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# Nutritional and cognitive deficits of school-age children

## A study in helminth-endemic fishing and farming communities in Ghana

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**Abstract**

**Purpose** – The purpose of this study was to elucidate the association between helminth infections, dietary parameters and cognitive performance, as well as the predictors of undernutrition among school-age children (SAC) living in helminth-endemic fishing and farming communities in Ghana.

**Design/methodology/approach** – This was a cross sectional study involving 164 (9 to 12 years old) SAC from fishing (n = 84) and farming (n = 80) communities of the Kwahu Afram Plains South District of the Eastern Region of Ghana, using structured questionnaires and anthropometric and biochemical assessments.

**Findings** – Overall, 51.2% of the children were males, with no significant gender difference between the communities ($p = 0.88$). Average age of the children was 10.5 ± 1.25 years, with no significant difference between the farming and fishing communities ($p = 0.90$). About 53.1% of all children were anemic, with no significant differences between farming versus fishing communities ($p = 0.87$). Helminth-infected children were significantly anemic ($p = 0.03$). Mean serum zinc level of all children was 13.1 ± 4.57 $\mu$mol/L, with zinc deficiency being significantly higher in children in the farming community ($p < 0.0001$). About 7.5% of all the children were underweight, whilst 13.8% were stunted with a higher proportion of stunting occurring among older children ($p = 0.001$) and girls ($p = 0.117$). There was no significant difference in the Raven's Colored Progressive Matrices cognitive test scores between the two communities ($p = 0.79$). Predictors of anemia were helminthiasis and pica behavior.

**Originality/value** – These findings are relevant and have the prospect of guiding the development of intervention programs in addressing the persistent problem of nutritional and cognitive deficits among SAC.

**Keywords** Ghana, Nutrition, Cognitive performance, Kwahu Afram plains, Fishing, Helminths, Farming

**Paper type** Research paper

## Introduction

Undernutrition and helminth infections are common problems among children in low-and middle-income countries (LMICs) (Kosinski *et al.*, 2012; Shaw and Friedman, 2011; Tandoh *et al.*, 2015), contributing to thousands of morbidities every year. Although helminth infections affect populations across the lifecycle, children are the worst affected (Bethony

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*et al.*, 2006; Hotez *et al.*, 2008; WHO, 2011b), with infections occurring as early as at the age of 2 years and persisting into later years (Colley, 2014a; King, 2010; van der Werf *et al.*, 2003). Populations of LMICs with chronic helminths infection experience a cycle of undernutrition and frequent ill-health that can continue from generation to generation. For instance, growth retardation and anemia have been reported in children with helminth infections compared with uninfected children (Echazú *et al.*, 2017; Grantham-McGregor, 2002).

Helminth infections (helminthiasis) can occur as a result of infections due to either soil-transmitted helminths (STH) such as roundworm (*Ascaris lumbricoides*), whipworm (*Trichuris trichiura*) and hookworm (*Ancylostoma duodenale* and/or *Necator americanus*). These affect about a third of the world's population (Colley, 2014b; WHO, 2011a), whilst infection by the human schistosome (*Schistosoma haematobium*, *Schistosoma mansoni* and/or *Schistosoma japonicum*) affects about 200 million people of the world (WHO, 2011a).

Undernutrition, a common consequence of helminthiasis (Ayeh-Kumi *et al.*, 2016; Hailegebriel, 2018; Sanchez *et al.*, 2013; Shaw and Friedman, 2011; Tandoh *et al.*, 2015), is still a public health problem, with an estimated 16 per cent, 26 per cent and 8 per cent of children globally being underweight, stunted and wasted, respectively (Carmen Casanovas *et al.*, 2013). In Ghana, 19 per cent, 11 per cent and 5 per cent of children under five are reported stunted, underweight and wasted, respectively (GSS, 2015). Stunting in Ghana occurs more (22 per cent) in rural areas than in the urban areas (15 per cent). Similarly, underweight also occurs more in rural children (13 per cent) than those in urban areas (9 per cent; GSS, 2015). This could be attributed to several factors, including those that propagate the spread of helminths such as inappropriate stool disposal methods. For instance, about 43 per cent of children in urban areas are more likely to dispose their stools safely compared to 37 per cent of those in the rural areas (GSS, 2015).

Micronutrient deficiency (hidden hunger) also continues to be a major public health problem in LMICs (Best *et al.*, 2010; Chakrabarty and Bharati, 2012), with over two billion people including 250 million children affected (Ramakrishnan, 2002). In some coastal areas in Indonesia, for instance, low serum zinc levels have been reported among school-age children (Pramono *et al.*, 2017). Other studies have also shown evidence of micronutrient deficiencies with *Ascaris* infection among children in Mexico (Long *et al.*, 2007). An association has also been established between micronutrient deficiencies, stunting and impaired immunity among SAC (Best *et al.*, 2010; Brown *et al.*, 2002; Fraker *et al.*, 2000; Gibson *et al.*, 2007; Sommer and Davidson, 2002). A study among SAC in Thailand, for example, reported that stunted males recorded the lowest concentrations of serum zinc (Gibson *et al.*, 2007). Zinc has also been reported as, possibly, the most deficient micronutrient among school-age children in LMICs due to the high consumption of plant-based diets and low intakes of bioavailable zinc source foods (Yeudall *et al.*, 2005). Other studies have also reported an association between zinc deficiency and reduced appetite (Umeta *et al.*, 2000). Thus, chronic helminth infections may aggravate the existing underlying problem of undernutrition (Coutinho *et al.*, 2006) as well as impair cognitive function and development (Drake and Bundy, 2001; Drake *et al.*, 2000) of SAC.

Helminths tend to affect optimal health (Hailegebriel, 2018; Njaanake *et al.*, 2015) and impair digestion and absorption of nutrients in humans, leading to undernutrition such as anemia, stunting and wasting (Casmo *et al.*, 2014; Hailegebriel, 2018; Kinung'hi *et al.*, 2017; Njaanake *et al.*, 2015). Undernutrition in turn contributes to weakened immune system, making individuals vulnerable to infections (Katona and Katona-Apte, 2008).

Helminthiasis has also been associated with decreased outcomes in cognitive assessments and impaired mental functioning (Al-Mekhlafi *et al.*, 2008; Ezeamama *et al.*, 2005; Gall *et al.*, 2017). This relationship has been attributed to iron-deficiency anemia and overall undernutrition related to helminth infections (Crompton, 2000; De Silva *et al.*, 2003; Grigorenko *et al.*, 2006; Hotez *et al.*, 2005). Other nutritional indicators such as underweight and wasting, which are common consequences of *Ascaris* and schistosome infection (Ayeh-Kumi *et al.*, 2016; Hailegebriel, 2018), have also been associated with deficits in cognitive performance and school absenteeism (Al-Mekhlafi *et al.*, 2008; Ezeamama *et al.*, 2005).

Although studies on micronutrient deficiencies and undernutrition among SAC in LMIC have been done over the years, there is lack of studies that examine associations between helminthiasis, undernutrition and cognitive performance, in relation to the disparities between diverse communities. Thus, the purpose of the current study was to examine the existing disparities in the cognitive and nutritional outcomes (serum zinc, hemoglobin, underweight and stunting) and helminth infections (helminthiasis) among SAC, in rural fishing and farming communities in the Kwahu Afram Plains South District of Ghana.

## Methodology

### *Study design and subjects*

Data for this paper came from a previously described cross-sectional study that evaluated the prevalence and predictors of helminth infection in helminth-endemic communities in the Kwahu Afram Plains South District in the Eastern Region of Ghana (Tandoh *et al.*, 2018). Briefly, the original study recruited 164 pupils between the ages of 9 and 12 years from fishing (n = 84) and farming (n = 80) communities of the Kwahu Afram Plains South District of the Eastern Region. The study was conducted between May and June 2017. Four schools were randomly selected (two from each community) for the study.

### *Ethical consideration*

The study was reviewed and approved by the Human Subjects Institutional Review Board of the University of Georgia (STUDY00004580) and the Ethical Committee Board at the Kwame Nkrumah University of Science and Technology, Ghana (CHRPE/RC/182/17). Also, the Regional Directors of the Ghana Education Service, Ghana Health Services of the Eastern Region and the Head Teachers of the selected schools gave their respective permission for the conduct of the study with pupils in the schools. Parents/caregivers of the children also provided their consent, while the children provided assent for their participation.

### *Inclusion and exclusion criteria*

To qualify to participate in the study, pupils had to be (1) living within the selected communities (farming or fishing), (2) 9 to 12 years old and (3) be a pupil of one of the randomly selected schools in the Kwahu Afram Plains South District. To prevent older siblings standing in as parent/guardian for index children, the parents/guardians of eligible children had to be 25 years or older to provide accurate information on the child. Children who did not fall within the inclusion criteria and who self-reported to have malaria and/or sickle cell anemia, and those who had obvious physical ailments such as goitre and elephantiasis, as well as those on any nutritional supplement at the time of data collection were excluded from the study.

### *Data collection*

*Socio-Demographic information.* Index children and their parents or primary caregivers were assisted to complete a questionnaire that collected data on sanitation and hygiene practices, and demographic information as described previously (Tandoh *et al.*, 2018).

*Dietary assessment (24-hour recall).* A 3-day 24-hour dietary recall (two weekdays and a weekend day) was used to assess dietary intakes of subjects to estimate caloric and nutrient intake as described by Gibson (2005). Using household handy measures, the respective masses of the food eaten by index children were recorded by identifying them with weights or handy measures from the University of Ghana, Department of Nutrition and Food Science Handy Measure Grammage Database (2010). Their caloric and nutrient intakes were then analysed using "Nutrient contents of some Ghanaian Foods" (Tayie and Lartey, 1999) and Food and Agriculture Organization (2012) West African Food composition (Stadlmayr *et al.*, 2012). The adequacy of the estimated nutrient intakes were then determined based on Dietary Reference Intakes of the National Academy of Sciences (NAS, 2004).

*Anthropometric assessment.* Based on standardized protocol described by Apprey *et al.* (2014), the weight and height of the index children were measured by trained personnel. As an indicator of the nutritional status of the index children, the height and weight measures were used to compute body mass index (BMI)-for-age *z*-scores (BAZ) for each participant using the WHO anthropometric calculator (Anthro Plus version 1.0.3, http://whoanthroplus.software.informer.com/1.0/). Children who fell below −2*SD*) from the median of the reference population were classified as moderately malnourished, whereas those who fell below −3*SD* were classified severely malnourished, with those above −2*SD* classified as normal. For the purpose of statistical analysis in this study due to small sample size, the "severe" and "moderate" malnutrition were combined and classified as "undernutrition."

*Biochemical assessment.* A volume of 5 mL of venous blood was collected from each subject by a qualified phlebotomist to determine serum zinc and hemoglobin. Serum zinc was analysed by the calorimetric method using 1.2 mL serum aliquoted into labelled 1.5-mL micro tubes, refrigerated at 4°C and transported to the Molecular Medicine Research Laboratory at the Kwame Nkrumah University of Science and Technology, Kumasi for analysis. Cut-offs for zinc deficiency for morning non-fasting blood samples were set at $<9.9\ \mu$mol/L (10-year-olds for both gender), $<10.7\ \mu$mol/L ($\geq$10year-old-males) and $<10.1\ \mu$mol/L ($\geq$10-year-old females), based on standard protocols (Houghton *et al.*, 2016).

The analysis of serum hemoglobin (Hb) was done using the HemoCue Hb 201$^{+}$ portable machine. The cut-offs for Hb levels for $\leq$11-year-olds were 115 g/L or higher (non-anemia), 110 g/L to 114 g/L (mild anemia), 80g/L to 109 g/L (moderate anemia) and <80 g/L (severe anemia), whereas for the 12 year olds, the cut-offs were 120 g/L or higher (non-anemia), 110 g/L to 119 g/L (mild anemia), 80g/L to 109 g/L (moderate anemia) and <80 g/L (severe anemia) (WHO, 2001). The different categories of anemic status (mild, moderate and severe anemia) were combined (due to small sample size) and re-classified as "anemia" for statistical analysis.

*Parasitic infections assessment.* In the parent study (Tandoh *et al.*, 2018), the stool and urine samples of index children were collected and assessed microscopically for intestinal helminth and urinary schistosomiasis using standard protocols (the Kato-Katz technique; WHO, 1994) and the urine filtration technique (WHO, 1991), respectively. The presence of eggs in urine and stool were counted as egg per gram (epg) of sample and classified as the presence of a helminth infection (helminthiasis).

*Cognitive performance assessment.* To adopt and use the cognitive test, Raven's Colored Progressive Matrices (RCPM) with our target population, we pilot tested it among a similar population and setting in Ghana among children of the same age group as our study participants. For the piloting, 15 randomly selected pupils aged 9 to 12 years (seven boys and eight girls) from the Ayeduase M. A. Primary School in the Oforikrom Municipality, Kumasi were used. This assessment tool was chosen because it is designed for use with young children and specifically for people who cannot understand or speak the English language fluently. The RCPM is made up of 36 items in three sets of 12. The three sets of 12 problems that make up the RCPM are arranged to assess the cognitive process of children and it is designed in such a way that children under 11 years of age are usually capable of solving them. The total set of 36 problems is designed to assess the mental development and intellectual maturity as accurately as possible.

In pilot testing the RCPM, the concept of the cognitive assessment was first explained to the children in the presence of their class teacher in both English and the local language "Twi". To ensure that the children had understood the concept, the first page of the test book was drawn on the blackboard and the test demonstrated to them by the researcher (MAT) whereas the test books were opened before them. The children were randomly called to point to the correct piece of shape. If a child pointed to the wrong shape in his/her book, further explanation was given until the nature of the assessment was clearly grasped. The first question in the test book (Question 1 in section AI) was used as a demonstration question and answered correctly for all participants. On the average, the entire assessment process took about an hour. Participatory response to the pilot testing of the cognitive assessment tool showed the questionnaire and activities were well understood, thus the tool was adopted for the study. Because there is no standardized reference scores based on the cognitive assessment tool (RCPM) for the Ghanaian population, to compare with, the test scores of the children were grouped into categories such that those who scored more than 50 per cent ($\geq$18) were classified as "passed", whereas those who scored below 50 per cent ($<$18) were classified as "failed" and used for the logistic regression analysis. The school attendance record of children at the time of the study (out of 28 days) was also obtained and compared between the two communities.

*Data analysis*

IBM SPSS Version 24 for Windows (SPSS Inc., Cary USA) was used for all statistical analysis. Descriptive statistics of means, standard deviations and ranges were then determined for continuous variables. Proportions were determined for categorical variables. Bivariate analysis was conducted using the chi square ($\chi^2$) and the Fischer exact tests where appropriate to determine significant differences between the categorical variables.

Univariate logistic regression analyses were conducted to examine the association between the independent variables and the dependent variables. Multivariate logistic regression was then used to determine the independent predictors of undernutrition. For the parasitic assessment, we present findings of helminthiasis prevalence (a combination of either/both STH and schistosome infections). The level of statistical significance was defined as $p < 0.05$.

## Results

*Characteristics of the study population by communities*

A total of one hundred and sixty-four (164) school-age children between the ages of 9 and 12 (10.53 ± 1.25) years together with their primary caregivers were recruited from two communities; farming (n = 84) and fishing (n = 80). Table I presents a description of the study participants. The majority of caregivers were mothers (55.5 per cent), with 64.3 per cent being in the farming compared to 46.3 per cent in the fishing community ($p = 0.028$). About 5.5 per cent of caregivers were identified as male guardian of the index child, other than the father. Overall, more than four-fifth of the caregivers were married, with a significantly higher number of them being in the fishing (97.5 per cent) compared to the farming (72.6 per cent) community ($p < 0.0001$). Furthermore, almost half of the caregivers had no formal education, with a significantly higher number of them in the farming (57.1 per

| Variable | Overall *n* (%) | Farming *n* (%) | Fishing *n* (%) | *p* value |
|---|---|---|---|---|
| *Primary caregiver* | | | | |
| Father | 32 (19.5) | 10 (11.9) | 22 (27.5) | 0.030 |
| Mother | 91 (55.5) | 54 (64.3) | 37 (46.3) | |
| Male guardian | 9 (5.5) | 6 (7.1) | 3 (3.8) | |
| Female guardian | 32 (19.5) | 14 (16.7) | 18 (22.5) | |
| *Primary caregiver tribe* | | | | |
| Northerner | 56 (34.1) | 56 (66.7) | 0 (0.0) | $<$0.0001 |
| Ewe | 94 (57.3) | 19 (22.6) | 75 (93.8) | |
| Others | 14 (8.5) | 9 (10.7) | 5 (6.3) | |
| *Marital status of primary caregiver* | | | | |
| Married | 139 (84.8) | 61 (72.6) | 78 (97.5) | $<$0.0001 |
| not married | 25 (15.2) | 23 (27.4) | 2 (2.5) | |
| *No. of children in household* | | | | |
| 1-4 | 57 (36.1) | 28 (33.3) | 29 (39.2) | 0.574 |
| 5-8 | 68 (43.0) | 36 (42.9) | 32 (43.2) | |
| $>$8 | 33 (20.9) | 20 (23.8) | 13 (17.6) | |
| *Caregiver highest education* | | | | |
| No school | 71 (43.3) | 48 (57.1) | 23 (28.7) | 0.001 |
| Elementary | 36 (22.0) | 16 (19.0) | 20 (25.0) | |
| Junior high | 40 (24.4) | 12 (14.3) | 28 (35.0) | |
| Senior high | 17 (10.4) | 8 (9.5) | 9 (11.3) | |
| *Caregiver job title* | | | | |
| Crop farmer | 121 (73.8) | 69 (82.1) | 52 (31.7) | 0.008 |
| Fish farmer | 9 (5.5) | 0 (0.0) | 9 (11.3) | |
| Business person | 18 (11.0) | 6 (3.7) | 12 (7.3) | |
| Skilled worker | 8 (4.9) | 5 (6.0) | 3 (3.8) | |
| Service provider | 8 (4.9) | 4 (4.8) | 4 (5.6) | |
| *Index child age* | | | | |
| 9 years | 49 (30.1) | 23 (27.7) | 26 (32.5) | 0.16 |
| 10 years | 35 (21.5) | 18 (21.7) | 17 (21.3) | |
| 11 years | 22 (13.5) | 16 (19.3) | 6 (7.5) | |
| 12 years | 57 (35.0) | 26 (31.3) | 31 (38.8) | |
| *Index child gender* | | | | |
| Male | 83 (50.6) | 43 (51.2) | 40 (50.0) | 0.88 |
| Female | 81 (49.4) | 41 (48.8) | 40 (50.0) | |
| *Pica practice* | | | | |
| Yes | 40 (24.4) | 26 (31.0) | 14 (17.5) | 0.05 |
| No | 124 (75.6) | 58 (69.0) | 66 (82.5) | |
| *Fingernails biting* | | | | |
| Yes | 94 (57.3) | 39 (46.4) | 55 (68.8) | |
| No | 70 (42.7) | 45 (53.6) | 25 (31.3) | |
| *Helminthiasis* | | | | |
| Present | 36 (22.0) | 9 (10.7) | 27 (33.8) | $<$0.0001 |
| Absent | 128 (78.0) | 75 (89.3) | 53 (66.3) | |
| *Cognitive test scores* | | | | |
| Fail | 134 (84.8) | 71 (85.5) | 63 (84.0) | 0.79 |
| Pass | 24 (15.2) | 12 (14.5) | 12 (16.0) | |

**Notes:** Data were analyzed using a chi-square analysis. Farming community schools (Kwasi Fanti D/A Primary and Asayansu R/C Primary), Fishing community schools (Trebu D/A Primary and St. Michael Primary), Index Child (the child of the caregiver who is being studied

**Table I.**
Characteristics of the study population by community type

cent) compared to the fishing (28.7 per cent) community ($p = 0.001$). Also, about two-thirds of all the caregivers were crop farmers, with 82.1 per cent being in the farming versus 31.3 per cent in the fishing community ($p = 0.008$). Overall, the children were almost evenly divided by gender, with the majority being 12 years old. About a quarter of them engaged in pica practice, with this occurring more among children in the farming (31.0 per cent) compared to those in the fishing (17.5 per cent) community ($p = 0.045$). The overall prevalence of helminthiasis (STH and/or schistosome) was 22 per cent, with 10.7 per cent occurring in the farming versus 33.8 per cent in the fishing community ($p < 0.0001$) (Table I).

*Participants nutritional and cognitive characteristics by communities*

Table II shows the nutritional and cognitive measures of the children based on the type of community they live. The mean BMI-for-Age z-score (underweight) was −0.7 versus −1.0 for children from the farming compared to the fishing communities, respectively ($p = 0.03$.), whereas the mean HAZ (stunting) was −1.0 versus −0.6 for the farming versus the fishing communities, respectively ($p = 0.09$). The mean blood hemoglobin levels were similar, whereas the mean serum zinc levels were significantly higher among children from the fishing community compared to their counterparts from the farming community ($p < 0.0001$). Furthermore, mean estimated total carbohydrate intakes by children in the fishing community were higher (328.0 g/d), compared to their counterparts in the farming community (265.2 g/d; $p = 0.003$). Conversely, the estimated vitamin C intake was higher among children in the farming community (131.9 mg/d) than those in the fishing community (71.5 mg/d; $p < 0.0001$). However, there were no significant differences in the estimated total calories and other nutrient intakes of the children from the two different communities (based on their nutrient adequacy; Figure 1. The mean scores on the cognitive test were similar between the two communities, with children in the farming community performing slightly better (12.5 ± 5.47) compared to their counterparts in the fishing community (12.2 ± 6.10) ($p = 0.75$), whereas for school attendance, children in the fishing community recorded a higher average attendance of 22.8 days out of 28 days, compared with children in the farming community (21.2 days; Table II).

| Variables | Farming (Mean ± SD) | Fishing (Mean ± SD) | $p$ value |
|---|---|---|---|
| Index child age (years) | 10.6 ± 1.21 | 10.5 ± 1.30 | 0.90 |
| Height-for-Age-Z (Stunting) | −1.0 ± 0.93 | −0.6 ± 1.49 | 0.09 |
| BMI-for-Age-Z (Underweight) | −0.7 ± 0.83 | −1.0 ± 1.20 | 0.03 |
| Hemoglobin (g/L) | 11.5 ± 1.04 | 11.6 ± 1.24 | 0.77 |
| Serum zinc (μmol/L) | 10.4 ± 2.57 | 15.8 ± 4.58 | <0.0001 |
| Total energy/day (Kcal) | 1715.7 ± 642.57 | 1897.3 ± 898.37 | 0.14 |
| Total carbohydrate (g/d) | 265.2 ± 99.59 | 328.0 ± 162.19 | 0.003 |
| Total protein (g/d) | 48.3 ± 23.70 | 53.3 ± 27.25 | 0.22 |
| Total zinc (mg/d) | 7.3 ± 5.04 | 10.3 ± 15.84 | 0.10 |
| Total iron/ (mg/d) | 10.7 ± 5.89 | 11.6 ± 7.37 | 0.35 |
| Total vitamin C (mg/d) | 131.9 ± 73.54 | 71.5 ± 25.11 | 0.001 |
| Raven's Cognitive Test Score | 12.5 ± 5.47 | 12.2 ± 6.10 | 0.75 |
| School attendance | 21.2 ± 4.91 | 22.8 ± 4.86 | 0.03 |

**Notes:** Data were analyzed using the independent-samples $t$ test. Index child (the child of the caregiver who is being studied)

**Table II.** Nutritional and cognitive measures of participants by community type

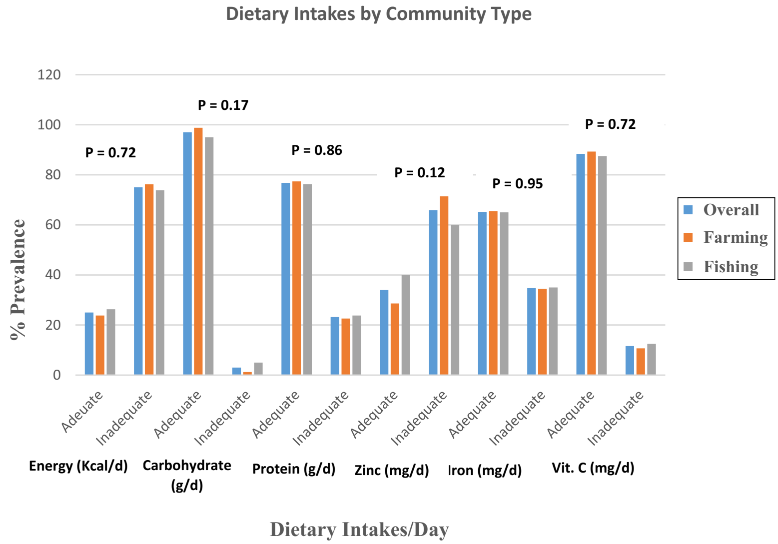


**Figure 1.**
Estimated Total Daily Dietary Intakes of Index Child N = 164

*Index child nutritional status*

Overall, the total calorie and zinc intake of children were inadequate (75.0 per cent and 65.9 per cent, respectively; Figure 1). Similarly, there was no significant differences in the total dietary intakes of carbohydrate, protein, iron and vitamin C with regards to their adequacies (Figure 1).

Based on the BAZ values, however, 7.5 per cent of all the children were underweight, with slightly higher proportion of underweight occurring in fishing community compared to the farming community ($p = 0.23$; Table III). Similarly, for stunting (HAZ), overall, 13.8 per cent of the children were stunted, with those in the fishing community having a higher stunting rate (15.0 per cent) than those in the farming community (12.5 per cent) ($p = 0.65$). The male children generally exhibited a better nutritional outcome than the females, with the exception of anemia, which was higher among males (60.2 per cent) compared to the females (45.6 per cent) (P = 0.06) (Table III). Furthermore, compared to other age groups, 12-year-olds had the worst nutritional outcomes with regards to stunting ($p = 0.001$), underweight ($p = 0.43$), anemia ($p = 0.53$), and zinc deficiency ($p = 0.16$) (Table III). Helminth–infected children exhibited a higher prevalence of anemia (69.4 per cent) compared to their non-infected counterparts (48.4 per cent) ($p = 0.03$), whereas for all other nutritional indicators (stunting, underweight and zinc deficiency), helminth-infected children had a lower prevalence, although the differences were not statistically significant ($p > 0.05$) (Table III).

About 22.4 per cent of all the children were zinc deficient according to their measured serum zinc levels with significantly higher percentage of them found in the farming compared to the fishing communities ($p < 0.0001$) (Table III). Over half of the children were anemic (53.1 per cent) with no significant differences in anemia prevalence between the two communities ($p = 0.87$) (Table III).

*Index child cognitive performance*

Table I shows that more children in the fishing community (16.0 per cent) met the pass mark of 50 per cent set for the RCPM cognitive test, compared to their counterparts in the farming

| Variable | Stunting $n$ (%) | $p$ value | Underweight $n$ (%) | $p$ value | Zinc Deficiency $n$ (%) | $p$ value | Anemia $n$ (%) | $p$ value |
|---|---|---|---|---|---|---|---|---|
| *Community type* | | | | | | | | |
| Overall | 22 (13.8) | 0.65 | 12 (7.5) | 0.23 | 36 (22.4) | $<$0.0001 | 86 (53.1) | 0.87 |
| Farming | 10 (12.5) | | 4 (5.0) | | 34 (41.5) | | 43 (52.4) | |
| Fishing | 12 (15.0) | | 8 (10) | | 2 (2.5) | | 43 (53.8) | |
| *Gender* | | | | | | | | |
| Male | 8 (9.6) | 0.12 | 4 (4.8) | 0.18 | 18 (21.7) | 0.83 | 50 (60.2) | 0.06 |
| Female | 14 (18.2) | | 8 (10.4) | | 18 (23.1) | | 36 (45.6) | |
| *Age* | | | | | | | | |
| 9 years | 3 (6.1) | 0.001 | 3 (6.1) | 0.43 | 5 (10.4) | 0.16 | 28 (57.1) | 0.53 |
| 10 years | 2 (5.9) | | 3 (8.8) | | 8 (24.2) | | 15 (44.1) | |
| 11 years | 1 (4.8) | | 0 (0.0) | | 5 (23.8) | | 10 (47.6) | |
| 12 years | 16 (28.6) | | 6 (10.7) | | 16 (28.1) | | 33 (57.9) | |
| *Helminthiasis* | | | | | | | | |
| Overall | 22 (13.8) | 0.60 | 12 (7.5) | 0.62 | 36 (22.4) | 0.022 | 86 (53.1) | 0.026 |
| Yes | 4 (11.1) | | 2 (5.6) | | 3 (8.3) | | 25 (69.4) | |
| No | 18 (14.5) | | 10 (8.1) | | 33 (26.4) | | 61 (48.4) | |

**Notes:** Data were analyzed using a chi square analysis. Helminthiasis represents infection due to both/either soil-transmitted helminths (STH) and schistosome

**Table III.** Nutritional deficiencies by community, gender, age and helminthiasis burden

community (14.5 per cent), although not significantly different ($p = 0.79$) (Table I). Table IV also shows a comparison between the average RCPM cognitive test scores of the children and the type of community, gender, age, helminth infection. There was no significant difference in the cognitive test scores between children in the two communities (Farming: 12.5 ± 5.47 versus Fishing: 12.2 ± 6.10) ($p = 0.75$). Also, there were no significant differences between status of helminthiasis and the cognitive test scores ($p = 0.68$). Similarly, there were no significant differences observed in test scores based on age, gender, hemoglobin and zinc levels of children in the study ($p > 0.05$) (Table IV).

Table VII shows a binary logistic regression performed to determine the predictors of cognitive performance. Helminthiasis and the studied nutritional indicators (hemoglobin, zinc, underweight and stunting) were not significant independent predictors of cognitive performance.

### *Predictors of childhood undernutrition*

The univariate analysis of this study further showed that the helminthiasis status as well as pica behavior of children were associated with anemia (Table VI). Multivariate analysis adjusting for child age, gender and community type revealed that the helminthiasis (AOR = 0.42, CI; 0.18-0.89) and pica habit (AOR = 0.39, CI; 0.18-0.89) were independent predictors of anemia (Table VI).

## Discussion

This was a cross-sectional study in which one hundred and sixty-four (164) school-age-children between the ages of 9 and 12 together with their primary caregivers were recruited from two communities; farming (n = 84) and fishing (n = 80). From Table I, most of the caregivers were mothers (55.5 per cent) while 5.5 per cent were male guardians of the index

**Table IV.**
A Comparison of cognitive outcome by community type, gender, age, helminthiasis and undernutrition

| Variable (n) | Cognitive test scores Mean ± SD | *p* value |
|---|---|---|
| *Community type* | | |
| Farming | 12.5 ± 5.47 | 0.749 |
| Fishing | 12.2 ± 6.10 | |
| *Gender* | | |
| Male | 13.1 ± 5.97 | 0.074 |
| Female | 11.4 ± 5.51 | |
| *Age (Years)* | | |
| 9 | 10.4 ± 5.33 | 0.142 |
| 10 | 12.0 ± 4.22 | |
| 11 | 12.4 ± 5.88 | 0.270 |
| 12 | 14.2 ± 6.47 | |
| *Helminthiasis* | | |
| Yes | 12.7 ± 5.13 | 0.679 |
| No | 12.2 ± 5.94 | |
| *Anemia* | | |
| Yes | 12.4 ± 6.08 | 0.961 |
| No | 12.3 ± 5.48 | |
| *Zinc deficiency* | | |
| Yes | 13.4 ± 4.66 | 0.218 |
| No | 12.0 ± 6.06 | |

**Note:** Data were analyzed using the independent-samples $t$ test. $p$ value $< 0.05$

child, other than the father. The prevalence of intestinal helminthiasis as reported in the parent study was 4.9 per cent while urinary schistosomiasis was 17.1 per cent (Tandoh *et al.*, 2018). For the purpose of this paper, however, the two types of infection (STH and/or schistosomiasis) were combined and labeled as "helminthiasis". Prevalence rate of helminthiasis therefore was 22.0 per cent, and this was significantly higher among children living in the fishing community (33.8 per cent) compared to those in the farming community (10.7 per cent) (Table I).

Even though an overall prevalence of stunting (13.8 per cent) was observed in the current study with a majority of them within the fishing (15.0 per cent) than the farming (12.5 per cent) community, this is in contrast to findings from a study by Fentiman *et al.* (2001), which reported a higher prevalence of stunting (44 per cent) among SAC in the Eastern Region of Ghana; with children living in the farming community being more stunted than those in the fishing community. They attributed their findings to children in the fishing community being more nourished than those in the farming community. Similar to their finding, another study in the Ashanti Region of Ghana (mainly farming community) found that 52.2 per cent of SAC were stunted regardless of whether they were benefiting from the Ghana School Feeding Program or not (Danquah *et al.*, 2012). Furthermore, another study in Southern Regional State of Ethiopia also reported higher stunting levels (26 per cent) among SAC than was observed in this study. We attribute our findings of the relatively lower prevalence of stunting (13.8) to the national periodic deworming program among Ghanaian children (Abdul-Rahman and Agble, 2012; Coutinho *et al.*, 2006; PCD, 1999), which could be improving on the nutritional outcome of children.

The significant differences in stunting ($p = 0.001$), observed in the different age groups in the study (Table III) could be attributed to a lack of well-defined nutrition policy and public health interventions in some LMICs (Getachew and Argaw, 2017), adversely affecting their nutritional intakes and growth outcomes. Furthermore, SAC are in a period of intense growth which demands higher nutritional intake to support their growth, especially, as they approach their teenage years potentially leading to growth impairments (Fink and Rockers, 2014; Lundeen *et al.*, 2014). Also, the observation that 12-year-olds had the worst nutritional outcomes in this study (Table III) is consistent to findings from a cross-sectional study conducted among SAC in Kenya (Chesire *et al.*, 2008), where children who were above the age of 9 years were more stunted and underweight than those below age 9. This confirmed the assertion that children become shorter and lighter as they grow older compared to their reference population (Drake *et al.*, 2002).

The observation of higher rates of stunting occurring in females (Table III) is also in contrast to findings in a Southern Regional Ethiopian study in which there were higher stunting rates among boys than girls (30 per cent vs 22 per cent) ($p = 0.037$) (Getachew and Argaw, 2017). In addition, Gibson *et al.* (2007), reported very high levels of stunting among male children, forming about two-thirds of all participating children. We could attribute these observed differences in our studies to the slightly higher prevalence of *S. haematobium* infection rates observed among the female children (18.5 per cent) compared to males (15.7 per cent) ($p = 0.68$) as has been previously reported (Tandoh *et al.*, 2018), that the *S. haematobium* competes with the host for nutrients and potentially leads to undernutrition.

Our findings on zinc deficiency corroborates findings by Egbi (2012), in which zinc deficiency was reported among SAC in a farming community in Ghana. However, the slightly higher prevalence of zinc deficiency among females compared to males in the present study (Table III)) is also in contrast with a study among SAC in Thailand which reported higher prevalence of zinc deficiency among males (Gibson *et al.*, 2007). In addition, other studies have shown that males have a higher tendency of being zinc deficient than females (Parnell *et al.*, 2003), which have been attributed to males having more muscles per kilogram body weight than females. Thus, since muscles have a higher composition of zinc compared to fat (Hotz and Brown, 2004), which is higher in females, males tend to have a higher requirement of zinc, making them more likely to be deficient. Similarly, our univariate analysis did not show significant association between stunting and zinc deficiency ($p > 0.05$) (Table V), which is in contrast to other studies which found associations between zinc deficiency and stunting (Gibson *et al.*, 2007). This observation could be attributed to most of the children in the current study meeting their protein requirement (Fig. I), since protein-energy malnutrition has also been implicated in stunting, underweight and wasting in children (Ndukwu *et al.*, 2013; Papier *et al.*, 2014).

The prevalence of underweight observed in our study (7.5 per cent) (Table III) is similar to a cross-sectional study conducted in Nairobi, Kenya among 6-12 year old SAC who reported a higher prevalence of underweight (14.9 per cent) (Chesire *et al.*, 2008). Compared to their study, the children in this study had a relatively lower underweight status, which could be attributed to the ongoing national deworming program in Ghana.

Overall, the most prevalent nutritional deficit observed in this study was anemia (Table III), with over half of the children (53.1 per cent) being anemic with no significant differences in anemia prevalence between communities ($p = 0.87$). This could be attributed to blood loss associated with helminth infections (Hall, 2007). Helminthiasis has typically been associated with hematuria leading to anemia (Brito *et al.*, 2006; Casmo *et al.*, 2014; Grimes *et al.*, 2017). This was the case as seen in a study by Njaanake *et al.* (2015), among 261 school children at

| Variable | Stunting | | | Underweight | | |
|---|---|---|---|---|---|---|
| | $n$ | Unadjusted OR (95%CI) | Adjusted OR (95%CI) | $n$ | Unadjusted OR (95%CI) | Adjusted OR (95%CI) |
| *Helminthiasis* | | | | | | |
| Absent | 124 | 1.36 (0.43-4.30) | 1.89 (0.53-6.77) | 124 | 1.49 (0.31-7.14) | 2.31 (0.43-12.38) |
| Present | 36 | 1.00 | 1.00 | 36 | 1.00 | 1.00 |
| *Pica behavior* | | | | | | |
| No | 40 | 0.87 (0.32-2.40) | 0.74 (0.23-2.41) | 40 | 1.00 (0.26-3.90) | 0.75 (0.17-3.36) |
| Yes | 120 | 1.00 | 1.00 | 120 | 1.00 | 1.00 |
| *Anemia* | | | | | | |
| No | 75 | 0.94 (0.38-2.31) | 0.85 (0.31-2.36) | 75 | 0.80 (0.24-2.62) | 0.53 (0.14-2.07) |
| Yes | 85 | 1.00 | 1.00 | 85 | 1.00 | 1.00 |
| *Serum Zinc* | | | | | | |
| Normal | 124 | 1.27 (0.40-4.05) | 1.73 (0.44-6.85) | 124 | 1.25 (0.26-6.09) | 0.60 (0.08-4.50) |
| Deficient | 34 | 1.00 | 1.00 | 34 | 1.00 | 1.00 |

**Notes:** Data were analyzed using the univariate and multivariate logistic regression. The multivariate analysis was adjusted for child age, gender and community type. Hosmer and Lemeshow test for stunting: chi-square = 8.24, $p$ value = 0.41; for underweight: chi-square = 9.30, $p$ value = 0.32

**Table V.** Predictors of childhood anthropometric measures of undernutrition

Tano River delta of coastal Kenya, who reported that anemia among school children was associated with high intensity of *S. haematobium* (OR: 2.08, $P < 0.05$) and hookworm infection (OR: 4.75, $p < 0.001$). The observed anemia prevalence (53.1 per cent) in the current study was nevertheless similar to findings by Fentiman *et al.* (2001), who reported (56 per cent) anemia among SAC near the Volta Lake in the Eastern Region of Ghana. Furthermore, findings from this study also confirm their observation of no significant differences in mean hemoglobin levels of children in fishing versus farming communities. This similarity could be attributed to the fact that there is no significant differences in the dietary intakes of children between the two communities in terms of their iron and zinc intakes (Figure 1), which are required together with other micronutrients for normal erythropoiesis (Friis *et al.*, 2003). Similarly, Egbi (2012), reported much higher prevalence of anemia (72 per cent) among SAC (2-10 years) at the Manya-Krobo District, a farming community in Ghana which was above the threshold for public health concern as suggested by the World Health Organization (WHO, 2001). His study, however, did not report on helminth infections in that community which could have potentially contributed to the observed nutritional outcomes. Furthermore, since farming communities tend to have higher rates of STH (ex. Hookworm infection) as was reported in a study from the Kintampo Municipality (a farming community in Ghana) (Humphries *et al.*, 2013), it is plausible that the loss of iron due to hookworm infection could have led to a higher prevalence rate of anemia as observed in the study by Egbi (2012), relative to the present study.

The average hemoglobin level observed in the farming communities in our study (11.53 g/dL ± 1.04) was higher than that reported in an earlier study in a farming community in the Upper East Region of Ghana (Bongo District) (10.8 g/dL ± 1.51) among enrolled SAC (Tandoh *et al.*, 2015). This observed difference could be due to the higher mean iron and vitamin C intakes among children in the Kwahu Afram Plains District (iron = 10.66 mg/d ± 5.89; Vit. C = 131. 92 mg/d ± 73.54) compared to those in Bongo District (iron = 8.7 mg/d ± 1.9; vit. C = 76.4 mg/d ± 24.2), since higher dietary heme iron and vitamin C intakes enhance iron absorption (Creed-Kanashiro *et al.*, 2000).

The over two-thirds of overall helminth-infected children being anemic in this study (69.4 per cent) compared to about one-half of non-infected children (48.4 per cent) (Table III) supports the assertion that a strong association exists between helminthiasis and iron deficiency anemia (Casmo *et al.*, 2014; Njaanake *et al.*, 2015). Hence, it is not surprising that although males do not lose blood through menstruation, they could be losing blood by way of hematuria through helminth infections. Thus, the observation of more males being anemic (60.2 per cent) than females (45.6 per cent) ($p = 0.06$) in this study (Table III), corroborates findings by Fentiman *et al.* (2001), who reported that more unenrolled adolescent males were likely to be anemic than their counterparts who were in school ($p = 0.02$). Their observation was attributed to higher level of *S. haematobium* infection among the teenage males who were not enrolled in school, and possibly fishing or engaging in commercial activities in the schistosome-infested fresh water body. Although from the parent study (Tandoh *et al.*, 2018), more females than males had schistosome infection, the intensity of helminth infections were not reported, which potentially could have been higher among the male children than the females, and possibly leading to a greater level of blood losses among the male children leading to higher anemia rates.

Based on the univariate logistic regression analysis, factors associated with anemia were helminthiasis and pica behavior (Table VI). This is similar to a cross-sectional study conducted among 640 (8-18 year old school children) in New Halfa, Eastern Sudan where 17.3 per cent and 5.2 per cent of the children had *S. mansoni* and *Hymenolepsis nana* infections, respectively, and *S. mansoni* infections were associated with severe anemia in their univariate analysis (Mahgoub *et al.*, 2010). In addition to that, another cross-sectional study conducted among 156 primary school pupils in Western Kenya also reported that geophagia (pica behavior) was an independent predictor of serum ferritin using the multiple regression analysis (Geissler *et al.*, 1998).

The mean cognitive test scores of the children were similar between the two communities ($p = 0.68$; Table II). Moreover, compared to the baseline RCPM (0–30) mean test scores

**Table VI.** Predictors of childhood micronutrient measures of undernutrition

| Variable | Anemia | | | Zinc deficiency | | |
|---|---|---|---|---|---|---|
| | *n* | Unadjusted OR (95%CI) | Adjusted OR (95%CI) | *n* | Adjusted OR (95%CI) | Unadjusted OR (95%CI) |
| *Helminthiasis* | | | | | | |
| Absent | 126 | 0.41 (0.19-0.91)* | 0.42 (0.18-0.98)* | 36 | 3.95 (1.13-13.73)* | 2.01 (0.46-8.72) |
| Present | 36 | 1.00 | 1.00 | 125 | 1.00 | 1.00 |
| *Pica Behavior* | | | | | | |
| No | 122 | 0.39 (0.18-0.83)* | 0.39 (0.18-0.89)* | 121 | 1.20 (0.50-2.91) | 1.64 (0.59-4.57) |
| Yes | 40 | 1.00 | 1.00 | 40 | 1.00 | 1.00 |
| *Anemia* | | | – | | | |
| No | | – | – | 75 | 1.09 (0.52-2.31) | 0.94 (0.38-2.35) |
| Yes | | – | | 85 | 1.00 | 1.00 |
| *Serum zinc* | | | | | | |
| Normal | 125 | 1.09 (0.52-2.3) | 0.92 (0.37-2.28) | | – | – |
| Deficient | 35 | 1.00 | 1.00 | | – | – |

**Notes:** Data were analyzed using the univariate and multivariate logistic regression. The multivariate analysis was adjusted for child age, gender and community type. Hosmer and Lemeshow Test for anemia: chi-square = 6.42, $p$ value = 0.60; for zinc deficiency: chi-square= 3.18, $p$ value = 0.92; *represents significant difference ($p < 0.05$)

(17.31 ± 2.56) of a study among 555 SAC in rural Kenya (Whaley *et al.*, 2003), it suggests that the mean performance of our study participants was relatively lower. Also, in their systematic review and meta-analysis, Ezeamama *et al.* (2018) asserted that there was an association between schistosomiasis infection and lower cognitive outcomes as well as poor school attendance among children living in helminth-endemic areas. This seems to corroborate our findings because a relatively lower mean cognitive test score was observed among children living in the fishing community (12.19 ± 6.10) than their counterparts in the farming community (12.48 ± 5.47), and they equally bore a higher prevalence of the helminthiasis burden (33.8 per cent versus 10.7 per cent) ($p < 0.0001$; Table I), with a significant difference of *S. haematobium* infection also occurring between children from the two communities: fishing (33.8 per cent) versus farming (1.2 per cent) ($p < 0.0001$) in the report from the parent study (Tandoh *et al.*, 2018). Conversely, in terms of school attendance, children in the fishing community had a lower absenteeism rate than those in the farming community ($p = 0.033$; Table II). This could be attributed to children in the farming community engaging in more farming activities with their parents on the farms (Tandoh *et al.*, 2018) and potentially missing out more on school attendance.

No significant differences were observed between the mean cognitive test scores of the children relative to their community type, gender, age, helminthiasis status, anemia and zinc deficiency ($p > 0.05$; Table IV). Similarly, the binary logistic regression did not show any significant association between the cognitive performance of the children, and their anthropometric, as well as their biochemical (helminthiasis, Hb and serum zinc) levels (Table VII). These findings corroborate findings in other studies (Lobato *et al.*, 2012) in which no significant differences in test scores existed between helminth-infected children and healthy children. Similarly, findings from a systematic review (Pabalan *et al.*, 2018) did not find any difference between infected or uninfected (treated) children interns of their scholastic achievement, reaction time and school attendance. However, contrary to these

**Table VII.** Predictors of cognitive performance based on the ravens colored progressive matrices

| Variable | *n* | Unadjusted OR (95% CI) | Adjusted OR (95% CI) |
|---|---|---|---|
| *Helminthiasis* | | | |
| Absent | 124 | 2.11 (0.59-7.54) | 3.37 (0.81-13.94) |
| Present | 34 | 1.00 | 1.00 |
| *Hemoglobin* | | | |
| Normal | 75 | 0.49 (0.20-1.23) | 0.45 (0.16-1.23) |
| Anemic | 82 | 1.00 | 1.00 |
| *Serum Zinc* | | | |
| Normal | 121 | 0.68 (0.26-1.79) | 0.89 (0.25-3.16) |
| Deficient | 36 | 1.00 | 1.00 |
| *Stunting* | | | |
| Normal | 134 | 0.75 (0.23-2.45) | 1.51 (0.38-5.95) |
| Stunted | 21 | 1.00 | 1.00 |
| *Underweight* | | | |
| Normal | 144 | 0.46 (0.11-1.86) | 0.37 (0.07-1.90) |
| Underweight | 11 | 1.00 | 1.00 |

**Notes:** Data were analyzed using the univariate and multivariate logistic regression. The multivariate analysis was adjusted for child age, gender and community type. The Hosmer and Lemeshow Test for cognitive performance: chi square = 6.095, $p$ value = 0.64

findings, a study among Indonesian school children reported an inverse relation between hookworm infection and cognitive function (Sakti *et al.*, 1999). Other studies on schistosomiasis, have also reported that *S. japonicum* infection also impairs scholastic achievement (Ezeamama *et al.*, 2005).

This study had a number of limitations as it was a cross-sectional study, and hence it did not offer the opportunity to assess the nutritional and cognitive status of the children over a longer period of time, and causality cannot be inferred. Also, the 24-hour dietary intake recall of index children was self-reported by the children, which could have introduced potential recall bias, but this method of dietary assessment has been established to be reliable and recommended for children who are 8 years and above (Livingstone and Robson, 2000; Young, 1981). In addition, care-givers of index children assisted with the 24-hr dietary recall assessment. Secondly, malaria was not directly tested among the study participants and could have affected the anemic status of the children, but this was indirectly assessed before the study through a verbal screening of children through their care takers to ensure that children who had fever or malaria within 1 month of the study were excluded from the study.

In conclusion, findings from this study show that cognitive and nutritional deficits are prevalent in the study area, with anemia, zinc deficiency and stunting being the most common nutritional problems. Factors that significantly influenced the nutritional status of the study population were the helminthiasis status and pica behavior. A higher level of undernutrition occurred among children in the fishing, compared to those in the farming community, whereas the mean cognitive performance between the two communities were below the average score but similar. Thus, the cognitive performance of school children in general needs improvement regardless of their community affiliation.

This implies that the type of community children live in could affect their nutritional outcome. There is, therefore, the need for public health personnel to implement interventions that are designed to suit the specific needs of children based on their communities.

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