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British Journal of Nutrition, page 1 of 15
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School feeding contributes to micronutrient adequacy of Ghanaian schoolchildren

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Abstract

Without gains in nutritional outcomes, it is unlikely that school feeding programmes (SFP) could improve cognition and academic performance of schoolchildren despite the improvements in school enrolment. We compared the nutrient intake adequacy and Fe and nutritional status of SFP and non-SFP participants in a cross-sectional survey involving 383 schoolchildren (aged 5–13 years). Quantitative 24 h recalls and weighed food records, repeated in 20 % subsample, were used to estimate energy and nutrient intakes adjusted for day-to-day variations. The probability of adequacy (PA) was calculated for selected micronutrients and the mean of all PA (MPA) was calculated. The concentrations of Hb, serum ferritin, and soluble transferrin receptor (sTfR) and anthropometric measurements were used to determine Fe and nutritional status. Energy and nutrient intakes and their adequacies were significantly higher among SFP participants ($P<0{\cdot}001$). The MPA of micronutrients was significantly higher among SFP participants (0·61 *v.* 0·18; $P<0{\cdot}001$), and the multiple-micronutrient-fortified corn soya blend was a key contributor to micronutrient adequacy. In SFP participants, 6 g/l higher Hb concentrations ($P<0{\cdot}001$) and about 10 % points lower anaemia prevalence ($P=0{\cdot}06$) were observed. The concentration of sTfR was significantly lower among SFP participants (11·2 *v.* 124 mg/l; $P=0{\cdot}04$); however, there was no difference in the prevalence of Fe deficiency and Fe-deficiency anaemia between SFP and non-SFP participants. There was also no significant difference in the prevalence of thinness, underweight and stunting. In conclusion, the present results indicate that school feeding is associated with higher intakes and adequacies of energy and nutrients, but not with the prevalence of Fe and nutritional status indicators. The results also indicate an important role for micronutrient-dense foods in the achievement of micronutrient adequacy within SFP.

Key words: Ghana School Feeding Programme: Iron-deficiency anaemia: Micronutrient adequacy: Nutrition of schoolchildren: 24 h dietary recalls

Chronic malnutrition is highly prevalent in sub-Saharan Africa, especially among poor rural households[1], and it is mainly caused by morbidity and inadequate dietary intake[2]. Infants and young children are most affected by the physical and mental deficits occurring due to chronic malnutrition. These deficits are carried over into the school-age period, where they retard cognitive function, educability and future productivity[1]. Most interventions at the household and community levels are, however, preferentially targeted outside the first 1000 d of life[1,3]. 'The school' may serve as a platform for targeted interventions, such as school feeding programmes (SFP), to contribute to the fulfilment of the nutritional needs of children outside the first 1000 d of life. However, in settings where school enrolment and attendance are low, targeting interventions at schoolchildren may still be problematic. In Africa and other developing continents, SFP have therefore

Abbreviations: 24 hR, 24 h recalls; CRP, C-reactive protein; CSB+, Corn Soy Blend Plus; HHS, Household Hunger Scale; ID, Fe deficiency; IDA, Fe-deficiency anaemia; PA, probability of adequacy; SF, serum ferritin; SFP, school feeding programmes; sTfR, soluble transferrin receptor; WAFCT, West African Food Composition Table.

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British Journal of Nutrition

been instituted primarily as food-for-education programmes in resource-poor settings not only to improve school enrolment and attendance but also as means to improve nutritional status through improved energy and nutrient intakes[4].

Following the formulation of the UN Millennium Development Goals, SFP received renewed interest for their potential contribution to the achievement of Millennium Development Goals 1 and 2. In line with the recommendations of the UN Hunger Task Force, there has been a shift in the paradigm of SFP towards linking local food production to consumption at schools (home-grown school feeding) with the aims of creating and improving access to market for poor rural farmers, stimulating local food production and also improving the local economy of beneficiary communities[5]. The shift in paradigm received support from African Governments through the Comprehensive Africa Agricultural Development Programme of the New Partnership for Africa's Development, thereby putting SFP on the political agenda of Africa[6]. Since 2005, the Government of Ghana has piloted and up-scaled the Ghana School Feeding Programme through which schoolchildren are provided one nutritious meal per school day to encourage educational participation (enrolment, attendance and retention) and also improve nutrient intake and nutritional status[7].

However, comprehensive reviews of empirical research[3,4,8] and programme evaluation reports[9–11] have shown that although SFP have had positive impacts on educational participation, their impacts on nutritional outcomes have been rather unclear[3,4,8–11] and partly blamed substitution effect of school feeding on home consumption for the lack of effect. Moreover, in the Lancet series on Maternal and Child Undernutrition, SFP targeting children aged >2 years have been described as interventions that are unlikely to improve nutritional status[12] because such interventions are outside the window of opportunity for improvement in nutritional outcomes, particularly stunting.

Without evidence of a positive impact on nutritional outcomes, it is unlikely for SFP to improve cognition and academic performance despite the demonstrable improvements in educational participation. Therefore, in the present study, we aimed to assess the nutrient intake adequacy and Fe and nutritional status of schoolchildren participating in a government-supported SFP in northern Ghana relative to non-participating children.

Subjects and methods

Study design

This was a cross-sectional study involving the quantitative measurement of energy and nutrient intakes and Fe and nutritional status of children in school feeding and non-school feeding schools. At the inception of the government-supported pilot SFP in northern Ghana in October 2005, baseline usual nutrient intakes and Fe and nutritional status of schoolchildren in the study area were not measured. Therefore, in the present study, only children in schools participating in a SFP were compared with their neighbouring non-school feeding counterparts at a point in time. At the time of the study, the government-supported SFP had been operational in the study area for about 3 years and all children in primary school in both beneficiary schools received lunch at school, but not all participated in the present study.

Data collection for the survey was conducted over a period of 1 month (1st week of November 2008 to 2nd week of December 2008). Ethical clearance was given by the Institutional Review Board of Noguchi Memorial Institute for Medical Research, University of Ghana (NMIMR-IRB 022/08-09). Permission was also sought from the District Administration, District Education Office, head teachers and local authorities in each community. After information sessions, parents/caregivers who volunteered to participate in the study gave written informed consent.

Study area

The study was conducted in four of the 132 primary schools in Tolon-Kumbungu District of Northern Region, Ghana. The four rural primary schools (from four communities) were approximately 50 km away from the main city in the region, Tamale, and within 5 km radius from each other. Of these schools, two (Tibung and Kpalgung primary) were the pilot schools for the government-supported SFP in Tolon-Kumbungu District, which started in October 2005 and was still running at the time of the study. The other two schools (Wayamba and Jegbo primary), which qualified to benefit from SFP but were not yet enrolled, were selected as control schools based on their similarity with the pilot schools with respect to the following characteristics: number of children enrolled in school; school infrastructure; size of community; absence of market infrastructure; water and sanitation facilities; proximity to each other. The study area is within the Guinea Savanna vegetation zone, having a typical unimodal rainy season (April–September) and one dry season (December–March) characterised by relatively high temperatures (35–40°C). People living in this area are mostly subsistence farmers[13]. Malaria is hyperendemic in this area[14] and is the main cause of morbidity among children[13]. Malaria transmission peaks towards the end of the rainy season (October and November)[15].

Subjects and sampling

Subjects

Children (aged 5–13 years) in classes 1–3 from the four schools in Tolon-Kumbungu District were included if they were enrolled in school for at least one academic year at the time of the study. Mothers or alternate caregivers were interviewed to obtain data on the dietary intake of children because they prepared and served meals in the households.

Sample size and sampling procedure

Due to paucity of literature on the usual nutrient intake of schoolchildren in the study area, anaemia prevalence (proxy for Fe status) among schoolchildren was used for the

determination of sample size. Based on an assumed anaemia prevalence of 50 % among non-school feeding participants, a sample size of about 180 children per group was required to estimate a 15 % point difference in anaemia prevalence between the school feeding and non-school feeding groups with 95 % confidence (one-sided) and a power of 90 %. Taking into account 10 % attrition, sample size was rounded to 200 per group.

A total of 383 schoolchildren were recruited for the study: 196 from the school feeding group and 187 from the non-school feeding group. In each of the four schools, children were randomly selected from a sampling frame of pupils in lower primary (classes 1–3). The sampling frame was constructed separately for each school by pooling together the registers of lower primary. If two or more children were selected from one household, one of them was randomly selected by lottery to participate in the study.

Data collection and measurements

Household questionnaire

A semi-structured survey instrument was used to collect information on the sociodemographic characteristics of children and their households. Parents/caregivers were asked to indicate whether their child was ill during the 2 weeks preceding the survey. The instrument also included the standardised and validated[16] Food and Nutrition Technical Assistance Household Hunger Scale (HHS). The HHS is a three items-by-three frequencies of occurrence scale and was used for the assessment of the food supply situation of participating households[17]. The survey instrument was translated into the local language (Dagbani) and pretested by trained research assistants before being used in the survey. The standard reference period of 30 d was used for the HHS assessment[17].

24 h recall method

Quantitative 24 h recalls (24 hR), repeated in 20 % subsample, were collected by six trained research assistants (first degree nutrition graduates), who spoke the local language and had knowledge of the study area. A minimum duration of 2 d was allowed between repeated recalls to avoid dependency of intake on two consecutive days, especially caused by the consumption of leftover foods[18]. Weekend days were excluded. Days of the week and interviewers were randomly allocated to children to account for differences between days and interviewers, and interviewers were not allowed to interview the same household twice. All 24 hR were completed within the same post-harvest season, a period of minimum food scarcity.

A standard multiple-pass procedure was used for all 24 hR[18]. First, mothers/caregivers were asked to provide details on all foods and beverages that their child had consumed during the preceding 24 h (wake up-to-wake up) including anything consumed outside home. After probing for likely forgotten foods with the help of the index child[19], they were asked to give a detailed description of foods and beverages consumed, including ingredients and cooking methods for mixed dishes and place and time of consumption. The amount of each food and beverage and ingredients of mixed dishes was weighed or, when not available, estimated in household measures or their monetary equivalent. The weight of foods and ingredients of mixed dishes was measured using a digital kitchen scale (Soehnle Plateau, model 65 086), precise to 2 g with a maximum capacity of 10 kg. Factors for converting household measures and monetary values into weight were determined afterwards. The total volume of all foods and mixed dishes cooked, volume consumed by child and leftover from child's food were determined to derive the proportion of total prepared food consumed by the child. For SFP participants, the 24 hR did not include detailed recall of lunch served at school under SFP. Rather, the weighed food record (done at school) was used to measure the quantity of lunch consumed (see the 'Weighed food record' section).

Communal eating is a common practice in this area; therefore the number of children who shared meals with the index child was obtained and used as a divisor to obtain an estimated quantity of food consumed by the index child. In such situations, equal sharing of food was assumed. The weight of the various ingredients consumed by the child was obtained by multiplying the weight of ingredients used in cooking the food by the proportion of total prepared food consumed by the index child.

Weighed food record

In the two schools participating in the SFP, lunch was consumed by the children at school and was usually served by the kitchen staff before 12.00 hours. Therefore, weighed food records were collected from Monday to Friday to assess the food and nutrient intakes from the school lunch. For the 20 % of children who had a repeated 24 hR, a second weighed food record was collected on a non-consecutive day to match their day of repeated 24 hR. Weighed food records were collected on days preceding the scheduled 24 hR for each child. All raw ingredients used in preparing the school lunch for a particular day were weighed using a digital kitchen scale (HD-801 model; Yuyao Fuming Electrical Appliance Co., Ltd), precise to 1 g and a maximum capacity of 3 kg. Bulk food ingredients were weighed using a platform scale (Camry FD-250; Zhongshan Camry Electronic Co., Ltd), precise to 500 g and a maximum capacity of 250 kg. The weight of the total food cooked, the quantity served to each child and the quantity left over from each child's meal (when applicable) were determined to derive the proportion consumed by the child from the total dish prepared at school. Sharing of meals with peers was not a problem as all children in participating schools received the school lunch. All other meals not consumed in school were considered as home consumption for SFP participants, while all meals consumed were considered as home consumption for non-SFP participants.

Anthropometric measurements

The weight and height of children were measured according to standard procedures[20,21]. Weight was measured precise

British Journal of Nutrition

to 0·1 kg with an electronic scale (Uniscale; Seca GmbH). A known weight (20 kg) was used to calibrate the scale on each measurement day. A microtoise (Bodymeter 208; Seca GmbH) was used to measure the height of children precise to 0·1 cm. For both weight and height, an average of two measurements was taken. The ages of children were determined using the date of birth (from a verifiable document) and the date of measurement. In the absence of verifiable documents, parents/caregivers estimated the age based on another child's records or an event on the traditional calendar.

Blood sample collection

From each child, venous blood (6 ml) was drawn through venepuncture. One-third (2 ml) of the whole blood was transferred into EDTA-coated vacutainers (Becton-Dickinson Diagnostics) and used for the determination of Hb concentration on the same day. The remaining 4 ml of blood was stored in a plain tube without anticoagulant at ambient temperature. Serum was separated at room temperature at 500 ***g*** for 10 min (Hettich GmbH) and stored at −80°C (Thermo Fisher Scientific). Serum samples were transported on dry ice to Germany via The Netherlands for the analysis of serum ferritin (SF), soluble transferrin receptor (sTfR) and C-reactive protein (CRP).

Data analysis

Household hunger score

Following the standard coding, each of the three items in the HHS was coded 0, 1 or 2 corresponding to hunger frequencies of 'never', 'rarely or sometimes' or 'often'. This yielded total scores ranging from 0 to 6 based on which households were categorised into three standard groups: 1 = little/no household hunger (HHS ≤1); 2 = moderate household hunger (HHS 2–3); 3 = severe household hunger (HHS = 4–6)[17].

Food composition and nutrient intake calculation

The calculation of nutrient intake was based on a food composition database primarily created using nutrient values from the West African Food Composition Table (WAFCT)[22]. In case of missing foods (twenty-one of 138 foods), the following food composition tables were used in the order indicated: Mali Food Composition Table[23]; the United States Department of Agriculture National Nutrient Database for Standard Reference[24]; the Ghana Food Composition Table[25]. When food values were taken from the Ghana Food Composition Table, values of missing nutrients (vitamins and some minerals) were updated with those of close substitutes from the WAFCT. Phytate values were taken from the International Minilist[26]. For Corn Soy Blend Plus (CSB+) consumed under SFP, nutrient content values were obtained from the World Food Programme[27]. Where appropriate, yield[22] and nutrient retention factors[24,28] were applied to account for nutrient losses during cooking before computing nutrient intake values. The Atwater general factors for carbohydrate, protein and fat and the recommended metabolisable energy value for dietary fibre in an ordinary diet (8·4 kJ/g) were used for calculating energy intake[29]. Total vitamin A (retinol activity equivalent) was calculated as the sum of retinol and 1/12 β-carotene[22]. The food consumption data were analysed using the VBS Food Calculation System, version 4 (BaS Nutrition Software). Using the National Research Council method, data on dietary intake from the 24 hR were adjusted for day-to-day variations to obtain the estimated usual intake values for the children[30]. Individual foods were categorised into thirteen food groups[22]. Due to implausible dietary intake (energy intake >20 000 kJ), thirty-one (8 %) children were not included in the dietary intake analysis.

Energy and nutrient intake adequacy calculation

Estimated energy requirement was calculated separately for each child by multiplying the estimated energy requirement per kg body weight per d by the child's weight assuming a moderate physical activity level[31]. Similarly, sex- and age-specific safe levels of protein intake/kg body weight per·d were multiplied by the weight of the child to determine the safe levels of protein intake for each child[32]. To assess the prevalence of adequate or inadequate intake, each child's adjusted energy and protein intake values were compared with their respective calculated requirements.

The probabilities of adequacy (PA) for vitamins A, C, B_{12} and folate, Zn and Ca were calculated using their respective estimated average requirement and distribution values[33–35]. Because the distribution of Fe requirement is skewed, we used the PA values derived by the Institute of Medicine[33], but adjusted them for 5 % bioavailability to reflect the inhibitory nature of the predominantly cereal-based diet in rural northern Ghana. Similarly, the estimated average requirement for Zn was adjusted for low (15 %) bioavailability[36]. The mean probability of adequacy, a summary measure of micronutrient adequacy, was computed from PA of all the seven micronutrients investigated in the study.

Anthropometry

Anthropometric *Z*-scores were calculated using AnthroPlus (version 1.0.3; WHO). Underweight, stunting and thinness were defined as weight-for-age, height-for-age and BMI-for-age *Z*-scores < −2 SD, respectively[20,21].

Biochemical analysis

The cyanmethaemoglobin method (using a colorimeter) was used to measure the Hb concentration of schoolchildren[37]. Measurements of serum parameters (ferritin, sTfR and CRP) were done in an accredited laboratory (Labor Centrum Nordhorn, Nordhorn, Germany). The concentration of ferritin was measured using the ElectroChemiLuminescence Immunoassay on a Roche E170 clinical analyser (Roche Diagnostics) with intra-assay and inter-assay variations of 2–5 %. The concentration of sTfR was measured using the Ramco ELISA kit

British Journal of Nutrition

(Ramco Laboratories, Inc.) with intra-assay and inter-assay variations ranging from 5 to 8 %. Turbidimetry was used to measure CRP on a Beckman Coulter Synchron clinical analyser (Beckman Coulter) with combined intra-assay and inter-assay variations ranging from 1·6 to 3·5 %.

Anaemia was defined as Hb concentrations <115 g/l for children aged <12 years and as concentrations <120 g/l for children aged ≥ 12 years. Fe deficiency (ID) was defined as SF concentrations <15 μg/l and/or sTfR concentrations $>8{\cdot}5$ mg/l (Ramco Laboratories, Inc.) and Fe-deficiency anaemia (IDA) as concurrent anaemia with ID. Inflammation was defined as CRP concentrations >10 mg/l. Body Fe concentration was calculated using Cook's formula[38].

Statistical analysis

Data entry was done using Epi Info for Windows version 3.2.1 (CDC). Data cleaning and analysis were done in SPSS version 18.0 (SPSS, Inc.) and SAS version 9.2 (SAS Institute, Inc.). The distribution of data was checked by visual examination of Q–Q plots and normal-curve-fitted histograms and also tested for normality using the Kolmogorov–Smirnov test. Nutrient and Fe status variables that were not normally distributed were log-transformed and the transformed variables were used in subsequent analysis. ANOVA was used to generate a within-person day-to-day variance component, which was used to adjust energy and nutrient intakes.

Descriptive statistics were computed for background and household characteristics of children, and Pearson's χ^2 test and independent-samples t test were used to test between-group differences in proportions and means, respectively. ANCOVA was used to test differences in the mean adjusted nutrient intake and Hb concentration values as well as serum Fe parameters between the two groups while controlling for age, household size and nutritional status (BMI-for-age Z score; BAZ). Differences in the prevalence of anaemia, inflammation, ID, IDA and inadequate nutrient intakes between the two groups were checked using Cox regression[39,40]. Where appropriate, child and household characteristics were included in the regression model as covariates. In all analyses, $P<0{\cdot}05$ was the default value for an outcome to be considered statistically significant.

Results

Background characteristics of schoolchildren

Characteristic of the study area, more than 55 % of the children in both school feeding and non-school feeding groups were boys. The average age of children in both groups was 8·5 (SD 2) years; however, SFP participants were, on average, 6 months older than non-SFP participants ($P = 0{\cdot}007$). There was no significant difference in the proportion of children who were reported ill during the 2 weeks preceding the survey between the two groups ($P=0{\cdot}257$). Household size was larger for SFP participants than for non-SFP participants ($P<0{\cdot}001$). More than half of the children in both groups were from polygamous households. There was no difference in the proportion of households that reported moderate or severe hunger between the two groups ($P=0{\cdot}434$). In both groups, the majority of parents/caregivers were illiterate and engaged in farming as their main occupation (Table 1).

Table 1. Background characteristics of school feeding programme (SFP) and non-school feeding programme (non-SFP) participants in northern Ghana

(Mean values, standard deviations and percentages)

	SFP		Non-SFP		
	Mean	SD	Mean	SD	*P*
n	194		180		
Boys (%)	55·2		57·8		0·676
Age of child (years)	9·0	2·1	8·4	2·0	0·007
Sick 2 weeks preceding the survey (%)	26·9		32·8		0·257
Household size (*n*)	8·0	3·0	7·0	2·0	<0·001
Household type (%)					0·552
Monogamous	36·8		39·4		
Polygamous	56·5		52·2		
Other	6·7		8·4		
Household hunger category (%)					0·434
Moderate	30·5		31·7		
Severe	4·7		7·8		
Mother of index child					
Education (literate) (%)	5·6		3·4		0·778
Occupation (%)					0·005
Farmer	65·6		57·8		
Trader	22·6		23·8		
Other	11·8		18·4		
Father of index child					
Education (literate) (%)	21·5		16·0		0·754
Occupation (%)					0·160
Farmer	90·7		91·2		
Trader	2·6		2·8		
Other	6·7		6·0		

Food consumption patterns at home and school

At home, the three main meals served to children in both groups consisted of maize porridge (koko) with or without sugar served as breakfast and tuo zaafi – a thick/stiff maize porridge – served as lunch and dinner with varying vegetable soups. At the time of the survey (post-harvest season), the most dominant soup consumed by more than 50% of the children consisted of dried powdered okra with or without groundnut paste/groundnut flour. When available, green leaves such as amaranth, *Hibiscus sabdariffa* and baobab (fresh and dried) were also used to prepare the soups accompanying tuo zaafi. A key ingredient of the soups, among all households, was powdered amani (small dried whole fish also known as anchovies, eaten with bones).

For SFP participants, school lunch was more varied and based on a menu. The menu was generally planned around three main food items: rice; cowpea; multiple-micronutrient-fortified corn soya blend (CSB+ from the World Food Programme). Eggs, meat and fish were served at least once a week, while oranges were served twice a week. The following dishes were prepared with these food items: jollof rice (rice cooked in tomato sauce); waakye (rice and cowpeas cooked together and served with tomato sauce); gari and beans (roasted cassava grits and boiled cowpeas usually served with palm oil); tuo zaafi or gable (both prepared from CSB+).

Energy and nutrient intakes and their adequacies among schoolchildren

The median intakes of energy, macronutrients and selected minerals and vitamins were higher among SFP participants than among non-SFP participants ($P<0{\cdot}001$) and remained higher after controlling for child and household covariates. Whereas the contribution of fat to total energy intake was significantly higher among SFP participants (20 *v.* 16%; $P<0{\cdot}001$), the contribution of carbohydrate to total energy intake was significantly higher among non-SFP participants (64 *v.* 65%; $P<0{\cdot}01$). Even though the contribution of protein to total energy intake was similar (12%) between the two groups, the proportion of total protein intake from animal sources, a measure of protein quality, was greater among SFP participants than among non-SFP participants (5 *v.* 3%; $P<0{\cdot}001$). However, there was no difference ($P=0{\cdot}268$) in the proportion of total Fe intake from animal sources (meat, fish and poultry) between the two groups (Table 2).

The proportion of SFP participants with energy intake below the requirement was significantly lower than that of non-SFP participants (4·7 *v.* 21·8%; $P<0{\cdot}001$). However, none of the children in both groups had intake below the requirement for protein. The PA for Fe, Zn, Ca, and vitamins A and C, and folate were significantly higher ($P<0{\cdot}001$) among SFP participants than among non-SFP participants, with a mean PA of 0·61 (SD 0·13) among SFP participants compared with 0·18 (SD 0·11) among non-SFP participants (Table 3).

Table 2. Energy, nutrient and phytate intakes of school feeding programme (SFP) and non-school feeding programme (non-SFP) participants in northern Ghana

(Median values and interquartile ranges (IQR))

	SFP		Non-SFP		
Variables	Median	IQR	Median	IQR	*P*
n	174		178		
Energy (kJ)	9493	8669–10 652	7590	6895–8289	<0·001
Macronutrients					
Protein (g)	68	66–71	54	46–62	<0·001
Percentage of energy	12	11–13	12	11–13	0·22
Percentage from animal sources*	5	2–10	3	2–5	<0·001
Fat (g)	49	49–49	32	32–33	<0·001
Percentage of energy	20	18–21	16	15–17	<0·001
Carbohydrate (g)	365	319–422	294	270–319	<0·001
Percentage of energy	64	61–67	65	63–66	<0·01
Dietary fibre (g)	43·1	36·0–51·3	40·4	36·0–45·1	<0·01
Minerals					
Fe (mg)	28·3	23·2–28·4	23·4	20·5–26·1	<0·001
Percentage from animal sources†	0·7	0·4–1·3	0·6	0·4–1·2	0·268
Zn (mg)	13·1	11·0–14·1	8·6	7·7–9·8	<0·001
Ca (mg)	399	398–400	287	237–322	<0·001
Vitamins					
Vitamin C (mg)	47·1	42·1–47·3	8·6	8·6–8·7	<0·001
Vitamin A (μg RAE)	493·0	492·2–494·8	64·3	40·9–102·2	<0·001
Vitamin B_{12} (μg)	1·0	0·7–1·0	0·1	0·1–0·1	<0·001
Folate (μg)	245·8	236·2–255·8	134·0	114·8–173·6	<0·001
Phytate (mg)	3065	2526–3730	3083	2730–3355	0·95

RAE, retinol activity equivalent.
* Meat, fish, eggs and milk.
† Meat and fish.

British Journal of Nutrition

British Journal of Nutrition

Home consumption and the contribution of school lunch to energy and nutrient intakes

There was no difference in energy, fat, carbohydrate, Ca, vitamin C and phytate intakes from home consumption between the two groups of children ($P>0·05$). Home intake was significantly higher among non-SFP participants for protein ($P=0·041$), Fe ($P=0·011$), Zn ($P=0·005$) and vitamin A ($P=0·005$). For energy, macronutrients and selected minerals, 22–37 % of the daily intake was contributed by the school lunch served to SFP participants. For vitamins A and C, however, >90 % of the daily intake was contributed by the school lunch (Table 4). The school lunch provided approximately 418 kJ more energy than home lunch ($P<0·001$) and about 2 g more protein (18 (SD 1) *v.* 16 (SD 3) g; $P<0·001$). The contribution of school lunch to the estimated average requirement for energy among SFP participants was significantly greater than that of home lunch among non-SFP participants, i.e. 37 (SD 7) *v.* 31 (SD 8) %; $P<0·001$. However, the contribution of school lunch to daily protein requirement among SFP participants did not differ from that among non-SFP participants, i.e. 88 (SD 17) *v.* 84 (SD 26) %; $P=0·096$.

Relative contribution of individual foods and food groups to energy and nutrient intakes

In Fig. 1, the five topmost individual foods contributing to ≥70 % of the intake of energy, selected nutrients and anti-nutrients related to Fe absorption are shown. Except for vitamin C, maize was the main source of intake of total energy and selected nutrients. The relative contribution of maize to the intake of energy and selected nutrients ranged from 43 to 70 % for non-SFP participants and from 30 to 60 % for SFP participants. Cowpeas and corn soya blend (CSB+ from the World Food Programme) were additional sources of energy and nutrient intakes for SFP participants.

For both groups of children, the main food groups that contributed to dietary intake were cereals (maize, rice and sorghum), vegetables (dried okra and green leaves), nuts (groundnuts) and fish (amani). Food groups such as meat, eggs and fruits were rarely consumed by non-SFP participants (Fig. 2). SFP participants received meat at school twice a week, but the average quantity per serving was <10 g/d. The overall dietary diversity (number of different food groups consumed out of the thirteen food groups) among SFP participants was greater than that among non-SFP participants, i.e. 8·5 (SD 0·9) *v.* 6·2 (SD 1·1); $P<0·001$.

Eating moments and portion sizes of meals of schoolchildren

Almost all children in both groups ate during each of the three main eating moments per d: breakfast; lunch; dinner. Whereas a higher proportion of SFP children consumed a meal before the main breakfast meal (36 *v.* 25 %; $P=0·018$), the reverse was true for children who ate a meal before lunch (13 *v.* 40 %; $P<0·001$). Compared with only 20 % of the non-SFP children, almost every SFP child consumed a meal before the main dinner meal. For SFP participants, the meal before the main dinner meal could best be described as a second lunch (Fig. 3) after the school lunch. On the average, SFP participants had about one more eating moment (meal) compared with non-SFP participants (4·5 *v.* 3·8; $P<0·001$).

Except for 'lunch' and the meal 'before dinner', the average portion sizes of meals during all other eating moments in a day were similar between SFP participants and non-SFP participants (data not shown). The median portion size of lunch for non-SFP participants (which was taken at home) was significantly greater than that for SFP participants (which was taken at school), i.e. 1037 *v.* 456 g; $P<0·001$. Conversely, the median portion size of the meal 'before dinner' was significantly greater for SFP participants than for non-participants,

Table 3. Proportion of school feeding programme (SFP) and non-school feeding programme (non-SFP) participants with values below the estimated average requirement for energy and protein and probabilities of adequacy for selected micronutrients

(Mean values and standard deviations)

	SFP		Non-SFP		
Variables	Mean	SD	Mean	SD	*P*
n	174		178		
Prevalence of inadequate intake (%)					
Energy	4·7		21·8		<0·001
Protein	0		0		
Probability of micronutrient adequacy					
Fe	0·94	0·02	0·72	0·23	<0·001
Zn	0·65	0·29	0·32	0·32	<0·001
Ca	0·00	0·00	0·00	0·00	NA
Vitamin C	0·97	0·03	0·00	0·00	<0·001
Vitamin A	0·86	0·13	0·02	0·09	<0·001
Vitamin B_{12}	0·19	0·23	0·00	0·00	<0·001
Folate	0·70	0·31	0·19	0·35	<0·001
Mean probability of adequacy*	0·61	0·13	0·18	0·11	<0·001

NA, not applicable.

* Computed from the PA values of micronutrients.

Table 4. Difference in home consumption between school feeding programme (SFP) and non-school feeding programme (non-SFP) participants and the contribution of school lunch to nutrient intakes among SFP participants

(Median values and interquartile ranges (IQR))

	SFP		Non-SFP		
	Median	IQR	Median	IQR	*P*
n	174		178		
Energy (kJ)					
Home consumption*	7439	5234–9996	7590	6895–8289	0·064
School lunch	2397	2033–2858	–		
Percentage of total intake	24		–		
Protein (g)					
Home consumption	50	36–67	54	46–62	0·041
School lunch	19	13–24	–		
Percentage of total intake	28		–		
Fat (g)					
Home consumption	29	19–48	32	32–33	0·135
School lunch	18	14–22	–		
Percentage of total intake	38		–		
Carbohydrate (g)					
Home consumption	292	205–386	294	270–319	0·147
School lunch	81	68–93	–		
Percentage of total intake	22		–		
Fe (mg)					
Home consumption	20·4	15·4–29·3	23·4	20·5–26·1	0·011
School lunch	7·0	3·2–12·5	–		
Percentage of total intake	26		–		
Zn (mg)					
Home consumption	8·2	5·9–11·2	8·6	7·7–9·8	0·005
School lunch	4·2	2·4–8·2	–		
Percentage of total intake	34		–		
Ca (mg)					
Home consumption	230	169–336	287	237–322	0·110
School lunch	134	74–240	–		
Percentage of total intake	37		–		
Vitamin A (μg RAE)					
Home consumption	50·8	24·6–116·2	64·3	40·9–102·2	0·005
School lunch	556·6	76·5–1090·3	–		
Percentage of total intake	92		–		
Vitamin C (mg)					
Home consumption	7·8	0·44–10·7	8·6	8·6–8·7	0·143
School lunch	63·4	2·6–81·6	–		
Percentage of total intake	97		–		
Phytate (mg)					
Home consumption	2940	1984–4167	3083	2730–3355	0·064
School lunch	242	201–333	–		
Percentage of total intake	8		–		

RAE, retinol activity equivalent.
* Including foods bought outside home and consumed by children.

i.e. 962 *v.* 508 g; $P<0·001$. The caregivers of SFP participants indicated that even though their children ate lunch at school, they still served them the lunch that was prepared at home. It should be noted that the portion size of the meal before dinner for SFP participants is similar to the portion size of the home lunch for non-SFP participants.

Iron and nutritional status of schoolchildren

The mean Hb concentration of children was 100 (SD 16) g/l. SFP participants had 6 g/l higher Hb concentration than non-SFP participants ($P<0·001$) even after controlling for household and child characteristics. There was no difference in the concentration of SF between the two groups. The concentration of sTfR was significantly lower among SFP participants than among non-SFP participants ($P=0·04$). There was no difference in the calculated body Fe store between the two groups ($P=0·08$). There was no difference in the mean concentration of CRP and the proportion of children with inflammation between the two groups. The prevalence of anaemia was marginally lower ($P=0·06$) in SFP participants, while there was no significant difference in the prevalence of ID and IDA between the two groups. SFP participants were about 3 cm taller; however, the difference was not significant after controlling for age differences. Weight-for-age and height-for-age *Z*-scores were similar between the two groups. BMI-for-age *Z*-score was significantly higher for non-SFP participants ($P=0·008$). There was no difference in the prevalence of underweight, stunting and thinness between the two groups (Table 5).

British Journal of Nutrition

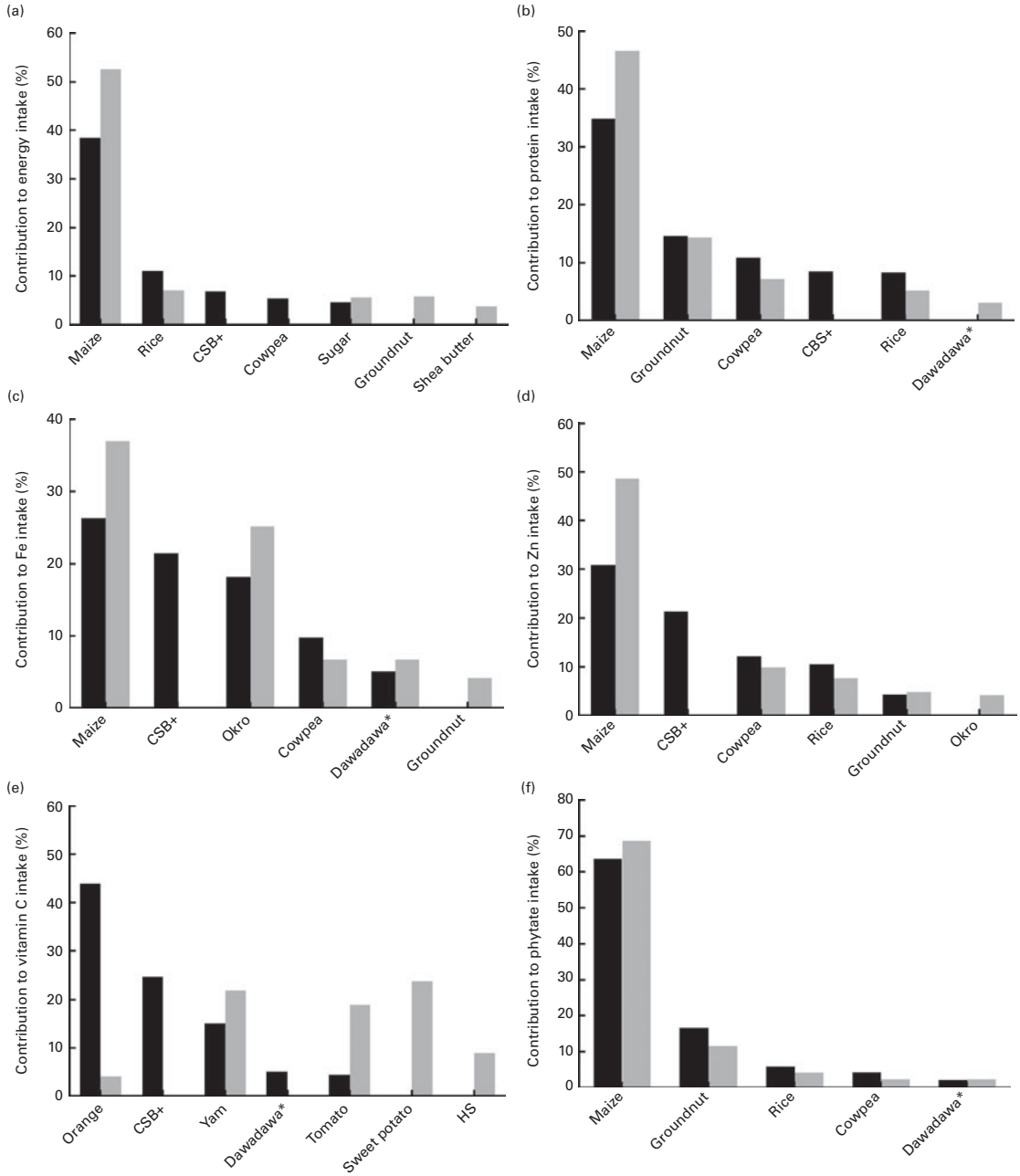

Fig. 1. The top five foods contributing to (a) energy, (b) protein, (c) iron, (d) zinc, (e) vitamin C and (f) phytate intakes among school feeding programme (SFP, ■) and non-school feeding programme (non-SFP, ▨) participants in northern Ghana. CSB +, Corn Soya Blend Plus; dawadawa, local condiment made from fermented African locust bean (*Parkia biglobosa* seeds); HS, *Hibiscus sabdariffa*.

Discussion

In the present study, we compared the energy and nutrient intakes and Fe and nutritional status of children in school feeding and non-school feeding schools. Energy and nutrient intakes and their adequacies were significantly higher among the school feeding participants than among the non-participants. However, there were no differences in the prevalence of Fe status indicators, underweight, stunting and thinness between the two groups.

The significantly higher intake of energy and nutrients among the school feeding participants is attributable to the supplementary effect of school meals[41–45] and superior energy density of the school lunch[43]. The school lunch was served before 12.00 hours, so children were probably hungry again by the time school closed at 14.00 hours and therefore were still able to eat a late lunch served at home. However, a different study has reported that school feeding rather replaces home consumption[46]. The school lunch also increased the diversity of meals of participating children,

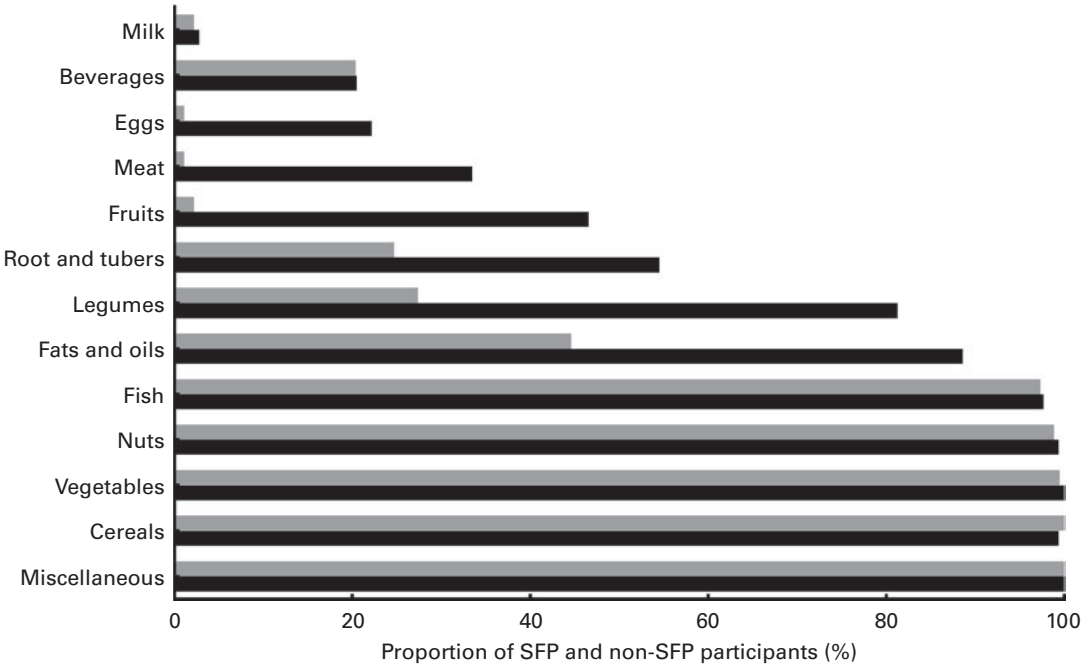

Fig. 2. Proportion of school feeding programme (SFP, ■) and non-school feeding programme (non-SFP, □) participants in northern Ghana consuming foods from thirteen food groups.

which has been shown to be related to increased quality and quantity of nutrient intakes in other studies[47–51]. In both groups, all children met their safe levels of intake for protein. However, the biological value of the protein may be low, given that only an average of 4% is animal source protein and cereal protein is limiting in growth-supporting lysine. Even though we did not adjust for protein quality[52,53], the digestibility of the protein may also be compromised given the high concentration of dietary fibre in the meals of both groups of children[52].

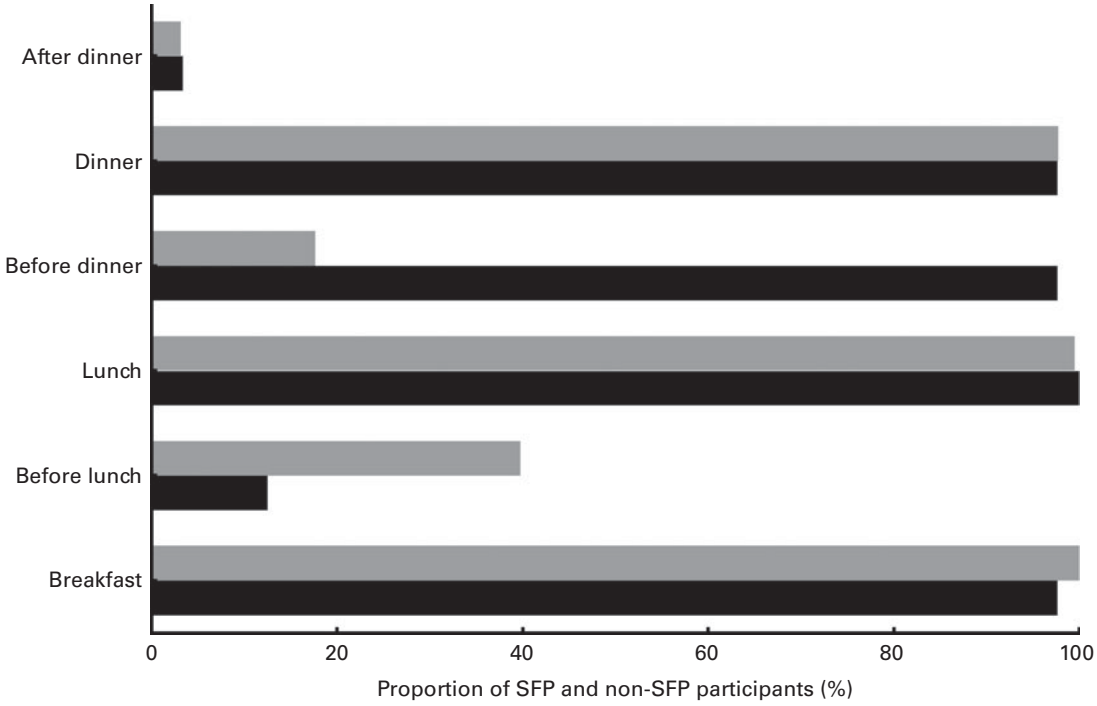

Fig. 3. Proportion of school feeding programme (SFP, ■) and non-school feeding programme (non-SFP, □) participants in northern Ghana who ate meals across the six daily eating moments.

Table 5. Iron and nutritional status of school feeding programme (SFP) and non-school feeding programme (non-SFP) participants in northern Ghana

(Mean values and standard deviations; geometric means and interquartile ranges (IQR))

	SFP		Non-SFP		
	Mean	SD	Mean	SD	*P**
n	194		180		
Fe status markers					
Hb (g/l)	103	15	97	18	<0·001
SF (μg/l)					0·234
Geometric mean	41·3		35·9		
IQR	22·3–75·4		19·3–70·6		
SF, excluding elevated CRP† (μg/l)					0·433
Geometric mean	37·7		34·4		
IQR	21·3–69·8		18·5–67·3		
sTfR (mg/l)					0·04
Geometric mean	11·4		12·6		
IQR	8·7–14·4		9·3–16·5		
Body Fe‡ (mg/kg body weight)	3·2	4·1	2·3	4·3	0·08
Inflammation marker and classification					
CRP (mg/l)					0·595
Geometric mean	1·7		1·9		
IQR	0·8–2·8		0·8–3·6		
CRP >10 mg/l (%)	9·8		10·5		0·865
Fe status classification (%)					
Anaemia	75·8		84·9		0·06
ID, SF <15 μg/l	14·4		17·8		0·480
ID, SF <15 μg/l excluding elevated CRP†	14·9		18·6		0·465
ID, sTfR >8·5 mg/l	77·3		80·0		0·528
ID, SF <15 μg/l and/or sTfR >8·5 mg/l	77·8		80·7		0·806
IDA§	62·7		69·4		0·561
Nutritional status indices					
Weight (kg)	23·6	5·0	22·8	5·2	0·718
Height (cm)	125·3	10·4	122·1	11·9	0·208
Weight-for-age‖ (*Z*-score)	−0·95	1·1	−0·92	1·1	0·987
Height-for-age (*Z*-score)	−1·1	1·6	−1·1	1·5	0·176
BMI-for-age (*Z*-score)	−0·93	0·84	−0·62	0·82	0·008
Nutritional status indicators (%)					
Underweight‖	16·3		14·4		0·757
Stunting	23·3		28·9		0·09
Thinness	11·9		5·6		0·253

SF, serum ferritin; CRP, C-reactive protein; sTfR, soluble transferrin receptor; ID, Fe-deficiency; IDA, Fe-deficiency anaemia.

* Adjusted for background difference between the groups.

† *n* 175 for the SFP group and 161 for the non-SFP group.

‡ To convert body Fe from mg/kg to mmol/kg multiply by 0·0171[74].

§ Defined as anaemia and SF concentrations <15 μg/l and/or sTfR concentrations >8·5 mg/l.

‖ AnthroPlus software (version 1.0.3; WHO) allows weight-for-age calculation only for children aged 5–10 years old (*n* 136 for the SFP group and 139 for the non-SFP group).

A few food items contributed to the better micronutrient intake among the school feeding participants: orange for vitamin C; fortified corn soya blend for Fe and vitamins A and C; palm oil for vitamin A. The multiple-micronutrient-fortified corn soya blend, in particular, appears to play a key role in increasing micronutrient intake and adequacy among the school feeding participants. This may thus indicate that adequate micronutrient intake may not be achieved by the mere provision of an extra meal through school lunch, but achieved by deliberate supply of micronutrient-dense foods[3,54]. However, the bioavailability of the relatively higher amounts of Fe and Zn consumed among SFP participants may be reduced given the high phytate content of the diet in general[55] and the meagre contribution of animal protein to total dietary intake[56]. Moreover, the oranges that were served (twice a week) with lunch, which could improve Fe bioavailability when consumed together with the school lunch[57,58], were rather taken home and often shared with younger siblings not in school. In the absence of school feeding, the probability of adequate micronutrient intake among schoolchildren is low (approximately 0·20). This to a large extent reflects the poor quality of diets at the household level as almost all meals consumed by the non-school feeding children were from home. In other studies, the micronutrient quality of cereal- and legume-based diets of rural African households has been reported to be poor and to contribute to the inadequate intake of bioavailable Fe[59,60].

The measurement of habitual dietary intake of individuals and groups remains a major challenge in dietary intake assessment[18], but our use of 24 hR with a non-consecutive duplicate recall in a subsample has been recommended and shown to be adequate for such a measurement[18,61,62] and

for the assessment of nutrient intake of schoolchildren[63]. Major sources of systematic bias in the use of 24 hR include under- or over-reporting of intake[18,64], which could have resulted in the misclassification of nutrient intake adequacy. To minimise misreporting of food intake, mothers/caregivers were taken through a systematic multiple-pass procedure which aided recollection of foods and ingredients used in preparation of meals at home[18]. Out-of-home food intake may have been omitted by mothers/caregivers and may have led to an underestimation of nutrient intake[19]. However, in this area, almost all meals are prepared and consumed at home and mothers/caregivers are fully involved in serving meals. Also, the presence of children during the interviews helped mother/caregivers to recall likely forgotten foods. We therefore believe that underestimation of nutrient intake was unlikely to have occurred.

The high prevalence of anaemia among these children is not unexpected. The study area is malaria endemic and malaria is among the leading causes of anaemia[14] in this area. As the present study was conducted during the peak of malaria transmission (November–December), it is most likely that malaria contributed to the high prevalence of anaemia among these children[65]. Notwithstanding the apparent contribution of malaria to anaemia, the high prevalence of IDA among these children may indicate that anaemia in a large proportion of these children is due to ID. The low prevalence of ID observed based on SF values alone rather than when combined with sTfR values highlights the difficulty of reliably measuring ID prevalence in settings where the prevalence of infections and infestations may be high. In an intervention trial in the same area, Abizari *et al.* found that baseline SF values (similar to the SF values observed in the present study) decreased in response to deworming and malaria treatment, thus giving credence to the use of sTfR values as the measure of Fe status in the present study. However, the low prevalence of elevated CRP (an acute-phase protein) among these children does not seem to indicate that SF values in the present study were possibly influenced by inflammation. Unlike CRP, α_1-acid glycoprotein values increase and return to baseline values slowly[66] and therefore it may be better to measure the concentrations of both CRP and α_1-acid glycoprotein as composite markers of cross-sectional inflammation[65,67,68], but the concentration of α_1-acid glycoprotein was not measured in the present study.

It is tempting to suggest that the higher Hb concentration, better sTfR concentration and the relatively lower prevalence of anaemia among SFP participants may be associated with the overall better Fe content of the school lunch. However, the absence of a significant difference in SF and body Fe concentrations between the two groups coupled with a similar prevalence of ID and IDA does not support the observation that SFP may have contributed to Fe status. Fe status may also be influenced by non-dietary interventions. Health- and nutrition-related interventions associated with SFP, such as deworming, could have also contributed to the relatively better Hb and sTfR concentrations[4], but neither group of schools reported receiving deworming treatments in the 6 months preceding the study. In a randomised trial in the same area, it has been shown that school feeding coupled with deworming and malaria treatment significantly improves Hb concentrations and Fe status and reduces anaemia prevalence[65].

Contrary to our expectation, the higher energy and nutrient intakes among SFP participants did not result in a significant difference in nutritional status. The lack of effect of school feeding on nutritional status has also been observed elsewhere[69,70], and the main reason for the lack of effect has been ascribed to the substitution effect of SFP. In the present study, the reason for the lack of differences in nutritional status despite the absence of home lunch substitution remains unclear as further exploration was limited by the study design. Others have argued that SFP targeting children >2 years are unlikely to affect stunting in particular[12]. In settings where stunting prevalence is already high, there is increasing fear that the excess energy intake due to SFP could lead to obesity[1]. The basis for such fear was not apparent in the present study. However, it is possible that the higher energy and nutrient intakes among SFP participants increased their activity levels at the expense of weight gains[71]. Based on the differences between the estimated energy requirements for children and the adjusted energy intakes, it was found that a majority of the schoolchildren in both groups were in positive energy balance, but there was no evidence of positive energy balance in the nutritional status of the schoolchildren. On the other hand, it is also possible that the schoolchildren were more physically active and thus required more energy than what we estimated using a moderate physical activity level. The positive energy balance could have also been a result of caregivers overestimating the dietary intake of their children. However, if overestimation occurred, it is less likely to have affected the differences observed in nutrient intakes between the two groups as total energy intake from home consumption was not significantly different.

The evidence of the impact of SFP (e.g. government-run SFP) has been described as lacking rigour because of their non-experimental design[4]. The design of the present study is also non-experimental, thus limiting the rigour of the inferences that can be drawn. The absence of measures of nutrient intakes and Fe and nutritional status for both groups at the start of the SFP and the non-random allocation of the pilot SFP did not allow us to isolate the impact of school lunch, even though we controlled for differences in child and household characteristics in the analysis. We matched SFP communities with non-SFP communities that were otherwise also qualified to receive school feeding, but were not enrolled at the time of the study. We examined our assumptions that intervention communities had starting status similar to their controls by comparing the outcomes of interest between all four SFP–non-SFP pairs (2 SFP $\times$ 2 non-SFP) to determine whether differences were consistently in favour of SFP. We observed consistent differences in favour of school feeding with respect to energy and nutrient intakes but not with respect to Fe and nutritional status, indicating that our assumption for similarity may not be strongly supported. However, it is possible that the paired comparisons lacked power to detect the consistent direction of effect because

British Journal of Nutrition

sample sizes were half of what the present study was powered for. Moreover, unobservable differences between communities may have altered the effects attributable to SFP[72]. It is recommended that studies that match schools to evaluate the effects of SFP include a large number of schools to account for differences in school and community characteristics[73]. It therefore remains a limitation of the present study that only two pairs of schools could be matched and included.

In conclusion, the present results indicate that school feeding is associated with higher intakes and adequacies of energy and nutrients, but not with the prevalence of Fe and nutritional status indicators. The results also indicate an important role for micronutrient-dense foods in the achievement of micronutrient adequacy within SFP.

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