

## Supplement 3

### Milk or cowpea-containing peanut-based ready-to-use foods for school feeding of Ghanaian children 5-12 years of age to improve cognition

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This supplemental material has been provided by the authors to give readers additional information about their work.

## **METHODS S1** Acceptability pilot study

Prior to trial initiation, a pilot study was undertaken to determine whether ready-to-use school foods would be acceptable in a school feeding quantity (80g) in the target population. The study setting and participants were chosen to mirror the planned trial. It took place in Mion District, in the Northern Region of Ghana, among children 5-12 years old, with exclusion criteria being diagnosis of severe acute malnutrition, presence of a chronic debilitating disease, allergy to peanut or milk. The pilot was done at a community level, rather than within a school, due to nationwide closure of schools due to the COVID-19 pandemic.

Four peanut-based ready-to-use foods (RUFs) and a locally available biscuit were provided. The four RUFs were: peanut/cowpea, peanut/cowpea + cocoa, peanut/cowpea + ginger, and peanut/milk. All RUFs contained vegetable oil, sugar, and micronutrients. A daily dose was 80 grams, sealed in a foil package.

Parents or caregivers were instructed on the study procedures and risks and, if agreeable, provided written and verbal consent. 60 children were enrolled and introduced to the study and its objectives. The pilot took place over 16 days, with 3 consecutive days allotted to each food except peanut/cowpea + ginger, which underwent 4 days of testing in error. Following consumption, participants completed a likeability survey with a study monitor, ranking the likeability of the food on a 5-point Likert scale, ranging from 1 (“dislike very much”) to 5 (“like very much”). Additionally, the study monitor would identify (1) whether the child consumed all the food and (2) measure the weight in grams of the RUF that was not consumed.

Participant demographics were as expected for Mion District, including 51/60 (85%) households relying on subsistence farming. Attendance averaged 81% over the 16 study days. Biscuits were tested first, followed by peanut/milk, peanut/cowpea, peanut/cowpea + ginger, and peanut/cowpea + cocoa. Results are displayed in eTable 3 in Supplement 3.

**TABLE S1** Nutrient content of school foods<sup>1</sup>

<b>Nutrient</b>	<b>Peanut/milk ready-to-use food</b>	<b>Peanut/cowpea ready-to-use food</b>	<b>Fortified Porridge</b>
Energy, kcal	402	416	412
Protein, g	17.6	14.5	11.9
Fat, g	24.7	28.9	5.4
Essential amino acids, g	7.13	4.78	5.16
Calcium, mg	341	46	45
Vitamin B12, mg	1.6	0.6	0.6

<sup>1</sup> For water soluble vitamins and minerals, the fortified school foods provided 50-100% of the Recommended Daily Allowance, as per reference values from the Food and Nutrition Board of the National Academies of Sciences, Engineering, and Medicine Dietary References Intakes (<https://ods.od.nih.gov/HealthInformation/nutrientrecommendations.aspx#dri>)

**TABLE S2** Micronutrient content of 3 school foods (before fortificant added) and the fortificant<sup>1</sup>

<b>Micronutrient</b>	<b>Peanut/milk ready-to-use food</b>	<b>Peanut/cowpea ready-to-use food</b>	<b>Fortified millet porridge</b>	<b>Micro-nutrient fortificant</b>	<b>Recommended Daily Allowance for 4-8 year-old children<sup>2</sup></b>
Vitamin A, µg	10	3	0	189	400
Vitamin C, mg	14	0.2	0	17.3	25
Vitamin D, µg	0	0	0	3.2	15
Vitamin E, mg	1.6	2.0	2.7	4.1	7
Vitamin K, µg	0.40	0.2	1	5.2	55
Thiamin, mg	0.19	0.2	0.41	0.28	0.6
Riboflavin, mg	0.51	0.32	0.07	0.50	0.6
Niacin, mg	5.3	7.0	6.0	3.0	8
Vitamin B6, mg	0.23	0.2	0.37	0.43	0.6
Folate, µg	148	143	42	58.7	200
Vitamin B12, µg	1.0	0	0	0.6	1.2
Pantothenic acid, mg	0.52	0.7	1.3	0.32	2
Biotin, µg	25	32	0	12.6	12
Calcium, mg	309	31	14	32.4	1000
Copper, µg	163	134	535	216	440
Iodine, µg	0	0	0	20	90
Iron, mg	1.6	2.5	3.9	1.8	10
Selenium, µg	6.7	9.3	33	2.7	30
Zinc, mg	1.5	2.1	2.6	2.0	5.0

<sup>1</sup> Daily consumption for any given child is estimated to be the total of the school food and the fortificant. The amounts listed for the three school foods are prior to addition of the fortificant.

<sup>2</sup> As per the Food and Nutrition Board of the National Academies of Sciences, Engineering, and Medicine Dietary References Intakes (<https://ods.od.nih.gov/HealthInformation/nutrientrecommendations.aspx#dri>)

**TABLE S3** Consumption and acceptability of a local biscuit and 4 ready-to-use foods among 60 Ghanaian children 5–12 years of age<sup>1</sup>

<b>Outcome</b>	<b>Biscuit (n = 185)</b>	<b>Peanut/cowpea + cocoa (n = 176)</b>	<b>Peanut/cowpea + ginger (n = 225)</b>	<b>Peanut/milk (n = 147)</b>	<b>Peanut/cowpea (n = 143)</b>
Amount consumed, %	99 ± 7	90 ± 27	88 ± 27	90 ± 24	94 ± 19
Consumed all, n (%)	167 (90)	150 (85)	185 (82)	121 (85)	114 (78)
Likert score, median (IQR)	5 (2, 5)	5 (3, 5)	5 (4, 5)	5 (2, 5)	5 (2, 5)

<sup>1</sup> Values are presented as mean ± SD unless otherwise indicated. Group ns represent the number of occasions a food was consumed among the 60 participants over 3-4 days of consumption. The ready-to-use foods were provided in 80g packets. Amount consumed was determined by weighing packets after the participant finished eating.

**TABLE S4** Baseline fluid cognition test results among children randomized to 1 of 3 school foods<sup>1</sup>

Test	Peanut/milk RUF (PM-RUF) (n = 282)	Peanut/cowpea RUF (PC-RUF) (n = 292)	Fortified Porridge (FP) (n = 297)
Dimensional change card sort			
Total score			
Median (IQR)	3.8 (3.1, 4.6)	3.8 (3.2, 4.5)	3.9 (3.4, 4.5)
Mean ± SD	3.8 ± 1.4	3.9 ± 1.4	3.9 ± 1.4
Speed score			
Median (IQR)	0 (0, 0)	0 (0, 0)	0 (0, 0)
Mean ± SD	0.2 ± 0.7	0.2 ± 0.7	0.2 ± 0.7
Accuracy Score			
Median (IQR)	3.9 (3.0, 4.4)	3.9 (3.2, 4.3)	3.9 (3.4, 4.4)
Mean ± SD	3.6 ± 1.0	3.6 ± 1.0	3.7 ± 1.0
Flanker inhibitory control and attention			
Total score			
Median (IQR)	5.0 (3.8, 6.1)	4.8 (3.3, 5.6)	5.0 (3.9, 5.8)
Mean ± SD	4.9 ± 1.5	4.6 ± 1.6	4.8 ± 1.5
Speed score			
Median (IQR)	0.2 (0, 1.2)	0 (0, 0.9)	0 (0, 1.1)
Mean ± SD	0.7 ± 0.9	0.5 ± 0.9	0.7 ± 1.0
Accuracy Score			
Median (IQR)	4.8 (3.5, 5.0)	4.5 (3.3, 5.0)	4.5 (3.5, 5.0)
Mean ± SD	4.3 ± 0.9	4.1 ± 1.0	4.2 ± 0.9
Pattern comparison processing speed score			
Median (IQR)	11 (4, 22)	11 (5, 20)	11 (3, 21)
Mean ± SD	14 ± 11	13 ± 11	13 ± 12
Listing sorting working memory score			
Median (IQR)	4 (3, 6)	4 (3, 5)	4 (3, 5)
Mean ± SD	4.4 ± 2.2	4.3 ± 2.2	4.5 ± 2.1

<sup>1</sup>The maximum possible total score for dimensional change card sort and flanker is 10, while it is 130 for pattern comparison processing speed and 26 for list sorting working memory. Dimensional change card sort and flanker total scores are composed of both speed and accuracy scores. Several participants did not undergo baseline testing of dimensional change card sort (PM-RUF n = 2, PC-RUF n = 1, FP n = 1) or pattern comparison processing speed (FP n = 1). FP, fortified porridge; PC-RUF, peanut/cowpea ready-to-use food; PM-RUF, peanut/milk ready-to-use food.

**TABLE S5** Endline fluid cognition test results among children randomized to 1 of 3 school foods<sup>1</sup>

Outcome	Peanut/milk RUF (PM-RUF) (n = 253)	Peanut/cowpea RUF (PC-RUF) (n = 273)	Fortified Porridge (FP) (n = 271)	OR (95% CI) PM-RUF vs. FP	OR (95% CI) PC-RUF vs. FP	OR (95% CI) PM-RUF vs. PC-RUF
<b>Dimensional change card sort</b>						
Total score				1.5 (1.1, 2.0)	1.2 (0.9, 1.6)	1.2 (0.9, 1.7)
Median (IQR)	4.3 (3.8, 5.4)	4.1 (3.8, 5.1)	4.0 (3.7, 5.1)			
Mean ± SD	4.6 ± 1.7	4.3 ± 1.4	4.2 ± 1.6			
Speed score				1.3 (1.0, 1.9)	1.0 (0.7, 1.4)	1.4 (1.0, 1.9)
Median (IQR)	0 (0, 1.0)	0 (0, 0.7)	0 (0, 0.7)			
Mean ± SD	0.7 ± 1.2	0.4 ± 0.8	0.5 ± 0.9			
Accuracy Score				1.5 (1.1, 2.0)	1.3 (1.0, 1.8)	1.2 (0.9, 1.6)
Median (IQR)	4.0 (3.9, 4.5)	4.0 (3.8, 4.5)	4.0 (3.7, 4.4)			
Mean ± SD	3.9 ± 0.9	3.9 ± 1.0	3.7 ± 1.1			
<b>Flanker inhibitory control</b>						
Total score				1.2 (0.9, 1.6)	1.1 (0.9, 1.5)	1.1 (0.8, 1.4)
Median (IQR)	5.4 (4.3, 6.4)	5.3 (4.0, 6.3)	5.2 (4.1, 6.3)			
Mean ± SD	5.3 ± 1.5	5.1 ± 1.5	5.1 ± 1.4			
Speed score				1.2 (0.9, 1.7)	1.2 (0.9, 1.7)	1.0 (0.7, 1.3)
Median (IQR)	0.6 (0, 1.5)	0.4 (0, 1.5)	0.5 (0, 1.5)			
Mean ± SD	0.8 ± 0.9	0.8 ± 0.9	0.8 ± 0.9			
Accuracy Score				1.2 (0.9, 1.7)	1.1 (0.8, 1.5)	1.2 (0.8, 1.6)
Median (IQR)	5.0 (4.3, 5.0)	4.9 (3.9, 5.0)	4.9 (3.9, 5.0)			
Mean ± SD	4.5 ± 0.9	4.4 ± 0.9	4.4 ± 0.9			
Pattern comparison processing speed score				1.4 (1.0, 1.9)	1.3 (1.0, 1.7)	1.1 (0.8, 1.5)
Median (IQR)	20 (8, 30)	18 (6, 28)	16 (6, 27)			
Mean ± SD	19 ± 13	18 ± 13	17 ± 13			
Listing sorting working memory score				1.1 (0.8, 1.5)	0.8 (0.6, 1.1)	1.3 (1.0, 1.8)
Median (IQR)	8 (6, 10)	7 (6, 9)	7 (6, 10)			
Mean ± SD	8.0 ± 2.3	7.6 ± 2.3	7.8 ± 2.3			
Composite median rank <sup>2</sup>				1.5 (1.1, 2.0)	1.2 (0.9, 1.6)	1.3 (0.9, 1.7)
Median (IQR)	434 (222, 629)	388 (188, 572)	365 (187, 567)			
Mean ± SD	425 ± 230	387 ± 227	381 ± 230			

<sup>1</sup> The maximum possible total score for dimensional change card sort and flanker is 10, while it is 130 for pattern comparison processing speed and 26 for list sorting working memory. Pairwise comparisons of endline cognitive test results were performed using ordinal logistic regression, with endline test score as the dependent variable, food group as the independent variable of interest, and baseline score and participant age as covariates. Several participants did not undergo dimensional change card sort testing at baseline (PM-RUF n = 2, PC-RUF n = 1, FP n = 1) or endline (FP n = 1), or pattern comparison processing speed at endline (PM-RUF n = 1), and thus were not included in statistical analyses. Abbreviations: FP, fortified porridge; PC-RUF, peanut cowpea ready-to-use food; PM-RUF, peanut milk RUF, peanut milk ready-to-use food.

<sup>2</sup> Composite median rank was obtained by ranking all scores within each test, computing the median of each participant's test ranks, and ranking these median ranks. Pairwise comparisons were done using ordinal logistic regression with the same procedure as above.

**TABLE S6** Changes in anthropometry among children randomized to 1 of 3 school foods<sup>1</sup>

<b>Outcome</b>	<b>Peanut/milk RUF (PM-RUF) (n = 253)</b>	<b>Peanut/cowpea RUF (PC-RUF) (n = 273)</b>	<b>Fortified porridge (FP) (n = 271)</b>	<b>Difference (95% CI) PM-RUF vs. FP</b>	<b>Difference (95% CI) PC-RUF vs. FP</b>	<b>Difference (95% CI) PM-RUF vs. PC-RUF</b>
Change in height-for-age z-score	0.03 ± 0.25	0.03 ± 0.21	0.06 ± 0.28	-0.03 (-0.07, 0.01)	-0.03 (-0.07, 0.01)	0.00 (-0.04, 0.04)
Change in BMI-for-age z-score	-0.03 ± 0.31	-0.03 ± 0.37	-0.03 ± 0.37	0.00 (-0.06, 0.06)	0.00 (-0.06, 0.06)	0.01 (-0.05, 0.07)
Change in fat-free mass, kg	1.42 ± 1.31	1.34 ± 1.23	1.34 ± 1.29	0.09 (-0.13, 0.32)	0.00 (-0.22, 0.22)	0.09 (-0.13, 0.32)
Change in MUAC, cm	0.0 ± 0.9	0.0 ± 0.7	0.0 ± 0.8	0.0 (-0.1, 0.2)	0.0 (-0.1, 0.1)	0.0 (-0.1, 0.2)

<sup>1</sup>All changes were calculated by subtracting the baseline value from the value measured at the end of the trial. Positive differences indicate PM-RUF or PC-RUF gained more than FP, or PM-RUF gained more than PC-RUF. Fat-free mass was measured using bioelectrical impedance. Pairwise comparisons were made using linear regression adjusted for baseline anthropometric value. Several participants did not undergo baseline or endline measurements of height (PM-RUF n = 6, PC-RUF n = 13, FP n = 10), weight (PM-RUF n = 3, PC-RUF n = 3, FP n = 3), fat-free mass (PM-RUF n = 9, PC-RUF n = 20, FP n = 15), or mid-upper arm circumference (PM-RUF n = 2, PC-RUF n = 2, FP n = 2). Abbreviations: BMI, body mass index; FP, fortified porridge; MUAC, mid-upper arm circumference; PC-RUF, peanut/cowpea ready-to-use food; PM-RUF, peanut/milk ready-to-use food.



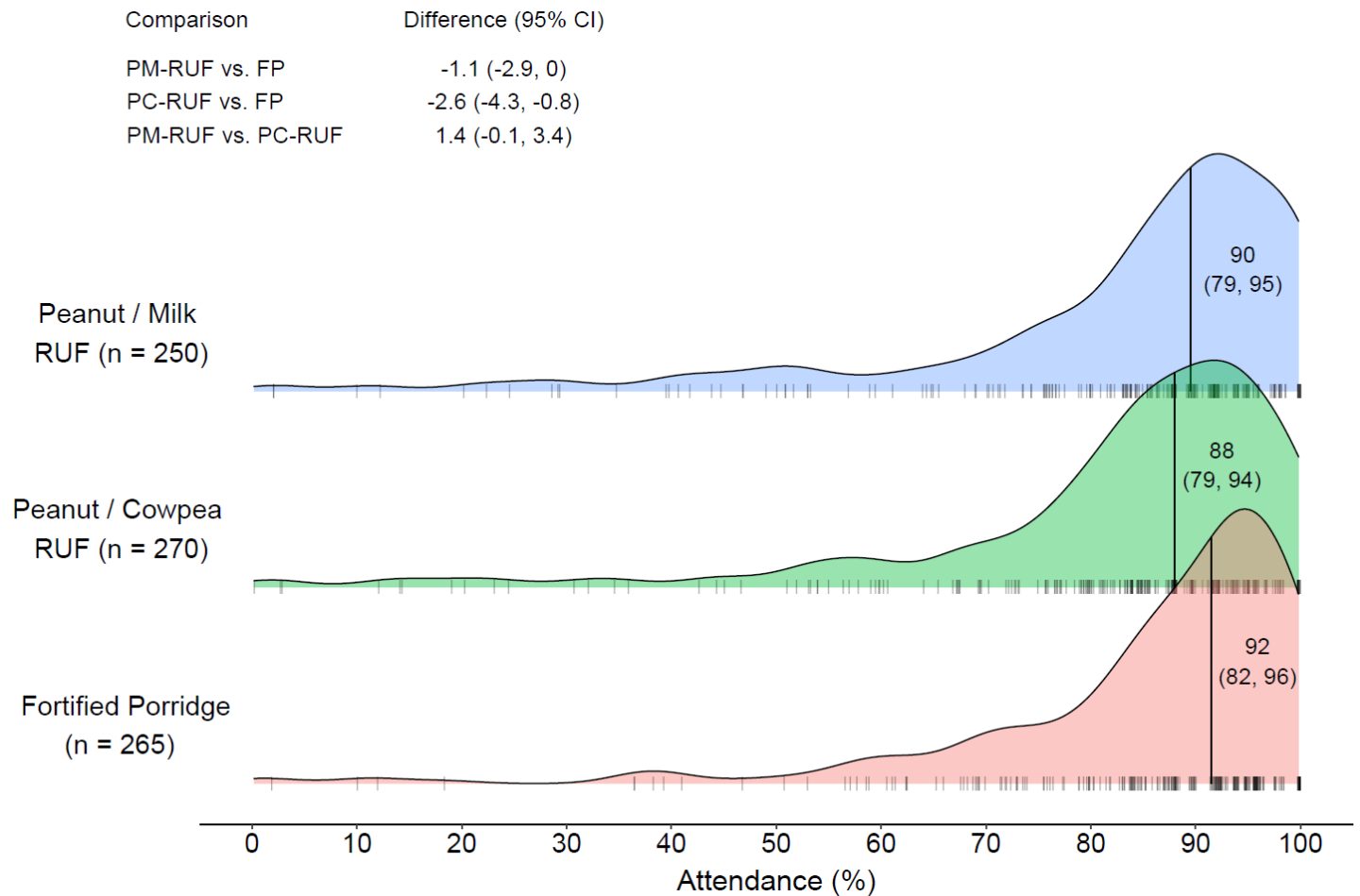
**TABLE S7** Endline DCCS and FICA cognitive test results by food group computed using the NIH Toolbox Cognition Battery algorithm scoring method, and comparison of study food effects by this method vs. the method used in this trial's primary analysis<sup>1,2</sup>

Outcome	Peanut/milk RUF (PM-RUF) (n = 253)	Peanut/cowpea RUF (PC-RUF) (n = 273)	Fortified Porridge (FP) (n = 271)	NIH Toolbox scoring	Scoring used in present trial	NIH Toolbox scoring	Scoring used in present trial
				OR (95% CI) PM-RUF vs. FP		OR (95% CI) PC-RUF vs. FP	
Dimensional change card sort							
Total score				1.5 (1.1, 2.0)	1.5 (1.1, 2.0)	1.2 (0.9, 1.6)	1.2 (0.9, 1.6)
Median (IQR)	4.5 (4.0, 5.6)	4.3 (4.0, 5.2)	4.1 (3.9, 5.3)				
Mean ± SD	4.6 ± 1.9	4.2 ± 1.7	4.1 ± 1.9				
Speed score							
Median (IQR)	0 (0, 1.0)	0 (0, 0.7)	0 (0, 0.7)				
Mean ± SD	0.7 ± 1.2	0.4 ± 0.8	0.5 ± 0.9				
Accuracy Score							
Median (IQR)	4.3 (4.0, 4.6)	4.1 (4.0, 4.6)	4.1 (3.9, 4.5)				
Mean ± SD	3.9 ± 1.2	3.8 ± 1.3	3.7 ± 1.4				
Flanker inhibitory control							
Total score				1.1 (0.8, 1.5)	1.2 (0.9, 1.6)	1.1 (0.8, 1.5)	1.1 (0.9, 1.5)
Median (IQR)	5.4 (4.6, 6.5)	5.4 (4.0, 6.4)	5.3 (4.3, 6.4)				
Mean ± SD	5.1 ± 1.9	4.9 ± 1.9	5.0 ± 1.8				
Speed score							
Median (IQR)	0.6 (0, 1.5)	0.5 (0, 1.5)	0.5 (0, 1.5)				
Mean ± SD	0.8 ± 0.9	0.8 ± 0.8	0.8 ± 0.9				
Accuracy Score							
Median (IQR)	5.0 (4.4, 5.0)	4.9 (4.0, 5.0)	5.0 (4.1, 5.0)				
Mean ± SD	4.3 ± 1.3	4.2 ± 1.3	4.3 ± 1.2				

<sup>1</sup> The maximum possible total score for dimensional change card sort and flanker is 10. Pairwise comparisons of endline cognitive test results were performed using ordinal logistic regression, with endline test score as the dependent variable, food group as the independent variable of interest, and baseline score and participant age as covariates. Several participants did not undergo dimensional change card sort testing at baseline (PM-RUF n = 2, PC-RUF n = 1, FP n = 1) or endline (FP n = 1), or pattern comparison processing speed at endline (PM-RUF n = 1), and thus were not included in statistical analyses. Abbreviations: FP, fortified porridge; PC-RUF, peanut/cowpea ready-to-use food; PM-RUF, peanut/milk ready-to-use food.

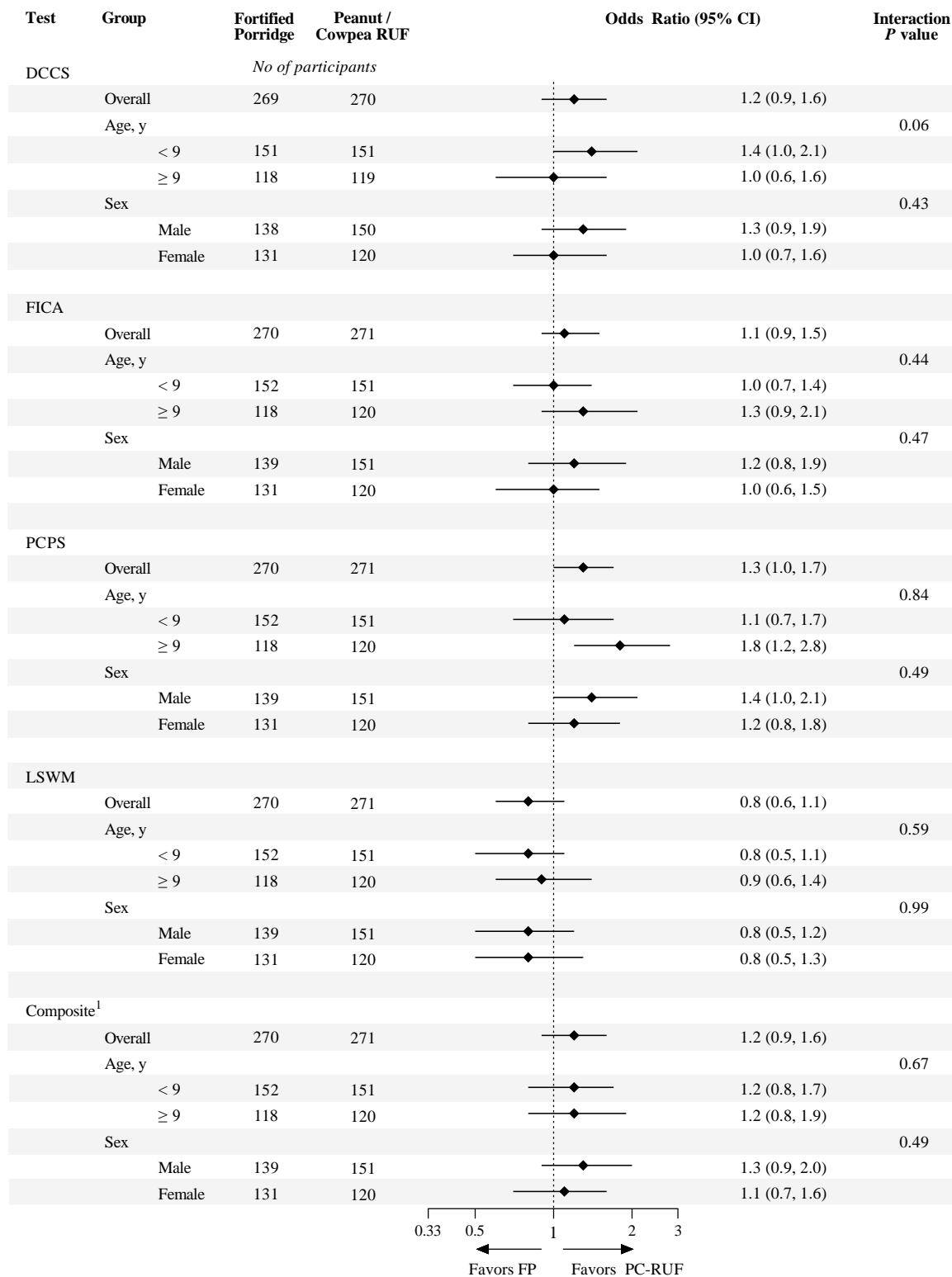
<sup>2</sup> Speed scores were calculated by the tablet and were the same under both scoring methods. Using the NIH Toolbox Cognitive Battery algorithm, accuracy scores were calculated by multiplying the number of correct responses by 0.125 (thereby scaling the score to 5), with an automatic 10 correct responses (1.25 points) being given to all children ≥ 8 years of age for DCCS, and an automatic 20 correct responses (2.5 points) being given to all children ≥ 8 years of age for FICA. The assumption of near-ceiling scoring underlying the automatic points given to children ≥ 8 years was not tenable in this study population. Thus, for this trial, accuracy scores were instead calculated by taking the proportion of correct answers and scaling to 5.

**FIGURE S1**



Attendance in the final 10 weeks of the trial by study group. Attendance was calculated over the final 10 weeks of the study by dividing the number of days each child attended school and received their intervention by the total number of possible days of attendance and is presented as a percentage. Shown are ridgeline plots containing kernel density-estimated smoothed histograms separated by randomization group. The vertical black line within each plot is the median, and the values reported to the right of these lines are medians (IQRs). The shorter vertical lines underlying each plot correspond to individual values, with random horizontal jittering within 0.3 percentage points. Attendance rates were compared using the Wilcoxon rank-sum test, with a continuity correction used to generate medians of differences with 95% CIs for percent attendance by group. Differences > 1 indicate greater attendance for PM-RUF or PC-RUF vs. FP, or PM-RUF vs. PC-RUF. Among participants with ending cognitive scores, several did not have attendance data available (PM-RUF n = 3, PC-RUF n = 1, FP n = 5). Abbreviations: FP, fortified porridge; PC-RUF, peanut/cowpea ready-to-use food; PM-RUF, peanut/milk ready-to-use food.

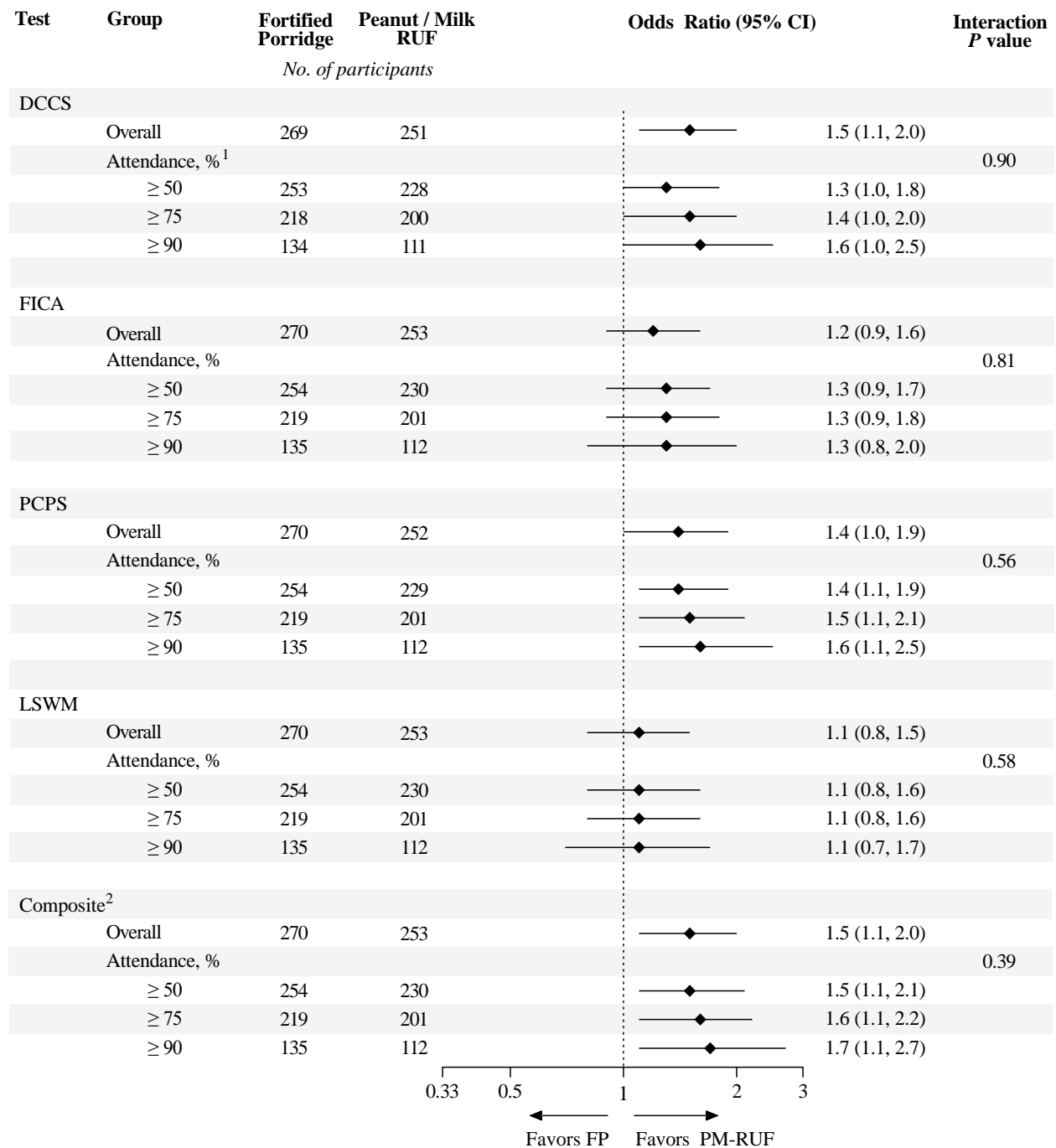
FIGURE S2



Subgroup analysis of cognitive outcomes comparing PC-RUF and FP. Ordinal logistic regression was used to compare food groups, with endline score as the dependent variable, and food group, baseline score, participant age, and an interaction term between food group and age (as a continuous variable) or sex as independent variables. P values were computed using the Wald test and are shown for the interaction between food group and age or sex. Abbreviations: DCCS, dimensional change card sort test; FICA, flanker inhibitory control and attention test; FP, fortified porridge; LSWM, list sorting working memory test; PCPS, pattern comparison processing speed test; RUF, ready-to-use food.

<sup>1</sup> Composite median rank was obtained by ranking all scores within each test, computing the median of each participant's test ranks, and ranking these median ranks.

**FIGURE S3**

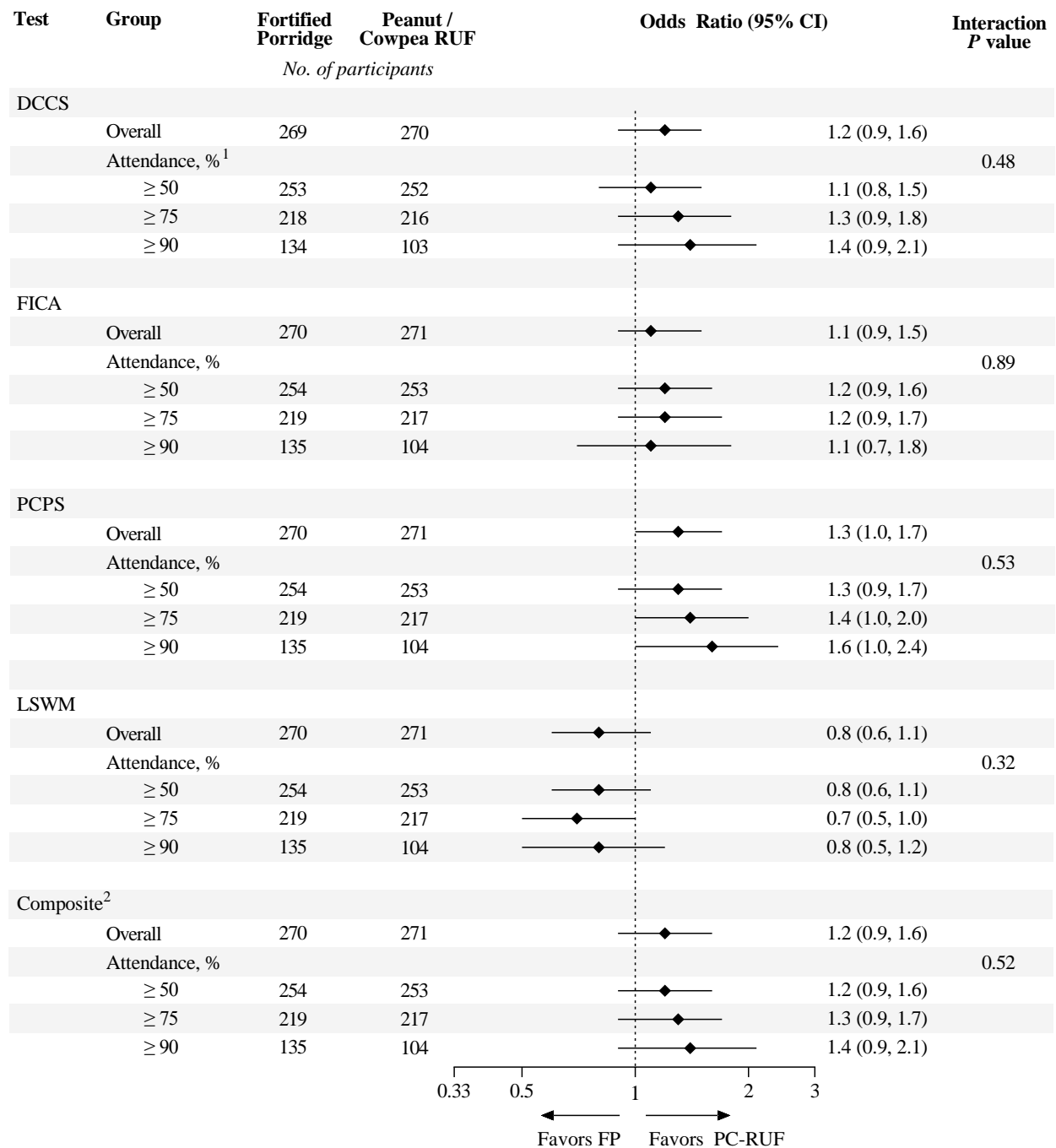


Cognitive outcomes by rate of attendance comparing PM-RUF and FP. Ordinal logistic regression was used to compare food groups, with endline score as the dependent variable, and food group, baseline score, participant age, and an interaction term between food group and attendance (as a continuous variable) as independent variables. *P* values were computed using the Wald test and are shown for the interaction between food group and attendance. Abbreviations: DCCS, dimensional change card sort test; FICA, flanker inhibitory control and attention test; FP, fortified porridge; LSWM, list sorting working memory test; PCPS, pattern comparison processing speed test; RUF, ready-to-use food.

<sup>1</sup> Attendance was calculated over final 10 weeks of study as days in school with intervention received / total school days.

<sup>2</sup> Composite median rank was obtained by ranking all scores within each test, computing the median of each participant's test ranks, and ranking these median ranks.

**FIGURE S4**



Cognitive outcomes by rate of attendance comparing PM-RUF and FP. Ordinal logistic regression was used to compare food groups, with endline score as the dependent variable, and food group, baseline score, participant age, and an interaction term between food group and attendance (as a continuous variable) as independent variables. *P* values were computed using the Wald test and are shown for the interaction between food group and attendance. Abbreviations: DCCS, dimensional change card sort test; FICA, flanker inhibitory control and attention test; FP, fortified porridge; LSWM, list sorting working memory test; PCPS, pattern comparison processing speed test; RUF, ready-to-use food.

<sup>1</sup> Attendance was calculated over final 10 weeks of study as days in school with intervention received / total school days.

<sup>2</sup> Composite median rank was obtained by ranking all scores within each test, computing the median of each participant's test ranks, and ranking these median ranks.