score.

Discussion

This randomized, double-blind, controlled clinical trial showed that the consumption of 8.8 g milk protein given as skimmed milk powder during school attendance among Ghanaian children aged 6–9 y improved cognition on 2 of 5 tests after 4.5 mo. The consumption of any quantity of milk protein led to the accretion of more lean body mass after 9 mo but did not have an effect on linear growth. The strong correlation between a child’s change in cognition from enrollment to 4.5 mo with the change from enrollment to 9 mo shows a parallel-response effect. The same strong correlation was seen for change in growth.

Several study limitations should be considered with respect to the generalizability of our data. First, our hypotheses did not identify the specific cognitive variables for which milk protein supplementation would be beneficial, nor did it elucidate which nonlipid components of milk might be implicated in the improvement. Although the CANTAB tests we chose were aimed at broadly assessing cognition, future research might focus on tests that might be particularly important for students at selected developmental stages. We found positive correlation coefficients between the change in measures from enrollment to 4.5 and 9 mo, which suggest internal consistency of effects measured by CANTAB tests over time. This is important because it has been previously suggested that a criterion for the validity of CANTAB testing is the demonstration of stability of results (22). We did not carefully characterize the habitual diet in terms of nutrients and food types, but rather simply studied the question of whether adding milk powder and micronutrients was superior to adding micronutrients alone in rural Ghana. Any nutritional intervention is contingent upon the usual dietary intake of the population; therefore, these findings might be different in populations who consume more or less animal-source foods. Finally, the nonparticipation rate in our study was 350 of 1430 (24%), which represents children for whom a parent or guardian did not attend the orientation meeting. These children received operational school feeding with micronutrient-fortified porridge. We have no data on these children to speculate as to how they differed from the participants.

Daily supplementation with 8.8 g milk protein, compared with other protein and control supplements, supports cognition in discrete aspects of visual memory, attention, and executive function as assessed by CANTAB. The children who received 8.8 g daily milk protein supplement showed superior all comparisons). The false discovery rate was <10% for the 4 significant Milk8 findings. No significant trend effect was seen in CANTAB scores for the amount of protein added to the school porridge.

Greater improvements in PRM percentage correct and IED stages completed scores were seen in the Milk8 group than in the Milk/Rice group, a group who received an isonitrogenous amount of protein (Figure 4, Supplemental Table 6; $P < 0.001$ for both comparisons). For the PAL, BLC, and MOT CANTAB tests, no significant differences were seen between the 4 supplement groups, nor do the summary data suggest that any of the groups performed differently on these cognitive tests when compared to one another.

Spearman correlation coefficients between changes over 4.5 and 9 mo of participation for all children for all 13 CANTAB scores were directly correlated and showed moderate to strong positive correlations among changes in individual CANTAB scores (all $rs > 0.42$; and all $P < 0.001$; Supplemental Table 4).
FIGURE 3  (A–E) Changes in cognitive test scores among Ghanaian schoolchildren aged 6–9 y receiving varying amounts of milk protein as a supplement for 4.5 mo. The numbers of observations were 220, 221, and 227 for the Milk8, Milk4, and control groups, respectively. Boxes span the IQR (25th–75th percentiles); the middle line represents the median, and crosses indicate the mean. *Median change differs from Milk4 and control, \( P < 0.05 \) (Kruskal-Wallis test). IED, Intra/Extradimensional Set Shift; Milk4, 4.4 g milk protein/d; Milk8, 8.8 g milk protein/d; PRM, Pattern Recognition Memory.

performance on 2 of the 5 tests administered, PRM and IED. Differences between supplement groups were not seen for cognitive outcome variables measuring the speed of task completion or processing time of the information, but rather in the proficiency in completing the actual task, such as recognizing objects and shifting attention focus.

The PRM is a simple nonverbal recognition memory paradigm, validated in nonhuman primate research (23, 24), and used extensively in humans to examine both normal and disease conditions (25, 26). Factor analyses have found that this task is strongly associated with performance on other nonverbal memory tasks (27) and is diminished in diseases that affect the declarative memory system, such as Alzheimer disease (25–27). The declarative memory system relies on the medial temporal lobes, which include the hippocampus and associated regions such as the prefrontal, parietal, and premotor cortices, to lay down new information for later term recall or recognition (28–30). PRM accuracy improves with age during development and decreases during aging (25, 31) and in conditions that affect the integrity of the hippocampus and other declarative memory-associated regions (25). In the present study, PRM accuracy, but not reaction time, significantly improved in the Milk8 group, suggesting that the function of the medial temporally mediated declarative memory system may have benefited from this supplementation.

The IED test is a complex and demanding executive function test based on the classic Wisconsin Card Sorting test and validated in nonhuman primate studies (32). Optimal performance requires multiple cognitive components, all working in concert, including visual discrimination, attentional set formation and maintenance, response to feedback, and flexible shifting of attentional sets. Like many other complex executive tasks, the IED is impaired in conditions that affect the function of the prefrontal cortex and its dopaminergic innervation (30, 33) and improves over time periods during which the prefrontal cortex undergoes significant maturation (31, 34, 35). In the present study, IED accuracy, but not reaction time, significantly improved in the Milk8 group, suggesting that \( \geq 1 \) function of the prefrontally mediated executive system may have benefited from this supplementation.

When considering the Milk8 and Milk/Rice groups, both supplements had similar amounts of protein, carbohydrate, and lactose; the only difference was that the Milk8 group consumed 8.8 g milk protein, whereas the Milk/Rice group consumed 4.4 g milk protein. Children receiving Milk8 had better cognition when tested by PRM and IED. This finding implicates milk protein as the cause for this cognitive improvement.

We speculate that a bioactive peptide might be responsible for the improvement seen in cognition. Dairy protein, in particular, contains a number of such peptides, factions of whey and casein, which preserve and improve cognition and memory in animal models (36). Proline-rich polypeptides, found in colostrum, have been shown to improve memory in small trials in older individuals (37). \( \alpha \)-Lactalbumin is a major protein constituent of bovine milk and an excellent source of tryptophan and cysteine. \( \alpha \)-Lactalbumin enhances serotonin synthesis, which is associated with improved information processing and alertness (38–40). Thus, \( \alpha \)-lactalbumin may contribute to the improved cognition seen in the African children from our study.

One interesting finding with respect to the nutrient composition of the supplements is that the Milk8 group received more vitamin B-12, 2.6 \( \mu \)g/d compared with 1.9 \( \mu \)g/d in the Milk/Rice
FIGURE 4  (A–E) Changes in cognitive testing results among Ghanaian schoolchildren aged 6–9 y receiving milk protein or milk + rice protein as a daily supplement. The numbers of observations were 220 and 221 for the Milk8 and Milk/Rice groups, respectively. Boxes span the IQR (25th–75th percentiles); the middle line represents the median, and crosses indicate the mean. *Median results of Milk8 differ from Milk/Rice, \( P < 0.05 \) (Mann-Whitney \( U \) test). IED, Intra/Extradimensional Set Shift; Milk8, 8.8 g milk protein/d; Milk/Rice, 4.4 g milk protein + 4.4 g rice protein/d; PRM, Pattern Recognition Memory.

group and 1.0 \( \mu \)g/d in the control group (Supplemental Table 1). It is not likely that any of these quantities of vitamin B-12 were inadequate, given that the RDA is 1.2 \( \mu \)g/d and the supplement comprised just a small portion of the entire diet, and as a group the population reported consuming meat every other day. However, in a recent study from Nepal, vitamin B-12 status in infancy was associated with cognitive test performance during school age (41), highlighting that some relation may exist.

This trial also suggests that milk protein consumption promotes accretion of lean body mass. Lean body mass is associated with greater physical work capacity and less chronic illness (16, 17). We speculate that this effect might be even more beneficial in school feeding programs targeted at the adolescent population, because this is a period during which rapid growth takes place, second only to the growth that occurs during the first year of life. An observational study in American children highlights the plausibility of this speculation, reporting that although childhood milk consumption had no effect on height of children aged 5–11 y, adolescent consumption from 12 to 18 y was indeed a significant predictor of linear growth (10).

This study provides a practical option to enhance school foods in Africa, the addition of multiple micronutrients and powdered milk. These ingredients cost \( \sim \$0.06/d \) at present, which is within the budgetary scope of school feeding in Ghana, which currently spends \$0.25 \cdot d \cdot child^{-1} (2).

Our findings suggest that future exploration of milk protein supplementation of \( \geq 8.8 \) g/d in vulnerable African populations may benefit schoolchildren. It is important to note that only 5 of the 13 domains of CANTAB testing were administered in this study. Although significant, the effect found among our population was small, and participants performed below published norms at a mean level but within the very wide range of normal seen in European children. Additional studies in adolescents may be particularly important with regard to school feeding.

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