INTERVENTIONS TO IMPROVE NUTRITIONAL STATUS AND COGNITIVE PERFORMANCE OF SCHOOL-AGE CHILDREN LIVING IN HELMINTH -ENDEMIC FARMING AND FISHING COMMUNITIES IN RURAL GHANA

by

MARINA AFERIBA TANDOH

(Under the Direction of Alex Kojo Anderson)

ABSTRACT

School-Age Children (SAC) in Low-Middle-Income Countries (LMICs) such as Ghana are the most affected by a heavy burden of helminthiasis and its resultant undernutrition and poor cognitive outcomes. This dissertation sought to examine the prevalence rates of helminths, undernutrition and cognitive performance of SAC in two (2) unique communities (farming and fishing) in a rural area in Ghana, and to compare different interventions in the control of helminthiasis and its resultant undernutrition and cognition in the two communities. Three main areas covered in this dissertation are: (i) disparities of helminthiasis prevalence, sanitary conditions/habits of SAC, (ii) predictors of undernutrition and cognitive deficits among SAC in the two communities, and (iii) impact of interventions on the nutritional status (BAZ, HAZ, anemia and zinc deficiency) and cognitive performance of SAC. Children in the fishing community had the heaviest schistosome infection and overall poor nutritional status, poor sanitation and hygienic practices. Independent predictors of anemia were helminthiasis status and pica behavior. Zinc deficiency was significantly higher among children in the farming community ($p<0.0001$). The intervention arm with the greatest improvement in the mean BAZ (0.27 ± 0.81) ($p=0.002$), HAZ

(0.16±0.38) (P<0.001) and Hb levels (1.22±13) (p<0.0001) was the 'NutEd Only group'. Whereas the greatest improvement in blood zinc levels occurred in the 'NutEd+Suppl group' (46.39±22.3) (p<0.0001). The highest improvement in the mean cognitive test score occurred in the 'Suppl Only group' (3.08± 6.07) (p<0.0001). A univariate analysis revealed that compared to the 'Control group', the 'NutEd Only group' was significantly associated with less likelihood of stunting (OR=0.205, CI; 0.04-0.10). Also, being in the 'NutEd Only group'(R=0.29, CI; 0.13-0.69) and the 'NutEd+Suppl group' (OR=0.34, CI; 0.13-0.85) were significantly associated with less likelihood of anemia. However, the 'NutEd Only group' (OR=6.40, CI; 1.39-29.50) and the 'Suppl Only group' (OR=6.04, CI; 1.27-28.77) were significantly associated with a higher likelihood of zinc deficiency. Thus, our study showed that combining nutrition education with micronutrient supplementation together with ongoing deworming interventions will potentially yield significant improvement in undernutrition and cognitive outcomes in SAC.

INDEX WORDS: School-Age Children, Helminthiasis, Hygiene, Sanitation, Nutritional deficits, Cognitive deficits, Nutrition education, Micronutrient

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DOCTOR OF PHILOSOPHY

ATHENS, GEORGIA

2019

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August 2019

DEDICATION

I would like to dedicate this work to my daughter, Ceana Nhyira Quaye, for your unconditional love, dedication, resilience and support over the years as I embarked on this journey to pursue a higher degree. I couldn’t have made it without your strength Cece.

I would also like to dedicate this work to my best friend Dr. Charles Apprey and his wife Mrs. Aurelia Apprey for your unconditional love and support throughout our years of friendship. Through your examples, I have learnt to be selfless and supportive of others in achieving their goals. You have been a great pillar of support than I could ever ask for. I will forever be grateful for your acts of sacrifices. I would also like to dedicate this work to my Uncle, Mr. Kojo Ahlijah for believing in me, and not giving up on me over the years. You brought out the potential in me. Thank you. I love you all.

ACKNOWLEDGEMENTS

I would like to acknowledge the headmasters, teachers and pupils of Trebu D/A Primary School, Anglican Primary School, Eche D/A Primary School, Kwasi Fante D/A Primary School, Nyamebekyere D/A Primary School, Kwaekese Primary School, Samankwae Primary and Asanyansu Primary School for cooperating with us in the data collection. A big thanks also goes to the Regional and District Directors of Education and Ghana Health Service Afram Plains South District, Eastern Region, Ghana. I also acknowledge the Staff of The Holy Spirit Health Center, Kwasi Fanti, for their support during my data collection and analysis in their facility. I would also like to acknowledge the KNUST Staff (Dr. Charles Apprey, Mr. Frank Agyemang Bonsu, Mr. Odeafo Asamoah and Mr. Nat Ato Yawson) and the Laboratory Technicians of the Central and Food Science Lab of KNUST for assisting with the laboratory assessments.

I am also grateful to my major advisor Dr. Alex Kojo Anderson as well as all my committee members and the Department of Foods and Nutrition, UGA for their mentorship and support over the years. My final gratitude goes to the staff of Office of Global Programs, UGA and the United States Agency for International Development, as part of the Feed the Future initiative, under the CGIAR Fund, award number BFS-G-11-00002, and the predecessor fund the Food Security and Crises Mitigation II grant, award numberEEM-G-00-04-00013 and the 2017 and 2018 Innovative and Interdisciplinary Research Grant from the University of Georgia Graduate School. Thank You.

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CHAPTER 1

INTRODUCTION

Soil-transmitted helminths (STH) and schistosomes (helminths) are part of the common diseases that affect humans globally, especially people who live in deprived areas such as those in Low- Middle- Income countries (LMIC) (Bhutta *et al.* 2014). Helminthiasis (parasitic infections due to STH and /or schistosomes) constitute a sub group of the Neglected Tropical Diseases (NTDs) that still persist in sub-Saharan Africa. Helminthiasis are considered among the group of NTDs because they are mostly chronic and possess non-specific symptoms related to other causative species (Gordon *et al.* 2017).

STH are commonly found in the tropical and subtropical regions due to the moist nature of the soil, which promotes the nourishment and development of eggs or larvae of helminth (Gordon *et al.* 2017). Infections with helminths have become a global burden of diseases, responsible for an estimated 3.3 million disability-adjusted life years (Becker *et al.* 2018) and strongly correlated with malnutrition (de Gier *et al.* 2014), anemia and cognitive impairment in school-aged children (Bethony *et al.* 2006).

It is estimated that the global prevalence of NTDs is as high as that of malaria or tuberculosis (Hotez 2010). About 2 billion people are estimated to be infected with STH and schistosomes (Hotez *et al.* 2006) and 27,000 people die from STH infections and schistosomiasis related morbidities annually (WHO Expert Committee 2002). The common helminth species including hookworms, *Trichuris trichiura* and *Ascaris lumbricoides* are responsible for causing helminth infection in 471 million, 477 million and 804 million people in the world, respectively (Vos *et al.* 2015).

Round worm (*Ascaris lumbricoides),* whip worm *(Trichuris trichiura)*, and hookworms (*Necator amercanus* and *Ancylostoma duodenale*), collectively referred to as soil-transmitted helminths (STHs), are the most common intestinal parasites. Globally, an estimated 800 million people are infected with roundworms (*Ascaris lumbricoides*), 600 million people with hookworms (*Ancylostoma duodenale* and *Necator americanus*), 600 million people with whipworms (*Trichuris trichiura*) and 200 million people are infected with schistosomes (*Schistosoma mansoni*, *Schistosoma haematobium* and others) (Hotez 2010). Among children, it is estimated that about 600 million are infected with helminth infections from *Trichuris trichiura, hookworm*, *A. lumbricoides* and *Schistosoma mansoni* in the world (WHO 2011b).

Infection with helminths (STH and/or Schistosomes) occur during routine domestic, agriculture, occupational and recreational activities that tend to expose individuals to helminth infested soil or water bodies. A lack of adequate water and sanitation have been implicated in such infections (Bhutta *et al.* 2014). Other factors such as inequitable access to safe water, sanitary conditions/facilities and health-care also contribute to the widespread of parasitic infections (Hotez 2008).

Approximately 300 million people infected with helminths are severely ill and of those, at least 50% are school-age children (Mehraj *et al.* 2008). The school-age child is the most at-risk age-group for the morbidities associated with these helminth infections (Drake & Bundy 2001). For reasons which are not clearly understood, the highest worm loads are harbored by pre-school and school-age children. Thus, resulting in growth stunting, low physical activities, deficits in memory and cognition among others (Crompton & Nesheim 2002).

Helminth and schistosoma infections have become endemic in tropical and sub-tropical regions of the developing countries and are found in areas with poor access to clean water, unimproved sanitation and poverty (Adu-Gyasi *et al.* 2018). Helminth infections and schistosomiasis predominantly occur across African regions of varied geographical landscape, in which specific climate and human activities influence the spread of the disease (Brooker 2007). It is also known that *S. mansoni* and *S. haematobium* are the most abundant species causing helminth infections in sub-Saharan Africa. The *S. mansoni* infection is responsible for approximately 8.5 million cases of chronic hepatosplenic schistosomiasis disease and intestinal schistosomiasis in sub-Saharan Africa (Bethony *et al.* 2006, Gryseels 2006, Rujeni *et al.* 2017).

Recent estimates show that approximately 130 million people in sub-Saharan Africa are infected with hookworm, 50 million with *A. lumbricoides*, and 37 million people with *T. trichiura* (Karagiannis-Voules *et al.* 2015). Approximately 76% of people in sub-Saharan Africa are also reported to live in endemic transmission areas of helminth infection (Vos *et al.* 2015). Furthermore, an estimated 120 million people in sub-Saharan Africa are also reported to exhibit schistosomiasis-related symptoms; and of these, helminth infections is responsible for over 2.8 million years disabilities in the population (Vos *et al.* 2015).

In sub-Saharan Africa, the helminth infections are predominantly prevalent among school-aged children (van der Werf *et al.* 2003). Studies conducted in some African countries like Ethiopia, for instance, have reported high prevalence of helminth infections (Teshale *et al.* 2018). In a cross-sectional study among 410 school children, Teshale and colleagues found that 12.7% of the children were infected with helminth parasites; predominantly *Schistosoma mansoni*. In another cross-sectional study which was carried out among 562 pre-school children aged between 1 and 5 years in rural Uganda using the Expanded Program on Immunization (EPI) method, the authors reported 26.5% prevalence of helminth infections among the pre-school children which was attributed to poor hygiene, inadequate sanitation and irregular deworming (Ojja *et al.* 2018). Furthermore, Rujeni *et al.* (2017), reported on a population-based study conducted in Rwanda in 2008, and showed a national prevalence rate of *S. mansoni* as 2.7%, whilst infections due to STH was 65.8%.

The population of Ghana is considered 'at risk' for schistosomiasis (Rollinson *et al.* 2013), which is the most prevalent helminth infection in Ghana (Aryeetey *et al.* 2000). Populations living in poverty, without adequate sanitation and in close contact with infectious vectors and domestic animals and livestock are those worst affected. The national prevalence of schistosomiasis stands at 70.9% in Ghana (Rollinson *et al.* 2013), with all districts in Ghana having people at risk (Abdul-Rahman & Agble 2012b) The prevalence of the infection among children have ranged from between 17.1% (Fentiman *et al.* 2001) to 83.9% (Wagatsuma *et al.* 2003) in different regions of Ghana. In the 1960s, about 20% of the total population of Ghana was reported to have urinary schistosomiasis at a point in their lives (McCullough & Ali 1965). An estimated 59.4% of the adult population living in rural communities along the Volta Lake in Ghana were also reported to have urinary schistosomiasis (Yirenya-Tawiah *et al.* 2011), whilst the prevalence of schistosomiasis in children have ranged from between 17.1% (Fentiman *et al.* 2001) to as high as 83.9% (Wagatsuma *et al.* 2003) in different regions of Ghana. Lower prevalence rates (10.36%) of urinary schistosomiasis have also been reported among school-age children in the Volta Region of Ghana (Orish *et al.* 2017).

Urinary schistosomiasis (*S. haematobium* infection) has also been found to be significantly higher in fishing communities (33.8 %%) compared to farming communities in Ghana (1.2%) (Tandoh *et al.* 2018). The prevalence of STH infections (due to hookworm, round worm and/or whipworms) in Ghana, however, have ranged from 39.1% of hookworm infection among 6-11 year old children in the Kintampo north Municipality of Ghana (Humphries *et al.* 2013) to 12.5% (mixed STH infections) reported in a recent study among 200 pupils in Elmina, a fishing community in the Central Region of Ghana (Dankwa *et al.* 2017). A study by (Fentiman *et al.* 2001) also reported 14.0% of hookworm infection among school-age children in the Eastern Region of Ghana. However, over the years, schistosomiasis has been an increasing persistent burden in the population of Ghana, with prevalent rates increasing from between 5-10% prior to the construction of the Akosombo hydroelectric power dam to as high as 90% prevalence after its construction (Paperna 1970, Scott *et al.* 1982). The construction of irrigation dams for farming activities in the Upper East Region of Ghana is also reported to have increased the prevalence of schistosomiasis from 17% to 51% (Hunter 2003). Also, the rate of urinary schistosomiasis was reported to be between 54.8% to 60% in children above 5 years of age in the Southern part of Ghana, with the intensity of infection being highest among the 10-14 year old group (Aryeetey *et al.* 2000).

Due to their poor hygienic practices and poor play habits, children often come into contact with helminth-infested water and soil. Infections with helminths in children lead to increased morbidities and sometimes mortalities through their adverse effects on their nutritional status; leading to impaired growth, impaired cognitive process, and sometimes health complications that may require surgical intervention (WHO 2011a). Helminthiasis do not only result in increased morbidities and mortalities, but also promote poverty through both social and biological effects manifested in the impairment of both physical and intellectual development of children and reduced work capacity as well as productivity among adults (Montresor 2011). A negative association between helminthiasis and micronutrient deficiencies in school-age-children (SAC) has also been established (de Gier *et al.* 2014).

Periodic deworming has been recommended by the World Health Organization to control helminth infections in children (WHO Expert Committee 2002). This control strategy has been found to improve the nutritional status of school-age children (Stephenson 1993), but not in all cases (Greenberg *et al.* 1981). There has also been an improvement in the nutritional status of children using micronutrient supplementation either alone (Chwang *et al.* 1988) or together with dewormers (DeMaeyer *et al.* 1989, Gopaldas 1995). Although the use of micronutrient has been found to be effective in improving nutritional status, its use on a long term basis is not feasible or sustainable among populations of low and middle-income countries due to issues with logistics, economic and cultural factors (Abdul-Rahman & Agble 2012a, Bothwell 2000).

The widespread of helminth infections and schistosomiasis among majority of people globally has resulted in increased research, awareness and programs with the aim to control infection rates (Overbosch *et al.* 2018). Among such programs include the mass drug administration, Global Program to Eliminate Lymphatic Filariasis (GPELF, 2000) and Schistosomiasis Control Initiative (SCI, 2002) which have improved infection rate, controlled transmission and alleviated helminth infection-related symptoms (Fenwick *et al.* 2009, Overbosch *et al.* 2018). However, while relevant achievement and progress have been made from these programs, the global burden of schistosomiasis and helminth infection remains high in sub-Saharan Africa, including Ghana, causing an approximately 3.5 million disease-adjusted life years (WHO 2015). Hence, the need to research into appropriate and effective intervention programs which will be sustainable in the reduction of the prevalence rate of helminth infection and resultant improvement in the wellbeing of children residing in endemic areas of low-and middle-income countries such as Ghana. Thus this dissertation sought to ascertain the helminthiasis burden in fishing versus farming communities, implement and examine the effectiveness of different interventions to identify a more cost-efficient and sustainable way of improving the nutritional and cognitive status of school-age children living in high risk helminth endemic areas in rural Ghana.

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CHAPTER 2

LITERATURE REVIEW

Introduction

This section reviews the life cycle of helminths, their mode of transmission and their impact on the nutrition and cognitive status of school-age children. It also reviews intervention strategies employed in the control of infection and to improve the nutritional and cognitive outcome of school-age children (SAC).

Helminthiasis is a parasitic infection that is either due to STHs (roundworms, whipworms and hookworms) and/or schistosomes (*Schistosoma mansoni* and *Schistosoma haematobium*). The adult roundworms (*Ascaris*) parasitize the entire part of the small intestine of the human host whilst the hookworms (*Necator* and *Ancylostoma*) parasitize the upper gastro intestinal tract (GIT). The whipworms (*Trichuris*), however, parasitize the large intestine (caecum) (Despommier *et al.* 2012). These helminths come in different sizes and can live for several years in the human GIT. The female worms are relatively longer compared to the male worms (Despommier *et al.* 2012). They mate in the intestine of their human hosts, after which the females lay thousands of eggs per day, and these eggs leave the body through the feces.

The number of eggs that is harbored by the host is directly related to the morbidity as well as the rate of transmission of helminth eggs (Anderson *et al.* 1992). They have complex life cycles in their human host, and they are able to survive by averting immune attack and sabotaging the host's immune response. They then create niches in the GIT walls where they live, feed and reproduce (Maizels *et al.* 2004).

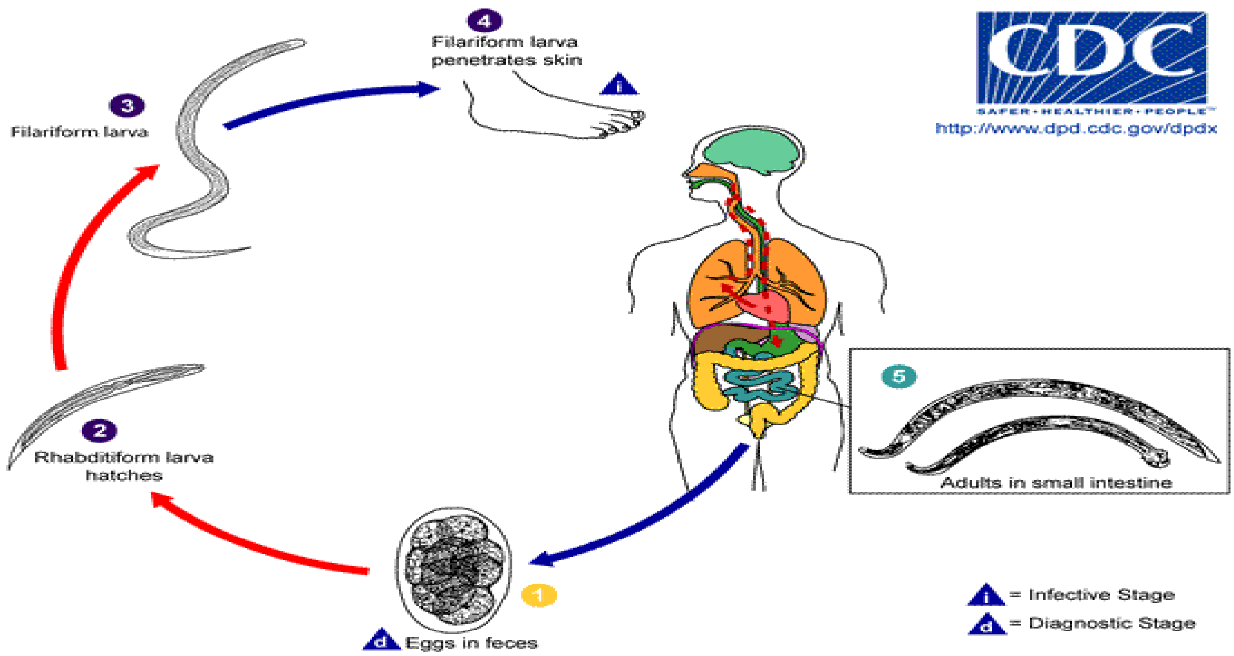

Figure 2.1: The intestinal hookworm life-cycle Adopted from CDC, 2017

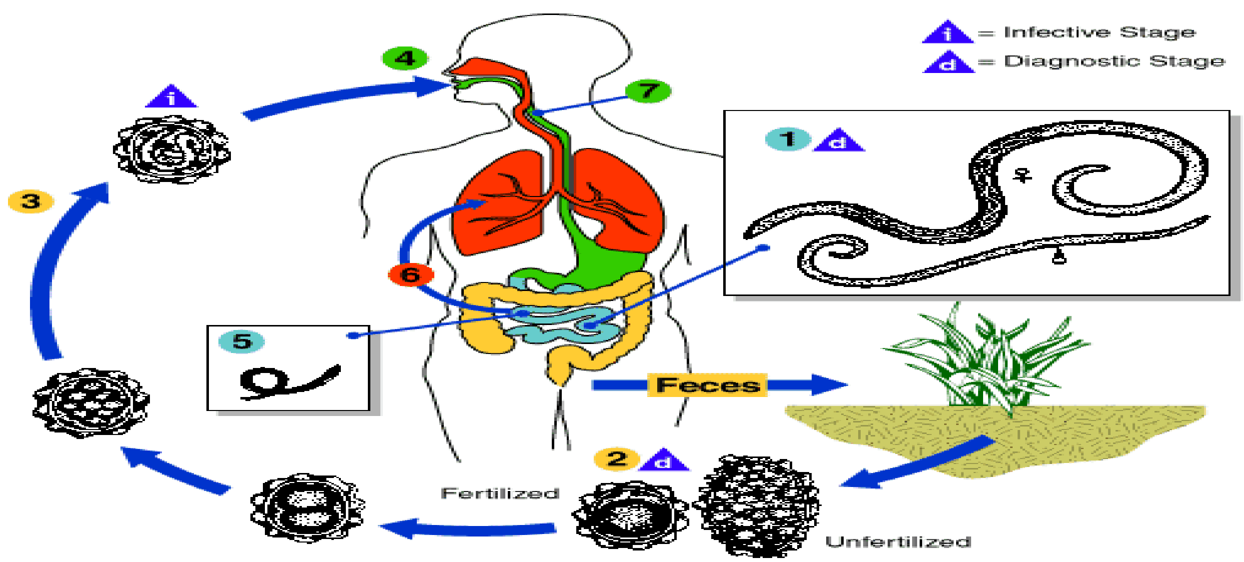

Figure 2.2: The *Ascaris* life-cycle Adopted from CDC, 2018

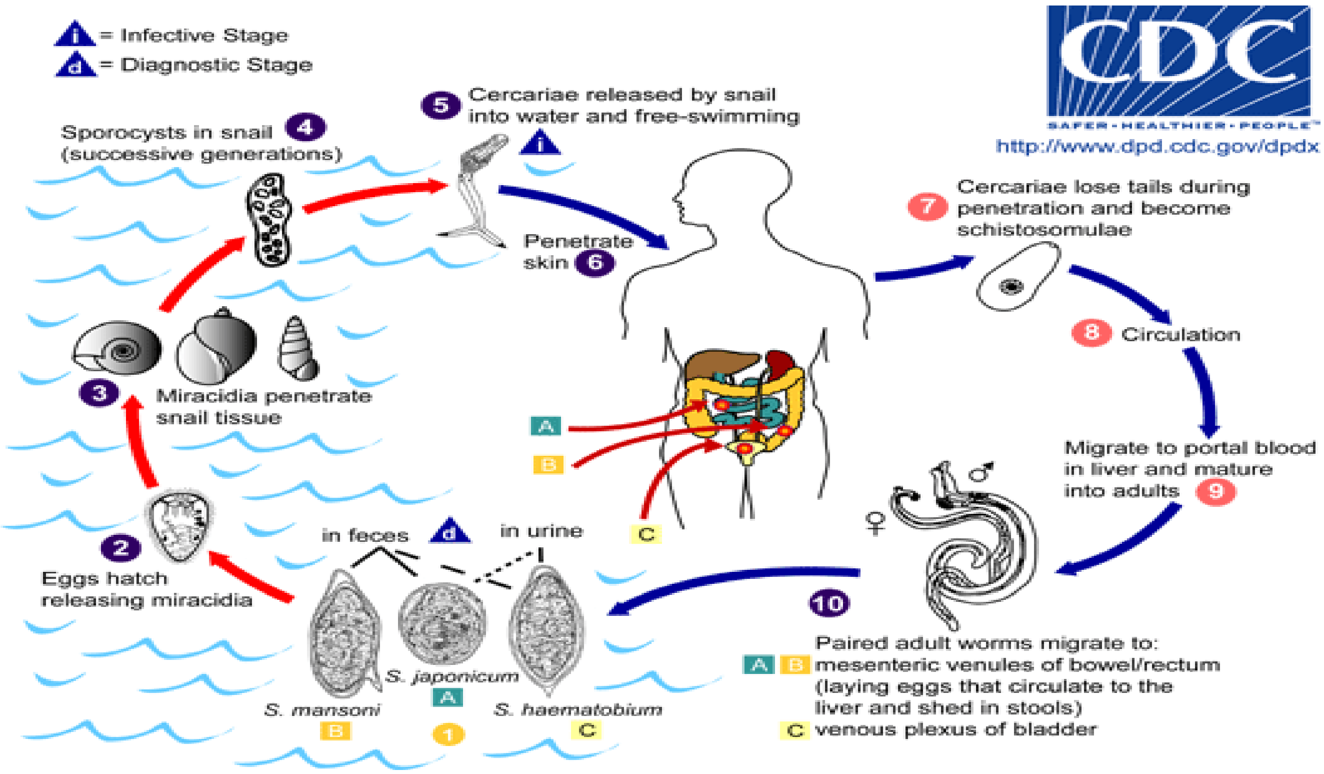

Figure 2:3: The schistosome life-cycle Adopted from CDC, 2017

<u>Mode of Transmission of Helminth Infections</u>

Infection with helminths occurs when an infected individual contaminates the soil with feces that contain the helminth eggs. The eggs then develop in the soil and contaminates foods or hands of other individuals. The larvae of the eggs (hookworms) can also penetrate the skin of other individuals directly or through ingestion of eggs on dirty hands and contaminated foods. These infected individuals become the hosts for the helminths which then develop into adult worms and lay several eggs within the GIT, and as these eggs are expelled through the feces in the soil and/or waterbody, the cycle of infection is continued (Montresor *et al.* 2002).

The spread of the schistosome parasite is mainly through the oral-fecal route and/or directly through the penetration of the skin by the larvae of the parasite. The life cycle of schistosomes require an intermediate fresh water snail host. When infected individuals contaminate the water bodies with contaminated urine or feces containing the eggs of the schistosomes, these eggs hatch into miracidia which then infect and develop within the fresh water snail (intermediate host).The snail then expels large numbers of cercariae which is the form of the schistosome that infect other individuals in contact with the fresh waterbody (Montresor *et al.* 2002). Fresh water bodies that harbor the intermediate snail vector are predominantly the main source of spread of the schistosome parasite, especially for those who live close to and use such water as sources for their domestic use and work activities (Yirenya-Tawiah *et al.* 2011).

Causes of Helminth Infections

Socioeconomic as determinant of helminths infections

Helminth infections are indirectly associated with poor socioeconomic conditions. The life cycles of helminths include environmental contamination with feces containing helminth eggs. Poor hygiene, sanitation and lack of access to clean water increases the access for helminth intermediate hosts to thrive in this environment (Campbell *et al.* 2016). These in turn are influenced by poor socioeconomic conditions such as low level of education, overcrowded settlement areas, poor health services, low- income, presence of animals in houses, inadequate sanitation facilities and poor access to clean drinking water (Al-Mekhlafi *et al.* 2008, Brooker *et al.* 2004, Campbell *et al.* 2016, Knopp *et al.* 2010, Knopp 2013, Pham-Duc *et al.* 2013, Traub *et al.* 2004).

Low-income countries, particularly poor communities are mostly affected with helminth infections. The association between them are complex and not well understood. However, high prevalence of helminth infection can be a contributing factor for poor economic growth in these countries and communities (De Silva *et al.* 2003). In a systematic review by Guyatt (2000), anemia resulting from helminth infection was associated with reduced work output, as well as impaired cognitive ability, school absenteeism among children and reduced productivity of adults.

A poor perception and lack of knowledge about schistosomiasis is also a determinant of the disease as it is generally not regarded as a disease in some African communities (Rollinson *et al.* 2013), with most parents in a rural community of Ghana not perceiving helminth infections as a major health problem for their children (Brooker *et al.* 2001). A study was conducted in 1994 which involved a focus group discussion organized among parents and teachers in three helminth-endemic districts in Ghana (Jasikan, Kpandu and Hohoe) with eighty-five (85) schools depicting rural, remote and urban schools employed in the study. Only 4.1% of parents reported 'worm/helminth' as a health problem, when they were asked about some common health problems faced by their children. The most common problems they reported included; fever, malaria and headache. In contrast to them, parents in Tanzania where a similar study was conducted, reported loss of appetite, weight loss and abdominal pain, as well as blood in the urine (for schistosomiasis), urinating problems, anemia and fatigue, when they were asked to report on symptoms associated with helminthiasis (Brooker *et al.* 2001). This suggests that parents in Tanzania were more knowledgeable with regards to helminthiasis-associated problems than Ghanaian parents, and symptoms associated with helminth infections were not perceived as a health-related problem in those settings in Ghana.

Water and sanitation as determinant of helminth infections

A global report by WHO (2015), estimates that 2.4 billion people live in poor sanitary conditions and the number of people practicing open defecation in Africa have increased since 1990. The burden of helminth and co-infections have been attributed to poor environmental sanitation, poor access to clean water and inadequate hygiene behavior (Prüss-Üstün *et al.* 2008, Vos *et al.* 2015), while improved sanitation and good source of drinking water are key factors for prevention, control, and elimination of helminthiasis (Raso *et al.* 2018).

Poor sanitation and play habits of children such as swimming in lakes or rivers makes them more prone to high burdens of schistosomiasis. In Ghana, 90% of children who attended a school close to the Volta Lake shores were found to have blood in their urine, which is a sign of urinary schistosomiasis (Fentiman *et al.* 2001). Also, teenagers (15-19years), tend to have the highest rates of infection (73%) compared to other age groups (Yirenya-Tawiah *et al.* 2011). For instance, adolescent boys were found to be more at risk of schistosomiasis as they tended to have more contact with the Volta Lake in Ghana by engaging in adult tasks or activities for household economic gains (Fentiman *et al.* 2001).

The habit of open defecation has also been identified as one of the drivers of helminth infections in some African countries (Acka *et al.* 2010, Orish *et al.* 2017), especially in rural communities that lack adequate sanitation and access to safe drinking water. In 2008, only 37% of the population of priority countries of UNICEF, including Ghana were estimated to have toilet facilities (Unicef 2009). It has also been established that safe stool disposal is practiced by 43% of children in urban areas compared to 37% of children in rural areas in Ghana (GSS 2015). In Ethiopia, a cross sectional survey by Oswald *et al.* (2017), between 2011 and 2014 using data from four population-based studies on helminth infection prevalence and household latrine usage found that households using latrine had lower prevalence of *A. lumbricoides* compared to households without latrines in the home. The authors concluded that the association between helminth infection and community sanitation may be complex and thus require further studies (Oswald *et al.* 2017).

Environmental determinants of helminth infections

STH and schistosomes are transmitted through environmental contamination with egg-carrying feces. Transmission of eggs is linked to lack of adequate sanitation, lack of access to safe water and inadequate hygiene; therefore, they typically occur where there is poverty (Montresor *et al.* 1998). The prevalence and intensity of helminth infections are influenced by certain social behaviors, household clustering (Forrester *et al.* 1988, 1990) and occupational factors (Bethony *et al.* 2001). The possible reason for their persistent presence in poor environments may be due to less priorities given in public health programs in affected areas because the intensity of helminthic infections are not directly measured explicitly in terms of mortality figures (Teshale *et al.* 2018).

Other factors that are said to also influence the transmission of helminths include water, climate and season. Suitable warmth and moisture are important for each of the STHs. Increased transmission is observed in wetter areas, however, in some endemic areas, both schistosome infections manifest striking seasonality (Brooker & Michael 2000). The construction of dams and aquatic environment also tend to extend the range of snail habitats which is the intermediate host, thus, promoting the reemergence of schistosomiasis (Hotez *et al.* 2006).

Climatic changes in the environment is reported to have greater impact on the incidence and prevalence of helminth infections in Africa. The quick change in climate such as hot temperatures, change in rainfall pattern, flood and water scarcity may have significant influence on the infection rate and viability of the helminth species (Blum & Hotez 2018). It is reported that the recent warmer temperatures in Africa might reduce the overall incidence of helminth and schistosome infection by eliminating or decreasing freshwater snail populations (Blum & Hotez 2018, Hotez 2018). However, it is also thought that not all helminth species might suffer from the environmental change. The larvae of the hookworm in African soils are reported to be able to thrive and reproduce at high temperatures (≥40°C) (Okulewicz 2017, Pullan & Brooker 2012), whereas, eggs of *Ascaris lumbricoides* and *Trichuris trichiura* become inviable at 38 degrees Celsius (Brooker *et al.* 2006).

<u>Clinical manifestations</u>

Clinical manifestations of helminthiasis are generally produced as a result of moderate to high intensity infections with helminths, and this commonly occurs in children (Chan *et al.* 1994). It is not clear what the threshold for helminths is for causing disease in children. The migration of the larvae of helminths through the tissues of humans can illicit several responses such as inflammation that consist of eosinophilic infiltrates. During heavy infections with *Ascaris*, it results in verminous pneumonia which is normally accompanied with a non-productive cough, fever, wheezing, dyspnea and blood-streaked sputum. Verminous pneumonia is a common occurrence in some places such as Saudi Arabia where it occurs after spring rains (Gelpi & Mustafa 1968). The death of an *Ascaris* larvae during migration through the liver can also promote eosinophilic granulomas (Kaplan *et al.* 2001). *Ascaris lumbricoides* and *Toxocara canis* have also been implicated in the environmental causal of asthma among a small group of children (Chan *et al.* 2001, Sharghi *et al.* 2001). Ground itching (a local erythematous and popular rash accompanied by itching of hands and feet) is another manifestation of infection from *N. americanus* and a duodenal third stage larvae (Hotez *et al.* 2004). Wanka syndrome, a condition characterized by pharyngeal irritation, cough, nausea, vomiting, hoarseness and dyspnea is another manifestation of infection with *A duodenale* larvae ingestion (Hotez *et al.* 2004). Lactose intolerance and malabsorption of vitamin A and other nutrients can also occur (Taren *et al.* 1987). Partial obstruction to the lumen can also occur in young children as the adult worms accumulate in the ileum due to their small size (Villamizar *et al.* 1996). In extreme cases, complications such as volvulus, intussusception and complete intestinal obstruction has been reported (Khuroo 2001).

Undernutrition as a result of helminth infections

Undernutrition

Undernutrition and helminth infections are common problems among children in LMICs leading to severe morbidities every year (Ayeh-Kumi *et al.* 2016, Hailegebriel 2018, Osakunor *et al.* 2018, Tandoh *et al.* 2015). According to the World Food Program Comprehensive Food Security and Vulnerability Assessment Analysis (CFSVA) in 2009 (Wiesmann *et al.* 2009), 9% of the population of Ghana had a diet that was inadequately low, which may have an adverse effect on children's growth and mental development. The burden of helminth infection is related to its host health and nutritional status (Stephenson *et al.* 2000, Tandoh *et al.* 2015). Populations of LMICs infected with chronic helminths tend to experience a cycle where under-nutrition, and repeated infections lead to frequent ill-health that can continue from generation to generation. People of all ages are affected by this cycle of parasitic infections; however, children are the worst affected (Curtale *et al.* 1998, Steketee 2003).

In their review, Hall *et al.* (2008b), cited several ways by which helminths can affect the nutritional status of their host. Some of the ways include; parasites feeding on the GIT contents such as the secretions of exoenteric circulation, feeding on host tissues such as blood and serum, promoting maldigestion, malabsorption and alteration of metabolism of important nutrients such as iron. They also lead to the escalation of the host's metabolic rate through their response to infections such as fever. Increased metabolic rates results in hypertrophy of muscles and immune responses to infection which leads to alteration of the utilization of energy and nutrients for other purposes other than what is required.

Undernutrition results in weakened immune system, making individuals vulnerable to infections (Katona & Katona-Apte 2008). The nutritional status of children in developing countries is already compromised due to a number of factors such as cultural, religious, economic and political reasons (Rush 2000). Helminthiasis also impairs optimal digestion and absorption of nutrients in humans, resulting in symptoms such as vomiting, diarrhea and loss of appetite, which ultimately impairs growth and optimum nutrition (WHO 2011b).

An estimated 16%, 26% and 8% of children are underweight, stunted and wasted respectively worldwide, (Carmen Casanovas *et al.* 2013). Whereas in Ghana, it is reported that among under 5 year old children, stunting, underweight and wasting prevalence is 19%, 11% and 5%, respectively (GSS 2015). It is also reported that stunting occurs more (22%) in rural areas than in the urban areas (15%) in Ghana. Likewise, more rural children in Ghana are reported to be more underweight (13%) than children in urban areas (9%) (GSS 2015). According to a draft report on a study conducted in Ghana, stunting among SAC (6-18 years) was 16.9% and ranged from 13.4% in the Forest-Savannah Transitional Zone to 20.9% in the Northern-Savannah Zones (Martens 2007).

Evidences from studies have also shown a strong association between STH infection and poor nutritional status among children living in helminth-endemic communities (Amare *et al.* 2013, Kosinski *et al.* 2012, Sanchez *et al.* 2013). In a cross-sectional survey by Njaanake *et al.* (2015), among 261 school children at Tano River delta of coastal Kenya, high intensity of *S. haematobium* (difference= -0.48, $p > 0.05$) and *A. lumbricoides* infections *(difference= -0.67, $p < 0.05$)* were associated with lower scores of BMI for age of participants. Another study by Hailegebriel (2018), found that underweight was strongly associated with *A. lumbricodes* but not hookworm infection among primary school children aged 7 and 13 years in Bahir Dar, Ethiopia

(AOR=2.43; 95% CI: 1.40–4.22, $p < 0.05$). Furthermore, a cross-sectional study investigated the association between intestinal helminth infection and nutrition status among 403 school children aged 5 and 15 years in Ethiopia, and it showed that the likelihood of being underweight was higher in children with any of helminth infections (adjusted OR = 1.61, 95% CI = 1.02, 2.53, $p < 0.05$) or hookworm infection only (adjusted OR = 2.17, 95% CI = 1.28, 3.66, $p < 0.05$), compared with uninfected children (Degarege & Erko 2013, Uneke & Egede 2009).

Even though helminth infections such as schistosomiasis have been shown to have negative consequences on growth such as stunting in children (Mekonnen *et al.* 2014), only few studies have reported relationships between the different helminth species and linear growth retardation in children (Gurarie *et al.* 2011, Uneke & Egede 2009). Other studies have also reported contradictory results (Mekonnen *et al.* 2014). Thus, the need for further studies on the association of helminthiasis and nutritional outcomes of SAC. For instance, in a cross-sectional study among Ghanaian school-aged children (6-13 years) in South Tongu district, Ayeh-Kumi *et al.* (2016) reported that children with *S. haematobium* infection were 11 times more likely to be stunted (AOR = 11.6; 95 % CI 3.1–33.6, $p = 0.001$). Also, another study which was prospective with 12 months follow-up among 1,502 children (6months to 5 years old) in Zimbabwe found that children with *S. haematobium* infection had about 2 times higher risk of being stunted (Osakunor *et al.* 2018). Similarly, a cross-sectional study by Assis *et al.* (2004), among 461 school children aged 7 and 14 years in Brazil showed that children with heavy *S. mansoni* infection (≥400 eggs/g of stool) were 2.74 times (95% CI: 1.32–5.67, $p < 0.01$) more likely to be stunted than children without STH infection. However, a cross-sectional survey conducted by Hailegebriel (2018), among primary school children between the ages of 7 to 13 years in Bahir Dar, Ethiopia, found that thinness but not stunting, was strongly associated with children with *A. lumbricodes* infection (AOR=1.92;

95% CI, 1.15–3.19, $p < 0.05$). In another study among 453 school-aged children (5-18 years) in rural part of west Ethiopia by Mekonnen *et al.* (2014), they found that stunting was not predictor of STH infection, and that children with *S. mansoni* infection were 0.46 times (95% CI; 0.25-0.81, $p = 0.01$) less likely to be wasted.

Studies have shown a strong association between undernutrition and infection with *Ascaris lumbricoides*, *Trichuris trichiura*, *Schistosoma spp* and the hookworms (Hall *et al.* 2008b, Stephenson & Holland 1987, Wolde *et al.* 2015). For instance in a study on the evaluation of Integrated Management of Childhood Illness in Western Kenya which focused on the impact of treatment with mebendazole given to children, they reported significant difference in their initial weight-for-age (-1.43 vurses -1.01, $P<0.001$) and significant differences in gains in weight, height and weight-for-age when infected and treated children were compared with infected and untreated controls (Garg *et al.* 2002). A high risk of stunting has also been associated with helminth infections (Wolde *et al.* 2015) and this is strongly correlated with reduced cognitive performance (Al-Mekhlafi *et al.* 2008, Simeon & Grantham-McGregor 1990). According to expert report by the World Health Organization, chronic infection with helminths have adverse effect on the physical and cognitive development of children, and this has been closely associated with iron-deficiency anemia (WHO 2002). This assertion was proved in a study conducted in Jamaica where 9-12 year old SAC who were treated for *T.trichiura* infection showed significant improvement in their auditory short-term memory and scanning and retrieval of long-term memory after nine weeks of treatment. After the nine weeks of treatment, they found that previously infected children performed as equally as uninfected children. They also found a higher rate of absenteeism among infected children compared to uninfected children (WHO Expert Committee 2002).

An association has also been established between micronutrient deficiencies among school-age children, stunting and impaired immunity (Kramer *et al.* 1993, Soemantri *et al.* 1985, Van Stuijvenberg *et al.* 1999). In their study, Van Stuijvenberg *et al.* (1999) determined the effect of micronutrient-fortified biscuits on the micronutrient status of primary school children. 115 SAC between the ages of 6 to 11 years versus 113 controls were recruited for the study. They were assessed for their micronutrient status at baseline and at the end of the study. It was an intervention study that involved the consumption of biscuits fortified with iodine, iron and B-carotene for a period of 43 weeks over 12 months. The control group were provided with non-fortified biscuits. Both groups were then assessed for their growth, morbidity and cognitive function. At the end of the study, they found that the fortified biscuits resulted in a significant impact on the micronutrient status and a positive effect on anthropometric status of the children (experimental group). Another strong relationship between malnutrition, infection and infant mortality has been established, because poor nutrition leaves children underweight, weakened, and vulnerable to infections, primarily because of disruption of epithelial integrity and inflammation (Katona & Katona-Apte 2008). Study done in Dibanda, Cameroon, among preschoolers and school-age children showed a malnutrition prevalence of 30.2% and a prevalence of intestinal helminth of 47.2% (125 out of 265) (Mbuh & Nembu 2013).

Micronutrient Deficiencies

Globally, over 2 billion people are affected by micronutrient deficiencies (Chakrabarty & Bharati 2012), with children in LMICs being the worst affected due the heavy burden of helminth infections (Stoltzfus *et al.* 1998). Micronutrient deficiency continue to be a major public health problem in LMICs (Chakrabarty & Bharati 2012), which can result in serious morbidities and mortalities, as well as poor growth and economic problems if not resolved (McGuire & Galloway

1994, Ramalingaswami 1998). A negative association between helminth infections and micronutrient deficiencies in SAC has been established (de Gier *et al.* 2014). For instance, some studies have shown evidence of micronutrient deficiencies with *Ascaris* infection among children in Mexico (Long *et al.* 2007). Helminth infections tend to affect optimal digestion and absorption of nutrients in humans and causes symptoms such as vomiting, diarrhea and loss of appetite, which leads to impaired growth and micronutrient deficiencies (WHO 2011b).

Infection with helminths tend to affect the optimal functioning of the GIT, thus influencing digestion and absorption stages of nutrients. These infections can cause symptoms such as vomiting and diarrhea which ultimately affects these essential nutrients. The most affected nutrients are the energy giving ones since energy intake during times of infection is adversely affected due to anorexia. However, micronutrients such as zinc, iron, iodine and vitamin A have been strongly associated with cognitive performance and growth in school-age children (Gibson *et al.* 2007, Solon *et al.* 2003). In their study, Gibson *et al.* (2007), compared the mean intakes of energy, protein and selected growth-limiting nutrients of 6-13 year olds (585 stunted children and 172 non-stunted controls) who attended ten rural schools in NE Thailand. Biochemical assessments were conducted on serum albumin, zinc, ferritin, transferrin receptor, retinol and iodine in casual urine samples. They found that significantly more males (n=38, 65.5%) than females (n=20, 34.5%) were stunted. Stunted males also had lower mean intakes of energy, protein, calcium, phosphorus and zinc than non-stunted males. They also had lower mean arm muscle area (P=0.015), after adjusting for age, than non-stunted males. They concluded that anorexia and hypogeusia which is induced by zinc deficiency could be responsible for the lower dietary intakes observed among the stunted males. Some studies have also shown evidence of micronutrient deficiencies with *Ascaris* infection among children in Mexico (Long *et al.* 2007).

Many essential micronutrients have a synergistic effect on each other for optimum effect. For instance, vitamin A is required for the metabolism and absorption of iron. During iron supplementation interventions in iron-deficient subjects, the effect of the iron supplement was greatly reduced when vitamin A deficiency was also present but not concurrently supplemented (Mejía & Chew 1988, Suharno *et al.* 1993). Iron absorption was also enhanced by vitamin C supplementation (Hallberg & Rossander 1984, Monsen 1988).

Zinc is a major cofactor for the function of several enzymes in the human body. Whilst iron is needed for the synthesis of hemoglobin. Low zinc concentrations have been recorded among stunted male children in Thailand (Gibson *et al.* 2007). Low serum zinc levels have also been reported among school-age children in some coastal areas in Indonesia (Pramono *et al.* 2017). In their study among SAC (8-12 years) in the coastal region of Semarang, Indonesia, Pramono *et al.* (2017), assessed the lead and zinc serum levels using Atomic Absorbent Spectrometry (AAS). The children were found to have high levels of lead whereas serum levels of zinc were low. Delayed secondary sexual maturation in boys has also been associated with zinc deficiency (Hotz & Brown 2004). In the 1960's, the first case of human zinc deficiency was reported in the Middle East (Chavan *et al.* 1989, Nout 1993). Among that group, the zinc deficiency was characterized by anemia, enlargement of liver and spleen, delayed sexual development, short stature and impairment in skeletal maturation. Other studies (Hotz & Gibson 2001, Thu *et al.* 1999), have shown that zinc supplementation resulted in significantly increased height, weight, bone development and sexual maturation (Hotz & Gibson 2001, Thu *et al.* 1999). Decreases in sperm counts and testosterone levels were also observed during experimental zinc depletion among adolescent males (Meeting & Organization 2007). Some studies have also reported an association between zinc deficiency and reduced appetite (Umeta *et al.* 2000), as well as poor tasting ability in children (Cavan *et al.* 1993). In a randomized, double-blind, placebo-controlled trial, Umeta *et al.* (2000), conducted a 6 months study among healthy breastfed infants. Hundred stunted children were randomly assigned to either a zinc supplement (10 mg/day zinc sulphate) or a placebo for 6 days a week. The zinc supplementation resulted in reduced incidence of anorexia and vomiting in stunted children.

STH infections have been associated with poor nutrition status including zinc deficiency (de Gier *et al.* 2015). Some studies have reported that zinc deficiency can increase risk of STH infection in endemic areas (Kongsbak *et al.* 2006, Koski & Scott 2001).

Blood loss and Anemia

Iron-deficiency is one of the most common causes of anemia in Ghana (Kraemer & Zimmermann 2007), and it has been attributed to increased blood loss due to helminthiasis as well as malaria and poor intakes of iron (Abdul-Rahman & Agble 2012a). A draft report by the Ghana Health Service (Martens 2007) showed a 38.8% prevalence of anemia among SAC, which varied across different ecological zones, with the highest prevalence (64.5%) occurring in the Northern Savannah zones, 58.6% in the Coastal zones and 16.4% in the Transitional Zones.

There is a strong association between helminth infection and iron-deficiency anemia. Infection with schistosomes for example can result in urinary schistosomiasis (bloody urine disease), which has been associated with anemia (Casmo *et al.* 2014). There are several intestinal helminths and urinary schistosomes that infect human beings. Of these, all the three main species of schistosomes, as well as the two species of hookworms, and the whipworm all contribute to blood loss through different ways (Hall 2007). Blood loss is also a major consequence of all the types of species of schistosomes, the two hookworms (*Necator amercanus* and *Ancylostoma* *duodenale)* and the whipworm parasites that infect humans (Stephenson *et al.* 2000). This however, occurs in different ways.

The mechanism through which STH infection cause anemia and undernutrition include destruction of intestinal mucosa which in turn cause interference with blood cell production, hematuria (blood in urine), malabsorption of nutrients, impaired immune growth and hematuria (Kinung'hi *et al.* 2017). Blood loss also occurs as *S. mansoni* and *S. japonicum* move through the gastro intestinal tract of humans (Friedman *et al.* 2005). *S. haematobium* infection leads to loss of iron in the hemoglobin through hematuria. With hookworm infection, blood loss occurs as the adult parasite invades and attaches itself to the mucosa and submucosa of the small intestine of the GIT (Hotez *et al.* 2004). Infections with hookworms have been long associated with the cause of iron-deficiency anemia through blood loss (Roche & Layrisse 1966). A cross-sectional survey by Brito *et al.* (2006) among 1709 school children aged 7 to 17 years in rural Brazil showed that the likelihood of being anemic when infected with *S. mansoni* and two other intestinal helminths was 1.7 (95% CI, 1.1–2.5, $p < 0.05$), and for *S. mansoni* and three intestinal helminths was 2.4 (95% CI, 1.2–4.6, $p < 0.05$) compared with participants with a single parasite infection. Furthermore, a cross-sectional study by Casmo *et al.* (2014), investigated the association between schistosomiasis and hookworm infection and hemoglobin level of 1,015 children aged 5 to12 years in Nampula, Mozambique, and they found low hemoglobin level among children with schistosome infection and also hookworm infection was a major contributing factor for mild and severe anemia among affected children (Casmo *et al.* 2014). A similar study by *Njaanake et al. (2015)*, among 261 school children at Tano River delta of coastal Kenya, found that anemia among school children was associated with high intensity of *S. haematobium* (OR: 2.08, $P < 0.05$) and hook worm infection (OR: 4.75, $p < 0.001$). However, a cross-sectional study by Munisi *et al.* (2016) among 513 SAC aged 6 to 16 years in north-western Tanzania, showed that *S. mansoni* infection was not associated with undernutrition or anemia (p>0.05). Thus, despite the high burden of helminthiasis as major causes of anemia and undernutrition among SAC in endemic communities, their combined effects and intervention strategies have not been thoroughly evaluated to control the spread of the parasite among high-risk populations (Kinung'hi *et al.* 2017).

Anorexia

Loss of appetite is common in helminth-infected individuals and this negatively affects their nutritional status (Crompton 1984). Deworming has been found to improve physical growth in children by improving appetite. Some studies using placebo-controlled trials have assessed appetite level of primary school children with helminth infections before and after treatment regimen (Hadju *et al.* 1996, Latham *et al.* 1990b, Lawless *et al.* 1994, Stephenson *et al.* 1993b). In one of these placebo-controlled field studies, primary school boys in Kenya infected with *S.haematobium* (100% at baseline) and hookworm (94 to 100% at baseline), were assessed for their physical fitness using the Havard Step Test (HST) and their appetite, using the consumption of a morning maize meal porridge as a measure of appetite. They were treated with a single dose of metrifonate (MT, 10mg/kg body weight) or praziquantel (PR, 40 mg/kg body weight) or a placebo (PL). After 5 weeks of treatment, their HST scores as well as their appetite (porridge intake) increased significantly in the MT and PR groups, with no change observed in the PL group (Latham *et al.* 1990b).

Protein-energy malnutrition

Protein-Energy malnutrition (PEM) is defined as a malnutrition resulting from frequent dietary deficiencies in protein and energy required for the body's optimal growth and function (De Onis *et al.* 1997). PEM is also classified as nutrient disorders which includes kwashiorkor and marasmus. Kwashiokor is basically an inadequate consumption of protein with fairly energy intake and characterized by nutritional edema, hair discoloration, thinness and reduced skin pigment (Heikens & Manary 2009, Walson & Berkley 2018), whilst marasmus is characterized as inadequate dietary consumption of protein and energy, which causes body emaciation (Adebayo & Balogun 2018).

The condition is often determined by low weight-for-age (underweight), low weight-for-height (wasting) and low height-for-age (stunting) (Bhutia 2014). Affected children tend to show behavioral changes such as apathy, attention deficit, irritation, anxiety and reduced social responsiveness (Adebayo & Balogun 2018). PEM has also been implicated in heavy infections of both round worms and whip worms (Stephenson *et al.* 1993a). Chronic losses of protein has also been reported with hookworm infections, leading to hypoproteinemia and anasarca (Hotez *et al.* 2004). In the Philippines, a cross-sectional study was conducted by Papier *et al.* (2014) in Northern Samar, which involved 693 school-aged children from 5 schistosomiasis-endemic villages. The study found that the number of children with *schistosoma japonicum* (15.6%, P = 0.03) and hookworm (22.0%, P = 0.05) were significantly higher among school children who did not meet the recommended total calorie and protein intakes, which supports the assertion that there are nutritional deficits in helminth endemic populations, which could be attributed to the fact that helminths can feed directly on its hosts' tissues leading to a physical damage and a resultant loss of nutrients. For example, when hookworms migrate from their original site of feeding to another site, there is the likelihood of persistent bleeding from that site into the GIT due to the continual consequence of anticoagulant secretion from the salivary gland of the worm into that region (Hotez & Cerami 1983). In addition to that, the physical disruption of the GIT surface can result in maldigestion as well as malabsorption due to helminth infections. For instance, in a study by

Martin *et al.* (1984), they reported flattened villi and villous atrophy among *Ascaris suun* experimentally-infected pigs. This villous destruction or atrophy has the potential of resulting in the loss of brush boarder enzymes as well as a reduction in the total surface area required for the digestion and absorption of nutrients (Hall *et al.* 2008a). Bacterial overgrowth within the small intestine due to the presence of helminths has also been implicated, although this has mainly been associated with *G. duodenalis* infection (Müller & Von Allmen 2005).

Helminth infection and cognition

Helminths infections among school-aged children have been associated with reduced cognitive performance (Al-Mekhlafi *et al.* 2008, Stoltzfus *et al.* 2001). Studies have shown that chronic infections from STHs potentially have drastic effects on the development of both physical and mental growth in children (WHO Expert Committee 2002). The adverse health effect of helminth infections all come together to impair childhood educational outcomes by reducing school attendance and academic performance, and ultimately affecting future wage earning capacity negatively (Bleakley 2007). Although helminth infections have been strongly associated with poor cognitive or intellectual development and achievement in children (Ezeamama *et al.* 2005, Sternberg *et al.* 1997, Whaley 2003), the actual mechanism by which this happens is not known, but it has been explained as an indirect one due to the occurrence of iron deficiency anemia (IDA) and undernutrition among such vulnerable groups (Drake & Bundy 2001). Several studies have also reported significantly low scores on psychological tests among children due to IDA (Lozoff *et al.* 1991, Lozoff *et al.* 1998). IDA and severe malnutrition have also been implicated in long term impairment in cognitive functioning (Grantham-McGregor *et al.* 2000).

Other studies have also shown relationships between helminth infection and economic and educational factors that are related to intelligence. For example, Bleakley (2007), studied the effects of eradication of hookworm in the southern US during the early twentieth century, and found that areas where hookworm infections had been greatly reduced had higher average incomes after treatment than areas that had not received treatment. In the year 1910, the campaign towards the eradication of hookworm infection began in the United States of America. One of the reasons for the inception of this campaign was the establishment of an association between myriad of health problems with hookworm infection. A survey of hookworm infection was then conducted by the Rockefeller Sanitary Commission (RSC) among such populations and reported a 50% prevalence rate of hookworm infection among SAC in South America. The eradication campaign then continued with the RSC providing dewormers and prevention education programs to the physicians and the general public. The construction of public and private latrines were also continued later years by the International Health Board (IHB), which succeeded the RSC. These interventions by the RSC are reported to have contributed positively on the human capital (Bleakley 2007).

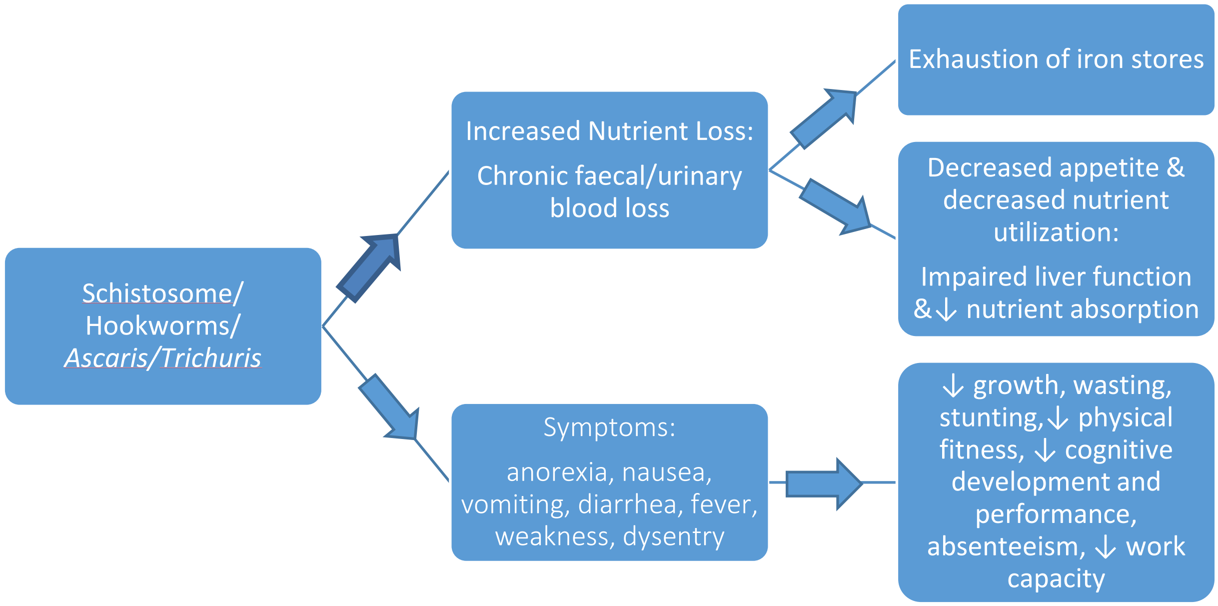

Figure 2.4: A conceptual framework of helminthiasis. ↓ = impaired/decreased.

Adopted from Stephenson &Holland, 1987, ACC/SCN, 1992

Interventional strategies against helminth infections

Three main helminth-control intervention strategies have been implemented in helminth-endemic areas globally. These are the periodic deworming drug treatment/Mass Drug Administration (MDA), sanitation and health education (Hotez *et al.* 2006). The use of periodic deworming intervention has been identified as a cheap and safe method of reversing the morbidities associated with helminth infections through the use of anthelmintics (King *et al.* 1988, N'goran *et al.* 2001, Smith & Brooker 2010, Taylor-Robinson *et al.* 2007). Drugs commonly used for treatment of STH are the bemidazole derivative mebendazole, and albendazole (ALB) which cause the death of the STH (Horton 2000, Stephenson 2001). Their administration is simple and can be given as a fixed single dose of 400 mg (ALB) and 500 mg (mebendazole). Praziquantel (PZQ) is the main drug used in the MDA for the treatment of schistosomiasis. Its dosage is dependent on the body weight of the person (40 mg/kg body weight for the treatment of

S.haematobium infection), and 60mg/kg for *S.japonicum* infection) (Idowu *et al.* 2007, Montresor *et al.* 2005). Moreover, the use of PZQ is safe with no serious side effects reported even among pregnant and lactating women (Adam *et al.* 2004, Olds 2003).

The frequent use of MDA has however, raised concerns with regards to its safety especially in very young children (Urbani & Albonico 2003). Furthermore, the resistance of drugs used in MDA among livestock has been reported due to its frequent use (Wolstenholme *et al.* 2004). In one study conducted in Pemba Island of Zanzibar for example, the researchers sought to evaluate the efficacy of either a single dose of mebendazole (500 mg) or in a combined dose with levamisole (40 or 80 mg) for the treatment of *Ascaris lumbricoides*, hookworm and *Trichuris trichiura* in school children. They reported significantly lower cure rates of mebendazole treatment of hookworm infections (7.6%) and an egg-reduction rate of 52.1% than reported values in an earlier study which was conducted prior to the commencement of periodic chemotherapy, with a cure rate of 22.4%, and an egg redaction rate of 82.4%. The combination of mebendazole and Levanisole, however, showed a significantly higher efficacy against infection rates of hookworm, but even with the combination of the two drugs, cure rates and egg-reduction rates were only up to 26.1% and 88.7%, respectively (Albonico *et al.* 2003). In another study conducted in the same region, Peru Island of Zanzibar (Albonico *et al.* 2004), researchers sought to determine the molecular evidence of benzimidazole (BZ) drug resistance among school-age children after they had received 13 rounds of treatment for hookworm over the years with mebendazole since they started school. They found a much reduced response to the drug, which was suggested to be due to a mutation at codon 200 in the B-tubulin gene that confers resistance in hookworms (*Necator americanus* and *Ancylostomer duodenale*).

In spite of the equally high prevalence rates of schistosomiasis among both adults and children in Ghana, schistosomiasis control has mainly focused on children since they are perceived to suffer most from the burden of the disease and are therefore targeted as a high risk group (Dickson & Benneh 1995, Ugbomoiko *et al.* 2009). The main challenges faced with the periodic deworming in most intervention studies in sub-Saharan Africa includes the fact that PZQ has been the main anti-schistosomal drug (Fenwick *et al.* 2009, Utzinger *et al.* 2011), and many intervention programs rely on donated drugs (Abdul-Rahman & Agble 2012a, WHO 2011b), which may not always be sustainable. Its high cost has also made it difficult to be used in a lot of countries where it is mostly needed (Doenhoff & Pica-Mattoccia 2006). The lack of funds for implementation, monitoring and surveillance of interventions in addition to missing baseline data have also been a major challenge in the control of NTDs (Rollinson *et al.* 2013). In Ghana, according to reports by Abdul-Rahman and Agble (2012b), low levels of praziquantel have been reported due to the shortage of the drug on the international markets. Comparing the financial cost of treatment with praziquantel in Ghana and Tanzania, The Partnership for Child Development (1999) reported a higher unit cost of praziquantel treatment in Ghana to be US$0.67 compared to that of Tanzania which isUS$0.21. This higher cost of unit treatment in Ghana, can be a challenge.

Although the use of PZQ has been found to be safe, the fear of developing drug resistance from the mass treatment medications of parasitic infections is an emerging problem (Albonico 2003). Also, its cure rates have been found to be mainly between 85-90%, with hardly any record of a 100% cure rate. For instance, in a multi-center randomized trial study conducted involving four different sites (the Philippines, Mauritania, Tanzania and Brazil), 856 patients were recruited using a common protocol to check the efficacy of either a single dose of 40 mg/kg body weight or a 60 mg/kg body weight praziquantel. The cure rates were then assessed in 21 days, and they found that both doses were effective with a cure rate of 91.7% (60mg/kg body weight) and 92.8% (40mg/kg body weight) (Olliaro *et al.* 2011). Also, the treatment with ALB for 3 or more days did not eradicate *T. trichiura* (whipworm) from 67% of patients effectively (Sirivichayakul *et al.* 2003).

In addition to that, the fact that PZQ treatment, as with all MDAs do not prevent re-infection, with some studies in other countries showing that once treatment for parasitic infections were ended, the disease prevalence returned to pre-treatment rates within 18-24 months (Clements *et al.* 2009a, Doenhoff *et al.* 2008), is also a challenge.

Other limiting factors reported in Ghana include poor motivation for teachers who are largely involved in such interventions, which has resulted in some teachers failing to return monitoring forms after the mass drug administration exercises. As well as challenges with the coordination of stake holder activities in deworming exercises (Abdul-Rahman & Agble 2012a).

Moreover, most intervention programs also have mainly focused on enrolled school children leaving out some potentially high risk group of individuals such as preschoolers who might be having high disease burdens and serve as potential sources for re-infection to other treated groups in the community (Fentiman *et al.* 2001). In addition to this, as many as 40% of the targeted children in sub-Saharan Africa for treatment may not even be enrolled in school (Rollinson *et al.* 2013), hence such groups cannot be effectively reached for treatment.

Conflicting outcomes

There has been conflicting results of the effect of deworming alone on the nutritional status of children. Whilst some studies have shown improvement in the growth and health status of children after deworming alone (Stephenson *et al.* 1993b), other studies have not shown any significant improvement (Greenberg *et al.* 1981). Conflicting results also exist for the effect of treatment on cognitive performance. For instance, the working memory and rapid retrieval of words of some Jamaican children with moderate to heavy infections with whipworm improved after deworming treatment compared to a randomly assigned placebo group (Nokes *et al.* 1992), but no improvement were found in other cognitive assessments such as problem solving ability, arithmetic and others. Among similar groups who had slightly lower levels of whipworm infections, Simeon *et al.* (1995), found that there was no improvement in performance in the cognitive tests they employed after treatment. However, among children who were already wasted, there was an improvement in verbal fluency after their treatment. Similar studies done in Guatemala (Watkins *et al.* 1996), also showed improvements among children who were heavily infected with round worm in Sternberg short-term memory scanning test and cognitive speediness using simple-choice reaction time after treatment. But children who were lightly infected by the same parasite performed poorly on these same tests after they were treated.

The Water, Sanitation and Hygiene (WASH) intervention program and STH infection

The WASH (Water, Sanitation and Hygiene) program has also been an effective intervention tool in various studies (Esrey *et al.* 1991, Kosinski *et al.* 2012), and it promotes the supply and use of safe drinking water, the provision of suitable sanitation facilities, a means of safe disposal of human excreta and advocacy of good hygienic practices like safe water treatment and storage, handwashing, bathing with safe water among others. With the use of the WASH intervention, there has been evidence of an effective reduction of contamination of the environment and the transmission of helminth eggs and larvae (Esrey *et al.* 1991, Kosinski *et al.* 2012). In India, two cluster randomized controlled trials by Clasen *et al.* (2014), in Odisha and in Madhya Pradesh by

Patil *et al.* (2014) was conducted using the WASH program, and included provision of flush pit latrines for 100 and 80 villages, with a total household population of 2902 and 3039 respectively. The studies purposively evaluated an intervention program to control the prevalence rates of helminth infection using the WASH approach. After 43 months intervention with improved toilet facility, they reported no significant difference in the prevalence of helminth infections between the experimental group (16.0%) and control group (16.4%) (Clasen *et al.* 2014). In addition, after 23 months intervention, no significant difference in the prevalence of *Ascaris* was found between the experimental group (4.3%) and control group (4.4%) (Patil *et al.* 2014). The two studies reported some evidence of behavioral change following the intervention but this did not significantly impact STH infections rates in the areas. The possible reason for high levels of STH infection could be due to rapid reinfections after the deworming exercise, thus, high quality and realistic interventions would be needed to control infection rates (Abraham *et al.* 2018). Hence, helminth infection control programs need to be complemented with other control interventions such as nutrition education, adequate sanitation and hygienic environment and access to quality water in high-risk infection areas (French *et al.* 2018).Furthermore, targets to control helminth infection-related morbidity should be realistic and measurable to further ascertain knowledge gaps and improve on intervention programs in endemic areas (French *et al.* 2018).

Micronutrient supplementation and food fortification

Taking into consideration the need for an urgent solution to the problem of micronutrient deficiencies especially in the Low to middle Income Countries (LMICs); two common interventional methods have been employed. These are micronutrient supplementation and food fortification of locally available foods (Friis *et al.* 2003, Latham *et al.* 2001). Supplementation is defined as the periodic administration of pharmacologic preparations of nutrients as either capsules or tablets or by injection to at-risk groups who require urgent nutritional needs. A micronutrient like iron for example can be found in meat as well as some vegetables, however, it is more readily available in meat than vegetable sources which mostly have the iron in an irreversible bond to lectins. Hence, it is important to make up for the losses of iron in plant foods for children by supplementing with iron tablets/syrup.

A typical condition like anemia is not only due to iron deficiency, thus there is the need to supplement with other micronutrients (Ramakrishnan *et al.* 2004). Especially in LMICs where there is the likelihood of multiple micronutrient deficiencies occurring concurrently (Solon *et al.* 2003), the need for a multiple micronutrient supplementation may be required. It was reported in some studies that a micronutrient intervention led to increased hemoglobin, but this was not only attributed to increased iron stores, but also to Vitamin A, riboflavin, folate, vitamin B12, zinc and other micronutrients which are required for normal erythropoiesis (Friis *et al.* 2003, Viteri 1997). Several supplementation studies have also included zinc and other nutritional supplements such as iron and folate which have been found to improve the effectiveness of zinc, whereas studies in which only zinc was supplemented in addition to a placebo, was found to be completely absent or lowered due to the possibility of the absence of a zinc deficiency or the limitation of the impact of zinc due to the concurrent deficiencies of other micronutrients (Ronaghy *et al.* 1974, Sandstead *et al.* 1998). Thus the deficiency of some nutrients can affect the absorption and utilization of the supplemented nutrient. For instance, vitamin C enhances iron absorption, and copper deficiency can result in Iron-deficiency anemia (IDA) (Allen 1998, Lönnerdal 1998). The conversion of beta carotene to vitamin A also requires zinc (Dijkhuizen & Wieringa 2001).

Vitamin A has also been found to play an important role in iron metabolism since during supplementation with iron, if vitamin A deficiency is also present and not treated, the response to the former is greatly diminished (Mejía & Chew 1988, Suharno *et al.* 1993). WHO therefore recommends the use of multiple micronutrient powders containing at least iron, Vitamin A and zinc for home fortification of foods as a way of reducing anemia in infants and children (WHO 2011a).

Some studies have suggested that micronutrient supplementation could result in a lower reinfection rate or intensity of helminth infections (Friis *et al.* 1997, Olsen *et al.* 2000). There is also the evidence that children provided with zinc and/or vitamin A supplementation have a shorter duration and frequency of *Ascaris* infection as compared to those receiving placebo (Long *et al.* 2007). The loss of hemoglobin due to blood loss from helminth infection can be replenished by mixed micronutrients (Friis *et al.* 2003). However, the use of multiple micronutrient supplementation has faced some challenges in Ghana where the World Food Program (WFP) initiated a program in the Northern regions of Ghana whereby school meals were enriched with micronutrient (8 g of 14 micronutrients) powders twice weekly for an academic term (13-16 weeks), but some schools did not use the right quantities of the supplements and the cooking methods employed in the preparation of some school meals also had the potential to destroy the micronutrients (Abdul-Rahman & Agble 2012a).

Hence for a long-term and cost–effective approach to prevent and control micronutrient deficiencies like IDA, nutrition approaches have been suggested through food fortification with iron and other micronutrients (Nair *et al.* 1998, Rao 1994). Such was the approach used in a study in South Africa among 6-11-year-old children who were given cookies daily in school fortified with beta carotene, iodine and iron. This showed improvement in the three micronutrients of the children as compared to a control group (Van Stuijvenberg *et al.* 1999). Dietary modification is also one of the long-term and low-cost ways of improving the nutritional status of people. As they tend to use locally available food which is common to the people by increasing total food intake, consumption of locally available iron-rich foods and also dietary practices that will improve on iron absorption (DeMaeyer *et al.* 1989).

With regards to overall improved nutrition and cognition, some micronutrient interventional studies have shown improvement in nutritional status and growth in children (Chwang *et al.* 1988, Latham *et al.* 1990a, Sandstead *et al.* 1998). Supplementing with zinc has shown improvement in both growth and cognition (Sandstead *et al.* 1998). Interventional studies have consistently found improvement in cognitive function after supplementing with iron in young children (Idjradinata & Pollitt 1993). The effect of Iodine Deficiency Disorder (IDD) except congenital retardation has been reversed using iodine supplementation (Delange 1994, Van den Briel *et al.* 2000).

Supplementation programs have been found to be even more effective when combined with deworming (DeMaeyer *et al.* 1989, Gopaldas 1995). Furthermore, compliance to the use of nutritional supplements has been reported to improve if taken weekly than on a daily basis.

Despite its effectiveness in alleviating micronutrient deficiencies, not all micronutrient supplementation may be effective and sustainable on a long-term basis, as issues with logistics, economic and cultural factors come into play to hinder its progress in endemic areas (Abdul-Rahman & Agble 2012a, Bothwell 2000). In a randomized placebo controlled, double-blind trial study for example, the effect of iron supplementation on anemia was found to be limited. It involved 459 children (6-71 month olds), and sought to elucidate the effects of iron supplementation or mebendazole treatment on the appetite, anemia and growth in two groups. They found that iron supplementation did not have an effect on the hemoglobin concentration or anemia. Neither did it affect growth retardation, although it improved serum ferritin and erythrocyte protoporphyrin significantly. However, mebendazole rather had a significant reduction effect on wasting among very young children (Stoltzfus *et al.* 2004). Hence the need for a more sustainable approach is required.

Nutrition education

Nutrition Education is any combination of educational strategies accompanied by environmental supports, designed to facilitate voluntary adoption of food choices, and or other food and nutrition-related behaviors beneficial to health (Contento *et al*. 2002). It has been argued that Mass Drug Administration (MDA) alone is insufficient for catch-up growth and mental development of children infected with helminths (Dickson *et al.* 2000a, Dickson *et al.* 2000b, Hall 2007). For long-term resolutions to micronutrient deficiencies in LMICs, educational programs and nutrition diversification is needed. Changes in lifestyle through education can yield major changes in health outcomes even in resource-limited settings (Smits 2009). For instance through health education coupled with the improvement in water supply through filtration and snail vector control, the prevalence of NTDs have successfully been reduced from almost half of the countries where they were endemic (Ruiz-Tiben & Hopkins 2006, Voelker 2007).

Moreover, not all studies have shown a significantly positive effect of deworming and micronutrient supplementation on the child's nutritional status, due to the variations and difficulty in measuring child health indicators such as their nutritional status, helminths infections and cognitive development (Longfils *et al.* 2005). For instance, a study conducted in Zanzibar showed that anemia was associated with hookworm infections among older children (>3 months), whereas among younger children, it was associated with malaria (Stoltzfus *et al.* 2000). Hence the critical need to employ an integrated approach such as health/nutrition education, vector control, improved hygiene and environmental sanitation (Lansdown *et al.* 2002, Solomon *et al.* 2004) in tackling the issue of helminthiasis and improvement in the nutritional and cognitive status of children in helminth-endemic areas. This would also potentially reduce re-infection rates among helminth-endemic populations after deworming drug administration, since it has been recommended that health education in addition to community participation interventions be initiated as soon as the prevalence of disease is reduced by the Mass Drug Administration (MDA), as seen in Europe and other developed countries where through economic development, improvement in hygiene and sanitation, the prevalence of NTDs has been eradicated (Stettler 1991).

Globally, nutrition education is being employed in several education systems as part of a course or as a developmental skill program (Howie 1983, Perry *et al.* 1985). It has been used in studies to improve on iron status and reduce anemia in a peri-urban community in Peru (Creed-Kanashiro *et al.* 2000). Their study was a community–based, randomized behavioral and dietary intervention which was conducted among adolescent girls for 9 months to improve their dietary iron intake and availability. Their intervention strategy included an educational campaign to improve their community kitchen menus as well as to incorporate low cost heme-iron sources and iron absorption enhancers such as vitamin C in their diets. In addition to that, it involved the motivation of participants through a better understanding of their nutritional needs and tendencies to be deficient at their adolescent age, and the required diets that would be beneficial to their health. At the end of their study, there was an improvement in dietary iron intakes and a change in knowledge about anemia among participants (n=72) of the intervention group compared to 66 of the control group. Furthermore, a protective effect was observed in the maintenance of iron status in the intervention group compared to those in the control group (Creed-Kanashiro *et al.* 2000).

There is a gradual progress observed with the intervention programs in addressing the endemicity of NTDs such as helminthiasis burden in LMICs like Ghana as observed in a decline in national prevalence rates of infection. However, with the several challenges being faced by the various stakeholders in intervention/control programs, especially with the supply of praziquantel, a more sustainable approach is needed for the eradication and complete elimination of helminthiasis, especially schistosomiasis in Ghana. Thus, there is the need for additional measures such as health/nutrition education, vector control and improved hygiene and sanitation to make the MDA more effective and sustainable (Lansdown *et al.* 2002, Solomon *et al.* 2004). One of such interventions was employed in a randomized controlled study involving school-age children (7-15) years in Lushoto district of the Tanga Region of Tanzania who were enrolled in a health education intervention study for the control of schistosomiasis and STH infections (Lansdown *et al.* 2002). Their health education intervention message focused on personal hygiene, drinking clean water and good nutrition. Tools employed in their health education intervention included songs, short sketches, poetic dramas among others. They also held focus group discussions with the children, their parents and community members for 3 school terms. At the end of the intervention period, children showed an increased knowledge in good health practices such as handwashing with soap after toilet use, the need to cover food to avoid contamination from flies among others.

Hence, for long-term solutions to undernutrition such as micronutrient deficiencies in LMICs, nutrition education programs and dietary modification strategies have been suggested (Bundy *et al.* 2006). A report by the London, U.K Partnership for Child Development (PCD) on the School Health and Nutrition and Mapping of Existing Programs in Ghana (Abdul-Rahman & Agble 2012a) suggests that school health and nutrition programs have great potential of improving the growth and nutritional status of SAC in Ghana. According to their report, during school visits in Ghana, head teachers/ School Health and Education Program (SHEP) of the Ghana Health Service Coordinators of 3 out of 5 schools indicated a lack of in-service nutrition training on the promotion of nutrition in their various schools. The only nutrition-related training they obtained was during their pre-service training. A lack of specific times allocated for nutrition education in their schools was also reported. The team also observed a lack of nutrition education materials in the participating schools. This shows a nutrition education gap in schools in Ghana that needs to be rectified.

A much more sustainable approach such as the provision of hardwares like building of toilet facilities, the provision of portable water and education of less contact with fresh water bodies, as well as good hygienic practices (ex. handwashing) is required together with the ongoing deworming programs for the eradication/elimination of helminthiasis in helminth-endemic populations (Clarke *et al.* 2018, WHO 2015). However in low socioeconomic communities with poor educational standard, complementing with nutrition education can also show greater impact on the nutritional health and wellbeing of school children, and thus support the rationale for conducting such intervention studies.

Relevance of the helminth infection study in Ghana

The morbidity and prevalence of soil-transmitted helminth infection and schistosomiasis continue to be a public health threat among children in sub-Saharan Africa, including Ghana. Over the last decade, there has been research improvement on schistosomiasis-related morbidity, but there are still knowledge gaps on the association between helminth infection prevalence rate and morbidity in school children in endemic areas (French *et al.* 2018). Moreover, inspite of the progress made with the reduction on helminthiasis prevalence through the Mass Drug

Administration (MDA) programs, there are about 10,000 more cases of NTDs which are reported to be predominant in Sudan and Ghana (Smits 2009), and these cases have been found to be common in communities that rely mainly on unsafe water sources such as rivers and wells as their drinking water (Iriemenam *et al.* 2008, Tandoh *et al.* 2018).

Additionally, the burden of helminth infections is associated with the host's health, cognitive development and nutritional status (Stephenson *et al.* 2000, Tandoh *et al.* 2015). Also, a strong association has been established between under nutrition and infection from *Ascarias lumbriocoides*, *Trichuris trichiura*, *Schistosoma* spp and hookworm (Hall *et al.* 2008b, Wolde *et al.* 2015). Furthermore, another study has established strong association between helminth infection and reduced cognitive performance in school-aged children (Al-Mekhlafi *et al.* 2008). Helminth infection prevalence remain under studied in several impoverished endemic areas in Ghana. Studies conducted in Ghana by various research groups (Dankwa *et al.* 2017, Humphries *et al.* 2013, Yirenya-Tawiah *et al.* 2011) have reported increased infection rates of helminth and schistosome among school children and adults in some communities of Ghana. Given the high prevalence of helminth infections and schistosomiasis in Ghanaian communities, it becomes relevant to explore the effects and drivers of helminth infection in endemic communities and the consequences for helminth epidemiology and morbidity, and also to evaluate intervention programs which can work best to control the re-infection rates and improve on nutritional and cognitive outcomes.

Currently, there is a limitation on the existing literature on intervention studies which have evaluated the effects and drivers of helminth infection and how it can be controlled in Ghana. Thus, the relevance of this study which seeks to address helminthiasis burden and associated risk factors and provide sustainable evidence-based intervention approach which can be implemented to improve the nutritional and cognitive status of SAC in helminth-endemic areas. The studies contained in this dissertation will provide the needed understanding and knowledge towards the integration of comprehensive approaches into helminth infections control programs in Ghana.

<u>Rationale, specific aims and hypothesis</u>

This dissertation sought to investigate and compare different strategies to control helminth infections and undernutrition in Ghana. The Mass Drug Administration (periodic deworming) has been the main helminth control program in Ghana, and since its inception, the prevalence rates of helminthiasis have gradually declined, but infections with *S. haematobium* in particular, still remains high (70.9%) (Rollinson *et al.* 2013). Furthermore, there are problems with logistics with the deworming intervention, in terms of it being costly (Doenhoff & Pica-Mattoccia 2006), and most of the anti-schistosomal medications for instance being provided by donor agencies (Abdul-Rahman & Agble 2012a). There have also been reports of shortage of antischistosomal drugs on the international market (Abdul-Rahman & Agble 2012a). Also, issues of drug resistance has been a threat to the long-term use of antischistosomal drugs (Albonico 2003), and ultimately, the inability of anthelmintic drugs to prevent re-infection of helminths (Clements *et al.* 2009b, Doenhoff *et al.* 2008). Moreover, a review by Allen and Parker (2016), suggests that the results of most deworming studies have been overrated and that frequent repeated use of dewormers among SAC can be futile (Allen & Parker 2016).

Thus, the rational of this dissertation, which sought to examine the impact of different intervention strategies for helminthiasis control on the nutritional status (underweight, stunting, anemia and zinc deficiency), and cognitive performance, as well as to ascertain the most effective and sustainable approach. This dissertation first specific objective was to assess the burden and disparities of helminth infection and association between the prevalence and the sanitary/ hygienic conditions of the study participants. Our hypothesis was that, there would be a negative association between the prevalence of infection and the poor hygienic/ sanitary conditions of the children. These results are documented in chapter 3.

The second specific objective was to elucidate the association between the prevalence of helminth infections and the nutritional status and cognitive performance of the participants. The study hypothesis was that a high prevalence rate of infection would negatively impact the nutritional status of the children. These results are reported in chapter 4 of this dissertation.

Finally, the third specific objective was to assess the impact of three (3) main intervention strategies on the nutritional status and cognitive performance of the children. We hypothesized that children who received the nutrition education intervention would have improved nutritional and cognitive outcomes, compared to those who received the other types of intervention (Micronutrient Supplement Only and Nutrition Education+Supplement and the Control/Deworming Only). The results of this specific aim are reported in chapter 5.

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CHAPTER 3

DISPARITIES OF SANITARY CONDITIONS/HABITS AND HELMINTHIASIS PREVALENCE BETWEEN SCHOOL-AGE-CHILDREN LIVING IN FISHING AND FARMING COMMUNITIES IN GHANA: A CROSS SECTIONAL STUDY

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Abstract

Background: Helminthiasis is a sub group of the neglected tropical diseases that is still persisting in most countries in sub-Saharan Africa and is a major cause of chronic morbidity with associated poor intellectual and physical growth in children. Children are the most affected group, probably, due to their poor hygienic practices and poor play habits. This study determined the prevalence of helminth infections and disparities in the hygienic, sanitary conditions and health behaviors among school-age children living in two selected communities in Ghana. Methods and findings: This was a cross-sectional study conducted in fishing (n=84) and farming (n=80) communities in the Kwahu Afram Plains South District in the Eastern Region of Ghana among school-age children using structured questionnaires and laboratory analysis. One hundred and sixty-four (164) pupils (2 schools each from fishing and farming communities) participated in the study comprising 50.6% males and 49.4% females, as well as their parents or primary caregivers. About 9.6% Soil-transmitted helminths (STH) were observed in the farming communities with none recorded in the fishing communities ($p=0.007$). Conversely, 33.8% of *S. haematobium* infection occurred in the fishing compared to 1.2% in the farming community ($p<0.0001$). About 48.8% of all children obtained their drinking water from the Afram River compared to 51.2% from boreholes. Overall, 31.7% of all children lived close to a water source, with 48.8% versus 13.8% being in the farming and fishing communities respectively ($p<0.0001$). Handwashing after toilet use was reported by 61.0% participants with 86.9% versus 33.8% of children within the farming and fishing communities engaging in this practice respectively ($p<0.0001$). Conclusions: Poor hygienic practices and sanitary conditions were more prevalent in the fishing communities than in the farming communities. *S. haematobium* infection was significantly higher among the fishing communities while STH

infections solely occurred among children in the farming communities. The best predictors for schistosome infections were swimming in the river, water storage method, farming activities, and source of drinking and bathing water.

Introduction

According to the World Health Organization, over 610 million school-age children (SAC) are at high-risk of soil-transmitted helminth (STH) and schistosome-associated morbidities (WHO 2011), thus, children are considered as a high risk group for helminth infections (helminthiasis) due to their poor hygienic practices and poor play habits such as having direct contact with infested fresh water bodies through swimming (Gryseels *et al.* 2006, Knopp *et al.* 2013). The most common helminths of humans which causes intestinal helminthiasis include hookworms (*Necator americanus* and *Ancylostoma duodenale*), roundworm (*Ascaris lumbricoidedes*), and the whipworm (*Trichuris trichiura*) while those that cause urinary and intestinal schistosomiasis include schistosomes (*Schistosoma haematobium*, *S. japonicum*, *S. mansoni* and *S. mekongi*) (Hotez *et al.* 2006). In Ghana, the most common helminth is *Schistosoma haematobium* (McCullough 1965), with an estimated national prevalence rate of 70.9% (Rollinson *et al.* 2013). Infections with these helminths (STH and schistosomes) in children lead to increased morbidities through their adverse effects on their nutritional status (Stephenson *et al.* 1993), leading to impaired growth and anemia (Bundy & Cooper 1989), as well as impaired cognitive process (Sternberg *et al.* 1997).

The main control strategy for the control of STH and schistosomes has been through the use of periodic deworming drug treatment (anthelmintics), using albendazole or mebendazole for STH and praziquantel for schistosomiasis (Molyneux & Malecela 2011). However, the long-term control of these helminths is still a public health concern as there are some challenges with the periodic deworming interventions. For instance, the availability of the deworming drugs is not sustainable as most of the control programs depend on drug donors (WHO 2011). This has led to the observation of increased helminth infection rates similar to their pretreatment levels by the 18th to 24th months after the cessation of periodic deworming programs (Clements *et al.* 2009, Doenhoff *et al.* 2008). Furthermore, drug resistance from the periodic deworming is a major public health concern as there is evidence of this occurring in some livestock (Albonico *et al.* 2004, Jackson & Coop 2000).

The World Health Organization together with UNICEF (2009), have therefore provided guidelines on the improvement of sanitation, water and hygiene (WASH) as a more sustainable approach of controlling helminth infections (WHO 2011). This approach includes access to hardware such as toilet facilities, clean water in addition to healthy behaviors such as handwashing at critical times such as after the use of toilet. The WASH approach has been shown to reduce re-infection rates of helminth infections (Bieri *et al.* 2013, Freeman *et al.* 2013, Xu *et al.* 2001). However, the existing literature on the subject does not cover existing disparities of helminthiasis and sanitary conditions between the two distinct helminth-endemic communities (fishing and farming) in Ghana in order to identify the specific potential determinants of helminth infections between these communities. Thus the rationale of this cross-sectional study which aimed to determine the prevalence of schistosomiasis (due to *S. haematobium* and/or *S. mansoni*) and soil-transmitted helminthiasis (due to *A. lumbricoides*, *T. trichiura* and/or the hookworms) among the SAC within two distinct communities (farming and fishing) in the Kwahu Afram Plains South District in the Eastern Region of Ghana and to elucidate the disparities and associations of infection and hygienic practices, sanitary conditions and health behaviors among SAC in the two communities. These helminths were investigated because they commonly occur among SAC in Ghana (Humphries *et al.* 2013, Rollinson *et al.* 2013, Tandoh *et al.* 2015). Findings from this study will inform public health experts and policy makers to plan and implement interventions which will be tailored to suit the specific needs of the two unique communities and potentially reduce re-infection rates.

Methods

Study site

This study was conducted in the Kwahu Afram Plains South District in the Eastern Region of Ghana with Tease as its district capital. It has a total land area of approximately 3,095 sqkm. The land is undulating and rises to between 60 meters to 120 meters above sea level. The district falls within the savannah transitional zone and the savannah woodland which is made up of fire resistant trees. The district is drained to the south by the Afram River and the Volta River to the East. These rivers flow continuously throughout the year and are used for domestic as well as agricultural purposes (Fig. 3.1) (GSS 2014).

Study design and subjects

This was a cross-sectional study conducted during the summer (May-June 2017). A total of 164 pupils participated in the study together with their parents or primary guardian (caregiver). Two main communities; fishing (n=84) and farming (n=80) were used for this study. Pupils were recruited from four randomly selected schools (two schools from the fishing and two schools from the farming communities) in the Kwahu Afram Plains South District of Ghana). Although participants were selected from their respective schools, the primary focus of this study was based on which communities those schools were located and the communities in which the participants lived.

The estimated sample size for the study was 192, based on 80% power and 0.05 alpha and 95% confidence interval in hemoglobin level, to detect an odds ratio of 2.5 between infected versus uninfected children based on information from other studies. However, the number of pupils in the randomly selected schools within the proposed age range (9-12) were not adequate resulting in a relatively smaller sample size of 164.

Inclusion and exclusion criteria

Children who were living in the selected communities (farming and fishing communities of the Kwahu Afram Plains South District) and who were within the ages 9-12 years of the randomly selected schools (2 schools in each community) were included in the study. Parents/guardians of eligible children had to be 25 years or older to prevent minors (older siblings) standing in as caregivers of the children to participate in the study for accurate information on the index child.

Children who did not live in the randomly selected communities, as well as those who were out of the age range of 9-12 years were excluded from the study. Children who self- reported to have sickle cell anemia and malaria, as well as those who had obvious physical ailments such as goitre and elephantiasis, and those who were already taking nutritional supplements at the time of enrolment were excluded from the study.

Participant recruitment

To select the study sites, a random selection of the district was done to choose either the south or north district of the Kwahu Afram Plains, and a list of all schools within the fishing and farming communities in the selected district (Kwahu Afram Plain South District) was obtained from the Student Health and Education Program (SHEP) coordinator. Two (2) schools each from the farming and fishing communities were randomly selected through a balloting process. Participants (SAC) were then recruited from the two (2) randomly selected primary schools within each of the two selected communities. Data were collected on sociodemographic, parasitic (urine and stool analysis for STH and schistosome infections) as well as hygienic and sanitary conditions.

Questionnaire development

The WHO recommended child form for parasitological / nutritional survey was modified and used for data collection (Montresor *et al.* 2002). Our questionnaire comprised of two parts: one part for parents; consisting of 33 questions of 3 sections (sociodemographic, water and sanitation, and knowledge in helminth infection); and a second part for the children comprising of 17 questions (See Appendix P). A similar version of this questionnaire had been validated and used in a previous study among school-age children in Ghana (Tandoh *et al.* 2015).

Data Collection Procedure

Administration of children and parent questionnaires

Trained research assistants and teachers asked questions in the participants' local language in the filling of both the parent/caregiver and child questionnaires. The parents/ caregivers were questioned first, followed by the children.

Demographic information

Participants and their caregivers were assisted to complete the questionnaire in an in-person interview format. Demographic information including age, sex, ethnicity, number of children in the household, sanitation and hygiene knowledge and practices, source of drinking water, parental employment, and educational status among others were obtained through interviews with the participants and their caregivers using well-structured questionnaire (Montresor *et al.* 2002).

Parasitic infections assessment and treatment

The participants (children) were provided with labelled plastic stool and urine containers during the time of their registration into the study. They were then given directions on how much urine and stool were to be deposited into each container such that the urine did not have to exceed a certain mark on the urine container provided. They were also given directions on how to safely use the plastic scoop attached to the lid of the stool container to scoop the fecal sample and gently deposit it within the stool container. Stool and urine samples of study participants were collected at a designated point in the various schools by trained research assistants to assess the presence of intestinal helminths (Hookworm, *Ascaris lumbricoides*, *S. mansoni* and *Trichuris trichiura*) and urinary schistosomiasis (due to *S. haematbium* infection). Participants who could provide their urine and stool specimen on the same day were encouraged to do so.

The stool and urine samples were stored on ice (in chest) and transported to the Holy Spirit Health Centre Laboratory within the district for analysis. One gram of fresh fecal sample was examined microscopically for the eggs of intestinal worms using the Kato-Katz technique (Katz *et al.* 1972). The estimation of intensity of infection for each species was recorded as eggs per gram (epg) of stool. The fecal egg count was repeated 2 to 3 times to ensure the accurate measurement of helminths. The stool and urine analysis were done by a Laboratory technician. In order to detect the presence of hookworms in the stool, the slides were read within 30–60 min of preparation. The type and number of eggs were recorded on a recording form alongside the sample number. Finally, the number of eggs counted on each fecal sample was multiplied by a factor of 24 to get the number of eggs per gram (epg). The epg determined was used to classify the infection as either light (1-999), moderate (1000-9,999) or heavy ($\geq$ 10,000) intensity for *Trichuris*; and light (1-1,999), moderate (2,000-3,999) or heavy ($\geq$ 4000) intensity for Hookworm infections (Montresor *et al.* 2002).

For urine samples, a urine reagent strip (Combi ten) was used to analyze 163 of the urine samples of the subjects to test for the presence of blood. Furthermore, the urine filtration method was used to analyze the urine samples by filtering 10 mL of urine to extract and count the eggs of the worms microscopically in order to estimate the intensity of the infection. Visual measures of hematuria (macrohematuria) was also performed on the urine by trained personnel (World Health Organization 1987). The intensity of *S. haematobium* was classified as either low (</=50 eggs/10 ml urine) or high (>50 eggs/10 ml) (Montresor *et al.* 2002).

Statistical Analysis

All the data collected in this study were entered into Microsoft Excel (2016) and exported into IBM SPSS Version 24 for Windows for all statistical analysis. Descriptive statistics of means, median, standard deviations and ranges were determined for continuous variables (Index child age, caregiver age, among others). Proportions were determined for categorical variables (community type, education level, marital status, number of children in household, toilet facility at home, communal eating among others). This was followed by a bivariate analysis using the Chi square ($\chi2$) and the Fischer Exact tests where appropriate to determine significant differences between the categorical variables (community types, toilet facilities, handwashing habits among others). Univariate and multivariate logistic regression analyses were also conducted to examine the association between the independent variables and the dependent variables. The level of statistical significance was defined at $p<0.05$.

Results

Characteristics of the study participants

The age of the children ranged between 9 and 12 years old with no significant difference in mean age between the communities (p=0.880) (0 1). The mean age of the parents/ caregivers was 40.36 ± 10.11 years (farming) and 37.09 ± 10.20 years (fishing) communities (p=0.41) (Table 3.1). Randomly selected schools were Trebu Primary (28.0%), St. Michael Primary (20.7%), Kwasi Fante Primary (27.4%) and Asanyansu Primary (23.8%) (Table 3.1).

By gender, participants were observed to be 50.6% males and 49.4% females with 55.5% of caregivers being the real mothers of the participants. A significantly higher proportion of mothers were from the fishing communities 59.3% ($p=0.028$). About 84.8% of the children came from a household where both mother and father were present with majority (73.8%) of the parents/guardians being crop farmers. About 43.3% of the parents/guardians had had no formal education while only 10.4% had completed high school (Table 3.1). Over half (57.35%) of the participants were from the Ewe tribe, with a significantly greater proportion of them (93.8%) being in the fishing communities ($p<0.0001$), while overall, 34.1% were from the Northern tribe of Ghana (Table 3.1).

Sanitary conditions of the study population

Overall, 48.8% of the study population obtained their drinking water from the Afram River, whilst 51.2% of them obtained theirs from boreholes. All the participants who had borehole as their drinking water source were from the farming communities whilst those who obtained their drinking water from Afram River were from the fishing communities. Similarly, 50.6% of all the participants versus 49.4% obtained their bathing water from the borehole and Afram River, respectively. About 31.7% of the participants lived close to a water source, and of these, a significantly higher proportion of them were in the farming communities (48.8%) compared to only 13.8% in the fishing communities ($p<0.001$) (Figure 3.2).

Also, a majority of the all children (83.0%) who did not have toilet facilities at home engaged in open defecation and of these, 59.1% were in the farming communities compared to 70.5% of those in the fishing communities ($p<0.0001$). Also, 40.9% of those in the farming communities reported using public latrine, compared to none from the fishing communities.

Prevalence of STH and Schistosoma haemtobium infections

Figure 3.3 shows the prevalence of Soil-Transmitted Helminths (STH) and Schistosomiasis among the participants. Out of 163 children participants who provided their stool samples, 8 of them had the eggs of STH in their stools, of which 3 were eggs of *Trichuris trichiura* (whipworm) and 5 were eggs of Hookworm. All the 8 children with the STH infection lived within the farming communities. No eggs of *Ascaris* nor *S. mansoni* were detected in the stool samples. Of the 164 children who provided their urine, 28 of them had *Schistosoma haematobium* eggs in their urine. No visible macrohematuria was observed in the urine samples, however, a urinary reagent strip analysis showed that 26 children had microhematuria (Figure 3.3).

As shown in Table 3.3, the prevalence of STH in the farming community was only 9.6% with no case found in the fishing communities ($p=0.007$). One (1) child had a light intensity of *Trichuris*, two (2) had moderate infection of *Trichuris*, whilst five (5) of children had a light intensity of Hookworm infection. However, due to the lower prevalence of SHT cases, the major focus of the discussion of our results is based on the statistical analysis of *Schistosoma haematobium* infections (Table 3.3). A significantly higher percentage (33.8%) of *S. haematobium* infection occurred in participants in the fishing communities, whilst only one (1) child in the farming community (1.2%) had the infection ($p<0.0001$).

The intensity of *S. haematobium* was heavy amongst 18 of the infected children in the fishing communities compared to none in the farming communities. Those with light intensity infections in the fishing communities were nine (9) compared to only one (1) in the farming community, ($p=0.357$) (Table 3.3). Microhematuria was observed in 32.5% of children from the fishing communities compared to none in the farming communities ($p<0.0001$) (Table 3.3). Of the children who had urinary schistosomiasis, 9.9% of their parents were crop farmers, 55.6% were fish farmers and 32.4% were in a non-farming occupation ($p<0.0001$). No significant differences were observed in the prevalence of *S. haematobium* infection by age of the child. More females 18.5% than males 15.7% were infected with *S. haematobium*, but this was not significantly different ($p=0.681$).

Hygienic practices and habits of study participants

Among the variables that were considered for hygienic practices, waste disposal method, water treatment method, occasions of handwashing, frequency of handwashing, both adult and index child practice of handwashing after toilet use, type of hand washing agent used, hand washed with soap and water before eating, engaging in pica behavior, engaging in farming activities, swimming in river, and fingernails biting were all significantly different between the farming and fishing communities (Table 3.2). Overall, 59.1% disposed their waste in the bush, with a significantly higher proportion (85.0%) of this practice occurring in the fishing communities compared to 34.5% in the farming communities ($p<0.0001$). Overall, only 26.2% of the participants used the public refuse damp as their site of waste disposal (Table 3.2). Also, 51.8% of the household of the total study participants stored their water in containers (plastic/rubber bowls, buckets, gallons or water jar), with 48.2% storing their water in covered tanks. The habit of always treating drinking water was practiced by 13.4%, whilst 83.5% did not treat their drinking water at all (Table 3.2). The most common water treatment method among those who treated their water was the sieving method which was used by 37.9% of total households. This was significantly practiced among the fishing communities, (63.6%) compared to the farming communities (22.2%) ($p=0.030$). The use of Naphthalene balls was also commonly practiced by 34.5% of all households of participants. Other water treatment methods include the use palm fruit fiber, tank cleaning and Dettol disinfectant (Table 3.2).

The practice of frequent hand washing at home was reportedly practiced by 48.8%, with a significantly higher proportion of this practice occurring in the farming communities (69.0%) than the fishing communities (22.5%) ($p<0.0001$). Overall, the occasion during which hands were mostly washed was ‘before eating and after toilet use’, practiced by 53.0% of all participants, with a significantly higher proportion of this occurring in the farming communities (54.8%) than the fishing communities, (50.7%) ($p=0.025$). Also, a majority (90.2%) of all the adults (caregivers) reported that they washed their hands after toilet use, and this practice among caregivers was significantly higher among those in the farming communities (96.4%) than their counterparts in the fishing communities (83.8%) ($p=0.008$) (Table 3.2). Conversely, a lower percentage (61.0%) of all children reported washing their hands after toilet use, with this practice being significantly higher among children in the farming communities (86.9%), compared to their counterparts in the fishing communities which was just 33.8% ($p<0.0001$) (Table 3.2).

Generally, the most common washing agent reported being used for handwashing was ‘water and soap’ (79.1%), with this practice being significantly higher in the farming communities (91.7%) compared to the fishing communities (65.8%) ($p<0.0001$). Whilst the use of ‘only water’ was reportedly practiced by 20.2% of the total households of participants, it was disproportionately higher in the fishing communities (78.8%) compared to 8.3% of the farming communities ($p<0.0001$) (Table 3.2). About 48.2% of the children reported washing their hands with soap and water before eating which was significantly practiced in the farming communities (67.9%) compared to 27.5% in the fishing communities ($p<0.0001$).

Also, 24.4% of all children who participated in the study engaged in pica behavior (geophagia). This behavior was significantly higher among children in the farming communities (31.0%) compared to those in the fishing communities (17.5%) ($p=0.048$). About 57.3% of all children also reported the habit of fingernail biting with (68.8%) and (46.4%) of them in fishing versus farming communities, respectively involved in this practice ($p=0.005$) (Table 3.2). Whilst majority of all the children (62.8%) swam in the river, a significantly higher proportion of them (78.8%) were from the fishing communities compared to 47.6% of those in the farming communities ($p<0.001$). Similarly, 79.3% of all the children walked barefooted with no significant difference between the two communities (Table 3.2).

Health knowledge and practices towards helminth infections among study participants

As shown in Table 3.3, only 15.2% of the parents/caregivers of the participating children reported having very good knowledge about helminths. The habit of deworming the index child was also reported by 52.4% of all the parents/caregivers. Also, about 14.0% of all the caregivers reported that the index child always complained of abdominal pains, with 8.5% of them seeing blood in their stool (Table 3.3). Overall, 12.8% of all the caregivers reported seeing blood in the index child's urine with 18.8% of these within the fishing communities compared to 7.1% of in the farming communities ($p=0.035$). About 56.7% were reported to have experienced some fever in the past 6 months prior to this study, with significantly higher proportions (70%) occurring in the fishing communities compared to 44.0% of children in the farming communities ($p=0.001$) (Table 3.3).

Predictors of childhood S.haematobium infection

Table 3.4 shows the predictors of childhood *S. haematobium* infection in the Afram Plain South District of the Eastern Region of Ghana. Our univariate analysis shows that swimming in the Afram River and engaging in the practice of fingernails biting were associated with *S. haematobium* infection while using borehole water as both drinking and bathing water source, practicing frequent handwashing and having a toilet facility at home were protective against the infection. In the multivariate analysis adjusting for confounders, drinking water source, engagement in farming activities and water storage remained statistically significant protective predictors of *S. haematobium* infection. Borehole as drinking water source was 97% protective compared to the Afram River as drinking water source and using container for water storage was 84% protective compared to using tank against *S. haematobium* infection among the children studied. As expected, children who reported to swimming in the Afram River were more than 5 times (OR=5.27; 95% CI: 1.15–24.25, p=0.033) more likely to have *S. haematobium* infection (Table 3.4).

Discussion

In this study we evaluated the prevalence and predictors of helminth infections among school age children in farming versus fishing communities in Ghana. There were similarities in index child, caregiver and household characteristics irrespective of community. Significant disparities in hygienic practices and sanitation resources were found between the communities while significant differences in the source of drinking and bathing water, availability of toilet facilities at home (Figure 3.2), handwashing practices, waste disposal methods and water treatment methods were also found.

There were also significant differences in pica practices and habitual fingernails biting between children from farming communities versus those from the fishing communities (Table 3.2). Most importantly, the type of helminth infection differed by the community type (Table 3.3).

The burden of diseases associated with STH and schistosomes is higher in places where there is inadequate coverage of sanitation(Campbell *et al.* 2014). Thus, it is difficult to eliminate helminth infections in areas where there is poor access to water and sanitation. Almost half of all the caregivers (43.3%) had no formal education, which is likely to contribute to the helminth infection rate of their children by virtue of their lack of knowledge, practices and believes (Brooker *et al.* 2001). Significant disparities existed between the two communities in terms of their proximity to drinking and bathing water source, toilet facility at home, waste disposal methods, water treatment methods, handwashing frequency (after toilet use and before eating), washing agent used for handwashing, pica practice, farming activities, swimming in river and fingernail-biting habits. These disparities could be attributed to the close proximity or otherwise of the subjects to a fresh water source which may propagate the transmission of schistosomiasis in the fishing communities as the fresh water source is used for occupational activities such as fishing (Fentiman *et al.* 2001) or domestic activities like cooking, laundry, bathing, drinking etc. (Aryeetey *et al.* 2000).

Overall, children in the fishing communities were observed to engage in unhealthier hygienic practices such as not washing hands after toilet use, not washing hands with soap and water before eating, not washing fruits before eating, using only water as a hand washing agent, engaging in more pica behavior, swimming in the Afram River and finger nails biting than those in the farming communities (Table 3.2). All these poor hygienic practices have been associated with increased rates of helminth infections in other studies (Dankwa *et al.* 2017, Fentiman *et al.* 2001, Steinmann *et al.* 2006).

This study showed a relatively low overall prevalence (4.9%) of STH (Hookwowm and *Trichuris*) in the study communities, whilst the prevalence of urinary schistomiasis (*S. haematobium*) was 17.1%. The generally low prevalence of helminth infection observed could be attributed firstly to a relatively smaller sample size (164) than anticipated and secondly to the regular national deworming program which has been integrated with the School Health Education Program (SHEP), which is run together by the Ghana Education and the Ghana Health Services'

Neglected Tropical Disease Control Program (NTDCP) and other Non-Governmental Organizations with the primary aim of providing periodic dewormers for schistosome and STH control among school-age children (Abdul-Rahman & Agble 2012). Furthermore, the observed prevalence for STH infection (4.9%) in our study was lower than the 12.5% reported in a recent study among 200 pupils in Elmina, a fishing community in the Central Region of Ghana (Dankwa *et al.* 2017). In that study, only stools were examined, but not the urine of the pupils, therefore the presence of urinary schistosomiasis due to *S. haematobium* infection could not be investigated, which was rather highly prevalent in our study (17.1%). These observations suggest that using combined biomarkers may be an effective means of assessing the true prevalence and different species of helminth among children.

The higher prevalence *S. haematobium* observed in the fishing communities confirms an increased risk of schistosomiasis with close contact with fresh water bodies (Rollinson 2009, Steinmann *et al.* 2006). On the contrary, the relatively low *schistosoma haematobium* infection observed among the farming communities could be attributed to improved source of drinking water (borehole) in those communities compared to the Afram River source in the fishing communities. In another study among school-age children in the Amakwa Afram Plains District of Ghana, the most common STH infection found was hookworm (STH) (Fentiman *et al.* 2001), with prevalence rates higher (14.0%) than was observed in our current study. Similarly, another study in the Kintampo North Municipality in the Brong Ahafo Region of Ghana, also observed even higher prevalence rate of 39.1% for hookworm infection among school-age children (Humphries *et al.* 2013). This comparatively lower prevalence (4.9%) observed in our study could be due to the recent deworming program that had taken place in the Kwahu Afram Plains South District 10 months (August, 2016) prior to our study (Interview of headmaster and district nurse), suggesting lower reinfection rates of STH such as hookworm, *Trichuris* and *Ascaris.*

In the southern part of Ghana, another study observed very high prevalence (83.9%) of *S. haematobium* among 354 children. This was much higher than what we observed (17.1%) in the current study. This prevalence suggests pockets of high prevalence of helminth infections (both STH and schistosome) in Ghana which are likely not covered by the periodic deworming program or the lack of knowledge or awareness and appropriate practices by parents/caregivers. The situation calls for evaluation of reach of the national deworming program and awareness of helminth infection among parents/caregivers of children to inform appropriate interventions to eradicate these infections.

Others have asserted that the current diagnostic techniques used in the screening for helminths are usually not sensitive enough to detect light infections, which could be contributing to the underestimation of the helminthiasis burden (King 2010). It is, therefore, also possible that the relatively low prevalence of especially STH observed in the current study may be due to either missing out on the detection of light infections in the children or the collection of a single stool sample from our participants, which could have been improved with the collection of multiple stool samples (Trabelsi *et al.* 2012). Nevertheless, over the years, the prevalence of helminth infections (both STH and schistosomiasis) has declined in Ghana. A recent evaluation of the ongoing national deworming programs among school-age children in the Volta Region of Ghana reported low prevalence rates of helminths infection at 1.2% Ascariasis, 0.91% hookworm infection, 10.3% urinary schistosomiasis and with only 1 infection due to *S. mansoni* (Orish *et al.* 2017). The national prevalence of schistosomiasis in Ghana has also been gradually declining from 72.5% in 2003 to 70.9% in 2010 (Rollinson *et al.* 2013). These observed declining trend of helminth infections could be attributed to the nationwide deworming intervention programs.

In the latter part of the 20th century, the London-based Partnership for Child Development (1999), evaluated the delivery of deworming drugs to children in Ghana, and they also observed that deworming children was cost effective and was beneficial to their health and educational development. Such interventions could also have contributed to the decreasing trend of infections reported in various other studies in different parts of Ghana (Aryeetey *et al.* 2000, Bosompem *et al.* 2004, Orish *et al.* 2017, Rollinson *et al.* 2013).

It is common practice for children to play in water bodies and void their urine during such times. This potentially leads to the deposition of schistosome eggs from infected children into water bodies which propagates the transmission cycle of helminth infections (WHO 2011). With a majority of children in the fishing communities in this study (78.8%) admitting to swimming in a fresh water body (Afram River) compared to only 47.6% of those in the farming communities suggests that those in the fishing communities have more contact with fresh water body than those in the farming communities which is further away from the Afram River (over an hour drive). Frequent contact with fresh water bodies is likely to result in high transmission or prevalent rates of helminth infections even in places where there are improved latrines (Rollinson 2009).

Several studies have also shown that the closeness of human settlements to fresh water bodies and close contact with intermediate freshwater snail hosts create the right environment for disease transmission and high prevalence of helminth infections (Rollinson 2009, Steinmann *et al.* 2006). Thus, it is not very surprising that with the exception of one child who lived in the farming community, the remaining 27 cases of urinary schistosomiasis in this study were among children who lived in the fishing communities. It is likely the single urinary schistosome- infected child from the farming community might have been infected during a visit to families or friends in the fishing community or may have been a regular swimmer in the Afram River. Similarly, in another study, urinary schistosomiasis symptoms were found to be strongly associated with Lake Volta in Ghana where 43% of the children had blood in their urine (microhematuria; a symptom of urinary schistosomiasis), while almost 90% of children who attended school close to the shore of the lake had blood in their urine (Fentiman *et al.* 2001).

In this study, a majority of the total households who did not have toilet facility in their homes engaged in open defecation (83.0%). Similar findings in a study in Cote d'Ivoire observed that open defecation was a common practice among study participants, with only one out of five households having latrines. Thus, open defecation was reported as a determinant for helminths (Acka *et al.* 2010). However, it has been argued that having access to a safe source of water and good sanitation does not always translate into low infection rates of helminths, because it has been shown that the provision of latrines is not always used purposefully by some communities due to the poor maintenance of the facilities (Aagaard-Hansen *et al.* 2009). This could lead to children preferring to engage in the practice of open defecation than using poorly maintained latrines. For instance, 55% of some Kenyan school children complained of dirty latrines whilst 64% and 66% reported strong odor of latrines and uncomfortable latrines respectively, as responses to their impressions of latrines) Exploring the relationship between access to water, sanitation and hygiene and soil-transmitted helminth infection: a demonstration of two recursive partitioning tools. According to data from the 2014 Ghana Demographic and Health Survey (GSS & Demographic 2015), children who lived in households that had improved and unshared toilets (59% nationally) as well as 43% in urban centers were more likely to have their stools safely disposed than those in households without improved toilet facilities (30% nationally) and (37% rural areas). Since a greater proportion of the children within the farming communities in our study had access to toilet facilities at home than those in the fishing communities (Figure 3.2), it possibly contributed to their overall low prevalence of helminth infections observed, since the availability and use of sanitation facilities has been shown to significantly reduce STH infections (Freeman *et al.* 2013). So potentially, the safe disposal of stools among the farming community children protected them from high helminth infections. Sanitation and behavior change, and the prevention of contact with waterbodies or reservoirs/irrigation canals harboring the fresh water snails (intermediate host) are also strategies for helminth control interventions (Rollinson *et al.* 2013). Several studies have also asserted that having access to clean water, whilst improving on sanitary conditions are very important in the prevention of re-infection with helminths after they have been treated (Singer & de Castro 2007).

It is imperative that both adults and children in helminth- endemic areas are given health education to influence behaviors such as a reduction in the direct contact with infested fresh water bodies to reduce helminth transmission as was done in Zanzibar (Stothard *et al.* 2006, Stothard *et al.* 2009). In that study, 42.7% of all caregivers of children said they did not have any knowledge about helminth infections. In some settings, it is not regarded as a health problem at all by those who are infected with helminths in the community (Rollinson *et al.* 2013). In the Ghana Partnership for Child Development (GPCD) intervention study in the Volta Region of Ghana, they reported that most parents in Ghana did not perceive worm infections as a major health problem for children (Brooker *et al.* 2001). Only 4.1% of the parents reported that worms were a health problem for their children. They rather reported headache, fever and malaria as common health problems. Even though our study did not specifically ask caregivers detailed questions on helminth infections, the results in the Tanzania study showed that parents were able to report on symptoms of STH and schistosome. Also, more than 90% of the Tanzanian parents reported blood in urine as a symptom of schistosomiasis. Thus, more parents seemed more knowledgeable about helminth infections in Tanzania (Brooker *et al.* 2001).

In our study, only 52.4% of the caregivers reported to personally deworm their children and this was similar in both communities (farming versus fishing). Treatment for schistosomiasis can, however, have problems with adherence because of the likelihood of people alternating between the orthodox medication provided by healthcare workers and those they personally obtain from local herbalists (Rollinson *et al.* 2013).The existing problems of treatment adherence has also been attributed to other factors such as the level of knowledge of the infection status of the population, their educational level, the availability of transportation, as well as their perceived quality or benefit of treatment (Aagaard-Hansen *et al.* 2009).

Personal hygiene should be one of the focuses of health education in helminth endemic communities(Nock *et al.* 2006). Although the focus of our study was not on the sanitation, water, and hygiene (WASH) conditions within the school setting, it has already been reported by UNICEF that only 46% of schools have regular water supply and only 37% have toilets in priority countries (UNICEF, 2003). The higher frequency of handwashing observed among the farming communities in our study (Table 3.2) may be due to the constant supply of safe portable water obtained through the borehole in the farming communities, in contrast to the water source (Afram River) for those in the fishing communities.

The transmission of helminth eggs/larvae can also be through the oral-fecal route, thus contaminated hands could increase infection rate. Surprisingly, in a study conducted by Dankwa *et al.* (2017), a significantly higher percentage of children who reported washing their hands after toilet use (10%) were found to be positive for STH compared to those who did not (2%) (p=0.004), whilst of those who reported of washing their hands before eating (89.5%), 12.0% of them were still positive for STH infection but this was not statistically different from those who said they washed their hands sometimes or they did not wash their hands at all (Dankwa *et al.* 2017). This observed high prevalence could be attributable to other factors other than handwashing, as 35% of their total study population also engaged in the habit of sucking their fingers. Similarly, fingernail biting was practiced by about 57.3% of children in our study, with a significantly higher proportion of them living within the fishing communities compared to those in the farming communities, which could potentially have increased the helminth infection rates.

With a greater proportion of adults in the farming communities washing their hands after toilet use compared to those in the fishing community, could suggest the break in transmission from mothers (majority of the caregivers) to their children during cooking and serving of their foods in the former. Also, with a greater proportion of children within the farming communities engaging in handwashing than those in the fishing communities, could potentially reduce the contamination of foods and other surfaces with helminth eggs/larvae and ultimately contribute to low infection rates observed in the farming communities (Table 3.2). A majority of households reported using both soap and water (79.1%) for handwashing, with a significant proportion occurring among the farming communities. Conversely, in a study in Kenya among 1,106 pupils in 39 public primary schools, majority of them reported the unavailability of soap for handwashing (Gass *et al.* 2014b).

Pica behavior (geophagia) in our study was practiced by a quarter of the participating children, with majority of them from the farming communities. This could be attributed to a significantly higher proportion of the farming community children having more contact with the soil through farming activities than those in the fishing communities (which may have increased their chances of soil eating habits). Thus, this must have resulted in the observed STH infections (hookworm and *Trichuris*) only among the farming community children. Similarly, lower levels

(13.0%) of geophagia was practiced by pupils in one study in the Nyanza Province of Kenya (Gass *et al.* 2014a). In another study, in the same District of Kenya, 51% of the pupils reported soil eating behavior at home or in school (Freeman *et al.* 2013).

Walking bare footed was not significantly different between the two communities, and was not a predictor of helminth infection, which is in contrast to other studies where they observed that infection with hookworm was higher in pupils who walked barefooted (Dankwa *et al.* 2017). Since the majority of children in our study walked bare footed, they stood at a risk of contracting a soil-transmitted helminth (STH) infection which could occur through the direct penetration of the skin from contaminated soil. So the low levels of STH observed could be attributable to less contamination of the soil though open defecation, especially in the farming areas.

The best predictors for schistosome infections among the children in our study were swimming in the river, water storage method, farming activities, drinking and bathing water source. Children who swam in the Afram River were more likely to get schistosomiasis compared to those who did not (OR: 5.272, CI: 1.147-24.245, p=0.033). Similarly, one main factor that was significantly associated with *S. mansoni* infection among some Ethiopian school children was swimming (Alemayehu *et al.* 2017). Close contact with fresh water bodies have also been implicated in high rates of helminth infections in children living close to the Volta Lake in Ghana (Fentiman *et al.* 2001). This could potentially expose children to schistosome eggs or larvae as they have long contact with the water either through swimming or for occupational activities. This could also explain why children whose water source for either drinking or bathing were from the borehole, compared to those whose source were from the Afram River (farming versus fishing communities) were less likely to be infected with schistosome infections (OR=0.033, CI: 0.004-0.268, p=0.001). Hence, a reduction of exposure to environmental conditions that predisposes individuals to helminth eggs or larvae will potentially be more protective (Fentiman *et al.* 2001). It is therefore important that after deworming interventions, the use of clean water and adequate sanitation are implemented for the reduction of re- infection rates (Asaolu & Ofoezie 2003).

Also, those who stored their water in containers (plastic/ rubber bowls, buckets, gallons or water jar), were less likely to get schistosomiasis compared to those who stored their water in tanks (OR: 0.156, CI: 0.052-0.471, p=0.001). This could be attributed to the convenience of being able to wash the smaller containers frequently than the larger tanks (Table 3.4), because the use and safe storage of water in the home is very important in improving the health benefits of people in the community (Campbell *et al.* 2014).

Conclusions of the Study

Findings from this study shows the current disparities that still exist between fishing and farming communities in rural Ghana in relation to helminth infections (due to STH and schistosomes), as well as the knowledge, attitudes and practices of both adults and children towards it. Overall, *S. haematobium* infection was the most prevalent helminth infection observed among children in this study (17.1%), whilst STH (hookworm and *Trichuris*) infection was 4.9%, no infections due to *Ascaris* or *S. mansoni* were observed.

S. haematobium infection was significantly high in the fishing (33.8%) than the farming (1.2%) communities. This observation could be attributed to children in the fishing communities engaging in more activities in and around the Afram River that potentially exposed them to more schistosome parasites. There were general disparities in sanitation resources and hygienic practices between the farming and fishing communities. There is the need for awareness creation about helminth infection and their transmission in relation to poor hygienic practices and sanitary conditions among both children and adults in helminth endemic areas especially in fishing communities. Future studies should include the assessment of sanitation and hygienic practices in the school environment to determine pertaining conditions and awareness.

Limitations of the Study

Even though this study did not specifically assess the detailed knowledge of caregivers and children on the topic of helminth infections and associated risk factors or symptoms, it thoroughly assessed their hygienic practices and sanitation conditions which have a direct impact on transmission rates. Secondly, although the study placed much emphasis of sanitary conditions and hygienic practices in their homes without assessing such factors in the schools, the prevailing conditions in most high risk schools has already been established (Gass *et al.* 2014a). Thus, we see the hygienic practices and sanitary condition in their home environment as equally likely to impact their health and helminth infection compared to whatever factors they are likely to be exposed to in school. Another limitation is our lack of assessment on frequency of swimming in the Afram River to examine how it influenced helminth infection.

Declarations

Ethical approval

Approval to conduct this study was obtained from the Human Subjects Institutional Review Board of the University of Georgia (STUDY00004580) (See Appendix A), the Ethical Committee Board at the Kwame Nkrumah University of Science and Technology, Ghana (CHRPE/RC/182/17) (See Appendix C), the Regional Director of Ghana Education Service (See Appendix G) and the Regional Director of Health Services of the Eastern Region, Ghana (See Appendix E). The Head teachers of the selected schools that participated also gave permission to conduct the study with pupils in their respective schools. Also, the parents/ caregivers of the participants provided their consent (See Appendix K) for their index child to participate in the study whilst the children gave their assent for the study (See Appendix M).

Acknowledgements

The authors would like to acknowledge the headmasters, teachers and pupils of Trebu District Assembly Primary School, St. Mark School, Kwasi Fanti District Assembly School and Asanyansu Primary School for cooperating with us in the data collection. A big thanks also goes to the Regional Education Office, Koforidua, Eastern Region, as well as the Director of Ghana Education Service, Afram Plains South District, the Regional Director of Ghana Health Service, Koforidua, Eastern Region, and the District Director of Health Service of Afram Plains South for giving us the permission to carry out this study in the district. We also acknowledge the Staff of The Holy Spirit Health Center, especially, Reverend Father Andrew Evans Okwan, Sister Mary Nkrumah and Heriuta Acheaa, for all the assistance they gave during our data collection and analysis in their facility. We would also like to acknowledge the KNUST.

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Table 3.1: Characteristics of Children and Adult Caregivers by Communities.

Variable	Overall N (%)	Farming n (%)	Fishing n (%)	P.Value
Schools in Communities:				
Trebu Primary	46 (28.0%)	0 (0.0%)	46 (57.5%)	<0.0001
St. Michaels Primary	34 (20.7%)	0 (0.0%)	34 (42.5%)	
Kwasi Fante Primary	45 (27.4%)	45 (53.6%)	0 (0.0%)	
Asanyansu Primary	39 (23.8%)	39 (46.4%)	0 (0.0%)	
Adult Interviewed:				
Father	32 (19.5%)	10 (11.9%)	22 (27.5%)	0.028
Mother	91 (55.5%)	54 (59.3%)	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%)	
Tribe:				
Northerners	56 (34.1%)	56 (66.7%)	0 (0.0%)	<0.0001
Ewes	94 (57.35%)	19 (34.1%)	75 (93.8%)	
*Others	14 (8.5%)	9 (10.7%)	5 (6.3%)	
Marital Status:				
Married	139 (84.8%)	61 (72.6%)	78 (97.5%)	<0.0001
^Not married	25 (15.2%)	23 (27.4%)	2 (2.5%)	
Parent/Guardian Highest Education:				
Never attended school	71 (43.3%)	48 (57.1%)	23 (28.7%)	0.001
Elementary school	36 (22.0%)	16 (19.0%)	20 (25.0%)	
Junior High school	40 (24.4%)	22 (14.3%)	28 (35.0%)	
Senior High school	17 (10.4%)	08 (9.5%)	09 (11.3%)	
Parent/Guardian Job Title:				
Crop Farmer	121 (73.8%)	69 (82.1%)	52 (65.0%)	0.008
Fish farmer	9 (5.5%)	0 (0.0%)	9 (11.3%)	
Business Person	18 (11.0%)	6 (7.1%)	12 (15.0%)	
Skilled Worker	8 (4.9%)	5 (6.0%)	3 (3.8%)	
Service Provider	8 (4.9%)	4 (4.8%)	4 (5.0%)	
Number 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%)	

Index Child Gender:				
Male	83 (50.6%)	43 (51.2%)	40 (50.0%)	0.879
Female	81 (49.4)	41 (48.8%)	40 (50.0%)	
Index Child Age:				
9 yrs	49 (30.2%)	23 (28.0%)	26 (32.5%)	0.162
10 yrs	34 (21.0%)	17 (20.7%)	17 (21.3%)	
11 yrs	22 (13.6%)	16 (19.5%)	6 (7.5%)	
12 yrs	57 (35.2%)	26 (31.7%)	31 (38.8%)	

Mean Characteristics of Participants by Communities			
Variables	Communities		P. value
	Farming (mean ± SD)	Fishing (mean ± SD)	
Caregiver Age	40.36 ± 10.11	37.09 ± 10.20	0.41
Index Child Age	10.55 ± 1.21	10.53 ± 1.30	0.88

*Others constitute the ‘Akans’ and the ‘Gas’; ^Not married include adults who are ‘never married’, ‘widowed’ or ‘separated’.

Table 3.2: Participant Hygienic Practices (N=164)

Variables		Communities		P. Value
	Overall N (%)	Farming n (%)	Fishing n (%)	
Waste Disposal Method:				<0.0001
Public refuse dump	43 (26.2%)	38 (45.2%)	5 (6.3%)	
Dug out pit	24 (14.6%)	17 (20.2%)	7 (8.8%)	
Bush	97 (59.1%)	29 (34.5%)	68 (85.0%)	
Water Storage Method:				0.877
Container	85 (51.8%)	43(51.2%)	42 (52.5%)	
Tank	79 (48.2%)	41 (48.8%)	38 (47.5%)	
Treat Drinking Water:				0.658
Always	22 (13.4%)	13 (15.5%)	9 (11.3%)	
Sometimes	5 (3.0%)	3 (3.6%)	2 (2.5%)	
No	137 (83.5%)	68 (81.0%)	69 (86.3%)	
Treatment Method:				0.030
Use Palm fruit fiber	2 (6.9%)	2 (11.1%)	0 (0.0%)	
Tank cleaning	2 (6.9%)	2 (11.1%)	0 (0.0%)	
Sieving	11 (37.9%)	4 (22.2%)	7 (63.6%)	
Use Alum	3 (10.3%)	0 (0.0%)	3 (27.3%)	
Use Dettol Disinfectant	1 (3.4%)	0 (0.0%)	1 (9.1%)	
Use Naphthalene balls	10 (34.5%)	10 (55.6%)	0 (0.0%)	
Frequent Handwashing at Home:				<0.0001
Yes	80 (48.8%)	58 (69.0%)	22 (27.5%)	
Sometimes	70 (42.7%)	26 (31.0%)	44 (55.0%)	
No	14 (8.5%)	0 (0.0%)	14 (17.5%)	

Occasions of Handwashing: Before/After eating After Toilet After Work Before eating and after toilet	 43 (28.5%) 12 (7.9%) 16 (10.6%) 80 (53.0%)	 21 (25.0%) 11 (13.1%) 6 (7.1%) 46 (54.8%)	 22 (32.8%) 1 (1.5%) 10 (14.9%) 34 (50.7%)	0.025
Adult Handwashing After Toilet use: Yes No	 148 (90.2%) 16 (9.8%)	 81 (96.4%) 3 (3.6%)	 67 (83.8%) 13 (16.3%)	0.008
Index Child Handwashing After Toilet Use: Yes No	 100 (61.0%) 64 (39.0%)	 73 (86.9%) 11 (13.1%)	 27 (33.8%) 53 (66.3%)	<0.0001
Wash hands with Soap and Water Before Eating: Yes No	 79 (48.2%) 85 (51.8)	 57 (67.9%) 27 (32.1%)	 22 (27.5%) 58 (72.5%)	<0.0001
Hand Washing Agents Used: Water only Water and soap Ash	 33 (20.2%) 129 (79.1%) 1 (0.6%)	 7 (8.3%) 77 (91.7%) 0 (0.0%)	 26 (78.8%) 52 (65.8%) 1 (1.30%)	<0.0001
Communal Eating: Yes No	 146 (89.0%) 18 (11.0%)	 73 (86.9%) 11 (13.1%)	 73 (91.3%) 7 (8.8%)	0.457
Engage in Pica Behavior: Yes No	 40 (24.4%) 124 (75.6%)	 26 (31.0%) 58 (69.0%)	 14 (17.5%) 66 (82.5%)	0.048
Wash Fruits Before Eating: Yes No	 121 (73.8%) 16 (9.8%)	 66 (78.6%) 18 (21.4%)	 55 (68.8%) 25 (31.3%)	0.161

Engage in Farming Activities: Yes No	129 (78.9%) 35 (21.3%)	78 (92.9%) 6 (7.1%)	51 (63.8%) 29 (36.3%)	<0.0001
Index Child Barefooted Outside: Yes No	130(79.3%) 34 (20.7%)	68 (81.0%) 16 (19.0%)	62 (77.5%) 18 (22.5%)	0.701
Swim in River: Yes No	103 (62.8%) 61 (37.2%)	40 (47.6%) 44 (52.4%)	63 (78.8%) 17 (21.3%)	<0.0001
Fingernails Biting: Yes No	94 (57.3%) 70 (42.7%)	39 (46.4%) 45 (53.6%)	55 (68.8%) 25 (31.3%)	0.005

Table 3.3 Helminth Infections and Participant Health Knowledge and Practices (N=164)

Variable		Communities		P. Value
	Overall N (%)	Farming n (%)	Fishing n (%)	
Caregiver's Helminth Knowledge				
Very well	25 (15.2%)	12 (14.3%)	13 (16.3%)	0.859
Not adequate	69 (42.1%)	37 (44.0%)	32 (40.0%)	
No	70 (42.7%)	35 (41.7%)	35 (43.8%)	
Caregiver Deworms Index Child:				
Yes	86 (52.4%)	46 (54.8%)	40 (50.0%)	0.639
No	78 (47.6%)	38 (45.2%)	35 (50.0%)	
Frequency of Abdominal Pains in Index Child:				
Always	23 (14.0%)	13 (15.5%)	10 (12.5%)	0.381
Sometimes	86 (52.4%)	47 (56.0%)	39 (48.8%)	
Never	55 (33.5%)	24 (28.6%)	31 (38.8%)	
Blood in Index Child's Stool:				
Never	150 (91.5%)	76 (90.5%)	74 (92.5%)	0.782
Sometimes	14 (8.5%)	8 (9.5%)	6 (7.5%)	
Blood in Index Child's Urine:				
Never	143 (87.2%)	78 (92.9%)	65 (81.3%)	0.035
Sometimes	21 (12.8%)	6 (7.1%)	15 (18.8%)	
Index Child's Experience of Fever in 6 Months:				
Yes	93 (56.7%)	37 (44.0%)	56 (70.0%)	0.001
No	71 (43.3%)	47 (56.0%)	24 (30.0%)	
Helminth Eggs in Index Child's Stool:				
Yes	8 (4.9%)	8 (9.6%)	0 (0.0%)	0.007
No	155 (95.1%)	75 (90.4%)	80 (100%)	
S. haematobium Eggs in Index Child's Urine:				
Yes	28 (17.1%)	1 (1.2%)	27 (33.8%)	<0.0001
No	136 (82.9%)	83 (98.8%)	53 (66.3%)	
S. haematobium Intensity:				
Light	10 (35.7%)	1 (100%)	9 (33.3%)	0.357
Heavy	18 (64.3%)	0 (0.0%)	18 (66.7%)	
Microscopic Blood in Index Child's Urine:				
Yes	26 (16.06)	0 (0.0%)	26 (32.5%)	<0.0001
No	137 (84.0%)	83 (100%)	54 (67.5%)	

Table 3.4: Predictors of Childhood *S. haematobium* Infection in the Kwahu Afram Plains South District

Variable	n	Unadjusted OR (95%CI)	P. Value	Adjusted OR (95% CI)	P. Value
Drinking Water Source:					
Borehole	84	0.024 (0.003-0.179)	<0.0001	0.033 (0.004-0.268)	0.001
Afram River	80	1			
Bathing Water Source:					
Borehole	83	0.024 (0.003-0.185)	<0.0001	-------	-------
Afram River	81	1			
Fingernails Biting:					
Yes	94	4.211 (1.513-11.725)	0.006	-------	-------
No	70	1			
Toilet Facility at Home:					
Yes	58	0.177 (0.051-0.614)	0.006	-------	-------
No	106	1			
Engage in Farming Activities:					
Yes	129	0.183 (0.076-0.438)	<0.0001	0.267 (0.080-0.884)	0.031
No	35	1			

Swim in River:					
Yes	103	4.329 (1.424-13.162)	0.01	5.272 (1.147-24.245)	0.033
No	61	1			
Water Storage:					
Container	85	0.248 (0.099-0.622)	0.003	0.156 (0.052-0.471)	0.001
Tank	79	1			
Frequent Handwashing at Home:					
Yes	80	0.278(0.071-1.094)	0.067	-------	-------
Sometimes	70	0.741 (0.205-2.682)	0.648		
No	70	1			
Shoes Worn to School:					
Yes	140	0.429 (0.158-1.159)	0.095	-------	-------
No	24	1			

The multivariate analysis was adjusted for 'Index Child Age' and 'Community type'. Hosmer and Lemeshow Test: Chi-Square=1.974, p- value=0.982.

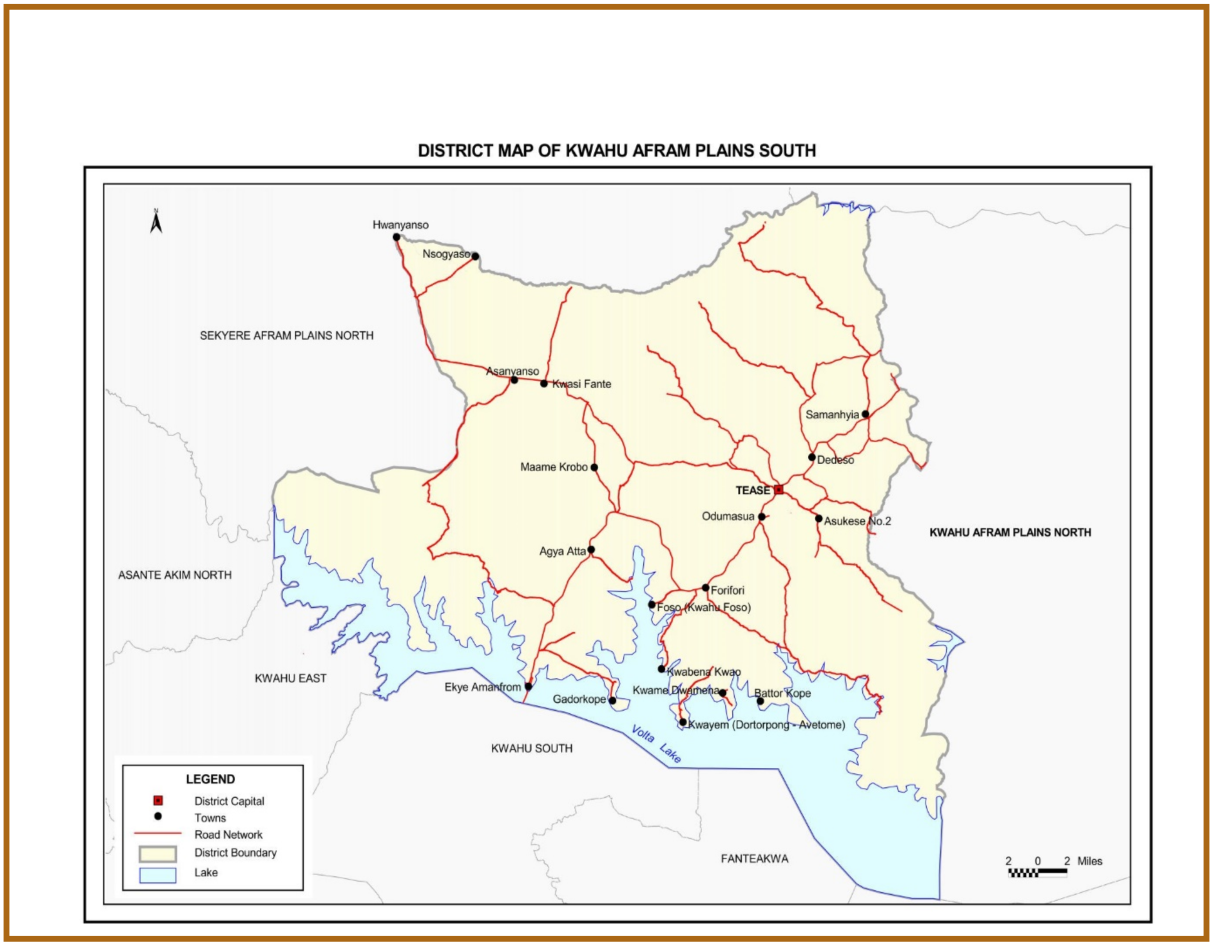

Figure 3.1: Map of Kwahu Afram Plains South

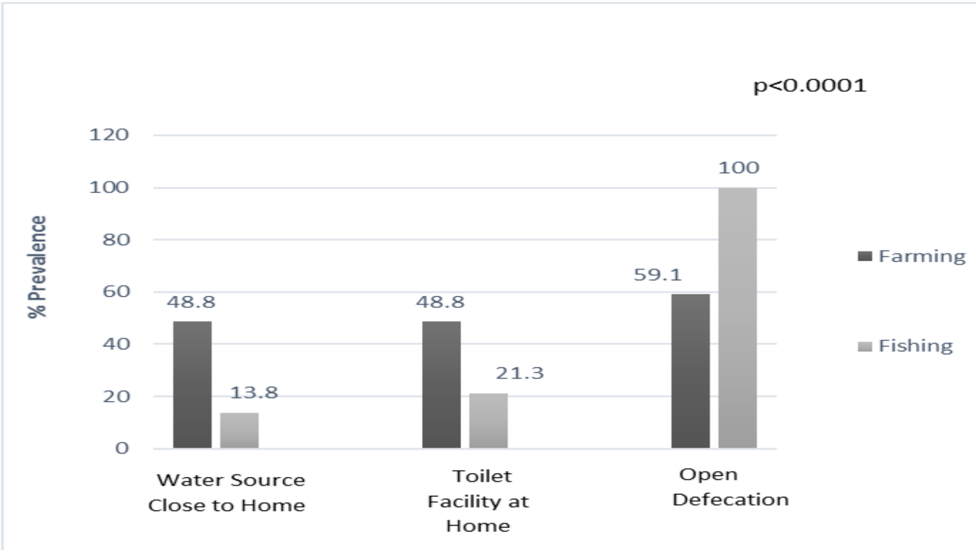

Figure 3.2: Sanitary Conditions by Community Type

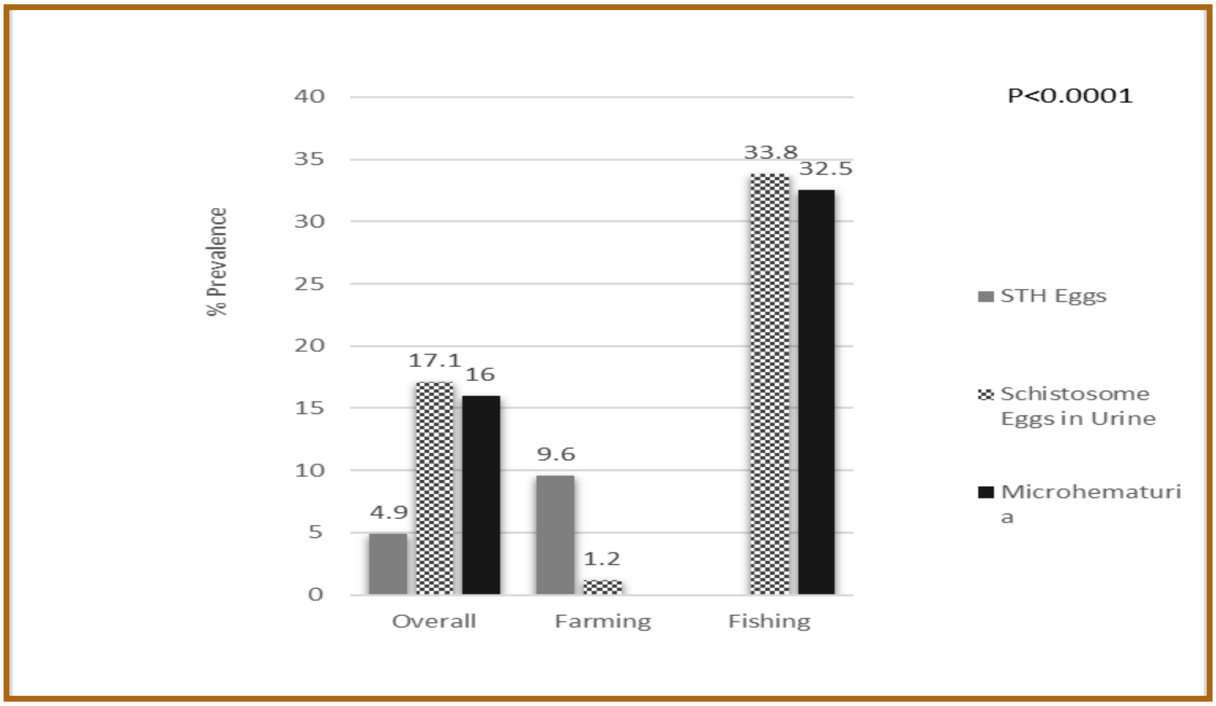

Figure 3.3: Helminth Prevalence

CHAPTER 4

NUTRITIONAL AND COGNITIVE DEFICITS OF SCHOOL-AGE-CHILDREN A STUDY IN HELMINTH-ENDEMIC FISHING AND FARMING COMMUNITIES IN GHANA

Tandoh MA, Mills-Robertson FC, Wilson MD and Anderson AK. Submitted to *Emerald Insight, Nutrition and Food Science .2019.*

Abstract

Purpose - This study sought 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. Methodology - This was a cross sectional study involving 164 (9 to 12 year 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, 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 10.53 ± 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 13.09 ± 4.57µmol/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 females ($p=0.117$). There was no significant difference in the Raven's Colored Progressive Matrices (RCPM) 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.

Introduction

Undernutrition and helminth infections are common problems among children in low-and middle-income countries (LMICs) (Kosinski *et al.* 2012, Shaw & 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 *et al.* 2006, Hotez *et al.* 2008, WHO 2011b), with infections occurring as early as age 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 to 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 (*S. haematobium*, *S. mansoni* and/or *S. japonicum*) affects about 200 million people in of the world (WHO 2011a).

Undernutrition, a common consequence of helminthiasis (Ayeh-Kumi *et al.* 2016, Hailegebriel 2018, Sanchez *et al.* 2013, Shaw & Friedman 2011, Tandoh *et al.* 2015), is still a public health problem with an estimated 16%, 26% and 8% of children globally being underweight, stunted and wasted, respectively (Carmen Casanovas *et al.* 2013). In Ghana, 19%, 11% and 5% of children under five are reported stunted, underweight and wasted, respectively (GSS 2015). Stunting in Ghana occurs more (22%) in rural areas than in the urban areas (15%).

Similarly, underweight also occurs more in rural children (13%) than those in urban areas (9%) (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% of children in urban areas are more likely to dispose their stools safely compared to 37% 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 & Bharati 2012), with over two (2) 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 & 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 existing underlying problem of undernutrition (Coutinho *et al.* 2006) as well as impair cognitive function and development (Drake & Bundy 2001, Drake *et al.* 2000) of SAC.

Helminths tend to affect optimal health (Hailegebriel 2018, Njaanake *et al.* 2015), 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 & 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 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 9-12 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 (4) schools were randomly selected (2 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) (See Appendix A) and the Ethical Committee Board at the Kwame Nkrumah University of Science and Technology, Ghana (CHRPE/RC/182/17) (See Appendix C). Also, the Regional Directors of the Ghana Education Service (See Appendix G), Ghana Health Services of the Eastern Region (See Appendix E) 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 (See Appendix K), whilst the children provided assent for their participation (See Appendix M).

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) 9-12 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 (See Appendix O).

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) (See Appendix P).

Dietary assessment (24-hour recall)

A 3-day 24-hour dietary recall (2 week days 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 & 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 BMI-for-age z-scores

(BAZ) for each participant using the WHO anthropometric calculator (Anthro Plus version 1.0.3, http://who anthroplus.software.informer.com/1.0/). Children who fell below minus two standard deviations (-2SD) from the median of the reference population were classified as moderately malnourished, whereas those who fell below minus three standard deviations (-3SD) were classified severely malnourished, with those above -2SD 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 5 mL 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 ºC 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 µmol/L (10-year-olds for both gender), <10.7 µmol/L (≥10year-old-males) and <10.1 µmol/L (≥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 ≤11 year olds were 115 g/L or higher (non-anemia), 110 g/L-114 g/L (mild anemia), 80-109 g/L (moderate anemia), and <80 g/L (severe anemia) whilst for the 12-14 year olds, the cut-offs were 120 g/L or higher (non-anemia), 110 g/L-119 g/L (mild anemia), 80-109 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 previous 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 to12 years (7 males and 8 females) 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 (See Appendix S), is made up of 36 items in three sets of 12. The three sets of 12 problems which 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) whilst 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. Since 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% (≥18) were classified as 'passed' whilst those who scored below 50% (<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 (χ^2) and the Fischer Exact tests where appropriate to determine significant differences between the categorical variables.

Univariate logistic regression analyses was 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 $p<0.05$.

<u>Results</u>

Characteristics of the Study Population by Communities

One hundred and sixty-four (164) school-age-children between the ages of 9 and 12 (10.53 ± 1.25) together with their primary caregivers were recruited from two communities; farming (n=84) and fishing (n=80). Table 4.1 presents a description of the study participants. The majority of caregivers were mothers (55.5%), with 64.3% being in the farming compared to 46.3% in the fishing community (p=0.028). About 5.5% 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%) compared to the farming (72.6%) 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%) compared to the fishing (28.7%) community (p=0.001). Also, about two-thirds of all the caregivers were crop farmers, with 82.1% being in the farming versus 31.3% 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%) compared to those in the fishing (17.5%) community (p=0.045). The overall prevalence of helminthiasis (STH and/or schistosome) was 22%, with 10.7% occurring in the farming versus 33.8% in the fishing community (p<0.0001) (Table 4.1).

Participants Nutritional and Cognitive Characteristics by Communities

Table 4.2 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 -0.68 versus -1.03 for children from the farming compared to the fishing communities, respectively (p=0.03.), whereas the mean HAZ (stunting) was -0.97 versus -0.63 for the farming versus the fishing communities, respectively ($p=0.09$). The mean blood hemoglobin levels were similar while 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 (328.03 g/d), compared to their counterparts in the farming community (265.15 g/d) ($p=0.003$). Conversely, the estimated vitamin C intake was higher among children in the farming community (131.92 mg/d) than those in the fishing community (71.50 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) (Fig. 4.1). The mean scores on the cognitive test were similar between the two communities, with children in the farming community performing slightly better (12.48 ± 5.47) compared to their counterparts in the fishing community (12.19 ± 6.10) ($p=0.749$), whereas for school attendance, children in the fishing community recorded a higher average attendance of 22.80 days out of 28 days, compared with children in the farming community (21.15 days) (Table 4.2).

Index Child Nutritional Status

Overall, the total calorie and zinc intake of children were inadequate (75.0% and 65.9%, respectively) (Fig. 4.1). Similarly, there was no significant differences in the total dietary intakes of carbohydrate, protein, iron and vitamin C with regards to their adequacies (Fig 4.1).

Based on the BMI-for-Age z-score (BAZ) values, however, 7.5% 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 4.3). Similarly, for stunting (HAZ), overall, 13.8% of the children were stunted, with those in the fishing community having a higher stunting rate (15.0%) than those in the farming community (12.5%) (p=0.646). The male children generally exhibited a better nutritional outcome than the females, with the exception of anemia, which was higher among males (60.2%) compared to the females (45.6%) (P=0.061) (Table 4.3). 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=0.532), and zinc deficiency (p=0.16) (Table 4.3). Helminth–infected children exhibited a higher prevalence of anemia (69.4%) compared to their non-infected counterparts (48.4%) (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 4.3).

About 22.4% 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 4.3). Over half of the children were anemic (53.1%) with no significant differences in anemia prevalence between the two communities (p=0.867) (Table 4.3).

Index Child Cognitive Performance

Table 4.1 shows that more children in the fishing community (16.0%) met the pass mark of 50% set for the RCPM cognitive test, compared to their counterparts in the farming community (14.5%), although not significantly different (p=0.79) (Table4.1). Table 4.4 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: 12.48 ±5.47 versus Fishing: 12.19 ±6.10) (p= 0.75). Also, there were no significant differences between status of helminthiasis and the cognitive test scores (p=0.679). 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 4.4).

Table 4.7 shows a binary logistic regression performed to determine the predictors of cognitive performance. Helmminthiasis 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 4.6). 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 4.6).

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 4.1, most of the caregivers were mothers (55.5%) while 5.5% were male guardians of the index child, other than the father. The prevalence of intestinal helminthiasis as reported in the parent study was 4.9% while urinary schistosomiasis was 17.1% (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%, and this was significantly higher among children living in the fishing community (33.8%) compared to those in the farming community (10.7%) (Table 4.1).

Even though an overall prevalence of stunting (13.8%) was observed in the current study with a majority of them within the fishing (15.0%) than the farming (12.5%) community, this is in contrast to findings from a study by Fentiman *et al.* (2001), which reported a higher prevalence of stunting (44%) 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% 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%) 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 & 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 4.3) could be attributed to a lack of well-defined nutrition policy and public health interventions in some LMICs (Getachew & 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 & Rockers 2014, Lundeen *et al.* 2014). Also, the observation that 12 year olds had the worst nutritional outcomes in this study (Table 4.3) 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 4.3) is also in contrast to findings in a Southern Regional Ethiopian study in which there were higher stunting rates among boys than girls (30% vs 22%) ($p=0.037$) (Getachew & 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%) compared to males (15.7%) ($p=0.68$) 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 4.3) 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 & 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 4.5), 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. 4.1), 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%) (Table 4.3) 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%) (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 4.3), with over half of the children (53.1%) being anemic with no significant differences in anemia prevalence between communities ($p=0.867$). 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 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%) in the current study was nevertheless similar to findings by Fentiman *et al.* (2001), who reported (56%) 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 (Fig. 4.1), which are required together with other micronutrients for normal erythropoiesis (Friis *et al.* 2003).

Similarly, Egbi (2012), reported much higher prevalence of anemia (72%) 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%) compared to about one-half of non-infected children (48.4%) (Table 4.3) 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%) than females (45.6%) ($p = 0.061$) in this study (Table 4.3), 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 4.6). 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% and 5.2% 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=0.684) (Table 4.2). Moreover, compared to the baseline RCPM (0-30) mean test scores (17.31 ± 2.56) of a study among 555 SAC in rural Kenya (Whaley 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 since 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% versus 10.7%) (p=<0.0001) (Table 4.1), with a significant difference of *S.haematobium* infection also occurring between children from the two communities; fishing (33.8%) versus farming (1.2%) ($p<0.0001$) in the report from the parent study (Tandoh *et al.* 2018). This was similarly observed in terms of school attendance, again with children in the fishing community having a higher absenteeism rate than those in the farming community (p=0.033) (Table 4.1). This could be attributed to children in the fishing community having more contact with the Afram river through swimming (Tandoh *et al.*, 2018) and/or engaging in more commercial activities in the river such as fishing (Fentiman *et al.* 2001), hence being exposed to the larvae of the schistosome parasites whose life-cycle is dependent on an intermediate fresh water snail host.

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 4.4). Similarly, the binary logistic regression did not show any association between the cognitive performance of the children, and their anthropometric, as well as their biochemical (helminthiasis, Hb and serum zinc) levels (Table 4.7). 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 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 since it was a cross-sectional study, 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 & 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 prior to 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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Table 4.1: Characteristics of the Study Population by Community Type

Variable	Overall n (%)	Farming n (%)	Fishing n (%)	P.Value
Primary Caregiver				
Father	32 (19.5)	10 (11.9)	22 (27.5)	0.03
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				
9yrs	49 (30.1)	23 (27.7)	26 (32.5)	0.162
10yrs	35 (21.5)	18 (21.7)	17 (21.3)	
11yrs	22 (13.5)	16 (19.3)	6 (7.5)	
12yrs	57 (35.0)	26 (31.3)	31 (38.8)	
Index Child Gender				
Male	83 (50.6)	43 (51.2)	40 (50.0)	0.879
Female	81 (49.4)	41 (48.8)	40 (50.0)	
Pica Practice				
Yes	40 (24.4)	26 (31.0)	14 (17.5)	0.045
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)	0.787
Pass	24 (15.2)	12 (14.5)	12 (16.0)	

Farming community schools (Kwasi Fanti D/A Primary & Asayansu R/C Primary)
Fishing community schools (Trebu D/A Primary & St. Michael Primary)
Index Child (the child of the caregiver who is being studied)

Table 4.2: Nutritional and Cognitive Measures of Participants by Community Type

Variables	Farming (Mean ± SD)	Fishing (Mean ± SD)	P. Value
Index Child Age (years)	10.55 ± 1.21	10.53 ± 1.30	0.90
Height-for-Age-Z (Stunting)	-0.97 ± 0.93	-0.63 ± 1.49	0.09
BMI-for-Age-Z (Underweight)	-0.68 ± 0.83	-1.03 ± 1.20	0.03
Hemoglobin (g/L)	11.53 ± 1.04	11.59 ± 1.24	0.77
Serum Zinc (µmol/L)	10.44 ± 2.57	15.84 ± 4.58	<0.0001
Total Energy /Day (Kcal)	1715.70 ± 642.57	1897.33 ± 898.37	0.14
Total Carbohydrate (g/d)	265.15 ± 99.59	328.03 ± 162.19	0.003
Total Protein (g/d)	48.32 ± 23.70	53.25 ± 27.25	0.22
Total Zinc (mg/d)	7.30 ± 5.04	10.30 ±15.84	0.10
Total Iron/ (mg/d)	10.66 ± 5.89	11.63 ± 7.37	0.35
Total Vitamin C (mg/d)	131.92 ± 73.54	71.50 ± 25.11	0.001
Raven's Cognitive Test Score	12.48±5.47	12.19±6.10	0.75
School Attendance	21.15±4.91	22.80±4.86	0.03

Helminthiasis represents infection due to both /either Soil-Transmitted Helminths (STH) and Schistosome

Table 4.3: Nutritional Deficiencies by Community, Gender, Age and Helminthiasis Burden

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								
9yrs	3 (6.1)	0.001	3 (6.1)	0.43	5 (10.4)	0.16	28 (57.1)	0.53
10yrs	2 (5.9)		3 (8.8)		8 (24.2)		15 (44.1)	
11yrs	1 (4.8)		0 (0.0)		5 (23.8)		10 (47.6)	
12yrs	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)	0.02	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)	

Table 4.4: 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	12.48 ± 5.47	0.749
Fishing	12.19 ± 6.10	
Gender		
Male	13.12 ± 5.97	0.074
Female	11.44 ± 5.51	
Age (Years)		
9 yrs	10.38 ± 5.33	0.142
10 yrs	12.00 ± 4.22	
11 yrs	12.40 ± 5.88	0.270
12 yrs	14.24 ± 6.47	
Helminthiasis		
Yes	12.71 ± 5.13	0.679
No	12.24 ± 5.94	
Anemia		
Yes	12.37 ± 6.08	0.961
No	12.32 ± 5.48	
Zinc Deficiency		
Yes	13.39 ± 4.66	0.218
No	12.03 ± 6.06	

$P<0.05$

Table 4.5: Predictors of Childhood Anthropometric Measures of Undernutrition

	Stunting			Underweight		
Variable	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

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 4.6: 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		----	----

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.

Table 4.7: Predictors of Cognitive Performance

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		
Anemic	82	0.49 (0.20-1.23)	0.45 (0.16-1.23)
		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

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.

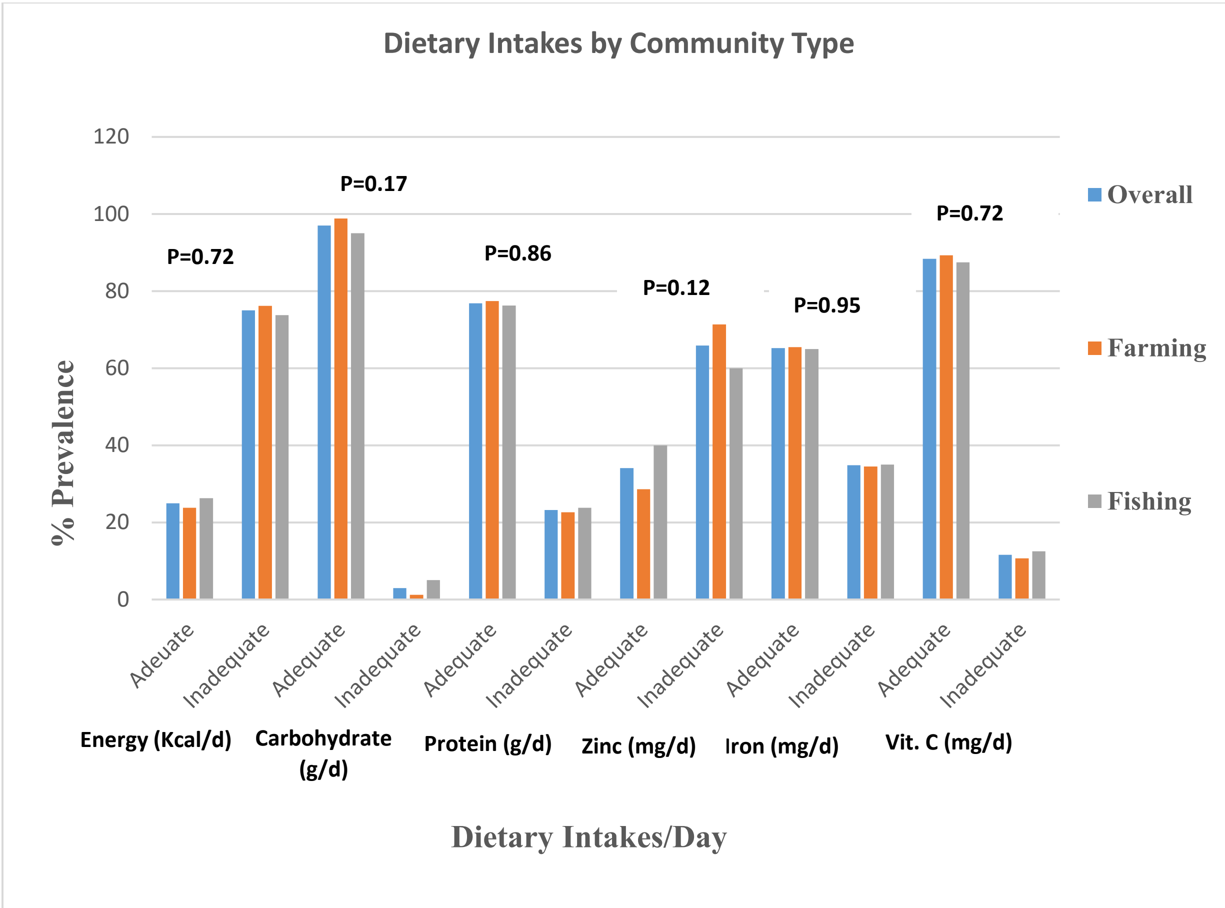

Fig 4.1. Estimated Total Daily Dietary Intakes of Index Child N=164

CHAPTER 5

A COMPARISON OF INTERVENTION STRATEGIES TO IMPROVE NUTRITION AND COGNITIVE STATUS AMONG SCHOOL-AGE CHILDREN IN HELMINTH ENDEMIC FISHING AND FARMING COMMUNITIES IN GHANA

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Abstract

Helminth infections continue to be a public health problem afflicting populations in the Low-Middle Income Countries. It is associated with morbidities leading to undernutrition in school-aged children (SAC). This intervention study was a community trial which sought to evaluate how 3 main intervention strategies using 'Nutrition Education Only' (NutEd Only), 'Supplementation Only' (Suppl Only), 'Nutrition Education+Supplementation' (NutEd+Suppl) versus a 'Control' (Deworming Only) impacted the nutrition and cognitive status of SAC living in helminth-endemic fishing and farming communities in the Kwahu Afram Plains South District of Ghana. Overall 358 SAC were recruited, comprising of 8 randomly selected schools (4 schools from fishing and 4 schools from farming communities). Data was obtained through a questionnaire, anthropometry and parasitology (fecal and urine) assessment. Hemoglobin (Hb) and whole blood zinc levels were also ascertained using the HemoCue Hb 201^{+} portable analyzer and the Flame atomic absorption spectroscopy (FAAS) respectively. The Ravens Colored Progressive Matrices (RCPM) was used for cognitive assessment. At baseline, 7.5% of all the children were underweight, 11.2% were stunted and 21.5% were acutely malnourished, whereas 46.1% were anemic and 31.4% were zinc deficient. At the 6th month (post intervention), anemic rates were significantly different between children in the fishing (8.1%) versus those in the farming community (23.6%) ($p<0.0001$). Also, rates of underweight was significantly lower among children in the farming (1.2%) than those in the fishing community (9.6%) ($p=0.002$). Children in the fishing community significantly had higher RCPM scores (16±6.9) than those in the farming community (14.5±6.3) ($p=0.010$). Univariate analysis showed that, compared to the 'Control group', the 'NutEd Only group' was significantly associated with less likelihood of stunting (OR=0.205, CI; 0.04-0.10). Also, the 'NutEd Only group' (OR=0.29, CI; 0.13-0.69) and the 'NutEd+Suppl group' (OR=0.34, CI; 0.13-

0.85) were significantly associated with less likelihood of anemia. The 'NutEd Only group' (OR=6.40, CI; 1.39-29.50) and the 'Suppl Only group' (OR=6.04, CI; 1.27-28.77) were significantly associated with more likelihood of zinc deficiency. These findings indicate that provision of nutrition education together with micronutrient supplementation in addition to existing deworming interventions have the prospect to reduce undernutrition prevalence and improve on cognitive performance among SAC.

Introduction

Helminthiasis is a parasitic infection caused by either Soil-Transmitted Helminths (STH) and/or schistosomes (schistosomiasis), and it remains one of the most common infections across the globe, which affects the most deprived communities, where poor sanitation and hygiene exist (Gizaw *et al.* 2019). Poor sanitation is implicated in several disease conditions such as STH infections, trachoma, lymphatic filariasis and schistosomiasis (Clasen *et al.* 2012). Also, because schistosomiasis is transmitted in infested freshwater streams and lakes, school-aged children (SAC) are mostly at greater risk of exposure to the infection (Uneke 2010).

The presence of a STH infection in an individual can be ascertained in two ways; the direct method (where expelled worms from an individual are counted after administering an anthelminthic treatment) or indirectly (where eggs of helminths which have been excreted into the feces are counted). The fecal excreted eggs in the indirect method are counted as the number of eggs per gram of feces (epg), and it is the most common and convenient method used to ascertain a helminth infection(Montresor *et al.* 2002). The indirect method is also used to examine the urine for schistosome eggs, and this is done by examining the eggs in 10 mL of urine.

The classification of helminths infection is based on the intensities of infection such as 'no infection', light, moderate or heavy infection; usually expressed in eggs per gram (epg) of feces, or in the case of schistosomiasis, eggs per 10mL of urine (WHO 2002). Light helminth infections may not usually show symptoms, but have been implicated in adverse health and nutritional deficiencies including iron deficiency anemia, protein energy malnutrition, stunting among others in children (Bethony *et al.* 2006, King *et al.* 2005). The intensity of infection with *Ascaris lumbricoides* for example has been associated with factors such as gender, ethnicity, agriculture and style of housing among children in Madagascar (Kightlinger *et al.* 1998).

Ghana is beset with a high burden of helminthiasis, with schistosomiasis being the most prevalent type (70.9%) (Rollinson *et al.* 2013). Furthermore, the burden of under nutrition among children globally is still high especially in Low-Middle-Income Countries (LMICs), with Ghana being part of the 36 countries with the highest prevalence rate of stunting (Black *et al.* 2008). Childhood undernutrition is a significant public health burden with recent rates of stunting, wasting and underweight in Ghana being 19%, 5% and 11% respectively (GSS & Demographic 2015).

Infections with helminths tend to increase the nutritional burden of their host since their prevailing relationship with the host is primarily parasitic in nature. For instance, infections by *Schistosoma haematobium*, causes blood loss, and also have a strong association with iron-deficiency anemia among children (Tandoh *et al.* 2015). Impairment of physical growth (Wolde *et al.* 2015) and poor cognitive performance (Ezeamama *et al.* 2005) have also been implicated with an increased burden of helminthiasis. Hookworm infections have also been implicated in iron-deficiency anemia due to intestinal blood losses (Crompton & Nesheim 2002). Factors such as community of residence (Danquah *et al.* 2012, Fentiman *et al.* 2001), schistosomiasis infection (Mahgoub *et al.* 2010), and pica (ingestion of non-food items) behavior (Geissler *et al.* 1998), have been implicated in poor nutritional outcomes of children. Similarly, Humphries *et al*. (2011), also reported some behavioral factors such as lack of latrine, walking barefooted, engage in farming as an occupation and poor nutritional status as risk factors for hookworm infection among 292 subjects in Kintampo North of Ghana.

To lessen the public health burden of helminth infection and its associated morbidities, the world Health Organization has developed some intervention strategies to address the burden of helminthiasis, especially among school-age children since they are considered the most at-risk group. The primary aim of their proposed intervention strategy was to ameliorate the load of parasitic infections and keep prevalence rates at a low level, which will have the potential of improving growth and learning abilities among SAC (Montresor *et al.* 2002). The key components of the proposed intervention strategies by the World Health Organization targeted at helminth control have focused on four key areas (Montresor *et al.* 2002, Rollinson *et al.* 2013) which include;

i. The use of mass drug administration (also known as preventive chemotherapy/periodic drug treatment) with the primary aim of killing the adult worms.
ii. Clean water and sanitation through the prevention of helminth infection of humans by avoidance of fresh water contact.
iii. Health and hygiene education; which focuses on improved hygiene behavior and sanitation habits leading to reduced contamination of the environment and water bodies.
iv. The use of biological/chemical control of vector snails which transmits the parasite in fresh water bodies (in the case of schistosomiasis).

Based on these outlined components, a strategic plan has been introduced for the eradication and elimination of helminth infections with a primary focus on the provision of preventive chemotherapy (periodic deworming) for at-risk groups living in helminth-endemic areas. This strategic plan also aims to use health and hygiene education to promote behavioral change that seeks to reduce helminth transmission rates, and provide safe water and sanitation (WHO 2012). In order to control morbidities that are associated with helminth infections, the WHO strategic plan focuses on populations that are at risk of helminth infections, which include children, adolescents, women of childbearing age (15 to 49 years) and pregnant women (within second and third trimesters) (WHO, 2017).

Current recommendations for infection treatment are that an annual single dose of 400 mg of albendazole or 500 mg of mebendazole be administered in areas with baseline STH prevalence of more than 20%. However, in areas with STH prevalence above 50%, the same dosage recommended should be administered twice a year (Abraham *et al.* 2018). Most interventions have been targeted at school children since they are considered to be the most at-risk group and the school structure serves as an existing infrastructure from which majority of the at-risk groups can be easily targeted. Better still, the interventions from schools can easily be extended to other populations in the whole community such as pre-school children and pregnant mothers (Montresor *et al.* 2002).

The main drug for schistosomiasis in sub-Saharan Africa is praziquantel (Utzinger *et al.* 2011), and even though treatment with deworming drugs such as praziquantel are safe and effective in helminthiasis treatment, they do not provide 100% cure rates nor prevent re-infection, with reported cure rates of 85-90% reported by Olliaro *et al* (2011). Moreover, there is the likelihood of prevalence rates returning to their baseline levels by the 18th month after treatment (Gray *et al.* 2010). Hence, the need for further control measures to prevent re-infections (Urbani *et al.* 2002).

There are a lot of intervention strategies and recommendation which have been used in the control of helminth infections, especially in children. One of such interventions is the use of 'Water, Sanitation and Hygiene' (WASH) program which has been used to reduce rates of helminth infection. For instance, the water treatment, improved sanitation and handwashing interventions have been associated with reduced prevalence of soil-transmitted helminth (STH) infection and reduced re-infection intensity (Steinbaum *et al.* 2019). In one study, the WASH intervention approach was used to investigate the effect of providing households with a pit latrine with a plastic slab and drop-hole cover and child feces management tools on reducing STH eggs in 2,107 households' soil in rural Kenya. The study found that households with WASH intervention (17.0%) had slightly lower prevalence of STH eggs in soil, compared to household without WASH intervention (18.9%). The authors, however, indicated that the WASH intervention did not significantly lower STH eggs in households in rural Kenya, and that WASH intervention alone may not be enough to improve STH infection in endemic areas where latrine coverage is already high (Steinbaum *et al.* 2019) .

Nutritional interventions have been suggested as part of the intervention strategies that can be integrated with a deworming program targeted at SAC to improve nutrition status and nutrient deficiencies as a result of chronic helminthiasis (Montresor *et al.* 2002, Solon *et al.* 2003). This is particularly important as the global prevalence of micronutrient malnutrition is over 2 billion (Chakrabarty & Bharati 2010), and infections with helminth places an extra burden on the nutritional status of children (Hailegebriel 2018, Tandoh *et al.* 2015). The use of micronutrient supplementation, for instance, has been suggested for areas where iron deficiency anemia is a public health problem (Montresor *et al.* 2002). Supplementation with iron (60 mg elemental iron) and folate (0.40 mg) weekly has been suggested in such areas (Risonar *et al.* 2008).

Micronutrient supplementation has been found to also improve cognitive performance of children (Solon *et al.* 2003) and also reduce helminth infection rates (Nga *et al.* 2011). For example, a randomized controlled trial (RCT) by Nga *et al*. (2011), assessed the effects of multi-micronutrient biscuits fortified with iron, zinc, iodine and vitamin A on undernutrition, as well as re-infection with soil-transmitted helminths in children aged 6 to 8 years in Vietnam. In the study, 416 participants were given multi-micronutrient fortified biscuits for five days per week for four months and albendazole (400 mg, single dose) at baseline. They found significant moderate reduction in infection intensity of all helminth species in children taking ‘multi-micronutrient fortified biscuits and albendazole’ compared to ‘albendazole alone’. Additionally, children taking the fortified biscuit had improved cognition and growth (Nga *et al.* 2011).

Another RCT which used multiple micronutrients supplement strategy in controlling helminth infection found that school children who were given ‘iron supplement only and ‘multi-micronutrients supplement only’ had reduction in prevalence of *A. lumbricoides* compared to placebo (Nchito *et al.* 2009). The study used 215 school-aged children between 7 and 15 years in Zambia, and the participants were given 400 mg albendazole on two consecutive days at baseline before daily iron only (60 mg ferrous dextran) and multi-micronutrients fortified tablet (vitamin A, B_1, B_2, B_6, B_{12}, C, D and E, niacin, folic acid, zinc, iodine, copper and selenium) supplement for 10 months (Nchito *et al.* 2009). In addition to that, a randomized, placebo-controlled trial by Friis *et al*. (2003), also evaluated the effect of micronutrient supplementation and helminth chemotherapy on hemoglobin of school aged children between 9 and 18 years in Bondo district of western Kenya. They showed an increased hemoglobin level in school children who were given multi-micronutrient supplementation (3.5 g/l, 95% CI: 1.7, 5.3; P= 0.0002) and helminth chemotherapy (2.0 g/l, 95% CI: 0.2, 3.9; P= 0.03) separately for eight months (Friis *et al.* 2003). Thus, micronutrients supplementation could be used as adjunct therapy in reducing helminth infections and improving nutritional status of school children.

Together with periodic deworming and micronutrient supplementation, health/nutrition education and behavioral change is another important intervention strategy employed in the control of helminth infections. The inclusion of health education in school-based deworming program has been found to reduce the cost of deworming, delay re-infection and improve overall knowledge and acceptability of deworming interventions (Gyorkos *et al.* 2013, Mascarini-Serra 2011). Health education borders on factors such as the prevention of open water excreta contamination, avoidance of playing in fresh water bodies (Stothard *et al.* 2006), and improvement in personal hygiene (Nock *et al.* 2006). Such health education interventions have been found to be beneficial (Aagaard-Hansen *et al.* 2009), as seen in a cluster-randomized trial by Gyorkos *et al*. (2013), who evaluated the impact of health education on STH infections in 1,089 school children in 18 different primary schools in Belen, Peru. The findings showed that among the children in intervention schools, the intensity of *Ascaris lumbricoides* infection at follow-up was significantly lower (by 58%) compared with children in control schools (Gyorkos *et al.* 2013).

In spite of all the advantages associated with the above mentioned intervention programs for the reduction of helminth infections and improvement of its resultant nutritional and cognitive deficits, there is lack of evidence-based 'nutrition education' intervention that is sustainable in LMICs. Few studies have focused on 'nutrition education' as a long term sustainable approach to provide nutritional knowledge of locally available foods that would improve on the nutrition status and resultant cognitive performance of children in helminth-endemic areas. Hence, there is the need for interventions that include nutrition education as an approach to ameliorate the adverse effect of helminthiasis burden on cognition and nutritional impairment such as undernutrition, anemia, wasting and stunting among SAC (Bhutta *et al.* 2013, Headey 2013). Prevailing disparities between communities in terms of prevalence rates of helminthiasis, undernutrition and cognition should also be addressed to inform specific interventions tailored to suit their respective needs. Thus, the rationale for this study was to identify a more cost-efficient and sustainable way of improving the nutritional status of school-age children living in high risk helminth-endemic areas in rural Ghana. The use of 'nutrition education' intervention is expected to increase the nutritional knowledge, and inform healthy eating choices as well as good personal and environmental hygienic and sanitation practices that would help reduce re-infection rates and promote nutritional health.

The aim of this study was to examine the effectiveness of different interventions to improve the nutritional status and cognitive performance of school-age children living in high risk helminth endemic areas in rural Ghana.

Specific Objectives:

1. To assess the impact of the nutrition intervention on the nutritional status (BAZ, HAZ, Hb, blood zinc) of the children.
2. To assess the impact of the nutrition intervention on the cognitive performance of the children.
3. To evaluate the response of the intervention between helminth endemic fishing versus farming communities in Ghana.

Methods

Study design

This study was a community level trial which was a follow up to a previous study conducted to assess helminth and undernutrition burden of school-age children in the summer of 2017 (Tandoh *et al.* 2018). This intervention study was conducted among 358 (9-12-year-old) school-age children in fishing and farming communities of the Kwahu Afram Plains South District of Ghana. Ethical clearance to conduct the study was obtained from the University of Georgia Human Subjects Institutional Review Board (MOD00005562) (See Appendix B) and the Kwame Nkrumah University of Science and Technology Committee on Human Research, Publication and Ethics (CHRPE/AP/355/18) (See Appendix D).

The study consisted of 3 month intervention with four intervention arms (nutrition education only, micronutrient supplement only, nutrition education plus micronutrient supplement, and a control/deworming only) in each of the communities. Data was collected at baseline (prior to the intervention), and at the 3rd and 6th month post-intervention. Data was collected on sociodemographic, anthropometrics, dietary and cognitive assessment (at baseline, 3rd and 6th month) whilst parasitology (schistosomes, roundworms, whipworms and hookworms infections) by stool and urine and biochemical parameters (hemoglobin and zinc) were assessed at baseline and the 6th month post-intervention.

Sampling Method

Multistage sampling was employed. A random sample of 4 farming and 4 fishing communities were selected from a list of all schools in the fishing and farming communities in the Kwahu Afram Plains South District obtained from the School Health and Education Program (SHEP) Coordinator in the district. A random selection of four (4) schools from each of the two communities (fishing and farming) were randomly assigned to one-arm of the intervention treatment mentioned above Fig 5.1). Informed consent and assent were (See Appendices L and N) obtained from parent and index child, respectively. Permission was sought from the Regional and District Directors of the Ghana Health Services and the Ghana Education Service before the commencement of the study (See Appendices F and H). Permission was also sought from community leaders, headmasters and teachers of the respective schools, which were randomly selected.

Intervention Arms of the Study

All participating children in all the treatment arms were dewormed at baseline. Each of the 4 randomly selected schools within each community (farming and fishing) were then randomly assigned to one of the intervention arms of the study.

'Nutrition Education Only group', which involved educating children on good nutrition and health practices (hygiene and sanitation), such as the washing of hands with soap and water after toilet use and before eating, avoiding open defecation, not walking bare footed, avoiding the habit of fingernail biting, not swimming in the Afram River among others (WHO, 2011) Nutrition component focused on avoiding pica behavior, increasing the consumption of a varied diet, and general information on locally available foods (Aagaard-Hansen, 2009, Gyorkos, 2013, Nock, 2006) (See Appendices T, and U). . This intervention was given once a week for three (3) months by a trained teacher in the school.

The 'Supplementation Only group' involved the use of two (2) micronutrient supplements (6.5 mg $FeSO_4$) (Stoltzfus, 1998), and (10 mg $ZnSO_4$) (Hotz, 2004), administered three (3) times a week for three (3) months by trained head-teachers of the school. Commercially available supplements containing these micronutrients were used; Zinc sulphate tablets (Zintab Zinc sulphate monohydrate BP) and Ferrous sulphate tablets (Ferrous Sulphate BP). The contents of the two micronutrient supplements were verified at the Food and Drug Authority of Ghana (Certificate number: PCM-18/06/0129) (See Appendix R).

Combination of 'Nutrition Education Only' and 'Supplementation Only' group. This group received both nutrition education (i.e; good nutrition, hygiene and sanitation practices) once a week for three (3) months, together with the two (2) micronutrient supplementation (6.5 mg $FeSO_4$ and 10 mg $ZnSO_4$) three (3) times a week for three (3) months.

The 'Control group', received only dewormers, using either 400 mg of albendazole (in the farming communities only) or 40 mg of praziquantel/kg body weight (in the fishing community only). The choice of dewormer for each community was based on helminth prevalence rates from the previous study conducted in the district (Tandoh *et al*, 2018). From that study, STH infection predominantly occurred among children in the farming community (9.6%) with no case in the fishing community (p=0.007), whereas *S.haematobium* predominantly occurred among children in the fishing community (33.8%) versus 1.2% in their farming community counterparts

($p<0.0001$). Hence, all participating children in the fishing community were dewormed with 40 mg of praziquantel/kg body weight (for the treatment of *S.haematobium*), whereas those in the farming community received 400 mg of albendazole (for the treatment of STH). The 'tablet pole' was used to ascertain how many praziquantel tablets of medication was to be administered to each index child in the fishing community for schistosomiasis (WHO 2011). The 'tablet pole' is a long calibrated piece of wood with indications for the number of praziquantel tablets that is supposed to be given to a child based on the height of the child for the treatment of schistosomiasis. It provides estimates for the number of praziquantel tablets for SAC who are between the height of 94 cm to 190 cm (WHO 2011).

Data Collection

Socio-Demographic information

Index children and their parents or primary caregivers were assisted to complete a questionnaire that included age, sex, ethnicity, sanitation and other demographic information.

In this study, a modified questionnaire based on the Child Form-Parasitological Nutrition Survey recommended by the WHO as a guide for managers of helminth control (WHO, 2011) was used. Our questionnaire comprised of three parts: the first section for parents; consisting of 32 questions of 3 constructs (sociodemographic, water and sanitation, and knowledge and practices); and a second section for the children consisting of 23 questions with three (3) sub sections (sociodemographic, sanitary conditions and dietary assessment). The third section was on data entry for survey workers, which consisted of sections for anthropometry, parasitology and hematological results (See Appendix Q). A previous study had validated and used a similar version of this questionnaire (Tandoh *et al.* 2015).

Anthropometrics

The anthropometric indicators of subjects were determined using standardized protocol (Apprey *et al.* 2014, Gibson 2005). Weight (in kg), height (in cm) and mid-upper arm circumference (MUAC) (in cm) were taken in duplicates by a trained personnel at the baseline, the 3rd month and the 6th month (post intervention). The means were then estimated at every point of measurement and this was achieved by the measurement of the children's weight (kg) to the nearest 0.1 kg in light clothing using a Seca scale, whilst the height (cm) was measured to the nearest 1 mm without shoes using a Seca stadiometer, and MUAC (cm), to the nearest 1 mm using a non-stretch flexible tape. This was measured by first bending the left arm, and locating the mid-point between the olecranon process and the acromium of the arm at a right-angled position. After that, with the arm hanging straight down, the non-stretch flexible tape measure was wrapped around the arm of the child at the mid-point region to measure the MUAC. Measurements were in duplicates and the average estimated to get the final MUAC measurement. Cut-offs for MUAC used were <13.5 cm (severe acute malnutrition), ≥13.5-14.5 cm (moderate acute malnutrition) and ≥ 14.5 cm (well nourished) for 9 year-olds, whereas <16.0cm (severe acute malnutrition), ≥16.0cm-18.5cm (moderate acute malnutrition) and ≥18.5 cm (well nourished) for 10-14 years old. For the purpose of statistical analysis, the moderate acute malnutrition and the severe acute malnutrition were merged and reclassified at acute malnutrition.

With the use of a WHO anthropometric calculator (Anthro Plus version 1.0.3, http://who anthroplus.software.informer.com/1.0/), information obtained for weight and height were used to compute the BMI-for-Age Z score (BAZ), which determines undernutrition whilst that of the height was used to compute for Height-Age-Z- score (HAZ), which determines stunting levels.

For the purpose of statistical analysis, severe underweight was merged with underweight. Likewise, severe stunting was merged with stunting.

Biochemical assessment

At the baseline and 6^{th}month of data collection, 5 mL of whole morning non-fasting venipuncture uncoagulated blood samples were collected from subjects by trained phlebotomists for micronutrient analysis (zinc and Hb). However, at the 3^{rd} month of the data collection, the finger prick method was used to collect blood samples for Hb analysis only. The hemoglobin was assessed (using HemoCue Hb 201^{+}). Cut offs for Hb levels used were; <11.5 g/dL (anemic) for 5-11 year olds, and <12.0 g/dL (anemic) for 12-13 year olds (Stoltzfus *et al.* 1998).

Digestion of blood samples

Digestion of the whole blood samples preceded the spectroscopic analysis by adding 2mL of whole blood samples to a 50mL volumetric digestion flask, and to that, 5mL of H_2SO_4 and 2mL of 1:1 HNO_3:$HCLO_4$ (1:1 v/v) were added. The resulting solution was then heated on a hot plate at 200°C ± 5°C for 30 min until the sample became colorless. This was then diluted with double distilled water to 50mL mark, and allowed to cool and transferred in 50ml falcon tubes for zinc readings with the Flame atomic absorption spectroscopy (FAAS) (Okyere *et al.* 2015).

Measurement of zinc levels

The Flame atomic absorption spectroscopy (FAAS) was used to measure the zinc levels in the blood samples by following standard protocols (Gibson 2005), at the Kwame Nkrumah University of Science and Technology. This was carried out on an Analytikjena model novAA400P atomic absorption spectrophotometer using the single-beam optical mode. Hollow cathode lamp (HCL) for the respective elements were used as light source for the analysis. An air (compressed air) and acetylene (N26 quality, Air Liquide, Ghana) was employed as the oxidant and the fuel gas respectively for the flame. The integration time for all the measurement was 3. Background correction was accomplished with a deuterium lamp (D2 – Lamp). All the reagents used for the FAAS analysis were of analytical grade. Concentrated HNO_3 (37% w/w) was obtained from Surechem Products (England). Deionized Water (Siemens Water Technologies – Ultra Clear RO EDI 10) was used in the preparation of the diluted acid, and a commercially prepared Zn standard solution (1000 mg/L) was obtained from Merck (Darmstadt, Germany).

To prepare standards for the instrument calibration, the stock solution was serially diluted with 0.1% HNO_3 to obtain calibration solutions of different concentrations. Analyte-free solution (0.1% HNO_3) was used as the blank during the instrument calibration. The different standards used to prepare the zinc analyte were 0.2, 0.4, 0.6, 0.8 and 1.0 mg/L. Using a pneumatic nebulizer, a small volume of the sample was aspirated into a flame where the ions are reduced to elements and vaporized. The elements present in the sample then absorbed the light at specific wavelengths in the visible or the ultraviolet spectrum. This was dependent on the wavelength of maximum absorption of the analyte. After absorption, the transmitted light was detected with a detector after going through a monochromator.

A calibration curve was prepared with standard solutions of at least five (5) different concentrations, and were used to calibrate the instrument before all the analysis. The measured absorbance of these standard solutions were used to prepare a linear calibration curve. The calibration curve was used to determine the unknown concentration of an element in the samples. Samples having high concentrations of elements beyond the linear range of the instrument was diluted prior to the analysis. The light absorbed by the flame containing the sample was compared with the absorption from the known standards to quantify the elemental concentrations.

The cut-offs for zinc deficiency for morning non-fasting blood samples were used to classify zinc values as either normal or deficient (<9.9 µmol/L for all children less than 10 years, <10.7 µmol/L for male children ≥10years, and <10.1 µmol/L for female children ≥10-years) based on standardized protocols (Gibson 2005).

Parasitic infections assessment

Trained research assistants collected the stools and urine samples on scheduled days in the various schools. Subjects who were unable to provide stool or urine samples on a designated day were asked to provide it the following day. The samples were kept in a cool ice chest and transported to the laboratory on site where assessment of the presence of intestinal worms such as *Trichuris trichiura*, *S. mansoni*, *Ascaris lumbricoides and* hookworm were done. At the baseline and 6th month, the stool and urine samples of subjects were collected to assess for STH and urinary schistosomes. The kato-katz (WHO 1994) and the urine filtration methods (WHO 1991) were used to achieve this.

To estimate for the number of eggs counted per 10 gram of stool (epg), a factor of 24 was used to multiply the total number of helminth eggs counted under the microscope (Williams 1992). Based on the epg obtained, the infection was classified as light (1-999), moderate (1000-9.999) or heavy (≥10,000) intensity for *Trichuris*; and light (1-1,999), moderate (2,000-3,999) or heavy (≥4000) intensity for Hookworm infections (Montresor *et al.* 2002).

To test for the presence of blood in the urine samples, a urine test strip was used. Furthermore, the urine filtration method was used to filter 10 mL of urine to separate the existing eggs for microscopic analysis and counting. Preceding that, a visual inspection of the urine samples were done to determine visible hematuria, which is usually a clear sign of *S.haematobium* infection (World Health Organization 1987). The assessment of 10 mL of the urine sample for the presence of *S. haematbium* eggs was done by a trained laboratory technician. Based on the number of eggs counted, the intensity of *S. haematobium* was then classified based on the following cut-offs; low (<50 eggs/10mL urine) or high (>50 eggs/10mL) (Montresor *et al.* 2002).

Assessment of Cognitive Performance

The cognitive performance of all subjects were assessed through the Raven's Coloured Progressive Matrices (RCPM) test scores obtained at baseline, 3rd month and 6th month of data collection (Raven 2003). The RCPM was the choice of cognitive assessment tool because it is a non-verbal assessment tool, and hence overcomes issues of language barrier. It is made up of 36 items in three sets of 12 (A, Ab, and B), and had previously been pilot tested in the study communities (Tandoh *et al*, 2019, in review) as well as other studies (Whaley *et al.* 2003). In addition to that, the school attendance of the subjects were also obtained at baseline and the 3rd month of the data collection to ascertain how the intervention impacted on their school attendance.

Statistical Analysis

For the statistical analysis, IBM SPSS Version 24 for Windows (SPSS Inc., Cary, NC USA) was used. For categorical variables such as gender, infection status, and nutritional status, proportions were determined, whereas for continuous variables such as age, weight, test scores, descriptive statistics of means, median and standard deviations were ascertained. The Chi-squared (χ^2) and the Fischer Exact tests were used to perform a bivariate analysis where necessary, in order to determine significant differences between the categorical variables.

The Paired sample T-test was used to compare differences in the nutritional indicators and cognitive test scores with the intervention arms at the different time points (baseline and 6 months post-intervention). Furthermore, a univariate logistic regression analysis was done to determine the associations between nutritional status and cognitive test scores and the type of intervention given. The level of statistical significance was ascertained at a p-Value of <0.05.

Results

A total of 358 SAC were recruited for this intervention study from 8 randomly selected schools (4 schools from the fishing, and 4 schools from the farming communities). Table 5.1 shows the characteristics of the study participants by type of community. Each of the 4 schools were randomly assigned to one arm of the intervention; 1 = 'NutEd Only' (22.6% and 34.3% for farming and fishing communities, respectively), 2 = 'Suppl Only' (27.7% and 19.9% for farming and fishing communities, respectively), 3 = 'NutEd+Suppl' (23.2% and 23.8% for farming and fishing communities, respectively) and 4 = 'Control' (26.6% and 22.1% for farming and fishing, respectively). There was no significant differences in participant numbers in the intervention arms by community at baseline ($p=0.063$) (Table 5.1).

A significantly higher number of mothers were interviewed in the fishing community than the farming community ($p=0.014$). Majority of those in the fishing community (81.2%), were 'Ewes' compared to those in the farming community (9.6%) ($p<0.0001$). Conversely, a higher proportion of parents from the farming community (90.4%) were farmers compared to those in the fishing community (50.8%) ($p<0.0001$). Furthermore, a higher proportion of those in the farming community (96.0%) obtained their food from the farm compared to those in the fishing community (35.4%) ($p<0.0001$) (Table 5.1). Nevertheless, the two communities did not differ in terms of the type of treatment given ($p=0.063$), parental marital status ($p=0.081$), parental education ($p=0.081$), and child's gender ($p=0.207$) (Table 5.1).

Helminthiasis Prevalence by Community Type

Table 5.2 represents results on the infection rates based on the type of community. At baseline, a total of 29.6% of all children had a parasitic infection with 13.6% and 45.3% occuring in the farming and fishing communities respectively, ($p<0.0001$). By the end of the 6th month (post intervention), helminth infection rates had reduced across board such that overall infection rates reduced from 29.6% to 6.3%, with corresponding reduction in the various communities;

13.6% to 4.3% (farming) and from 45.3% to 8.2% (fishing) communities ($p=0.153$) (Table 5.2).

Helminthiasis Type and Associated Symptoms Prevalence by Community Type

Table 5.3 represents the specific type of helminth infection prevalence and some associated symptoms by community type. At baseline, visible hematuria (bloody urine) was present in 3.4% of overall urine samples collected, with none occuring in the farming community whilst the fishing community recorded 6.6% (<0.0001). This decreased to 0.9% and 1.9%, respectively, by the end of the study (6th month) ($p=0.079$). Microhematuria (microscopic blood in urine) was also observed at 15.4% (overall) and 30.4% (fishing community), with none occuring at the farming community. Microhematuria also reduced to 3.8% (overall) and 5.7 (fishing) by the 6th month, however, it was observed in the farming community (1.9%). *S.haematuria* was prevalent at 22.3% (overall), 0.6% (farming) and 43.6% (fishing) community (<0.0001). This also reduced to 3.8% (overall), and 7.6% (fishing), with none occurring in the farming community at the 6th month (<0.0001). *S. mansoni* infection also occurred at 0.6% (overall), 1.1% (fishing), with none occuring in the farming community (0.161). This also reduced in the 6th month such that none occurred in the subjects. Hookworm infection occurred at 4.7% (overall), 9.0% (farming) and 0.6% (fishing) community (<0.0001). This also reduced to 1.6% (overall), 2.5% (farming) and 0.6% (fishing) communty by the 6^{th} month (p=0.183). *Trichuris* infection also occurred at baseline at 1.1% (overall), 2.3% (farming), with none in the fishing community (0.047). This also reduced to 0.9% (overall) and 1.9% (farming) with none occuring in the fishing community (p=0.085) *H. nana* infection also occurred at 1.45 (overall), 2.3% (farming) and 0.6% (fishing) community (p=0.169) at the baseline, and decresed to 0.3% (overall) and 0.6% (farming), with none occuring in the fishing community (p=0.321) . Other helminths were also present at 2.0% overall, 1.7% (farming) and 2.2% (fishing) community at baseline (p=0.725), but this no longer occurred at the 6^{th} month (Table 5.3).

Anthropometric and Biochemical Indices versus Community Type over Intervention Period

Table 5.4 represents the anthropometric and hematological indices of the children, based on the type of community. At baseline, there was no significant difference in the prevalence of underweight (BAZ) between children from the farming community (7.9%) compared to their counterparts from the fishing community (7.2) (p=0.810). At the end of the 3^{rd} month, howerver, a statistically significant difference was observed in the underweight and anemia status such that overall, underweight reduced from 7.5% to 5.7%, with a greater rate of reduction occuring in the farming community, whilst no reduction in the fishing community occurred but rather an increase in underweight status (p=0.002) (Table 5.4). By the end of the 6^{th} month, significant differences occurred in underweight such that the farming community had more decline in the proportion of underweight children (from 7.9% to 1.2%) compared to an increase in the proportion of children from the fishing community who were underweight (from 7.2% to 9.6%) (p=0.002). Also there was no significant difference in anemic status of the children in the two commnunities at baseline (p=0.106), but a significant difference was observed at the 3^{rd} month and the 6^{th} month of intervention such that, more children in the farming community were anemic (55.8%) compared to those in the fishing community (39.6%) (p=0.003). By the 6th month (post intervention), significant differences occurred again in anemia rates such that a higher rate of anemia was recorded in the farming (23.6%) compared to the fishing community (8.1%) ($p<0.0001$). Overall, in terms of anemia, the fishing community benefitted more with decreased rates compared to children in the farming community ($p<0.001$) (Table 5.4). With regards to blood zinc levels (µmol/L), significnt differences were observed such that at baseline, children in the fishing community were more zinc deficient (37.3%), compared to those in the farming community (25.7%) (p=0.021), however this trend reversed by the 6th month (post intervention), such that children in the farming community now had a higher prevalence rate of zinc deficiency (10.6%) than their counterparts in the fishing community (7.8%) (p=0.425), but this was still at a lower rate than was recorded at baseline (Table 5.4).

Helminthiasis Infection Prevalence by Type of Intervention

Table 5.5 represents results on the infection rates based on the type of intervention given. At baseline, 29.6% of all subjects had at least one type of helminth infection. By the 6th month (post intervention), overall prevalence of helminth infection had reduced from 29.6% to 6.3% with corresponding reduction in infection rates across the different treatment groups such that the 'Control group' had the highest rate of reduction of helminth infection by 28.7%, followed by the 'Suppl Only group' (26%), then the 'NutEd Only group' (24.8%) and the least difference in infection rate observed in the 'NutEd+ Suppl group' (13.3%) (p=0.104). Thus, at the end of the intervention period, the 'Control group' had the lowest prevalence rate of infection of 6.3% with the highest infection rate recorded among the 'Suppl Only group' (10.5%) (Table 5.5).

The Mean Test Scores versus Intervention and Type of Community

Table 5.6 represents the mean performance on the RCPM cognitive test by the study participants over the 6 months period and also by type of community and intervention. At baseline, there was a significant difference observed in the test score of the participants based on the type of community ($p=0.026$), with those in the fishing community having a higher mean test score (13.7±5.4) compared to those in the farming community (12.4±5.4). By the 6th month (post intervention), mean test scores of children in the fishing community increased from 13.7±5.4 to 16.9±6.9, and continued to be significantly higher than the mean test scores of children in the farming community, although their mean test scores also increased from 12.4±5.4 to 14.5±6.3 ($p=0.010$). Similarly, significant differences were observed in the mean test scores based on the different interventions given at baseline ($p<0.0001$), with the 'Control group' having the highest test score of 14.2±4.9 and the 'NutEd + Suppl group' having the lowest test score of 11.6±6.1. By the 6th month (post intervention), all the children in the different treatment groups had an increase in their mean test scores, but no significant differences were observed between them ($p=0.0131$), however, the 'NutEd Only group' had the highest mean test score (from 14.1±4.9 to 16.6±6.6) (Table 5.6). A further analysis with the Paired sample T- test however confirmed that overall, the mean cognitive test scores increased significantly by 2.62±5.77 ($p<0.0001$). However, the highest mean difference in the cognitive test scores occurred among the 'Suppl Only group' (3.08±6.07) ($p<0.0001$). Whereas the least mean difference in cognitive test scores was recorded among the 'Control group' (2.15±5.99) ($p=0.001$) (Table 5.7). For school attendance, there were significant differences in mean baseline attendance (out of 55 days) and that of the 3rd month (out of 71 days) for all the intervention groups ($p<0.0001$) (Table not shown). However, comparisons could not be made because total days of attendance at baseline and the 3rd month were different (55 versus 71 respectively). In addition to that, 6th month attendance could not be ascertained because school was still in session and the term was not over at the time of data collection.

Overall Assessment of Underweight by Intervention at Baseline, 3rd Month and 6th Month

Figure 5.2 shows the overall underweight data of this study at baseline, 3rd month and 6th month (post intervention) period in the various intervention arms, using the Chi square analysis. Overall, at baseline 7.5% of the children were undeweight. There was a reduction in underweight status from baseline to the 6th month (post intervention) for all the intervention groups except the 'Suppl Only group' and the 'Control group'. The overall prevalence rates of underweight reduced from 7.5% to 5.3%, whilst the greatest reduction in underweight seemed to occur among the 'NutEd Only group' (12.7% to 3.3%) and 'NutEd+Supp group' (9.5% to 7.1%) (Fig. 5.2). An increase in underweight rates were however observed in the 'Suppl Only group' (4.7% to 6.6%) and the 'Control group' (2.3% to 4.9%) (p=0.104) (Fig 5.2). This was confirmed in a further analysis using the Paired sample T-test (Table 5.7), which showed a significant improvement in the underweight rates (BAZ) for the 'NutEd Only group', with a mean difference of 0.27±0.81 (p=0.002) between the baseline and the 6th month BAZ values (Table 5.7). However, the 'Control group' had a significant decline in their BAZ between their baseline and the 6th month values (-0.31±0.58) (p<0.0001) (Table 5.7).

Overall Assessment of Stunting by Intervention at Baseline, 3rd Month and 6th Month

With regards to stunting (Fig.5.3) based on a Chi square analysis, there were declines in stunting rates overall by the 6th month post intervention (from 11.2% to 8.5%), with the highest reduction of stunting rates seemingly occuring in the 'Control group' (14.9% to 9.9%), followed by the 'NutEd+Supp group' (14.3% to 10.0%), and then the 'NutEd Only group' (4.9% to 2.2%), with no reduction in the 'Supp Only group', which rather increased in stunting rates (11.8% to 13.2%) (p=0.067) (Fig 3). A further analysis with the Paired sample T-test (Table 5.7) however, showed that stunting rates significantly improved in the 'NutEd Only group' and the 'NutEd+Suppl group' such that the 'NutEd Only group' had the highest mean difference of 0.16±0.38 (p<0.0001), followed by the 'NutEd+Suppl group', with a mean differnce of 0.10±0.040 (p=0.04) between the baseline HAZ values and the 6th month post intervention values. The 'Suppl Only' and the 'Control' groups also improved in stunting rates, but not significantly different (Table 5.7).

Overall Assessment of MUAC by Intervention at Baseline, 3rd Month and 6th Month

Figure 5.4 represents the Chi square analysis of the mid upper arm circumference (MUAC) of the participants based on the different treatment groups. At baseline, 21.5% of all the children in the study had acute malnutrition. There was a reduction in children with acute malnutrition from baseline to 6th month (post intervention) for all treatment groups such that overall, it drecreased from 21.5% to 9.8%, with the greatest decrease occuring in the 'NuteEd Only group' (25.5% to 7.7%), and the least reduction occuring in the 'Suppl Only' group (14.1% to 7.9%) (p=0.534) (Fig 5.4).

Overall assessment of Anemia and Zinc Deficiency by Intervention at Baseline, 3rd Month and 6th Month

Figure 5.5 represents data on the anemia prevalence based on the different treatment given using Chi square analysis. At baseline, 46.1% of all children were anemic with 52.5% of them being normal (p=0.222). By the end of the 6th month (post intervention), overall anemia levels had significantly reduced from 46.1% to 16.1%. The intervention that resulted in the highest decrease in anemia rates between baseline and the 6^{th} month (post intervention) was the ‘Supp Only group’, (56.5% to 16.0%), followed by the ‘NutEd+Suppl group’ (45.2% to 11.1%) and then the ‘NutEd Only group’ (43.1% to 9.9%), with the least decrease in anemia recorded among the ‘Control group’ (40.2% to 27.2%). All the observerved differences of anemia rates in the different intervention groups at the 6^{th} month (post intervention) were found to be significantly different ($p=0.011$) (Fig.5.5). A further analyis however, using the Paired sample T-test showed that the ‘NutEd Only group’ showed the highest mean diffrence in Hb levels between their baseline and 6^{th} month (post intervention) measures (1.22 ± 1.13) ($p<0.0001$), whereas the ‘Suppl Only group’ had a mean difference of 0.91 ± 0.99 ($p<0.0001$), with the ‘Control group’ having the least mean diffrence of 0.46 ± 1.21 ($p<0.0001$) (Table 5.7).

With zinc defciency, based on the Paired sample T.test, a significant diffrence was observed with children in all the intervention arms, such that the highest mean difference recorded in the ‘NutEd+Suppl group’ (46.39 ± 22.3) ($p<0.0001$) and the least recorded in the ‘NutEd Only group’ (8.58 ± 16.38) ($p<0.0001$) (Table 5.7).

Adequacies of dietary intakes, based on the 24 hour recall, were significantly different between the different intervention groups at baseline, but dietary adequacies further declined significantly by the 6^{th} month (post intervention) (Table not shown).

Predictors of Anthropometric and Biochemical Measures of Undernutrition Based on Intervention

Table 5.9 shows the predictors of anthropometric and biochemical measures of undernutrition based on the different intervention arms. Univariate analysis showed that the ‘NutEd Only group’ was the only intervention arm that was significantly associated with stunting such that they were 79.5% less likely to be stunted compared to the ‘Control group’(OR=0.21, CI;

0.04-0.99, p=0.049). All the other intervention groups did not show any significant associations with stunting (Table 5.9).

No significant associations were observed between the different intervention arms and underweight (p>0.05) (Table 5.9). However, with anemia, significant associations were observed between the 'NutEd Only group' and the 'NutEd+Suppl group' such that children in the 'NutEd Only group' were 70.6% less likely to be anemic compared to the 'Control group' (OR=0.29, CI; 0.13-0.69, p=0.005). Whereas, the 'NutEd+Suppl group' were also 66.5% less likely to be anemic compared to the 'Control group' (OR=0.335, CI; 0.13-0.85, p=0.02).

Similarly, significant differences were observed in some intervention arms with regards to blood zinc deficiency such that the 'NutEd Only group' were found to be 6.4 times more likely to be zinc deficient compared to the 'Control group' (OR=6.40, CI; 1.39-29.50, p=0.02), with the 'Suppl Only group' also being 6.04 times more likely to be zinc deficient compared to the 'Control group' (OR=6.04, CI=1.27-28.77, p=0.02) (Table 5.9).

Predictors of Cognitive Performance Based on Intervention

Table 6.0 shows both the univariate and the multivariate analysis of cognitive outcomes based on the different intervention arms. No significant associations were observed in both the univariate and the multivariate logistic regression analysis between the RCPM cognitive performance and the different intervention arms (p>0.05) (Table 6.0).

Discussion

In the present study, we evaluated how different intervention strategies (NutEd Only, Suppl Only, NutEd+Suppl and Control/Deworming Only) could improve nutrition and cognitive status among school-age children in helminth endemic fishing and farming communities in rural Ghana.

Majority of the school children in this study were males (50.8%) and from the Ewe tribe of Ghana (45.8%). Majority of the parents/caregivers were farmers (70.4%), and obtained their food primarily from the farm (65.4%). The most common helminth prevalence in this population was *S.haematobium* (22.3%), with no infection due to *Ascaris* observed (Table 5.3), but with a greater prevalence rate of helminth infection significantly occuring among children in the fishing community compared to those in the farming community (p<0.0001) (Table 5.3). This was similar to our previous studies which reported *S. haematobium* (17.1%), to be the most prevalent helminth infection among SAC in the Kwahu Afram Plains South District of Ghana, with infections due to other helminths being (4.9%) (Tandoh *et al.* 2018). Again, *S. haematobium* infection was found to be significantly higher in the fishing (33.8%) compared to the farming (1.2%) communities (P<0.0001) (Tandoh *et al.* 2018). Since urinary schistosomiasis is acquired through contact with fresh water bodies, it is not surprising that children in the fishing communities had the highest prevalence of the infection in this study.

In a randomized double-blind placebo study which was conducted to ascertain the efficacy of a fortified biscuit (FB) on the growth, cognition and parasitic infections among Vietnamese SAC between 6 to 8 years, the researchers found that, children who were on both the fortified biscuit (FB) and albendazole had the lowest level of helminthiasis prevalence after 4 months of intervention (Nga *et al.* 2011), which was in contrast to our findings which showed that although the overall prevalence of helminths reduced from 29.6% to 6.3% (from baseline to 6th month -post intervention-) (Table 5.5), the ‘Control group’ (deworming only) had the lowest prevalence of helminth infection, whilst the highest infection occured among the ‘Suppl Only group,’ post-intervention (Table 5.5). Nevertheless, our finding was consistent with another community directed intervention study conducted in Kenya, in which they found that after 6 months post treatment with praziquantel and albendazole, as an integrative treatment for schistosomiasis and STH, the prevalence rates of *S. mansoni*, hookworm and *Trichuris* had reduced by 33.2%, 69.4% and 42.6%, respectively (Mwinzi *et al.* 2012). Although the prevalence rates of helminthiasis at the 6th month was not significatly different between the various intervention arms (p=0.104), all the intervention arms had reduced infection rates comapared to their baseline prevalence. Reduced rates of helminthiasis among the 'NutEd Only group' for example (32.4% to 7.6%) from baseline to 6th month (post intervention), was consistent with another study by Gyorkos *et al.* 2013, that employed a school-based health hygiene education intervention, and found it to be effective in reducing the prevalence rates of *Ascaris* and improving helminthiasis knowledge of SAC in Peruvian Amazon. That was a paired-match cluster-randomized trial that involved 18 primary schools consisting of 9 intervention and 9 controls. Those in the intervention arms received a one hour education on health hygiene and sanitation at baseline, and a repeated education every two weeks for a total period of 4 months. Baseline stools were then examined for infection and a standardized questionnaire was used to obtain information. At the end of the intervention study, the children who received the education, were found to have significantly reduced infection rates of *A. lumbricoides* by 58%, with the prevalence levels of *S. mansoni,* hookworm and *Trichuris trichiura* reducing by 33.2%, 69.4% and 42.6%, respectively. Reduction in infection intensity rates due to hookworm and whip worm were however, not significantly different (Gyorkos *et al.* 2013).

Findings from this study also show a significant reduction in the prevalence of anemia at the 6th month (post-intervention) (Fig.5.5). Soil-transmitted helminth infection is particularly associated with iron-deficiency anemia in SAC because they tend to have high prevalence rates of the infection (Guyatt *et al.* 2001). The 'NutEd Only group' had the highest significant mean difference in hemoglobin levels from baseline to the 6th month (post intervention) (p<0.0001)

(Table 5.7), with a univariate regression analysis further showing the 'NutEd Only group' to be 70.6% less likely to be anemic (Table 5.9). However, comparing the reduction rates of anemia between the baseline and the 6th month, the micronutrient supplement (Suppl Only) group recorded the highest reduction rates in anemia (by 40.5%), followed by the 'NutEd+Suppl group' (by 34.1%) and then the 'NutEd Only group' (by 33.2%), with the least decrease recorded among the 'Control/Deworming Only group' (by 13%) (Fig.5.5). This is consistent with a randomized, double-blind placebo study conducted in the Philipines which sought to determine the effect of a multifruit-micronutrient fortified fruit powder beverage on the nutritional status and other outcomes of SAC. The fortified beverage was found to significantly improve the iron status of the children who initially had hemoglobin levels below 11 g/dl at baseline. They also found that among the children who received the fortified beverage, a significantly lower number of them were still anemic at the end point, the 16th week post intervention period (Solon *et al.* 2003). Findings from this study suggest that micronutrient supplementation as well as nutrition education are effective interventions in reducing anemia among school children in helminth endemic areas.

Findings also revealed that the various intervention strategies reduced the prevalence rate of underweight (BAZ), among the SAC in the helminth endemic fishing and farming communities, since at the end of the intervention, based on a Chi Square analysis, the overall rate of underweight had reduced from 7.5% to 5.3% (p=0.104), (Fig.5.2). No significant differences were, however, observed between underweight measures and intervention groups from the baseline to the 6th month (post intervention) (p= 0.104) (Fig.5. 2). The resultant reduction of mean underweight (BAZ) measures were however observed within the various intervention groups such that the 'NutEd Only group' showed the highest significant decline in the mean underweight measures (p=0.104). The findings indicate that provision of nutrition education has the tendency to reduce underweight outcomes among SAC in helminth endemic areas. This finding is consistent with a community-based study conducted among 536 children in four study areas in the Free State and Northern Cape Provinces in South Africa (Walsh *et al.* 2002), which employed the use of nutrition education versus a control and food aid for a period of two years. They concluded that, the education program in combination with the food aid successfully improved the weight status of the children (Walsh *et al.* 2002). Our finding is also consistent with one randomized controlled study in Lushoto district of the Tanga Region of Tanzania, which included 7-15 year old SAC who were enrolled in a health education intervention for the control of helminthiasis (schistosomiasis and STH infections) (Lansdown *et al.* 2002). They focused their intervention message on factors such as personal hygiene, clean water and good nutrition. They used songs, short sketches, poetic dramas among others to disseminate their information. Focus groups were also held with the children, their parents and community members for 3 school terms. At the end of their intervention period, the study participants (children) showed an increased knowledge in good health practices such as handwashing with soap after toilet use, the need to cover food to avoid contamination from flies among others. The researchers found improvement in knowledge and improved behaviors that promoted overall health (Lansdown *et al.* 2002).

Even though the overall prevalence of zinc deficiency in this study at baseline was 31.4% (Table 5.4), it was higher than values recorded in a study among under 12 year old Mexican children (19 to 24%) (Villalpando *et al.* 2003). However, by the 6th month (post intervention) of this study, the mean differences in blood zinc suggests that the 'NutEd+Suppl group' recorded the highest improvement in zinc deficiency (Table5.7), but another randomized controlled trial among Peruvian children on a daily supplement of 10 mg of zinc or a multiple micronutrient showed that the greatest change in plasma zinc from baseline to the 6th month was greater in the two (2) zinc groups; the zinc only supplementation (27.3 μg/dL, and the zinc+other vitamins and minerals group (6.2 μg/dL), compared to the placebo group (6.1 μg/dL) ($p<0.0001$) (Penny *et al.* 2004). Although the highest mean difference in zinc levels were observed in the 'NutEd+Suppl group' (Table 5.7), we found that, contrary to the positive effect of the NutEd Only' on the anemic status of the children in this study, children in the 'NutEd Only group' and the 'Suppl Only group' were 6.4 times and 6.0 times more likely to be zinc deficient respectively (Table 5.9).

Although it appears from the Chi Square analysis that the 'Control group' improved stunting prevalence rates the most, compared to the other treatment groups, ($p=0.067$) (Fig 5.3), another Chi square analysis showed that 36.8% of all the 12 year olds were in the control group ($p=0.051$) (Table not shown). Thus, it is possible that children in the control group must have been experiencing an adolescent growth spurt, leading to an exponential increase in height over the intervention period. Further analysis based on a Paired sample T-test however revealed that the mean differences in stunting (HAZ) significantly improved in the 'NutEd Only group' ($p=0.040$) and the NutEd+Suppl Only group' ($p=0.041$) (Table 5.7). In addition to that, the 'NutEd Only group' was the only intervention group that was significantly associated with stunting rates ($p=0.05$), based on the univariate logistic regression analysis, as they were found to be 79.5% less likely to be stunted (Table 5.9).These were however contradictory to findings in the South Africa study (Walsh *et al.* 2002), which found that there was no significant improvement of stunting rates based on their nutrition education intervention.

Findings in this study also suggests that the various intervention strategies had reduced the prevalence rate of acute malnutrition in the children, although not significantly ($p=0.0534$). However, at the end of the 6^{th} month (post intervention), those in the 'NutEd Only group' recorded the highest reduction rate of acute malnutrition (from 25.5% to 7.7%) compared to the other groups (p=0.534) (Fig 5.4). This suggests that nutrition education is the most beneficial intervention strategy to improve acute malnutrition in the children in this helminth endemic areas. Therefore, there is the need to complement deworming programs with nutrition eduction for a better nutritional outcome in SAC.

Even though there was no significant differences between the 'Suppl Only group' and the other intervention groups in relation to acute malnutrition by the 6th month (post intervention) (p=0.534) (Fig.5.4), it's reduced rate is consistent with a randomized, double placebo controlled study (Nga *et al.* 2011), among SAC in Vietnam which sought to use a multi-micronutrient fortified biscuit with or without deworming as an intervention to improve on growth, cognition and parasitic infections among SAC. Their study showed that the children improved on their MUAC status slightly by +0.082, although not significantly different (Nga *et al.* 2011).

In terms of cognitive performance (Table 5.6), this current study showed that by the end of the 6th month (post intervention) the 'NutEd Only group' had the highest mean test score (16.6±6.6) compared to the other groups (p=0.131) (Table 5.6). The intervention group with the least mean test score by the 6th month was the 'NutEd+Suppl group' (14.7±7.2) (p=0.131). Thus the 'NutEd+Supp Only group' as well as the 'Suppl Only group' seemed to have a relatively poorer performance on cognitive test scores based on the Chi Square analysis. However, further analysis revealed that the 'Suppl Only group' recorded the highest mean difference in cognitive scores (p<0.0001) from baseline to the 6th month (post intervention) (Table 5.7). This finding is similar to a study conducted in the Philippines using a multi-fruit fortified drink for 16 weeks, in which they found that children who were iron and/or iodine deficient at baseline, and received the fortified beverage improved their non-verbal ability test scores (Solon *et al.* 2003). Similarly, in another randomized double-blind placebo study which was conducted to ascertain the efficacy of a fortified biscuit (FB) on the growth, cognition and parasitic infections among Vietnamese SAC between 6 to 8 years, the researchers found that, children who received the FB for four months scored higher on two cognitive test (RCPM and the Digit Span Forward test) (Nga *et al.* 2011).

Overall, children in the fishing community significantly benefitted from the intervention in terms of reduction in anemia rates and increased test scores, whereas those in the farming community benefitted more interms of reduced rates of acute malnutrition, undernutrition (underweight and stunting) (Table 5.4) and infection rates. With regards to type of intervention given, the 'NutEd Only' treatment exhibited the most significantly improved mean outcomes in terms of underweight, stunting and anemia, whilst the 'NutEd+Suppl group' had the highest improvement in the mean difference of blood zinc between the baseline and the 6^{th} month (post intervention), with the 'Suppl Only group' exhibiting the highest improvement in the mean difference in baseline and 6^{th} month (post intervention) outcomes of cognitive performance (Table 5.7).

Limitation of the Study

This study had some limitations including higher attrition rates observed (Fig 5.1) at the 6^{th} month of the study, which could have affected the overall sample size and power of the study, and overall outcomes. Furthermore, there was a risk of reduced compliance to the micronutrient supplementation as some children in the intervention arm missed school and did not take it throughout the intervention period. But records were kept by headmasters of supplement administration, which ensured a maximum compliance of the intervention. Finally compliance to the nutrition education could not be guaranteed, but reminders were given to teachers once a week throughout the intervention period.

Conclusion

Findings from this study has proven to a great extent that nutrition education and deworming intervention strategies can be effective in reducing the high prevalence rates of undernutrition such as underweight, stunting, acute malnutrition zinc deficiency and anemia among school children in helminth endemic areas, as well as improving on their cognitive performances. The greastest impact of the intervention was observed in the 'NuEd Only group'. There is therefore the need for the integration of nutrition education approaches in school-based interventions for a more effective and sustainable nutritional and cognitive outcomes among SAC in helminth-endemic areas. Thus, similar intervention studies are needed to confirm the findings of the present study and subsequent scaling-up.

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Table 5.1: Characteristics of Study Participants by Community Types N=358

Variable	Overall N (%)	Farming n (%)	Fishing n (%)	X^2	P.Value
Type of Intervention					
NutEd Only	102 (28.5)	40 (22.6)	62 (34.3)	7.300	0.063
SupplOnly	85 (23.7)	49 (27.7)	36 (19.9)		
NutEd+Suppl	84 (23.5)	41 (23.2)	43 (23.8)		
Control	87 (24.3)	47 (26.6)	40 (22.1)		
Parent Questioned					
Father	119 (33.2)	73 (41.2)	62 (34.3)	10.539	0.014
Mother	167 (46.6)	75 (42.4)	36 (19.9)		
Male Guardian	27 (7.5)	11 (6.2)	43 (23.8)		
Female Guardian	45 (12.6)	18 (10.2)	40 (22.1)		
Tribe					
Akan	45 (12.6)	24 (13.6)	21 (11.6)	207.201	<0.0001
Ewe	164 (45.8)	17 (9.6)	147 (81.2)		
Northerner	135 (37.7)	126 (71.2)	9 (5.0)		
Other	14 (3.9)	10 (5.6)	4 (2.2)		
Marital Status					
Married/Cohabiting	321 (89.7)	157 (88.7)	164 (90.6)	0.418	0.811
Not Married	29 (8.1)	16 (9.0)	13 (7.2)		
Widowed	8 (2.2)	4 (2.3)	4 (2.2)		
Parent Education					
Never attended	153 (42.7)	88 (49.7)	65 (35.9)	8.300	0.081
Elementary	114 (31.8)	46 (26.0)	68 (37.6)		
Junior High School	63 (17.6)	29 (16.4)	34 (18.8)		
Senior High School	23 (6.4)	11 (6.2)	12 (6.6)		
Tertiary	5 (1.4)	3 (1.7)	2 (1.1)		
Job title					
Farmer	252 (70.4)	160 (90.4)	92 (50.8)	75.595	<0.0001
Fisherman	32 (8.9)	0 (0.0)	32 (17.7)		
Service provider	46 (12.8)	11 (6.2)	35 (19.3)		
Skilled worker	25 (7.0)	6 (3.4)	19 (10.5)		
Unemployed	3 (0.8)	3 (1.7)	3 (0.8)		
Source of Food					
Local market	118 (33.0)	5 (2.8)	113 (62.4)	147.505	<0.0001
From farm	234 (65.4)	170 (96.0)	64 (35.4)		
Other	6 (1.7)	2 (1.1)	3 (2.2)		
Child's Gender					
Female	176 (49.2)	81 (45.8)	95 (52.5)	1.619	0.207
Male	182 (50.8)	96 (54.2)	86 (47.5)		

P<0.05

Table 5.2: Helminthiasis Infection Prevalence by Community Type and Intervention Period

	Helminthiasis		
	Present n (%)	Absent n (%)	P.Value
Baseline			
Overall	106 (29.6)	252(70.4)	<0.0001
Farming	24 (13.6)	153 (86.4)	
Fishing	82 (45.3)	99 (54.7)	
6^{th} Month			
Overall	20 (6.3)	299 (93.7)	0.153
Farming	7 (4.3)	154 (95.7)	
Fishing	13 (8.2)	145 (91.8)	

P<0.05

Table 5.3: Helminth Type and Symptoms by Community Type and Intervention Period

	Community Type and Intervention Period							
	Baseline				6-Month			
Helminthiasis	Overall N (%)	Farming n (%)	Fishing n (%)	p-value	Overall N (%)	Farming n (%)	Fishing n (%)	p-value
Visible hematuria	12 (3.4)	0 (0.0)	12 (6.6)	<0.0001	3 (0.96)	0 (0.0)	3 (1.9)	0.079
Blood micro	55 (15.4)	0 (0.0)	55 (30.4)	<0.0001	12 (3.8)	3 (1.9)	9 (5.7)	0.072
S. heamatobium	80 (22.3)	1 (0.6)	79 (43.6)	<0.0001	12 (3.8)	0 (0.0)	12 (7.6)	<0.0001
S. mansoni	2 (0.6)	0 (0.0)	2 (1.1)	0.161	N/A	N/A	N/A	N/A
Hookworm	17 (4.7)	16 (9)	1 (0.6)	<0.0001	5(1.6)	4 (2.5)	1 (0.6)	0.183
Trichuris	4 (1.1)	4 (2.3)	0 (0.0)	0.047	3 (0.9)	3 (1.9)	0 (0.0)	0.085
H. nana	5 (1.4)	4 (2.3)	1 (0.6	0.169	1 (0.3)	1 (0.6)	0 (0.0)	0.321
Other Parasites	7 (2)	3 (1.7)	4 (2.2)	0.725	N/A	N/A	N/A	N/A

P<0.05

Table 5.4: Anthropometric and Biochemical Indices versus Community Type and Intervention Period

Variable	Community Type			P.Value
	Overall N (%)	Farming n (%)	Fishing n (%)	
Unerweight				
BL	27 (7.5)	14 (7.9)	13 (7.2)	0.810
3rd Month	19 (5.7)	2 (1.2)	17 (10.1)	0.002
6th Month	17 (5.3)	2 (1.2)	15 (9.6)	0.002
Stunting				
BL	40 (11.2)	22 (12.4)	18 (9.9)	0.456
3rd Month	24 (7.2)	12 (7.4)	12 (7.1)	0.927
6th Month	27 (8.5)	15 (9.3)	12 (7.6)	0.592
Acute Malnutrition				
BL	77 (21.5)	31 (17.5)	46 (25.4)	0.069
3rd Month	57 (17.2)	28 (17.2)	29 (17.2)	0.997
6th Month	31 (9.9)	9 (5.6)	22 (14.1)	0.011
Anemia				
BL	165 (46.1)	90 (50.8)	75 (41.4)	0.106
3rd Month	158 (47.6)	91 (55.8)	67 (39.6)	0.003
6th Month	50 (16.1)	38 (23.6)	12 (8.1)	<0.0001
Blood Zinc				
BL	108 (31.4)	45 (25.7)	63 (37.3)	0.021
6th Month	25 (9.3)	15 (10.6)	10 (7.8)	0.425

BL: Baseline, p<0.05

Table 5.5: Helminthiasis Infection Prevalence by Intervention Type

Intervention Type	Helminthiasis Present n (%)	Absent n (%)	P.Value
Baseline			
Overall	106 (29.6)	252 (70.4)	0.079
NutEd Only	33 (32.4)	69 (67.6)	
Suppl Only	31 (36.5)	54 (63.5)	
NutEd+Suppl	16 (19.0)	68 (81.0)	
Control	26 (29.9)	61 (70.1)	
6th Month			
Overall	20 (6.3)	299 (93.7)	0.104
NutEd Only	7 (7.6)	85 (92.4)	
Suppl Only	8 (10.5)	68 (89.5)	
NutEd+Suppl	4 (5.7)	66 (94.3)	
Control	1 (1.2)	80 (98.8)	

P<0.05

Table 5.6: The Mean Test Scores versus Intervention and Type of Community

	Raven cognition test score		
	Baseline	3 months	6 months
Intervention type			
NutEd Only	14.1±4.9	16.2±5.7	16.6±6.6
Suppl Only	11.8±5.3	14.3±5.4	14.9±6.0
NutEd + Suppl	11.6±6.1	14.7±6.3	14.7±7.2
Control	14.2±4.9	15.9±6.0	16.5±6.8
P. value	<0.0001	0.119	0.131
Community Type			
Farming	12.4±5.4	14.3±5.3	14.5±6.3
Fishing	13.7±5.4	16.3±6.3	16.9±6.9
P. value	0.026	0.03	0.010

Data is presented as means ± standard deviation (SD)

Table 5.7: Differences in Anthropometric and Biochemical Indices for Intervention Groups

			Stunting (HAZ)		
Intervention	Time	N	Means ± (SD)	Mean Difference	P.Value
Overall					
	Baseline	318	-0.77 ± 1.02	0.086 ± 0.54	0.050
	6thmo	318	-0.69 ± 1.00		
NutEd Only					
	Baselie	91	-0.68 ± 1.02	0.164 ± 0.31	<0.0001
	6thmo	91	-0.52 ± 1.00		
Suppl Only					
	Baseline	76	-0.77 ± 1.04	0.04 ± 0.88	0.690
	6thmo	76	-0.73 ± 1.06		
NutEd+Suppl					
	Baseline	70	-0.91 ± 1.02	0.10 ± 0.40	0.041
	6thmo	70	-0.81 ± 0.99		
Control					
	Baseline	81	-0.77 ± 0.99	0.03 ± 0.43	0.543
	6thmo	81	-0.74 ± 0.95		
			Underweight (BAZ)		
Intervention	Time	N	Means ± (SD)	Mean Difference	P.Value
Overall					
	Baseline	318	-0.59 ± 0.96	0.02 ± 0.06	0.602
	6thmo	318	-0.58 ± 0.85		
NutEd Only					
	Baseline	91	-0.87 ± 1.16	0.27 ± 0.81	0.002
	6thmo	91	-0.60 ± 0.89		
Suppl Only					
	Baseline	76	-0.55 ± 0.92	0.04 ± 0.51	0.528
	6thmo	76	-0.51 ± 0.87		
NutEd+Suppl					
	Baseline	70	-0.69 ± 0.88	0.06 ± 0.37	0.209
	6thmo	70	-0.64 ± 0.86		
Control					
	Baseline	81	-0.26 ± 0.65	-0.31 ± 0.58	<0.0001
	6thmo	81	-0.57 ± 0.78		
			Haemoglobin level		
Intervention	Time	N	Means ± (SD)	Mean Difference	P.Value
Overall					
	Baseline	310	11.65 ± 0.96	0.93 ± 1.16	<0.0001
	6thmo	310	12.58 ± 1.06		
NutEd Only					<0.0001

	Baseline	91	11.62 ± 0.87	1.22 ± 1.131	
	6thmo	91	12.83 ± 0.96		
Suppl Only					
	Baseline	75	11.59 ± 0.98	0.91 ±0.99	<0.0001
	6thmo	75	12.49 ± 0.90		
NutEd+Suppl					
	Baseline	63	11.65 ± 1.19	1.13 ± 1.14	<0.0001
	6thmo	63	12.79 ± 1.07		
Control					
	Baseline	81	11.7654 ± 0.83114	0.46 ± 1.21	0.001
	6thmo	81	12.2235 ± 1.19899		

	Blood Zinc				
Intervention	Time	N	Means ± (SD)	Mean Difference	P.Value
Overall					
	Baseline	266	17.49 ±10.54	21.35 ± 26.64	<0.0001
	6thmo	266	38.84 ± 24.64		
NutEd Only					
	Baseline	77	15.68 ± 10.02	8.58 ± 16.38	<0.0001
	6thmo	77	24.26 ± 12.62		
Suppl Only					
	Baseline	62	18.39 ± 11.08	18.39 ± 13.29	0.001
	6thmo	62	24.11 ± 10.99154		
NutEd+Suppl					
	Baseline	62	15.96 ± 10.40	46.39 ± 22.30	<0.0001
	6thmo	62	62.35 ± 19.56		
Control					
	Baseline		20.2508412 ± 10.29544832	27.48 ± 29.97	<0.0001
	6thmo		47.7310 ± 27.61147		

Data is presented as Means±Standard deviation (SD) and the differences within the baseline and the 6th month anthropometry and biochemical indices using the Paired sample T.test to compare the different treatments groups between their baseline and 6th month (post intervention) values. P<0.05.

Table 5.8 Differences in Cognitive Indices within Intervention Groups

RCMP Test Score					
Intervention	Time	N	Means ± (SD)	Mean Difference	P.Value
Overall					
	Baseline	321	13.11 ± 5.56	2.62 ± 5.77	<0.0001
	6thmo	321	15.73 ± 6.68		
NutEd Only					
	Baseline	92	14.41 ± 4.98	2.19 ± 5.89	<0.0001
	6thmo	92	16.61 ± 6.55		
Suppl Only					
	Baseline	76	11.79 ± 5.49	3.08 ± 6.07	<0.0001
	6thmo	76	14.87 ± 6.03		
NutEd+Suppl					
	Baseline	72	11.47 ± 6.13	2.99 ± 5.72	<0.0001
	6thmo	72	14.68 ± 7.21		
Control					
	Baseline	81	14.32 ± 5.11	2.148 ± 5.39	0.001
	6thmo	81	16.47 ± 6.816		

Data is presented as Means±Standard deviation (SD) and the differences within the baseline and the 6th month cognitive performance indices using the Paired sample T.test to compare the different treatments between their baseline and 6th month (post intervention) values. P<0.05.

Table 5.9: Predictors of Anthropometric and Biochemical Measures of Undernutrition Based on Intervention Type

Variable		Stunting			Underweight	
Intervention Given	n	Unadjusted OR (95%CI)	P. Value	n	Unadjusted OR (95%CI)	P. Value
NutEd Only	91	0.21 (0.04-0.99)	0.049	91	0.66 (0.14-3.02)	0.589
Control	81	1.00		81		
Suppl Only	76	1.38 (0.52-3.71)	0.520	76	1.36 (0.35-5.25)	0.660
Control	81	1.00		81		
NutEd+Suppl	70	1.01 (0.35-2.95)	0.980	70	1.48 (0.38-5.74)	0.570
Control	81	1.00		81	1.00	
Variable		Anemia			Zinc Def	
Intervention Given	n	Unadjusted OR (95%CI)	P. Value	n	Unadjusted OR (95%CI)	P. Value
NutEd Only	91	0.29 (0.13-0.69)	0.005	78	6.40 (1.39-29.50)	0.017
Control	81	1.00		66	1.00	
Suppl Only	75	0.51(0.23-1.12)	0.095	63	6.04 (1.27-28.77)	0.024
Control	81	1.00		63	1.00	
NutEd+Suppl	63	0.34 (0.13-0.85)	0.021	62	0.00 (N/A)	0.997
Control	81	1.00		63	1.00	

P<0.05

Table 6.0: Predictors of Cognitive Performance Based on Intervention Type

	Cognitive performance		
Variable Intervention Type	n	Unadjusted OR (95%CI)	P.Value
NutEd Only	92	1.27 (0.69-2.37)	0.444
Control	81	1.00	
Suppl Only	76	0.63 (0.32 -1.26)	0.192
Control	81	1.00	
NutEd+Suppl	72	0.73 (0.37-1.45)	0.367
Control	81	1.00	

$P<0.05$

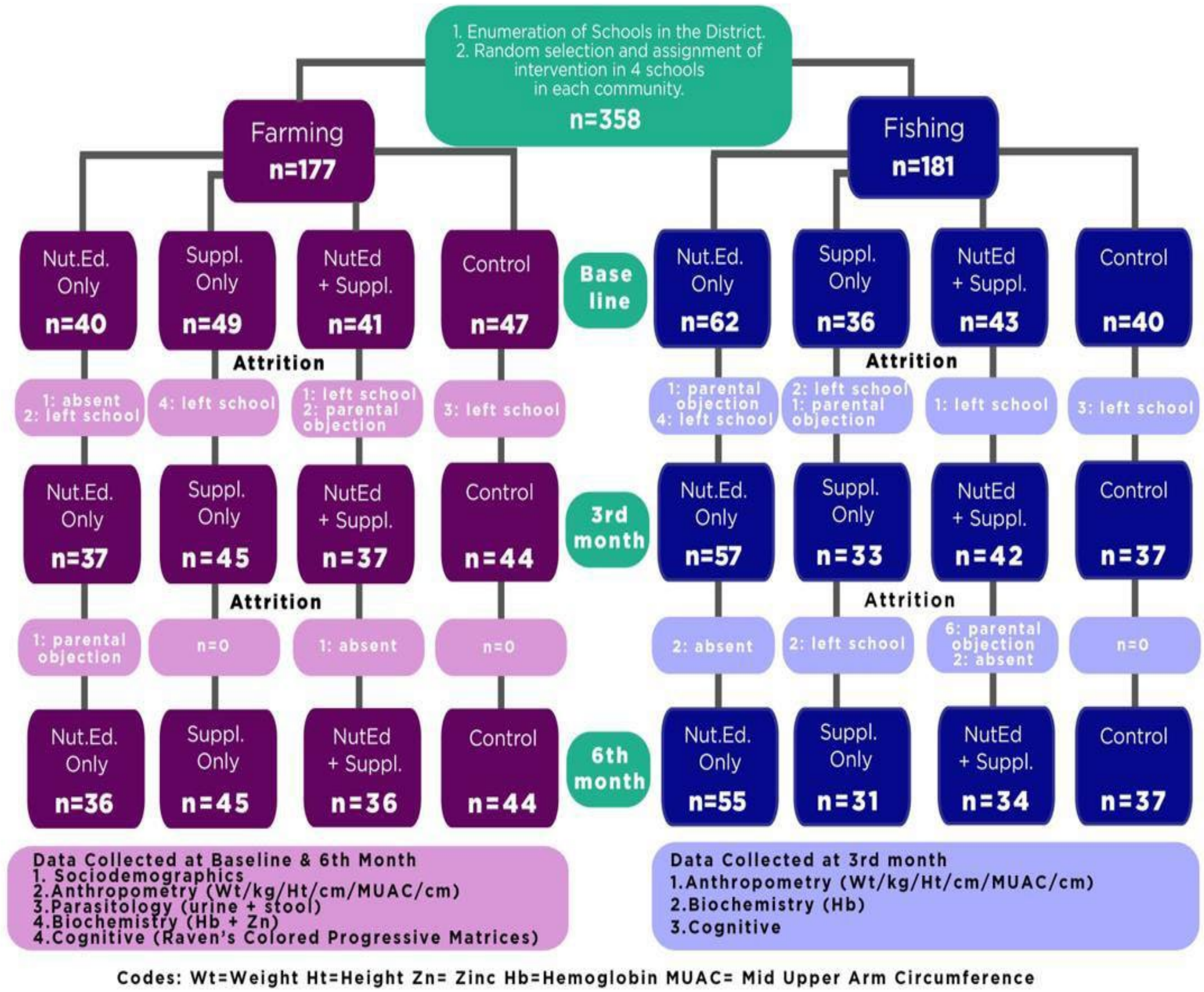

Fig.5.1: A flow chart of the intervention study

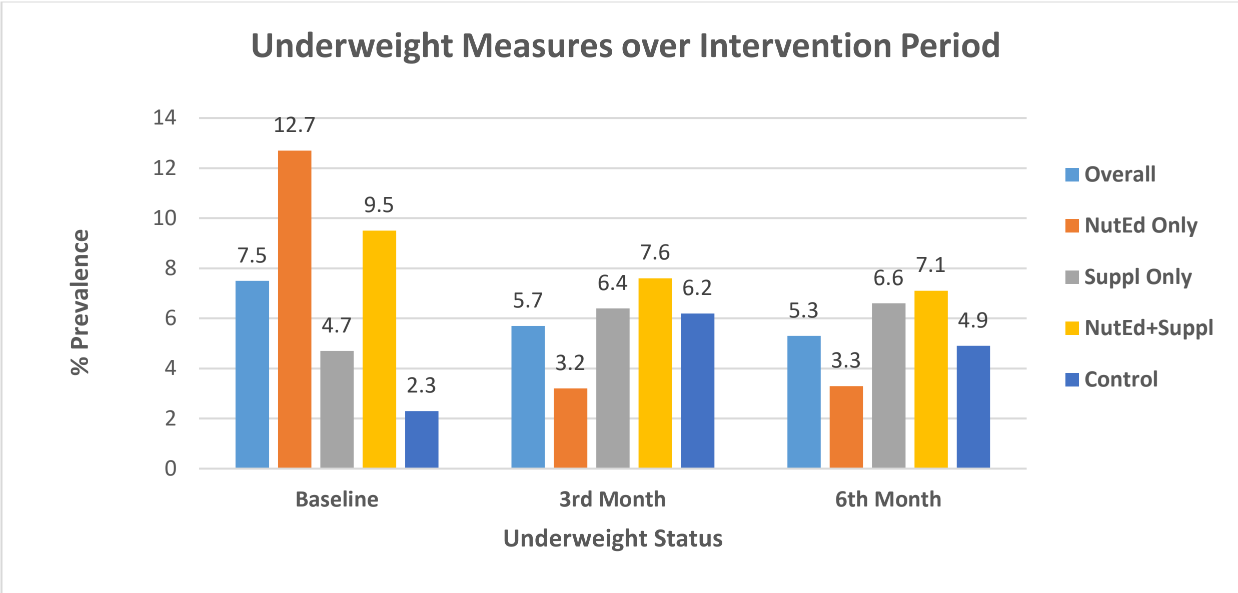

Figure 5.2: Overall Assessment of Underweight by Intervention at Baseline, 3rd Month and 6th Month

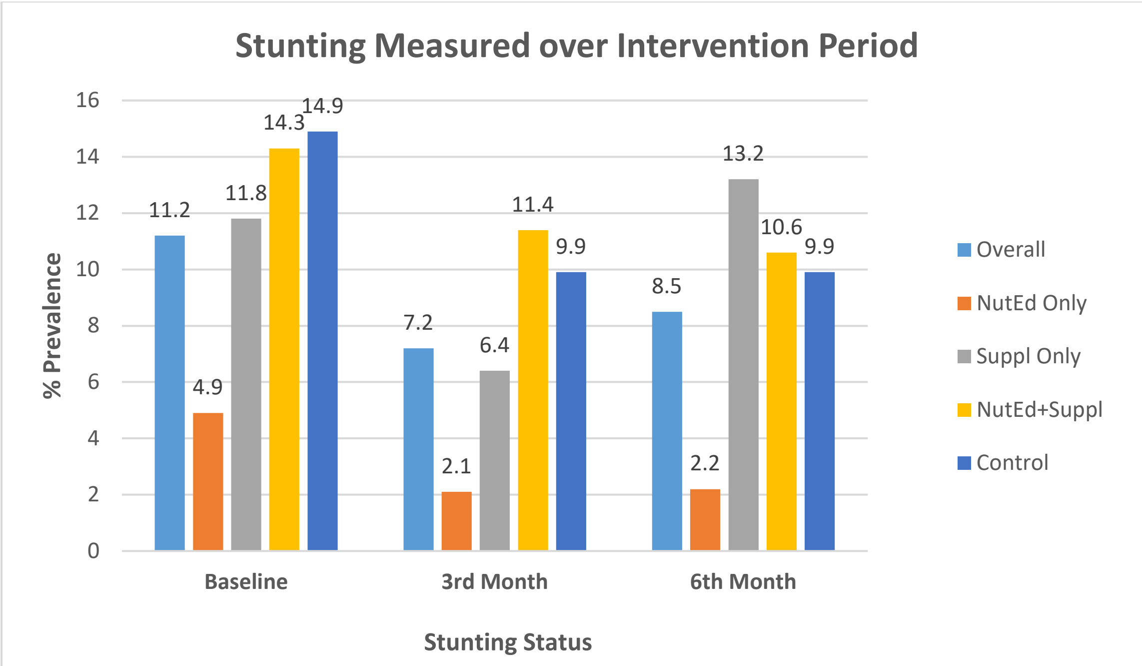

Fig 5.3: Overall Assessment of Stunting by Intervention at Baseline, 3rd Month and 6th Month

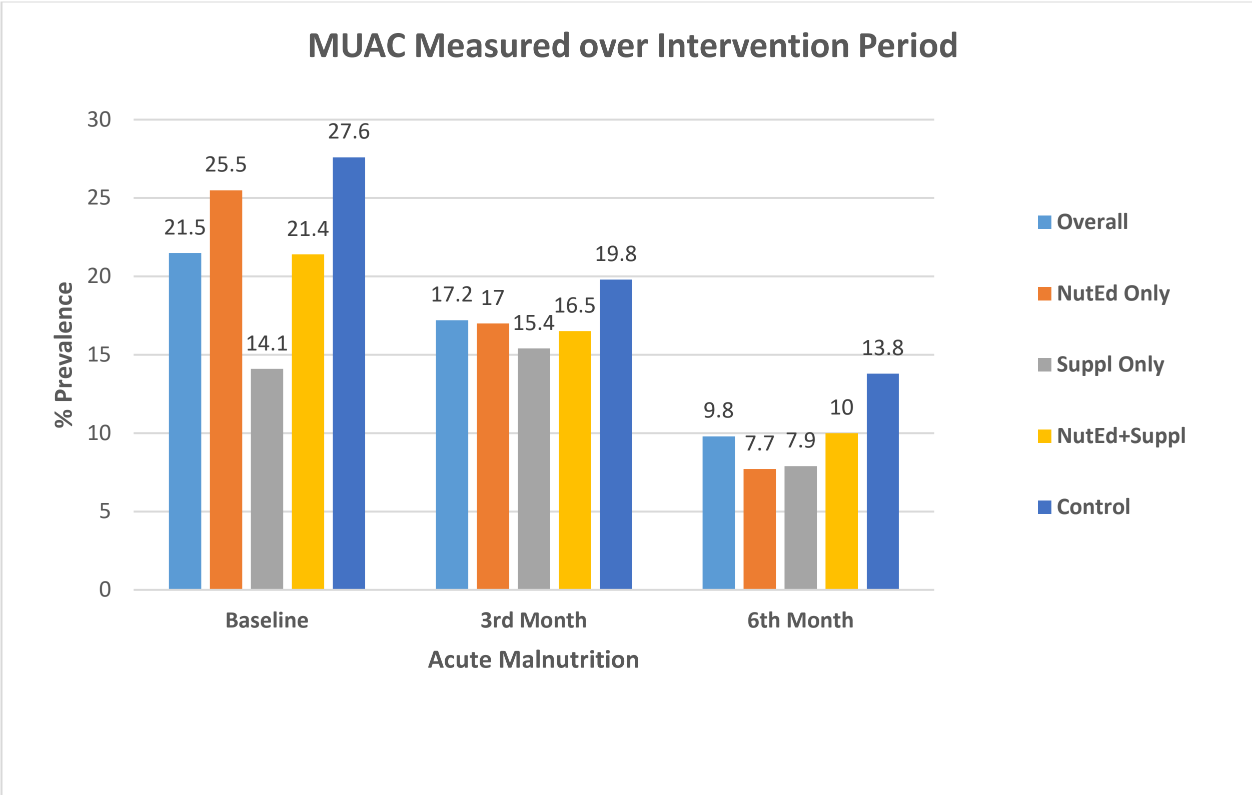

Fig 5.4: Overall Assessment of MUAC by Intervention at Baseline, 3rd Month and 6th Month

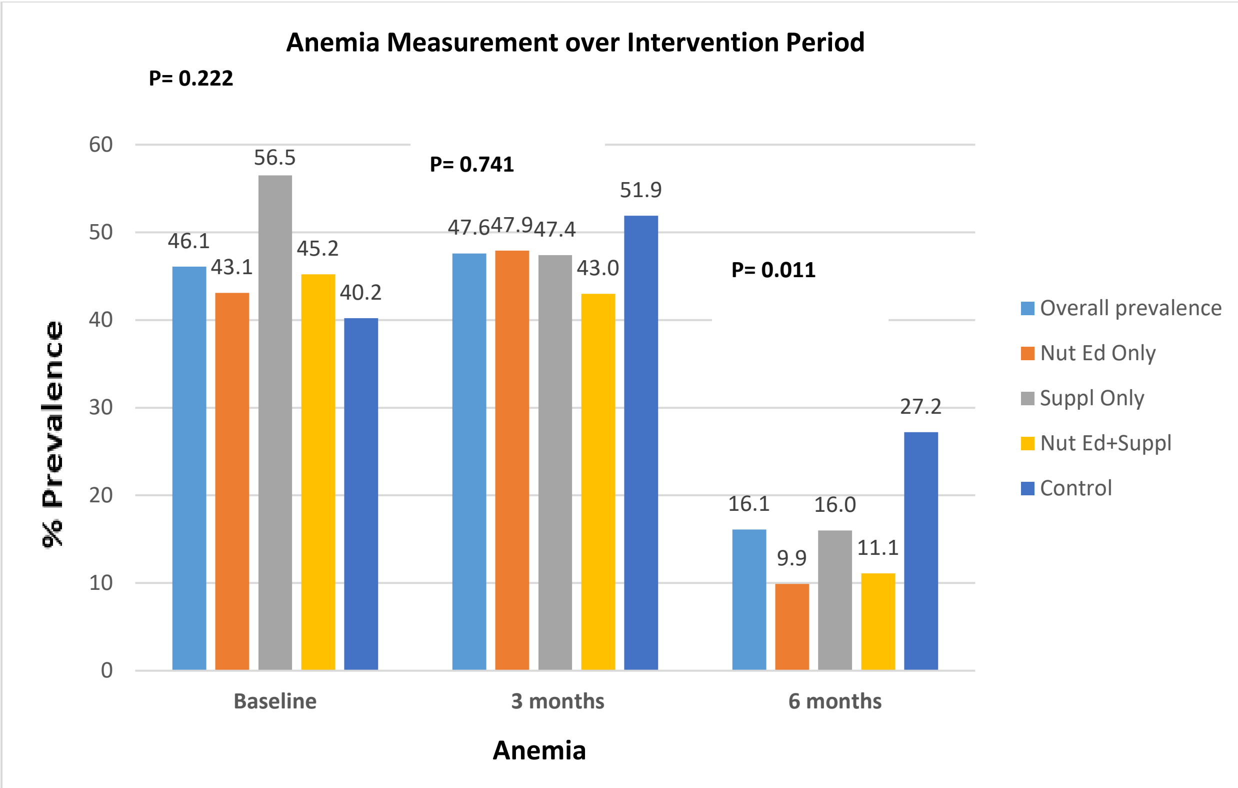

Fig 5.5: Overall Assessment of Anemia by Intervention at Baseline, 3rd Month and 6th Month

CHAPTER 6

CONCLUSION

About a third of the world's population are afflicted with one of the soil-Transmitted helminths (STH); *Trichuris trichiura*, *Ascaris lumbricoides* or hookworm (Colley 2014, WHO 2011), whereas an estimated 800 million people are afflicted with schistosomes (WHO 2011). Ghana continues to be one of the at-risk countries for schistosomiasis with prevalence levels as high as 70% (Rollinson *et al.* 2013). It is estimated that about 170 districts in Ghana are at risk of schistosomiasis, as it is the most important neglected tropic disease in the country (Abdul-Rahman & Agble 2012).

Certain factors are considered to propagate the spread of helminth infections. These are; poor hygienic practices and play habits such as having direct contact with infested fresh water bodies through swimming (Gryseels *et al.* 2006, Knopp *et al.* 2013), walking barefooted, biting fingernails, pica behavior (WHO 2011).

Undernutrition among school-age children is a major public health concern causing 16% underweight, 26% stunting and 8% wasting among school-age children (SAC) worldwide (del Carmen Casanovas *et al.* 2013), with stunting, underweight and wasting in Ghana standing at 19%, 11% and 5% respectively (GSS & Demographic 2015). In addition to that, micronutrient deficiencies continue to be a major public health problem globally with more than two (2) billion people estimated to be affected, of which 250 million are children (Ramakrishnan 2002).

Infections with helminths, tend to worsen the nutritional and health state of children leading to impairments in growth (Grantham-McGregor 2002, Stephenson *et al.* 1993) and cognitive performance (Ezeamama *et al.* 2005, Sternberg *et al.* 1997). Over the years, some nutritional deficiencies have been associated with helminth infections, and these include iron deficiency anemia (Bundy & Cooper 1989, Friis *et al.* 2003).

Some strategies employed to control helminth infections include periodic anthelmintic treatment or the Mass Drug Administration (Molyneux & Malecela 2011), and the 'Water, Sanitation and Health' (WASH) program (Steinbaum *et al.* 2019, WHO 2011). Other interventions have included the use of micronutrient supplementation, with 60mg elemental iron for example used in helminth-endemic areas (Risonar *et al.* 2008). There have been several advantages with micronutrient supplementation in children such as improvement in cognitive performance (Solon *et al.* 2003) and a reduction in helminth rates (Gyorkos *et al.* 2013, Nga *et al.* 2011). The use of multiple micronutrient supplementation has also been shown to increase the hemoglobin levels of children in Western Kenya (Friis *et al.* 2003). Also the use of deworming drugs have been found to improve the helminth infection rates (Mwinzi *et al.* 2012).

The main method of preventing and treating NTDs in Ghana has been through MDA (Abdul-Rahman & Agble 2012). Even though the use of the MDA has been effective in reducing infection rates, the long-term sustainability of such interventions and the challenge with the risk of infection returning to their pre-treatment levels after intervention resources have been removed remains a problem (Clements *et al.* 2009, Doenhoff *et al.* 2008).

This dissertation therefore sought to determine the prevalence of helminthiasis (due to schistosomiasis and/or STH) among SAC in helminth-endemic rural area in Ghana (Kwahu Afram Plains South District). It further sought to ascertain the existing disparities in the two unique settings within the district (farming and fishing communities) and to establish the associations of helminth infections and risk factors such as poor hygienic and sanitation practices and poor health behaviors. Furthermore, it sought to examine the existing disparities in the cognitive performance and some nutritional outcomes such as underweight, stunting, anemia and zinc deficiency.

Finally, it sought to compare the effectiveness of three (3) different intervention methods; using four arms of interventions; 'Nutrition Education Only' (NutEd Only), a 'Micronutrient Supplementation Only' (Suppl Only), a combination of the two (Nutrition Education+Supplementation Only' (NutEd+Suppl) and a 'Control' (deworming Only) groups. This aimed at identifying a more cost effective and sustainable approach that would improve the nutritional status and cognitive performance of SAC in helminth-endemic areas.

The results of the first study is presented in chapter 3, and this showed the overall prevalence rates of STH to be 4.9%, with 9.6% in the farming, and non occurring in the fishing community. Whilst for schistosomiasis, overall prevalence was 17.1%, with 1.2% in the farming and 33.8% in the fishing community. The type of helminths identified were *Trichuris* (3) and hookworms (5). There were no eggs of *Ascaris* nor *S. mansoni*. There was also no case of visible hematuria, but a reagent strip analysis showed that 26 of urine samples had it. The micro hematuria occurred among children in the fishing community ($p<0.0001$). No significant difference was observed in the prevalence of *S. haematobium* by age. However, more females (18.5%) than males (15.7%) were infected with *S. haematobium* ($p=0.681$).

With regards to hygienic practices, factors such as the method of waste disposal, water treatment method, occasions under which hands are washed and frequency with which hands are washed, washing hands before eating, as well as pica behavior, engaging in farming activities, swimming in river and fingernails biting were all significantly different between the fishing and farming communities.

As was observed in our study, overall, 24.4% of children practiced pica behavior, which was significantly higher in the farming community (31.0%) compared to those in the fishing community (17.5%) ($p=0.048$). Also, the farming community had the closest proximity to their source of drinking water (48.8%) compared to 13.8% of the fishing community ($p<0.0001$). Overall, 48.8% of the children drank from the Afram River, whilst 51.2% drank from boreholes. Also, 62.8% of all children swam in the river, with 47.6% of them being in the farming and 78.8% of them in the fishing community ($p<0.0001$) The habit of biting finger nails was also practiced by more than half of all the children, with 46.4% being in the farming and 68.8% in the fishing community ($p=0.05$). Also, about 83.0 % of children who did not have toilet facility in their homes engaged in open defecation, with 59.1% occurring in the farming compared to 70.5% in the fishing community ($p<0.0001$).

One of the most important findings in our study was the predictors of childhood *S. haematobium* infection, and this revealed that the source of drinking water, engaging in farming activities, swimming in river and water storage method were the predictors of helminth infection. This confirms the assertion that poor hygienic and sanitation practices increases the risk of helminth infections.

In our second study (Chapter 4), we aimed at identifying existing nutritional and cognitive deficits among SAC in the two unique settings in the district (farming and fishing). Findings from our studies showed significant differences in the mean values for underweight (BAZ) ($p=0.03$), serum zinc/µmol/L ($p<0.0001$), total carbohydrate/g/d ($p= 0.003$), total vitamin c/mg/d ($p=0.001$) as well as school attendance ($p=0.03$) between children in the farming and fishing communities.

Overall, 13.8% of all children were stunted, whilst 7.5% of them were underweight, with no significant differences between the two communities. Overall serum zinc deficiency was 22.4%, with a higher deficiency (41.5%) occurring in the farming community compared to 2.5% in the fishing community ($p<0.0001$). Also about half of all the children were anemic (53.1% with no significant differences observed in the two communities ($p=0.0867$). In terms of age, 12 year olds were found to be significantly stunted (28.6%) compared to all other age groups ($p=0.001$). They were also found to be the most anemic (57.9%), underweight (10.7%) and zinc deficient (28.1%) but this was not significantly different from other age groups. In terms of gender, more female were found to be stunted, underweight and more zinc deficient. Male children were however more anemic (60.2%) than females (45.6%) ($p=0.061$).

Our study showed the nutritional indicators which were significant in relation to helminthiasis to be serum zinc deficiency and anemia such that 8.3% of those who had helminth infection were zinc deficient compared to 26.4% of those who did not have the infection ($p= 0.002$). In addition to that, 69.4% of those who had helminth infection were significantly anemic, compared to those who did not have the infection (48.4%) ($p=0.026$). About 22.4% of all children were zinc deficient with a higher proportion occurring in the farming community ($p<0.0001$). Helminth infection did not affect the cognitive performance of children significantly, neither did Hb nor zinc levels affect cognition. Anemia was the most prevalent nutritional deficiency, with over half of all children being anemic (53.1%).

Univariate analysis revealed that helminthiasis status and pica behavior of children were associated with anemia, whereas a multivariate analysis, which was adjusted for child age, gender and community type revealed that helminthiasis status (AOR=0.42, CI; 0.18-0.89) and pica habit (AOR=0.39, CI; 0.18-0.89) were independent predictors of anemia.

In our third study (chapter 5), we found no significant differences between the various intervention groups ($p=0.063$), gender ($p=0.207$), parental marital status ($p=0.811$) and parental educational level ($p=0.081$). In terms of the impact of interventions on underweight (<-2SD BAZ), there was no significant improvement overall ($p=0.602$), but significant improvement in BAZ was observed in the 'NutEd Only group' with a mean difference of 0.266 ± 0.81 ($p=0.002$) between the baseline and the 6^{th} month post intervention. Stunting levels (HAZ), were also significantly improved by 0.164 ± 0.38 in the 'NutEd Only group' ($p<0.0001$) and the 'NutEd+Suppl group' (0.997 ± 0.04) ($p=0.041$). The 'Suppl only group' and the 'Control group' also had some improvement in their stunting rates, although not significant ($p>0.05$).

Significant improvement in mean Hb levels were also observed across all the intervention groups, with the 'NutEd Only group' showing the highest mean difference (1.216 ± 1.13) ($p<0.0001$), between the baseline and 6^{th} month (post intervention).

Significant differences were also observed in blood zinc levels such that the highest mean difference was recorded in the 'NutEd Only group' (8.578 ± 16.38) ($p<0.0001$).

In terms of cognitive assessment (RCPM), the 'Suppl Only group' recorded the highest improvement with a mean difference of 3.079 ± 6.07 ($p<0.0001$).

A univariate analysis revealed that the 'NutEd Only group' was the only intervention arm which was significantly associated with stunting (OR=0.205, CI; 0.042-0.996) compared to the 'Control group' ($p=0.049$). No significant associations were observed between the different intervention arms and underweight status. In terms of anemia however, significant associations were observed between the 'NutEd Only group' (OR=0.294, CI; 0.126-0.69) and the 'Control group' ($p=0.005$), whereas the 'NutEd+Suppl group' were also significantly associated with anemia (OR=0.335, CI; 0.133-0.85) ($p=0.021$). Significant differences were also observed between the 'NutEd Only group' and blood zinc deficiency (OR=6.4, CI; 1.388-29.503) compared to the 'Control group' ($p=0.017$). The 'Suppl Only group' were also found to be significantly associated with zinc deficiency (OR=6.038, CI; 1.267-28.767) ($p=0.024$).

No significant associations were however observed in the both the univariate and multivariate analysis with regards to the different intervention groups based on the cognitive performance ($p>0.05$).

Our overall results reinforces the need to use an integrated approach of interventions to effectively improve the nutritional and cognitive status of children living in helminth-endemic areas. More focus has to be placed on children living close to water bodies such as rivers and lakes. Interventions should be tailored to suit these specific needs of the children based on their geographical location. More emphasis should also be placed on nutrition education to improve nutrition, personal hygiene and sanitation, which would potentially lead to reduced helminth re-infection rates, and ultimately improved overall nutritional and cognitive status.

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APPENDICES

APPENDIX A: APPROVAL OF STUDY BY UGA IRB (2017)

The University of Georgia

Phone 706-542-3199

Office of the Vice President for Research
Institutional Review Board

APPROVAL OF PROTOCOL

April 5, 2017

Dear Alex Anderson:

On 4/5/2017, the IRB reviewed the following submission:

Type of Review:	Initial Study
Title of Study:	PREVALENCE OF HELMINTHIASIS AND ITS ASSOCIATION WITH NUTRITIONAL STATUS AND COGNITIVE PERFORMANCE OF SCHOOL-AGE CHILDREN LIVING IN HELMINTH ENDEMIC FISHING AND FARMING COMMUNITIES IN RURAL GHANA
Investigator:	Alex Anderson
IRB ID:	STUDY00004580
Funding:	Name: US AGENCY FOR INATL DEVEL; Funding Source ID: FP00004669,
Grant ID:	OAC-00587
Review Category:	Expedited 2b, 3, 7a

The IRB approved the protocol from 4/5/2017 to 4/4/2018 inclusive. Before 4/4/2018 or within 30 days of study closure, whichever is earlier, you are to submit a continuing review with required explanations. You can submit a continuing review by navigating to the active study and clicking Create Modification / CR.

If continuing review approval is not granted before the expiration date of 4/4/2018, approval of this study expires on that date.

In conducting this study, you are required to follow the requirements listed in the Investigator Manual (HRP-103).

Sincerely,

Dr. Gerald E. Crites, MD, MEd
University of Georgia
Institutional Review Board Chairperson

310 East Campus Rd, Tucker Hall Room 212 • Athens, Georgia 30602
An Equal Opportunity/Affirmative Action Institution

APPENDIX B: APPROVAL OF STUDY BY UGA IRB (2018)

UNIVERSITY OF GEORGIA

Tucker Hall, Room 212
310 E. Campus Rd.
Athens, Georgia 30602
TEL 706-542-3199 | FAX 706-542-5638
IRB@uga.edu
http://research.uga.edu/hso/irb/

Office of Research
Institutional Review Board

APPROVAL OF PROTOCOL

March 19, 2018

Dear Alex Anderson:

On 3/8/2018, the IRB reviewed the following submission:

Type of Review:	Modification and Continuing Review
Title of Study:	PREVALENCE OF HELMINTHIASIS AND ITS ASSOCIATION WITH NUTRITIONAL STATUS AND COGNITIVE PERFORMANCE OF SCHOOL-AGE CHILDREN LIVING IN HELMINTH ENDEMIC FISHING AND FARMING COMMUNITIES IN RURAL GHANA
Investigator:	Alex Anderson
Student Co-Investigator:	Marina Tandoh
IRB ID:	MOD00005562
Funding:	Name: US AGENCY FOR INATL DEVEL; Grant Office ID: OAC-00587, Funding Source ID: FP00004669,
Grant ID:	OAC-00587;
Review Category:	Expedited 2b, 3, 6, 7

Reviewed for Subpart D- 45 CFR 46.404; permission from one parent is sufficient; minor assent will be obtained.

Modifications Reviewed: Updated to include phase II of the study design
Documents Reviewed: Consent Document and Cover Letter, Minor Assent, Recruitment Letter, Data Collection Instruments, Drug Insert: Zinc Sulfate

The IRB approved the protocol from 4/5/2018 to 4/4/2019 inclusive. Before or within 30 days of study closure, whichever is earlier, you are to submit a continuing review with required explanations. You can submit a continuing review by navigating to the active study and clicking Create Modification / CR. If continuing review approval is not granted before the expiration date of 4/4/2018, approval of this study expires on that date.

If consent will be documented, use the consent documents that were approved and stamped by the IRB. Go to the Documents tab to download them.

Please close this study when all human subject research activities and data analysis of identifiable information is complete.

In conducting this study, you are required to follow the requirements listed in the Investigator Manual (HRP-103).

Sincerely,
Brooke M. Harwell
Institutional Review Board
University of Georgia
Commit to Georgia | give.uga.edu
An Equal Opportunity, Affirmative Action, Veteran, Disability Institution

APPENDIX C: APPROVAL OF STUDY BY KNUST ETHICS COMMITTEE (2017)

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY
COLLEGE OF HEALTH SCIENCES

SCHOOL OF MEDICAL SCIENCES / KOMFO ANOKYE TEACHING HOSPITAL

COMMITTEE ON HUMAN RESEARCH, PUBLICATION AND ETHICS

Ref: CHRPE/RC/182/17 2nd June, 2017.

Dr. Alex Kojo Anderson
Department of Foods and Nutrition
The University of Georgia
USA.

Dear Sir,

ETHICS REVIEW COMMENTS – CONDITIONAL APPROVAL

Protocol Title: ***"Prevalence of Helminthiasis and Its Association with Nutritional Status and Cognitive Performance of School-Age Children Living in Helminth Endemic Fishing and Farming Communities in Rural Ghana."***

Following an expedited review, your protocol was given a conditional approval subject to you addressing the following concerns/queries:

On the CHRPE Form:

Item 2.14: 1. Children found to be anaemic should be referred to the hospital for treatment. The name of the contact person at the hospital should be indicated.

Kindly make the necessary amendments and submit one copy each of all required documents to the CHRPE (Room 7, Block J, School of Medical Sciences, KNUST), along with a letter explaining the changes you have made to each document. The date and reference number of this letter should be quoted in your letter.

Thank you Sir, for your application.

Yours faithfully,

Osomfo Prof. Sir J. W. Acheampong MD, FWACP
Chairman

Room 7 Block J, School of Medical Sciences, KNUST, University Post Office, Kumasi, Ghana
Phone: +233 3220 63248 Mobile: +233 20 5453785 Email: chrpe.knust.kath@gmail.com / chrpe@knust.edu.gh

APPENDIX D: APPROVAL OF STUDY BY KNUST ETHICS COMMITTEE (2018)

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY
COLLEGE OF HEALTH SCIENCES

SCHOOL OF MEDICAL SCIENCES / KOMFO ANOKYE TEACHING HOSPITAL

COMMITTEE ON HUMAN RESEARCH, PUBLICATION AND ETHICS

Ref: CHRPE/AP/355/18

25th June, 2018.

Dr. Alex Kojo Anderson
Department of Foods and Nutrition
University of Georgia
USA.

Dear Sir,

LETTER OF APPROVAL

Protocol Title: ***"Interventions to Improve Nutritional Status and Cognitive Performance of School-Age Children Living in Helminth-Endemic Fishing and Farming Communities in Rural Ghana."***

Proposed Site: ***Kwahu Afram Plains South District in the Eastern Region of Ghana.***

Sponsor: ***Borlaug Higher Education for Agricultural Research and Development, U.S. and The University of Georgia Innovation and Interdisciplinary Research Grant.***

Your submission to the Committee on Human Research, Publications and Ethics on the above-named protocol refers.

The Committee reviewed the following documents:

- Notification letters from the Eastern Regional Health and Education Directorate (study sites) indicating approval for the conduct of the study at the Region.
- A Completed CHRPE Application Form.
- Participant Information Leaflet and Consent Form.
- Research Protocol.

The Committee has considered the ethical merit of your submission and approved the protocol. The approval is for a fixed period of one year, beginning 25th June, 2018 to 24th June, 2019 renewable thereafter. The Committee may however, suspend or withdraw ethical approval at any time if your study is found to contravene the approved protocol.

Data gathered for the study should be used for the approved purposes only. Permission should be sought from the Committee if any amendment to the protocol or use, other than submitted, is made of your research data.

The Committee should be notified of the actual start date of the project and would expect a report on your study, annually or at the close of the project, whichever one comes first. It should also be informed of any publication arising from the study.

Yours faithfully,

Osomfo Prof. Sir J. W. Acheampong MD, FWACP
Chairman

Room 7 Block J, School of Medical Sciences, KNUST, University Post Office, Kumasi, Ghana
Phone: +233 3220 63248 Mobile: +233 20 5453785 Email: chrpe.knust.kath@gmail.com / chrpe@knust.edu.gh

APPENDIX E: PERMISSION LETTER, GHANA HEALTH SERVICES (2017)

...e of the reply the number
...he date of this letter should
...oted.

...Ref. No. ERHD/ 1520/17

...our Ref. No. ....

GHANA HEALTH SERVICE

Your Health - Our Concern

REGIONAL HEALTH ADM...
GHANA HEALTH SERVIC...
EASTERN REGION
P.O. BOX 175
KOFORIDUA.

19th April, 2017
Tele: 03420-23341
Fax: 03420-23351
E-mail: rdhs.er@ghsmail.org

MARINA AFERIBA TANDOH
DEPARTMENT OF BIOCHEMISTRY &
BIOTECHNOLOGY, KNUST
KUMASI

RE: PERMISSION TO CONDUCT A SURVEY

We acknowledge receipt of your letter on the above subject matter and convey approval to conduct your survey in the Kwahu Afram Plains District.

Thank you.

ASARE BEDIAKO MICAH (MR.)
DEPUTY DIRECTOR (ADMIN.)
For: REG. DIR. OF HEALTH SERVICES
EASTERN REGION

Cc:

The District Director of Health Service
Kwahu Afram Plains North District
Donkorkrom

@ DDHS
Kwahu Afram Plains
North & South

Approved for the
2 (two) Districts

08/06/17

DEPUTY DIRECTOR (ADMIN.)
REG. HEALTH DIRECTORATE
KOFORIDUA—E/R.

APPENDIX F: PERMISSION LETTER, GHANA HEALTH SERVICE (2018)

In case of reply the number and the date of this letter should be quoted My Ref No: 2062/18 You're Ref. No	GHANA HEALTH SERVICE Your Health - Our Concern	**Eastern Reg. Health Directorate** GHANA HEALTH SERVICE P. O. Box KF 175 Koforidua GHANA Tel: (0342) 023341 Fax: (0342) 023351 Email: rdhs.er@ghsmail.org 26th June, 2018.

THE DISTRICT DIRECTOR OF HEALTH SERVICES,
KWAHU AFRAM PLAINS NORTH AND SOUTH.

LETTER OF INTRODUCTION.

This is to introduce to you of MARINA A. TANDOH ~~**DR F.C MILLS ROBERTSON**~~, an assistant lecturer in the Department of Biochemistry and Biotechnology, KNUST. She ~~He~~ is conducting a study titled ***'Intervention to improve Nutritional Status and Cognitive Performance of School-age children living in Helminth-Economic Fishing and Farming Communities in Rural Ghana.*** This is a follow-up on a previous study conducted last year looking at ***community trial study on the prevalence of helminth infection among school-age children within the District***.

Kindly facilitate his entry into your District and assist him for a successful study.

Attached is the letter of permission from his School.

Counting on your cooperation.

Thank you.

DR. ALBERT ANTOBRE BOATENG.
AG. REGIONAL DIRECTOR OF HEALTH SERVICES.
EASTERN REGION.

APPENDIX G: PERMISSION LETTER, GHANA EDUCATION SERVICE (2017)

GHANA EDUCATION SERVICE

In case of reply the number
and date of this
letter should be quoted.

My Ref. No.GES/ER/PG.114/Vol.4/......

REPUBLIC OF GHANA

REGIONAL EDUCATION OFFICE,
P. O. BOX KF 99,
KOFORIDUA.

24TH APRIL, 2017

Your Ref No..................................

MARINA A. TANDOH
DEPARTMENT OF BIOCHEMISTRY AND BIOTECHNOLOGY
KWAME NKRUMAH UNIVERSITY OF SCIENCE & TECHNOLOGY
KUMASI

PERMISSION TO CONDUCT A SURVEY

The directorate has received your letter seeking permission to conduct a survey in some selected communities on the prevalence of helminth infections among school-age children in the Kwahu Afram Plains South District.

Although you have been given permission to undertake the exercise, we would entreat you to seek the consent of the parents before you start the exercise.

You have to collaborate with the District SHEP Co-ordinator for a successful exercise and a report should be submitted to the directorate.

We appreciate your contribution to improve health care delivery among pupils in the Kwahu Afram Plains South.

Thank you.

GERTRUDE MENSAH (MS)
REGIONAL DIRECTOR (E)

GHANA EDUCATION SERVICE RECEIVED 14 JUN 2017 AFRAM PLAINS SOUTH

cc: The District Director
Ghana Health Service
Afram Plains South

The Co-ordinating Director
District Assembly
Afram Plains South

The District Director
Ghana Education Service
Afram Plains South

The directorate has given them the permission so please give them the necessary assistance

Mr. (Augustine Gbeku)
ASSISTANT DIRECTOR
SUPERVISION & MONITORING
GHANA EDUCTAION SERVICE
KWAHU AFRAM PLAINS SOUTH DIST
15/06/17

APPENDIX H: PERMISSION LETTER, GHANA EDUCATION SERVICE (2018)

GHANA EDUCATION SERVICE

In case of reply the number and date of this
Letter should be quoted
Tel 03420-22741

REPUBLIC OF GHANA

REGIONAL EDUCATION OFFICE
P. O. BOX 99
KOFORIDUA.

My Ref. No.:GES/PG559/V3

Your Ref No.:

26TH. JUNE, 2018.

MARINA A. TANDOH
DEPARTMENT OF BIOCHEMISTRY AND BIOTECHNOLOGY
KWAME NKRUMAH UNIVERSITY OF SCIENCE & TECHNOLOGY
KUMASI

RE:PERMISSION TO CONDUCT A STUDY

Your letter dated 10th April, 2018 on the above subject refers.
You wrote to seek permission to conduct a survey in some selected Helminth-Endemic Fish and Farming Communities in the Region.

You are hereby granted permission on condition that you collaborate with the District/Municipal Directors and the School Health Education Program(SHEP) Coordinators in the respective districts.

Your effort at improving health care delivery among pupils in these endemic areas is very much appreciated.

Thank you.

GERTRUDE MENSAH (MS)
REGIONAL DIRECTOR (E)

Cc:

The District Director
Ghana Health Service
Afram Plains South District

The Coordinating Director
District Assembly
Afram Pklains South

The District Director
Ghana Education Service
Afram Plains South

APPENDIX I: INVITATION LETTER (2017)

Recruitment Letter

Date

Dear:

I am a graduate student conducting research under the direction of Dr. Alex Kojo Anderson (PI) in the Department of Foods and Nutrition at the University of Georgia. The research is focused on assessing the prevalence of helminth infection and nutritional status of school age children.

We want to invite you and your child to participate in the study. To be included in the study your child will be screened to be sure he or she is between 9-12 years old and does not have sickle cell disease/malaria/fever or other chronic diseases such as Goiter and Elephantiasis at the time of enrolment. Also children taking nutritional supplement will be excluded from the study. Note that your child may be determined to qualify or not qualify for participation in the study. In addition, as a parent/guardian of the child, you must be 25 years or older to be included in the study.

If you decide to let your child participate in the study, you have to come to his or her school within 1 week of receiving this letter to be screened and have your permission to collect data on you and your child. The involvement of you and your child in this study is voluntary, and either or both of you may choose not to participate or to stop at any time without penalty or loss of benefits to which you are otherwise entitled.

For participating in this study, you and your child will receive an incentive of GH₵ 20 (GH₵10 on day-1 and GH₵10 on day-2) as compensation for your time (2 hours in total).

If you have questions later, you may contact Alex Kojo Anderson at fianko@uga.edu or at +233 24 165 0490 or Marina Aferiba Tandoh at mtandoh@yahoo.co orat +233248989545.

Thank you for your consideration! Please keep this letter for your records.

Sincerely,

……………………………………………

Marina Aferiba Tandoh

APPENDIX J: INVITATION LETTER (2018)

Recruitment Letter

Date

Dear:

I am a graduate student conducting research under the direction of Dr. Alex Kojo Anderson (PI) in the Department of Foods and Nutrition at the University of Georgia. The research is focused on assessing the effectiveness of different nutrition interventions on the nutritional status and school performance of school-age children living in helminth endemic areas.
We want to invite you and your child to participate in the study. To be included in the study your child will be screened to be sure he or she is between 9-12 years old and does not have sickle cell disease/malaria/fever or other chronic diseases such as Goiter and Elephantiasis at the time of enrolment. Also children taking nutritional supplement will be excluded from the study. Note that your child may be determined to qualify or not qualify for participation in the study. In addition, as a parent/guardian of the child, you must be 25 years or older to be included in the study.

If you decide to let your child participate in the study, you have to come to his or her school within 1 week of receiving this letter to be screened and have your permission to collect data on you and your child. The involvement of you and your child in this study is voluntary, and either or both of you may choose not to participate or to stop at any time without penalty or loss of benefits to which you are otherwise entitled.

For participating in this study, you and your child will receive an incentive of GH₵ 20 (GH₵10 on meeting-1, another GH¢10 a final meeting-3) as compensation for your time (4 hours in total).

If you have questions later, you may contact Alex Kojo Anderson at fianko@uga.edu or at 024 165 0490 or Marina Aferiba Tandoh at mtandoh@yahoo.co or at 0248989545.

Thank you for your consideration! Please keep this letter for your records.

Sincerely,

……………………………………………

Marina Aferiba Tandoh

APPENDIX K: PARENTAL CONSENT FORM (2017)

UNIVERSITY OF GEORGIA
CONSENT FORM

PREVALENCE OF HELMINTHIASIS AND ITS ASSOCIATION WITH NUTRITIONAL STATUS AND COGNITIVE PERFORMANCE OF SCHOOL-AGE CHILDREN LIVING IN HELMINTH ENDEMIC FISHING AND FARMING COMMUNITIES IN RURAL GHANA

Researcher's Statement

We are asking you to take part in a research study. Before you decide to participate in this study, it is important that you understand why the research is being done and what it will involve. This form is designed to give you the information about the study so you can decide whether to be in the study or not. Please take the time to read the following information carefully. Please ask the researcher if there is anything that is not clear or if you need more information. When all your questions have been answered, you can decide if you want to be in the study or not. This process is called "informed consent." A copy of this form will be given to you.

Principal Investigator: *Alex Kojo Anderson*
Department of Foods and Nutrition
Phone: 706-542-7614
Email: fianko@uga.edu

Purpose of the Study

Malnutrition and helminth (parasitic) infections are common problems among children in developing countries contributing to thousands of deaths every year. It is estimated that over 2 billion people including 250 million children are affected by micronutrient deficiencies in the world. In developing countries, children are the worst affected because of heavy infections with parasites. Infections with parasites tend to affect optimal digestion and absorption of nutrients in humans and causes symptoms such as vomiting, diarrhea and loss of appetite. This leads to micronutrient deficiencies which contributes to weakened immune system, making individuals further vulnerable to other infections. Growth retardation and anemia has been reported in children with heavy whipworm infections.

This proposed study is a preliminary study (cross-sectional) which will be descriptive in nature to involve collection of data on the prevalence of helminthiasis (by urine and stool), anthropometrics (height, weight and Mid-Upper Arm Circumference), socio-demographics, biochemical (hemoglobin and zinc), lifestyle, dietary habit and cognitive performance (school attendance and non-verbal reasoning ability, using Raven's progressive Matrices).

You are being asked to participate in this study because your child lives within the randomly selected rural communities where helminth infections are endemic, your child also falls within the ages 9-12 year olds of the randomly selected schools has passed the screening test for the study, and you are 25 years and above.

Study Procedures

If you agree to participate, it will require a two-time point meetings. During the first meeting (day-1), you and your child will be invited to the study site on a scheduled day for registration to participate in the survey. On this day, your child will be given urine and stool containers to provide stool and urine samples for the next day (morning). The process of collection and quantity of the stool and urine sample will be demonstrated to you to assist your child at home. You will then be guided to assist your child in filling out a brief questionnaire containing information about your socio-demographics (age, sex, employment, level of education, relationship to child etc). The questionnaire will also cover areas such as your sanitation and dietary practices and knowledge on parasitic infections among others with regards to your child. This will require about 40 minutes of your time, in addition to another 60 minutes that will be required to do some measurements on your child (weight, height, mid-upper arm circumference; venous blood draw (5ml) and cognitive assessment). For the second meeting (day-2), your child will return a fresh fecal and urine sample in the morning for submission and recording. The time required for this will be approximately 20 minutes. Thus total time in all required for this study will be 2 hours. Based on the results of the stool and urine analysis, your child may be invited back during the week to the school for a deworming medication.

Risks and discomforts

There will be no major risk associated with taking part in this survey except the slight discomfort of disclosing personal information about sanitation practices and dietary habits of you and your child. Also your child may find it a bit uncomfortable to provide his/her stool and urine samples. And is also likely to experience a slight discomfort and soreness at the site of the needle prick during the collection of venous blood. There is also the risk of fainting associated with blood draws. Also during the cognitive assessment, your child is likely to feel embarrassed if he/she feels unable to do the assigned test correctly. Should your child be tested positive for a parasitic infection, he/she will be treated with a dewormer, and this is usually safe, but in some rare circumstances can cause some minor and transient adverse effect such as nausea, vomiting, diarrhea. However, factors will be put in place to reduce all anticipated risks to the minimum. For the collection of stool and urine samples, your child will deliver them in sealed containers which will bear serial numbers/codes so their names will not be identified with them. Also with the blood sample collection, a qualified Phlebotomist will take the samples so optimum measures will be employed to reduce any pain or discomfort associated with the procedure. And the risk of fainting will be minimized by getting participants seated when drawing blood and monitoring them for safety before and after blood draws. With regards to the answering of questions in the questionnaire, you and your child are free not to answer any question that you deem uncomfortable. With the administration of dewormers, more water will be made available to minimize the possibility of an adverse effect, and should one occur a bed rest will be provided for your child to rest. Also for mixed parasitic infections, administration of different dewormers will be done on two separate occasions.

Benefits

By taking part in this study, your child will benefit by knowing their risk of parasitic infections and his/her nutritional status based on the parameters that will be measured (weight, height, MUAC, Hb and Zn). In addition to that, your child's participation will inform us of the current prevalence of parasitic infections within your community and enable us to plan a nutrition intervention in a follow up study among school-age children to improve their nutrition and school performance. This will ultimately help us come up with effective ways of preventing parasitic infections, and improve their nutritional status and cognitive performance, and to scale up such nutrition interventions as part of the periodic interventions among school-age children living in parasitic endemic places in Ghana.

Incentives for participation

For participating in this study, you and your child will receive an incentive GH₵ 20 (₵10 on day-1 and another ₵10 on day-2) as compensation for your time.

Photograph taking

You and your child's pictures may be taken during the survey which may be used for the purposes of presentations and publications.

Please provide initials below if you agree to have these pictures taken or not. You may still participate in this study even if you are not willing to have your pictures taken.

________I do not want to have our pictures taken.

________I am willing to have our pictures taken.

Privacy/Confidentiality

All information obtained from you in the survey will be done confidentially without recording your names directly onto any information collected. Serial numbers/codes will be used to represent you and your child. This coded information will be seen only by the researchers directly involved in the study and data analyses, and will be stored in locked secured files on a laptop which will be kept in locked drawers accessible only to the team leaders of the research group. Researchers will not release identifiable results of the study to anyone other than individuals working on the project and the District Health Management Team without your written consent unless required by law. The code key will be destroyed immediately after the data collection. The data will be kept for a period of 5 years.

Taking part is voluntary

Participating in this survey is totally voluntary, and you may choose not to participate or stop at any time without penalty or loss of benefits to which you are otherwise entitled. If you decide to stop or withdraw from the study, the information/data collected from you/child up to the point of your withdrawal will be kept as part of the study and may continue to be analyzed, unless you make a written request to remove, return or destroy the information.

If you are injured by this research

The researchers will exercise all reasonable care to protect you/your child from harm as a result of participation in this study. In the event that any research-related activities result in an injury, the sole responsibility of the researchers will be to arrange for your transportation to an appropriate health care facility. If you think that you have suffered a research-related injury, you should seek immediate medical attention and then contact Alex Kojo Anderson right away at 706-542-7614 (+233 24 165 0490 in Ghana). In the event that you or your child suffer a research-related injury, your medical expenses will be your responsibility or that of your third-party payer, although you are not precluded from seeking to collect compensation for injury related to malpractice, fault, or blame on the part of those involved in the research.

If you have questions

The main researcher conducting this study is Alex Kojo Anderson, a professor, and Marina Aferiba Tandoh, a graduate student at the University of Georgia. Please ask any questions you have now. If you have questions later, you may contact Alex Kojo Anderson at fianko@uga.edu or at +233 24 165 0490 or Marina Tandoh at mat07668@uga.edu or at +233248989545.

Research Subject's Consent to Participate in Research:

To voluntarily agree to take part in this study, you must sign/thumbprint on the line below. Your signature/thumbprint below indicates that you have read or had read to you this entire consent form, and have had all of your questions answered.

_________________________	_______________________	Date	_________
Name of Researcher	Signature / Thumbprint		
_________________________	_______________________	Date	__________
Name of Participant	Signature / Thumbprint		

Please sign/thumbprint both copies, keep one and return one to the researcher.

APPENDIX L: PARENTAL CONSENT FORM (2018)

UNIVERSITY OF GEORGIA
CONSENT FORM

INTERVENTIONS TO IMPROVE NUTRITIONAL STATUS AND COGNITIVE PERFORMANCE OF SCHOOL-AGE CHILDREN LIVING IN HELMINTH -ENDEMIC FARMING AND FISHING COMMUNITIES IN RURAL GHANA

Researcher's Statement

We are asking you to take part in a research study. Before you decide to participate in this study, it is important that you understand why the research is being done and what it will involve. This form is designed to give you the information about the study so you can decide whether to be in the study or not. Please take the time to read the following information carefully. Please ask the researcher if there is anything that is not clear or if you need more information. When all your questions have been answered, you can decide if you want to be in the study or not. This process is called "informed consent." A copy of this form will be given to you.

Principal Investigator: *Alex Kojo Anderson*
Department of Foods and Nutrition
Phone: 706-542-7614
Email: fianko@uga.edu

Purpose of the Study

Malnutrition and helminth (parasitic) infections are common problems among children in developing countries contributing to thousands of deaths every year. It is estimated that over 2 billion people including 250 million children are affected by micronutrient deficiencies in the world. In developing countries, children are the worst affected because of heavy infections with parasites. Infections with parasites tend to affect optimal digestion and absorption of nutrients in humans and causes symptoms such as vomiting, diarrhea and loss of appetite. This leads to micronutrient deficiencies which contributes to weakened immune system, making individuals further vulnerable to other infections. Growth retardation and anemia has been reported in children with heavy whipworm infections.

The study is a community trial which will involve collection of urine and stool samples to test for the presence of helminths, anthropometrics (height, weight and Mid-Upper Arm Circumference), socio-demographics, biochemical (hemoglobin and zinc), lifestyle, dietary habit and cognitive performance (school attendance and non-verbal reasoning ability, using Raven's progressive Matrices) and a nutrition education and/or micronutrient supplementation (with iron and zinc).

You are being asked to participate in this study because your child lives in this community, and your child also falls within the ages 9-12 year olds of the selected school, has passed the screening test for the study, and you are 25 years and above.

Study Procedures

If you agree to participate, it will require a three-time point meetings. During the first meeting (day-1), you and your child will be invited to the study site on a scheduled day for registration to participate in the survey. On this day, your child will be given urine and stool containers to provide stool and urine samples for the next day (morning). The process of collection and quantity of the stool and urine sample will be demonstrated to you to assist your child at home. You will then be guided to assist your child in filling out a brief questionnaire containing information about your socio-demographics (age, sex, employment, level of education, relationship to child etc). The questionnaire will also cover areas such as your sanitation and dietary practices and knowledge on parasitic infections among others with regards to your child. This will require about 40 minutes of your time, in addition to another 60 minutes that will be required to do other measurements on your child (weight, height, mid-upper arm circumference; venous blood draw (5ml) and cognitive assessment). Between the first and second meeting, depending on which school your child is, a nutrition educator will be visiting the school once a week to give a brief talk on nutrition and hygiene for 3 months, or your child will be receiving a micronutrient supplement of iron and zinc three times per week for 3 months or both. He/she will also receive a deworming medication during the first meeting. For the second meeting on the 3rd month (mid-point), your child's body measurements and blood (hemoglobin level by finger stick) will be taken as well as answering a brief questionnaire and learning assessment will be done. The time required for this will be approximately 40 minutes. The final data collection will be on the 6th month, when your child's final body measurements will be taken together with blood, urine and stool collection and a learning exercise. This will also take about 1 hour, 40 minutes. Thus the total time in all required for this study will be 4 hours.

Risks and discomforts

There will be no major risk associated with taking part in this survey except the slight discomfort of disclosing personal information about sanitation practices and dietary habits of you and your child. Also your child may find it a bit uncomfortable to provide his/her stool and urine samples. And is also likely to experience a slight discomfort and soreness at the site of the needle prick during the collection of venous blood. There is also the risk of fainting associated with blood draws. Also during the cognitive assessment, your child is likely to feel embarrassed if he/she feels unable to do the assigned test correctly. Should your child be tested positive for a parasitic infection, he/she will be treated with a dewormer, and this is usually safe, but in some rare circumstances can cause some minor and transient adverse effect such as nausea, vomiting, diarrhea. However, factors will be put in place to reduce all anticipated risks to the minimum. Also, if your child is found to be anemic, he/she will be referred to a Health Nurse for treatment. For the collection of stool and urine samples, your child will deliver them in sealed containers which will bear serial numbers/codes so their names will not be identified with them. Also with the blood sample collection, a qualified Phlebotomist will take the samples so optimum measures will be employed to reduce any pain or discomfort associated with the procedure. And the risk of fainting will be minimized by getting participants seated when drawing blood and monitoring them for safety before and after blood draws. With regards to the answering of questions in the questionnaire, you and your child are free not to answer any question that you deem uncomfortable. With the administration of dewormers, more water will be made available to minimize the possibility of an adverse effect, and should one occur a bed rest will be provided for your child to rest. Also for mixed parasitic infections, administration of different dewormers will be done on two separate occasions.

Benefits

By taking part in this study, your child will benefit by knowing his/her risk of parasitic infections and his/her nutritional status based on the parameters that will be measured (weight, height, MUAC, Hb and Zn). In addition to that, your child's participation will improve his/her knowledge on nutrition and good sanitation practices, which will ultimately prevent parasitic re-infections, and potentially improve their nutritional status and cognitive performance, and to scale up such nutrition interventions as part of the periodic interventions among school-age children living in parasitic endemic places in Ghana.

Incentives for participation

For participating in this study, you and your child will receive an incentive GH₵ 20 (₵10 on meeting-1, and another ₵10 on meeting-3) as compensation for your time.

Photograph taking

You and your child's pictures may be taken during the survey which may be used for the purposes of presentations and publications.

Please provide initials below if you agree to have these pictures taken or not. You may still participate in this study even if you are not willing to have your pictures taken.

________I do not want to have our pictures taken.

________I am willing to have our pictures taken.

Privacy/Confidentiality

All information obtained from you in the survey will be done confidentially without recording your names directly onto any information collected. Serial numbers/codes will be used to represent you and your child. This coded information will be seen only by the researchers directly involved in the study and data analyses, and will be stored in locked secured files on a laptop which will be kept in locked drawers accessible only to the team leaders of the research group. Researchers will not release identifiable results of the study to anyone other than individuals working on the project and the District Health Management Team without your written consent unless required by law. The code key will be destroyed immediately after the data collection. The data will be kept for a period of 5 years.

Taking part is voluntary

Participating in this survey is totally voluntary, and you may choose not to participate or stop at any time without penalty or loss of benefits to which you are otherwise entitled. If you decide to stop or withdraw from the study, the information/data collected from you/child up to the point of your withdrawal will be kept as part of the study and may continue to be analyzed, unless you make a written request to remove, return or destroy the information.

If you are injured by this research

The researchers will exercise all reasonable care to protect you/your child from harm as a result of participation in this study. In the event that any research-related activities result in an injury, the sole responsibility of the researchers will be to arrange for your transportation to an appropriate health care facility. If you think that you have suffered a research-related injury, you should seek immediate medical attention and then contact Alex Kojo Anderson right away at 706-542-7614 (+233 24 165 0490 in Ghana). In the event that you or your child suffer a research-related injury, your medical expenses will be your responsibility or that of your third-party payer, although you are not precluded from seeking to collect compensation for injury related to malpractice, fault, or blame on the part of those involved in the research.

If you have questions

The main researcher conducting this study is Alex Kojo Anderson, a professor, and Marina Aferiba Tandoh, a graduate student at the University of Georgia. Please ask any questions you have now. If you have questions later, you may contact Alex Kojo Anderson at fianko@uga.edu or at 0241650490 or Marina Tandoh at mat07668@uga.edu or at 0248989545. If you have any questions or concerns regarding your rights as a research participant in this study, you may contact the Institutional Review Board (IRB) Chairperson at 706.542.3199 or irb@uga.edu.

Research Subject's Consent to Participate in Research:

To voluntarily agree to take part in this study, you must sign/thumbprint on the line below. Your signature/thumbprint below indicates that you have read or had read to you this entire consent form, and have had all of your questions answered.

_________________________	_______________________		__________
Name of Researcher	Signature / Thumbprint	Date	
_________________________	_______________________		__________
Name of Participant	Signature / Thumbprint	Date	

Please sign/thumbprint both copies, keep one and return one to the researcher.

APPENDIX M: CHILD ASSENT FORM (2017)

Assent Script/Form for Participation in Research

PREVALENCE OF HELMINTHIASIS AND ITS ASSOCIATION WITH NUTRITIONAL STATUS AND COGNITIVE PERFORMANCE OF SCHOOL-AGE CHILDREN LIVING IN HELMINTH ENDEMIC FISHING AND FARMING COMMUNITIES IN RURAL GHANA

We are doing a research study to find out how children are growing and how worms affect the food you eat and your performance in school. We are asking you to be in the study because you are between the ages of 9-12 years old in this school. If you agree to be in the study, you will meet us on two occasions in this school with your parent/guardian. During the first meeting (day-1), you and your parent/guardian will be invited to the school on a scheduled day and time for registration to participate in the survey. On this day, you will be given urine and stool containers to provide your urine and stool samples for the next day (morning). The process of collection and quantity of the stool and urine sample will be demonstrated to you and your parent/guardian so that you can be assisted at home. Your parent/guardian will then guide you in filling out a brief questionnaire containing information about your lives, age, level of education, how you and your guardian are related, the number of people you live together with at home, etc. The questionnaire will also cover areas such as how you wash your hands and your surroundings and how you eat. You will also be asked about what you know about worms in the soil and waterbodies. This will require about 40 minutes of your time, in addition to that, another 60 minutes will be required to do some measurements on you (weight, height, arm size; venous blood draw (5ml) and a learning exercise). For the second meeting (day-2), you will return a fresh fecal and urine sample in the morning. The time required for this will be approximately 20 minutes. Thus total time in all required for this study will be 2 hours. Based on the results of the stool and urine analysis, you may be invited back during the week to the school for a deworming medication.

Being in this study will provide us the understanding of how infections with worms affect the growth and learning of children which will help other children in the future.

You do not have to say "yes" if you don't want to. No one, including your parents, will be mad at you if you say "no" now or if you change your mind later. We have also asked your parent's permission to do this. Even if your parent says "yes," you can still say "no." Remember, you can ask us to stop at any time. Your grades in school will not be affected whether you say "yes" or "no."

We will not use your name on any papers that we write about this project. We will only use a number so other people cannot tell who you are.

You can ask any questions that you have about this study. If you have a question later that you didn't think of now, you can contact Alex Kojo Anderson at fianko@uga.edu or at +233 24 165 0490 or Marina Tandoh at mat07668@uga.edu or at +233248989545 to answer your questions.

Name of Child: ______________________________ **Parental Permission on File:** ☐ Yes ☐ No**

***(If "No," do not proceed with assent or research procedures.)*

***(For Written Assent)* Signing/thumb printing here means that you have read this paper or had it read to you and that you are willing to be in this study. If you don't want to be in the study, don't sign/thumbprint.**

Signature/thumbprint of Child: ____ **Date:** -___________________

***(For Verbal Assent)* Indicate Child's Voluntary Response to Participation:** ☐ Yes ☐ No

Signature of Researcher: ________________________________ **Date:** ___________________

APPENDIX N: CHILD ASSENT FORM (2018)

Assent Script/Form for Participation in Research

INTERVENTIONS TO IMPROVE NUTRITIONAL STATUS AND COGNITIVE PERFORMANCE OF SCHOOL-AGE CHILDREN LIVING IN HELMINTH -ENDEMIC FARMING AND FISHING COMMUNITIES IN RURAL GHANA

We are doing a research study to find out how nutrition education or micronutrient supplementation in children can affect your growth and performance in school. We are asking you to be in the study because you are between the ages of 9-12 years old in this school. If you agree to be in the study, you will meet us on three main occasions in this school with your parent/guardian. During the first meeting (day-1), you and your parent/guardian will be invited to the school on a scheduled day and time for registration to participate in the survey. On this day, you will be given urine and stool containers to provide your urine and stool samples for the next day (morning). The process of collection and quantity of the stool and urine sample will be demonstrated to you and your parent/guardian so that you can be assisted at home. Your parent/guardian will then guide you in filling out a brief questionnaire containing information about your lives, age, level of education, how you and your guardian are related, the number of people you live together with at home, etc. The questionnaire will also cover areas such as how you wash your hands and your surroundings and how you eat. You will also be asked about what you know about worms in the soil and waterbodies. This will require about 40 minutes of your time, in addition to that, another 60 minutes will be required to do some measurements on you (weight, height, arm size; venous blood draw (5ml) and a learning exercise). Depending on which school you attend, between the first meeting and the second meeting, a nutrition educator will be visiting your school once a week to give a brief talk on nutrition and hygiene for 3 months, or you will be receiving a micronutrient supplement of iron and zinc three times a week for 3 months or both. You will receive a deworming medication during the first meeting. For the second meeting on the 3rd month (mid-point), you will have your weight and arm measurement taken and blood Hemoglobin level as well as answer a brief learning assessment. The time required for this will be approximately 40 minutes. The final data collection will be on the 6th month, when your final body measurements will be taken together with your blood, urine and stool collection and a learning exercise. This will also take about 1 hour, 40 minutes. Thus the total time in all required for this study will be 4 hours. Being in this study will provide us the understanding of how supplementing with micronutrients and/or nutrition education affects growth and learning of children who live in helminth-endemic areas which will help other children in the future.

You do not have to say "yes" if you don't want to. No one, including your parents, will be mad at you if you say "no" now or if you change your mind later. We have also asked your parent's permission to do this. Even if your parent says "yes," you can still say "no." Remember, you can ask us to stop at any time. Your grades in school will not be affected whether you say "yes" or "no."

We will not use your name on any papers that we write about this project. We will only use a number so other people cannot tell who you are.

You can ask any questions that you have about this study. If you have a question later that you didn't think of now, you can contact Alex Kojo Anderson at fianko@uga.edu or at 024165 0490 or Marina Tandoh at mat07668@uga.edu or at 0248989545 to answer your questions.

Name of Child: ______________________________ **Parental Permission on File:** ☐ Yes ☐ No**

***(If "No," do not proceed with assent or research procedures.)*

***(For Written Assent)* Signing/thumb printing here means that you have read this paper or had it read to you and that you are willing to be in this study. If you don't want to be in the study, don't sign/thumbprint.**

Signature/thumbprint of Child: ________________**Date:** __________________

***(For Verbal Assent)* Indicate Child's Voluntary Response to Participation:** ☐ Yes ☐ No

Signature of Researcher: ____________________________________ **Date:** __________________

APPENDIX O: ELIGIBILITY SCREENING SCRIPT

Eligibility Screening Consent Script

Thank you for responding to our invitation to be screened for this research. My name is Marina Aferiba Tandoh. I am a graduate student working under the direction of Dr. Alex Kojo Anderson in the Department of Foods and Nutrition at the University of Georgia, U.S.A.

The purpose of the research is to ascertain the current prevalence of helminth (parasitic) infections among school-age children, and also the nutritional status, and cognitive performance of the children.

The findings from this survey will provide information on the current prevalence of parasitic infections among school-age children living in in the Afram Plains North District, and their nutritional status and cognitive performance. And will enable us plan and implement an intervention that is tailored to their needs to help reduce the adverse effects of the infection in a more sustainable way.

Do you think you might be interested in participating in this study?

{If No}: Thank you very much for your time. Do not go on with screening.

{If Yes}: Continue with screening.

Before enrolling people in this study, we need to ask you some questions to determine if your child is eligible for the study. And so what I would now like to do is to ask you a series of questions about your child. This should only take about 10 minutes of your time.

There is a possibility that some of these questions may make you uncomfortable; if so, please let me know. Remember, the participation of your child is voluntary; you can refuse to answer any questions, or stop this interview at any time without penalty or loss of benefits to which you are otherwise entitled.
All information that I receive from you during this interview, including your name and any other information that can possibly identify you or your child, will be strictly confidential and will be kept under lock and key.
For participating in this study, you and your child will receive an incentive GH₵ 20 (₵10 on day-1 and ₵10 on day-2) as compensation for your time.

At the end of this screening we will let you know if your child can or cannot participate in the study. If you or your child does not qualify for the study, all of your information provided in this screening will be destroyed immediately.
Do I have your permission to ask these questions?
Thank You.
If you have questions later, you may contact Alex Kojo Anderson at fianko@uga.edu or at +233 24 165 0490 or Marina Aferiba Tandoh at mtandoh@yahoo.co or at +233248989545.

Q1. How old are you? **a. If >25 continue with screening**
b. If <25 thank parent and discontinue with screening
Q2. Does your child live within this community? **a. {If Yes} continue with screening**
b. {If No} thank parent and discontinue screening
Q3. How old is your child? **a. Between 9 and 12 continue screening**
b. > 12 or <9 Thank parent and discontinue screening
Q4. Has your child had malaria/fever this past week?
a. {If Yes} thank parent and discontinue with screening

b. {If No} continue with screening

Q5. Does your child suffer from any chronic disease like sickle cell disease, goiter, elephantiasis etc?

a. {If Yes} thank parent and discontinue with screening

b. {If No} continue screening

Q6. Is your child taking any nutritional supplements?

a. {If Yes} thank parent and discontinue with screening

b. {If No} continue screening

Note:

- If a parent answers 'Yes' to questions 4, 5 &6, but they fall within the required age range and live within the community, the child does not qualify to participate in the study.
- If a parent answers 'No' to questions 4, 5, &6, and they also fall within the required age range and live within the community, then the child is eligible. Proceed with consent.

APPENDIX P: STUDY QUESTIONNAIRE (2017)

PARENT (GUARDIANS) QUESTIONNAIRE:

Name of Interviewer ____________________ Student Code _____________School Code ___________
School Name ______________Community name ___________ Date of interview _ _/ _ _/ 20_ _
Day month year

SECTION 1: SOCIODEMOGRAPHICS

1. Parent to be questioned a. Father [ ] b. Mother [ ] c. Male guardian [ ] d. Female guardian [ ]
2. What is your age? …………………………………………………..
3. Which one of these groups would you say best represents your tribe?
a. Akan [ ] b. Ewe [ ] c. Ga [ ] d. Northerner [ ]
g. Other [specify] …………………………………………………………

4. Are you…? a. Married [ ] b. Separated [ ] c. Never married [ ] e. Widowed [ ]

5. How many children live in your household? ………………………………..

6. What is the highest grade or year of school you completed?
a. Never attended school or only attended kindergarten [ ] b. Elementary [ ] c. Junior High School [ ] d. Senior High School [ ] e. Tertiary 1 year to 3 years (Diploma/Certificate/Professional) [ ] f. Tertiary 4 years or more (Degree/Postgraduate/Professional) g. Other [Specify]…………………………………….. **7. What kind of work do you do? (Job Title)**………………………………………………..
(ex: Farmer, fisherman, dressmaker, registered nurse, personnel manager, accountant, etc.)
8. What kind of work does your partner do? (Job Title)...
(ex: Farmer, fisherman, dressmaker, registered nurse, personnel manager, accountant, etc.)
9a. Does your ward wear shoes every day?
i. a. Yes [ ] b. No [ ] c. sometimes [ ]
9b. If no, Why? ………………………………………………………………………………………..

SECTION 2: WATER AND SANITATION:

10a. Do you have a toilet facility at home?
a. Yes [ ] b. No [ ]
10b. If Yes, what is the toilet facility at your house like?
a. Public [ ] b. Latrine [ ] c. Private improved pit latrine [ ]
d. Flush toilet [ ] e. Open defecation f. Others (Specify)……………………
10c. If No, where do you defecate and what is the facility like?
……………………………………………………………………………….
11. How do you dispose off your waste?
………………………………………………………………………………..
12. Does your household deliberately wash their hands?
a. Yes [ ] b. No [ ] c. Sometimes [ ]
13. Under which instances do you deliberately wash your hands?
………………………………………………………………………………..
14. Do you wash your hands after using the toilet? a. Yes [ ] b. No [ ]
15. What washing agents do you use for washing your hands?
a. Plain water alone [ ] b. Soap alone [ ] c. Water and soap [ ] d. Ash [ ]
e. Other (please specify) ……………………………………………………
16. What is your usual source of drinking water?
……………………………………………………………………………….

17. Is your source of water close to your house?
a. Yes [ ]   b. No [ ]
18. How do you store your drinking water?
……………………………………………………………………………..
19a. Do you treat your drinking water before drinking or using in food preparation? Why?
a. Yes [ ]   b. No [ ]   c. Sometimes [ ]
……………………………………………………………………………..
19b. If yes above, then how do you ensure this? Give reasons
……………………………………………………………………………..
20. What is your household source of bathing water?
a. River [ ]   b. Lake [ ] c. Bore hole [ ]   d. Tap water [ ]   e. Other …………………………

SECTION 3: KNOWLEDGE IN TOPIC
21. Do you know about Helminths and Schistosomes (Nsonsono yadee and Dwonso yadee)?
a. Yes, very well [ ]   b. Yes but not very well [ ]   c. No [ ]
22. Is your ward benefiting from the school feeding program?
a. Yes [ ]   b. No [ ]
23. Has your ward ever reported blood in his/her urine?
a. Yes always [ ] b. Yes sometimes [ ]   c.   Never [ ]
24. Has your ward ever complained of passing blood in his/ her stool?
a. Yes Always [ ] b. Yes, sometimes [ ] c. Never [ ]
25. **Has your ward complained of frequent abdominal pains?**
a. Yes Always [ ] b. Yes, sometimes   c. Never [ ]
26a. Have you ever de-wormed your child personally?
i. a. Yes [ ]   b. No [ ]
26b. If no, why? ....
27. If yes above, when was the last time you dewormed your child?
a. <3 months [ ] b. 3 to 6 months ago [ ]   c. 6 months to 1 year ago [ ]
28. Within the past 6 months, has your child complained of fever, or malaria
a. Yes [ ]   b. No [ ]
THANK YOU FOR PARTICIPATING.

CHILD QUESTIONAIRRE
Name of Interviewer ____________________Student Code _______________ School Code ____________
School Name _______________Community name ____________ Date of interview _ _/ _ _/ 20_ _
Day month year

SECTION 1: DEMOGRAPHICS
1. Gender?   a. Female [ ]   b. Male [ ]
2. What is your age? ……………………………………………… (in full years and months).
3. How long have you been enrolled in this school? ………………………………………
4. Do you wear shoes to school routinely?
a. Yes [ ]   b. No [ ]
5. Do you walk bare footed outside sometimes?
a. Yes [ ]   b. No [ ]
6. Do you normally eat from the same bowl with your sibling(s)?
a. Yes [ ]   b. No [ ]
7a. Do you work on a farm in school or at home?
a. Yes [ ]   b. No [ ]
7b. If yes, do you wear safety boots on the farm?
a. Yes [ ]   b. No [ ]
8. Do you swim in the lake/river sometimes?

a. Yes [ ]   b. No [ ]
9. Do you wash your hands with soap and water before eating?
a. Yes [ ]   b. No [ ]
10. Do you wash your hands with soap and water after visiting the toilet?
a. Yes [ ]   b. No [ ]
11. What is the source of your drinking water? ………………………………………
12. What is the source of your bathing water? ………………………………………
13a. Do you have a toilet facility at home?
a. Yes [ ]   b. No [ ]
13b. If no, do you have a designated place for defecating?
a. Yes [ ]   b. No [ ]   Where? ……………………………………………
14. Do you wash your fruits before eating?
a. Yes [ ]   b. No [ ]
15. Do you like to bite your fingernails?
a. Yes [ ]   b. No [ ]
16. Do you like to eat clay/sand?
a. Yes [ ]   b. No [ ]

THANK YOU FOR PARTICIPATING.

Section 2: DIETARY BEHAVIOURS

24 Hr Food Recall for school-age children (Week Day 1)

Menu / Time	**Food**	**Handy Measures**	**Quantity (g)**
Breakfast	1. 2. 3.		
Mid-Morning Snack	1. 2. 3.		
Lunch	1. 2. 3.		

Mid-Afternoon Snack	1. 2. 3.		
Supper	1. 2. 3.		
Bed-time Snack	1. 2. 3.		

CODES: **Sd.T**- sardine tin size **St. sp**.-stewing spoon **Bwl 1 –** 500mls bowel **Sp.sp-** soup spoon **Dsp**-dessert spoon **ET**- empty ideal milk tin **TT**-empty tin tomato tin **Tsp** - teaspoon **Org.sz**. - ave. orange sz. **Mch.Bx**- small match box **Cp 1-** 100ml cup **Cp 2-** 250mls cup **Cp3** – 500mls cup

24 Hr Food Recall for school-age children (Week Day 2)

Menu / Time	**Food**	**Handy Measures**	**Quantity (g)**
Breakfast	1. 2. 3.		
Mid-Morning Snack	1. 2. 3.		
Lunch	1. 2. 3.		
Mid-Afternoon Snack	1.		

	2. 3.		
Supper	1. 2. 3.		
Bed-time Snack	1. 2. 3.		

<u>CODES:</u> **Sd.T**- sardine tin size **St. sp**.-stewing spoon **Bwl 1 –** 500mls bowel **Sp.sp-** soup spoon **Dsp**-dessert spoon **ET**- empty ideal milk tin **TT**-empty tin tomato tin **Tsp** - teaspoon **Org.sz**. - ave. orange sz. **Mch.Bx**- small match box **Cp 1-** 100ml cup **Cp 2-** 250mls cup **Cp3** – 500mls cup

24 Hour Food recall for school-age children (Weekend)

Menu / Time	Food	Handy Measures	Quantity (g)
Breakfast	1. 2. 3.		
Mid-Morning Snack	1. 2. 3.		
Lunch	1. 2. 3.		
Mid-Afternoon Snack	1. 2. 3.		
Supper	1.		

	2. 3.		
Bed-time Snack	1. 2. 3.		

<u>**CODES:**</u> **Sd.T**- sardine tin size **St. sp**.-stewing spoon **Bwl 1 –** 500mls bowel **Sp.sp-** soup spoon **Dsp**-dessert spoon **ET**- empty ideal milk tin **TT**-empty tin tomato tin **Tsp** - teaspoon **Org.sz**.- ave. orange sz. **Mch.Bx**- small match box **Cp 1-** 100ml cup **Cp 2-** 250mls cup **Cp3** – 500mls cup

INSTRUMENT FOR SURVEY WORKERS

Name of Interviewer ____________________ Student Code ______________School Code ___________
School Name ______________Community name ___________Date of interview _ _/ _ _/ 20_ _
Day month year

SECTION 1: ANTHROPOMETRIC

1.0 Height (cm) ___________ **Weight (kg)** ____________**MUAC (cm)** ____________

SECTION 2: LABORATORY ANALYSIS
2.0. Haemoglobin count___________ (g/dl) **Blood Zinc ___________ (g/dl)**
3.0a. Helminth eggs in Stool sample: a. Present [ ] b. Absent [ ]
3.0b. If present, which types?

a. *Ascaris* ……………. (epg**)** b. *Trichuris* …………….(epg) c. Hook worm ……………. (epg)

d. Others ……………. (epg**)** e. *S mansoni* ……………. (epg) f. Others ……………. (epg)

4.0a. Is there blood in the urine sample?

a. Yes [ ] b. No [ ]

4.0b. If yes to above, what is the intensity of infection?

a. S. haematobium ……………. (epg)

5. School attendance record…………………………….

6. Total cognitive performance test score……………....

APPENDIX Q: STUDY QUESTIONNAIRE (2018)

PARENT (GUARDIANS) QUESTIONNAIRE:

Name of Interviewer____________Student Code_________Community name ____________________

School Code ______________ Community Type______________Date of interview _ _/ _ _/ 20_

Day/ month / year

SECTION 1: SOCIODEMOGRAPHICS

1. Parent to be questioned a. Father [ ] b. Mother [ ] c. Male guardian [ ] d. Female guardian [ ]

2. What is your age? ……………………………………………………………………......

3. Which one of these groups would you say best represents your tribe?

a. Akan [ ] b. Ewe [ ] c. Ga [ ] d. Northerner [ ] e. Other [specify] ………………….

4. Are you…? a. Married/cohabitting [ ] b. Not married [ ] c. Widowed [ ]

5. How many children live in your household? ………………………………………………

6. What is the highest grade or year of school you completed?

a. Never attended school [ ] b. Elementary [ ] c. Junior High School [ ] d. Senior High School [ ]e. Other [Specify]………………………………………………………………………………

7. What kind of work do you do? (Job Title) ………………………………………………...

(ex: Farmer, fisherman, service providers, skilled worker, unemployed, etc.)

8. What kind of work does your partner do? (Job Title) ....

(ex: Farmer, fisherman, service provider, skilled worker, unemployed etc.)

9. Does your ward wear shoes routinely?

i. a. Yes [ ] b. No [ ] c. sometimes [ ]

ii. If no, Why? ……………………………………………………………………………….

10. What are your usual sources of food?

a. Purchase from local market [ ] b. Gift [ ] c. From the farm [ ] d. Other [Specify]………………

SECTION 2: WATER AND SANITATION:

11. What is the toilet facility at your house like?

a. None [ ] b. Public [ ] c. Latrine [ ] d. Private improved pit latrine [ ]

e. Flush toilet [ ] f. Others (Specify).……………………………………………………………

12. How do you dispose off your waste?

a. Public refuse dump [ ] b. Dug-out pit [ ] c. Bush [ ]

d. Others (Specify).……………………………

13. Does your household deliberately wash their hands as a routine?

a. Yes [ ] b. No [ ] c. Sometimes [ ]

14. Under which instances do you deliberately wash your hands?...

15. Do you wash your hands after visiting the toilet? a. Yes [ ] **b. No** [ ]

16. What washing agents do you use for washing your hands?..

17. What is your usual source of drinking water?

a. Bore hole/Well [ ] b. Outside Pipe [ ] c. Inside Pipe [ ] d. Rain water [ ] e. River/Lake [ ]

f. Other (Please specify) ……………………………………………………

18. Is your source of water close to your house?

i. a. Yes [ ] b. No [ ]

ii. b. What is the distance between your home and water source?...............................

19. If you do not have running water how do you store your water?

a. Open container [ ] b. Covered container [ ] c. Tank [ ] d. Other (please specify) ....

20. Do you treat your drinking water before drinking or using in food preparation? Why?

a. Yes [ ] b. No [ ] c. Sometimes [ ] ………………………………………………..

21. If yes above, then how do you ensure this? Give reasons

....

22. What is your household source of bathing water?

a. River [ ] b. Lake [ ] c. Bore hole [ ] d. Tap water [ ] e. Other …………………………

SECTION 3: KNOWLEDGE & PRACTICES

23. Do you know about Soil-Transmitted Helminths and Schistosomes?

a. Yes, very well [ ] b. Yes but not very well [ ] c. No [ ]

24. Is your ward benefiting from the Ghana National Deworming Program?

a. Yes [ ] b. No [ ]

25. Is your ward benefiting from the school feeding program?

a. Yes [ ] b. No [ ]

26. Within the past 6 months, has your ward reported of blood in his/her urine?

a. Yes always [ ] b. No [ ]

27. Within the past 6 months, has your ward complained of passing blood in his/ her stool?

a. Yes Always [ ] b. No

28. Do you think bloody urine or stool is a sign of disease?

a. Yes [ ] b. No [ ]

29. Within the past 6 months, has your ward complained of abdominal pains?

a. Yes Always [ ] b. No [ ]

30. Do you de-worm your child personally?

i. a. Yes [ ] b. No [ ]

ii. If yes, how do you ensure this?..

iii. If no, why? ....

31. If yes above, when was the last time you dewormed your child?

a. <3 months [ ] b. 3 to 6 months ago [ ] c. 6 months to 1 year ago [ ] d. Other……………

32. Within the past month, has your child complained of fever, or malaria

a. Yes [ ] b. No [ ]

THANK YOU FOR PARTICIPATING.

CHILD QUESTIONAIRRE

Name of Interviewer ________ Student Code ____Community name ____________________

School Code ______________ Community Type ________________ Date of interview _ _/ _ _/ 20_

Day/ month / year

SECTION 1: DEMOGRAPHICS

1. Gender? a. Female [ ] b. Male [ ]

2. What is your age? ……………………………………………… (in full years and months).

3. How long have you been enrolled in this school? …………………………………

4. Do you wear shoes routinely?

a. Yes [ ] b. No [ ]

5. Do you walk bare-footed outside sometimes?

a. Yes [ ] b. No [ ]

6. Do you normally eat from the same bowl with your sibling(s)?

a. Yes [ ] b. No [ ]

7. Do you work on the farm in school or at home?

a. Yes [ ] b. No [ ]

8. Do you wear safety boots on the farm?

a. Yes [ ] b. No [ ]

9. Do you wash your hands before eating?

i. a. Yes [ ] b. No [ ]

ii. **If 'Yes', which washing agents do you use for this?**..

10. Do you wash your hands after visiting the toilet?

i. a. Yes [ ] b. No [ ]

ii. If 'Yes', which washing agents do you use for this?..

11. What is the source of your drinking water at home?...

12. Is your source of water close to your house?

a. Yes [ ] b. No [ ]

13. Does your family treat your water at home before drinking?

i. a. Yes [ ] b. No [ ]

ii. **If 'Yes', how do they do this?**...

14. What is the source of your bathing water?...

15. Do you swim in River?

a. Yes [ ] b. No [ ]

16. Do you fish in Lake or River?

a. Yes [ ] b. No [ ]

17. Do you have a toilet facility at home?

i. a. Yes [ ] b. No [ ]

ii. **If 'No', where do you defecate?** ……………………………………………………………………

18. Do you like to bite your fingernails?

a. Yes [ ] b. No [ ]

19. Do you eat sand or clay (Pica behavior)

a. Yes [ ] b. No [ ]

20. Do you wash your fruits before eating?

a. Yes [ ] b. No [ ]

SANITARY CONDITIONS IN SCHOOL:

21. Is there a toilet facility in your school?

i. a. Yes [ ] b. No [ ]

ii. **If 'Yes', do you use the toilet facility in school?**

i. a. Yes [ ] b. No [ ]

iii**. If 'No', Why**?..

22. Is there a source of drinking water in your school?

i. a. Yes [ ] b. No [ ]

ii. **If 'Yes', what is the source of the drinking water in your school?**..

23. Is there a station for handwashing in your school?

i. a. Yes [ ] b. No [ ]

ii. **If 'Yes', what washing agents are provided?**...

Section 2: DIETARY BEHAVIOURS

24 Hr Food Recall for school-age children (Week Day 1)

Menu / Time	Food	Handy Measures	Quantity (g)
Breakfast	1. 2. 3.		
Mid-Morning Snack	1. 2. 3.		
Lunch	1. 2. 3.		
Mid-Afternoon Snack	1. 2. 3.		
Supper	1. 2. 3.		
Bed-time Snack	1. 2. 3.		

CODES: **Sd.T**- sardine tin size **St. sp**.- stewing spoon **Bwl 3** – 500mls bowel **Sp.sp** - soup spoon **Dsp** - dessert spoon **ET**- empty ideal milk tin **TT**-empty tin tomato tin **Tsp** - teaspoon **Org.sz**.- ave. orange sz. **Mch.Bx**- small match box **Cp 1-** 100ml cup **Cp 2** - 250mls cup **Cp3** - 500mls cup

24 Hr Food Recall for school-age children (Week Day 2)

Menu / Time	Food	Handy Measures	Quantity (g)
Breakfast	1. 2. 3.		
Mid-Morning Snack	1. 2. 3.		

Lunch	1. 2. 3.		
Mid-Afternoon Snack	1. 2. 3.		
Supper	1. 2. 3.		
Bed-time Snack	1. 2. 3.		

CODES: **Sd.T**- sardine tin size **St. sp**.- stewing spoon **Bwl 3** – 500mls bowel **Sp.sp** - soup spoon **Dsp** - dessert spoon **ET**-empty ideal milk tin **TT**-empty tin tomato tin **Tsp** - teaspoon **Org.sz**.- ave. orange sz. **Mch.Bx**- small match box **Cp 1-** 100ml cup **Cp 2** - 250mls cup **Cp3** - 500mls cup

24 Hour Food recall for school-age children (Weekend)

Menu / Time	Food	Handy Measures	Quantity (g)
Breakfasta	1. 2. 3.		
Mid-Morning Snack	1. 2. 3.		
Lunch	1. 2. 3.		
Mid-Afternoon Snack	1. 2. 3.		
Supper	1. 2. 3.		

Bed-time Snack	1. 2. 3.		

CODES: **Sd.T**- sardine tin size **St. sp**.- stewing spoon **Bwl 3** – 500mls bowel **Sp.sp** - soup spoon **Dsp** - dessert spoon **ET**-empty ideal milk tin **TT**-empty tin tomato tin **Tsp** - teaspoon **Org.sz**.- ave. orange sz. **Mch.Bx**- small match box **Cp 1-** 100ml cup **Cp 2** - 250mls cup **Cp3** - 500mls cup

THANK YOU FOR PARTICIPATING.

INSTRUMENT FOR SURVEY WORKERS

Name of Interviewer__________Student Code__________Community name ____________________
School Code ____________ Community Type _____________ Date of interview _ _/ _ _/ 20_ _
Day/ month / year

SECTION 1: ANTHROPOMETRIC

1.0 Height 1 (cm) ___________ Height 2 (cm) ___________ Final Height (cm) ___________

2.0 Weight 1 (kg) ____________ Weight 2 (kg) ____________ Final Weight (kg) ____________

3.0 MUAC 1 (cm) ____________ MUAC 2 (cm) ____________ Final MUAC (cm) ____________

SECTION 2: LABORATORY ANALYSIS

4.0. Hemoglobin count___________ (g/dl) Blood Zinc ___________ (g/dl)

5.0a. Helminth eggs in Stool sample: a. Present [ ] b. Absent [ ]

5.0b. If present, which types?

a. *Ascaris* ……………. (epg) b. *Trichuris* …………….(epg) c. Hook worm ……………. (epg)
d. Others ……………. (epg) e. *S mansoni* ……………. (epg) f. Others ……………. (epg)

6.0a. Is there blood in the urine sample?

a. Yes [ ] b. No [ ]

6.0b. If yes to above, what is the intensity of infection?

a. *S. haematobium* ……………. (epg)

7.0 School attendance record……………………………

8.0 Total cognitive performance test score……………..

APPENDIX R: VERIFICATION OF SUPPLEMENTS, FDA, GHANA (2018)

FOOD AND DRUGS AUTHORITY FDA GHANA

Food and Drugs Authority

Head Office
P. O. Box CT 2783,
Cantonments, Accra-Ghana
Tel: (+233-302)233200, 235100
Fax: (+233-302)229794, 225502
Email: fda@fdaghana.govgh

Certificate No.: **PCM-18/06/0130**

LABORATORY SERVICES DEPARTMENT

CERTIFICATE OF ANALYSIS

Sample Information			
Sample ID:	FDA/LSD18/DG0192	**Client Ref No.:**	DMSD/18/05-020
Sample Name: Zintab 10 Dispersible Tablets		**Generic Name:**	Zinc Sulphate Tablet
Formulation:	Tablet	**Environmental Condition (If applicable) Temp./Humidity:**	Not Applicable
Composition: Each dispersible tablet contains Zinc 10 mg (as Zinc sulphate monohydrate BP)		**Batch No:** ZT243Z	**Condition of Sample:** Satisfactory
Mfg. Date:	08 - 2017	**Exp. Date:**	08 - 2020
Manufacturer:	M & G Pharmaceuticals Limited	**Manufacturer's Address**	D 446/1, Bannerman Road, James Town, Accra
Submitted/Source	Drug Market Surveillance Department	**Method of Analysis (Test Reference):**	USP 41 NF 36
Sample receipt date:	21 - 05 - 2018	**Testing Date:**	30 - 05 - 2018
Date of Completion of Test:	07 - 06 - 2018	**Report Date:**	07 - 06 - 2018
Description:	A yellow, circular biconvex uncoated tablet plain on both sides in an aluminium PVC blister package.		

Test Parameter	Specification	Result	Compliance Statement
IDENTIFICATION *[Colour test]* *Test for Zinc*	A white precipitate should be formed on addition of NaOH solution. Solution should remain clear on addition of NH_4Cl solution and a white precipitate should be form on addition of sodium sulfide solution	A white precipitate was formed on addition of NaOH solution. Solution remained clear on addition of NH_4Cl solution and a white precipitate formed on addition of sodium sulfide solution	Passed
Test for Sulphates	A white precipitate should be formed on addition of Hydrochloric Acid and Barium Chloride to the sample solution.	A white precipitate was formed on addition of Hydrochloric Acid and Barium Chloride to the sample solution.	
ASSAY % *[Titrimetric]* *Zinc sulphate*	90.0 - 110.0	101.1	Passed
UNIFORMITY OF DOSAGE UNITS	NMT 15.0 at L1	9.0	Passed
Conclusion: The sample conforms to specification for Identification for Zinc and Sulphates, Uniformity of Dosage Units and Assay for Zinc Sulphate as per the United States Pharmacopoeia.			

"This test is accredited under the laboratory's ISO/IEC 17025 accreditation issued by ANAB. Refer to certificate and scope of accreditation AT -1870"

**** Test not accredited for ISO/IEC 17025-2005***

Page **1** of **2**

Certificate No.: PCM-18/06/0130

LABORATORY SERVICES DEPARTMENT
CERTIFICATE OF ANALYSIS

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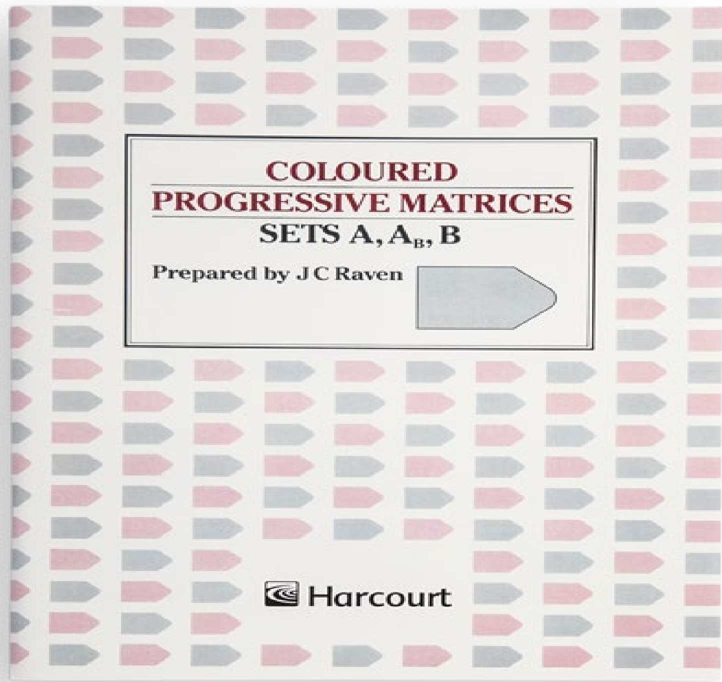
Date of Completion of Test:	07 - 06 - 2018	**Report Date:**	07 - 06 - 2018
Description:	A yellow, circular biconvex uncoated tablet plain on both sides in an aluminium PVC blister package.		

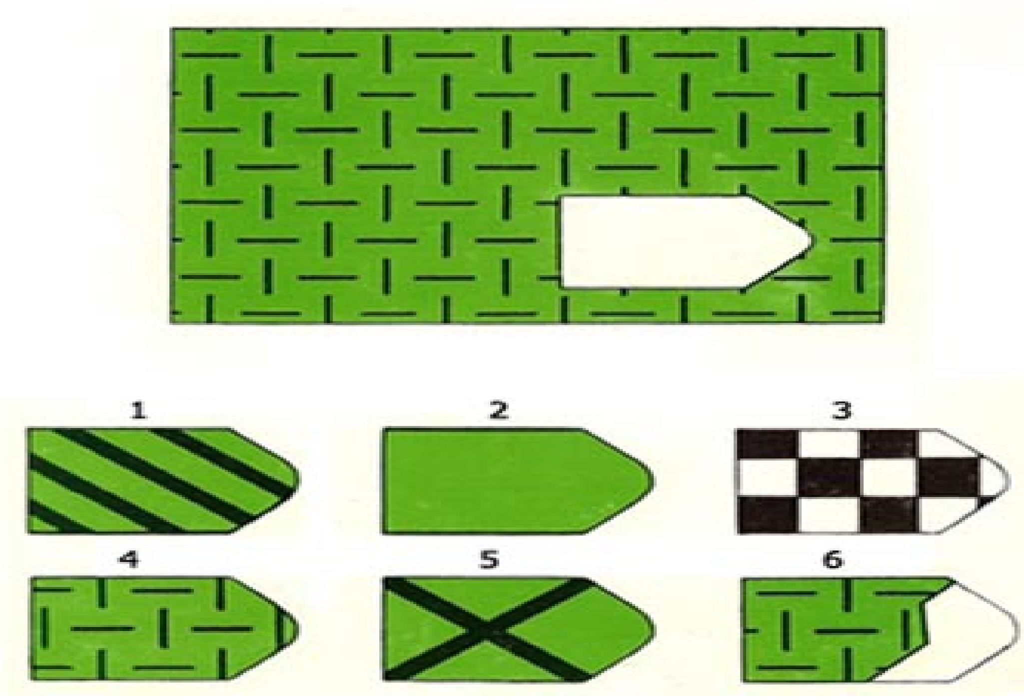
Remark

1. The test result is based on the tests carried out on the samples submitted to the laboratory by the customer.
2. This certificate is traceable to notebook number FDA/LSD/PCM18/WB003

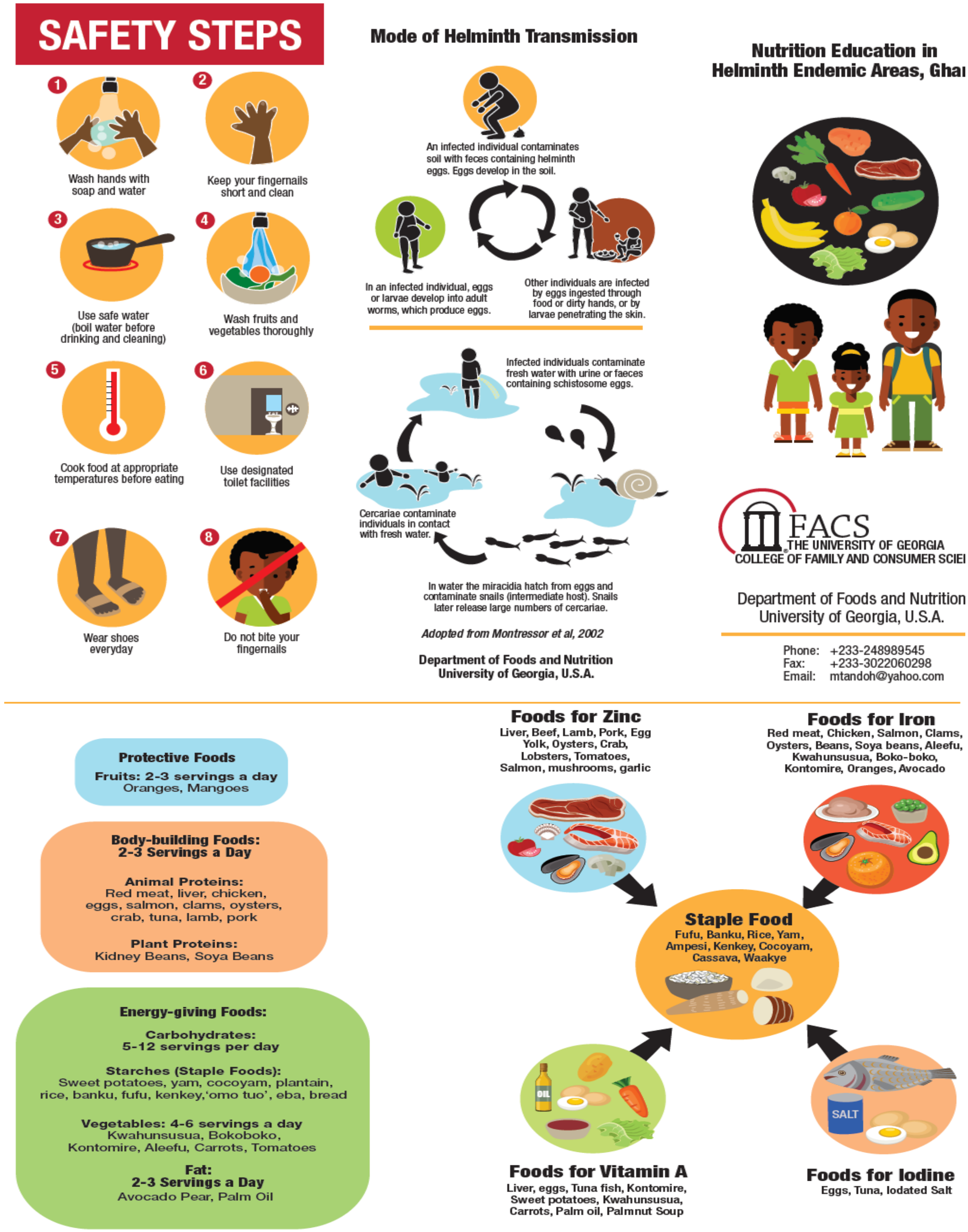
Analyst: -	*NICHOLAS AMOAH OWUSU*	**Sign: -**	**Date: -** 08/06/18
HOU: -	*ERNEST AFESEY*	**Sign: -**	**Date: -** 08/06/18
HQA: -	*JOSEPH OFOSU SIAW*	**Sign: -**	**Date: -** 08/06/18
HOD: -	*ERIC KARIKARI-BOATENG*	**Sign: -**	**Date: -** 11/06/18

APPENDIX S: COGNITIVE TEST TOOL





APPENDIX T: NUTRITION EDUCATION MATERIAL



APPENDIX U: HEALTH AND NUTRITION MANUAL FOR TRAINERS

HEALTH AND NUTRITION EDUCATION AGAINST PARASITES

A MANUAL FOR TRAINERS

Sample Menu

BREAKFAST (6-8AM)

MAIN MEAL	PLUS
CORN PORRIDGE/ WHEAT PORRIDGE/ RICE WATER/ CORN GRIT PORRIDGE/ OATS/ TOM BROWN/ MILO/ TEA	MILK+ SUGAR+ BREAD+ MAGARINE/ PEANUT BUTTER/ AVOCADO/ EGGS

SNACK (10AM)

ANY CHOICE	
ORANGE/ PAWPAW/ MANGOES/ WATERMELON/ BANANA/	PINEAPPLE/ CARROTS/ ROASTED/BOILD CORN ROASTED PLANTAIN+ ROASTED PEANUT

LUNCH (12-1PM) / SUPPER (5-6PM)

MAIN MEAL	PLUS SAUCE	PLUS PROTEIN
‘BANKU‘ ‘KENKEY‘ ‘FUFU‘ ‘TUOZARFI‘ ‘WAAKYE‘ ‘KOKONTE‘ NOODLES/ ‘TAALIA‘ ‘GARI’ PLANTAIN COCOYAM YAM CASSAVA	STEWS/SOUPS: ‘KWAHUNSUSUA‘ ‘BOKOBOKO’ ‘ALEEFU’ PALMNUT ‘KONTOMIRE’ CARROTS GARLIC TOMATOES RED/WHITE/BLACK LEGUMES IODATED SALT	RED MEAT/ FISH/ EGGS/ OYSTERS/ BEEF/ LAMB/ CHICKEN/ CLAMS

By: Marina Tandoh
Dept. of Foods and Nutrition
U.G.A

In Class Knowledge Test:
HELMINTHS

Circle (✓) for a good practice or (✘) for a wrong practice


Walking barefoot
✓ ✘


Bathing and playing in streams and lakes
✓ ✘


Open defecation in waterbodies and in the soil
✓ ✘


Drinking untreated water
✓ ✘


Making environment dirty
✓ ✘


Wearing shoes everyday
✓ ✘


Fetching clean water
✓ ✘


Using designated latrines and keeping them clean
✓ ✘


Boiling water before drinking
✓ ✘


Keeping the environment clean
✓ ✘


Eating dirty fruits
✓ ✘


Washing hands with only water
✓ ✘


Touching foods with dirty hands after toilet
✓ ✘


Keeping long and dirty fingernails
✓ ✘


Biting fingernails
✓ ✘


Washing fruits and vegetables before eating
✓ ✘


Cooking foods well before eating
✓ ✘

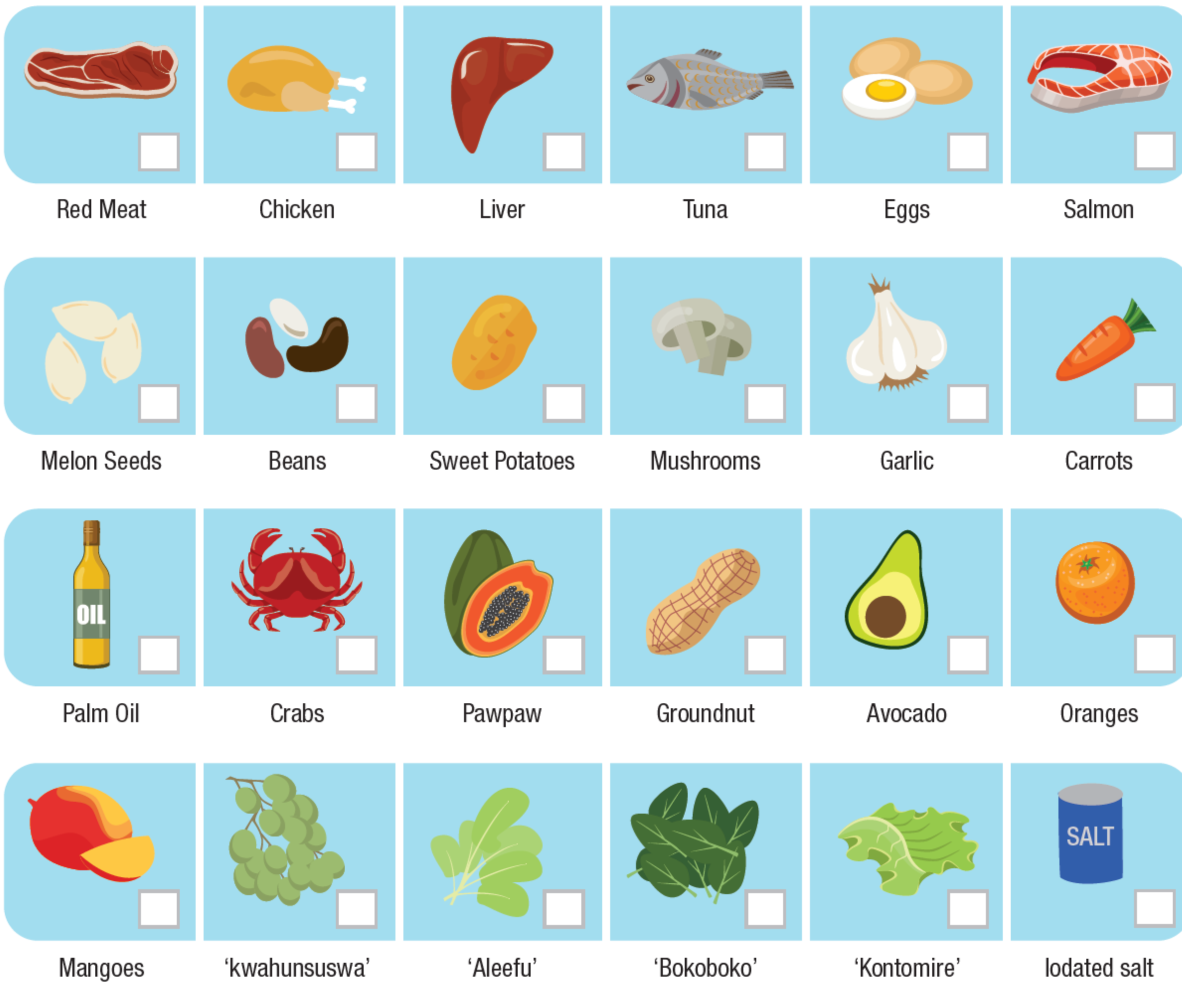

Washing hands with soap and water after toilet
✓ ✘


Keeping fingernails short and clean
✓ ✘


Taking your dewormer timely
✓ ✘

Homework
FOOD RECORD AT HOME

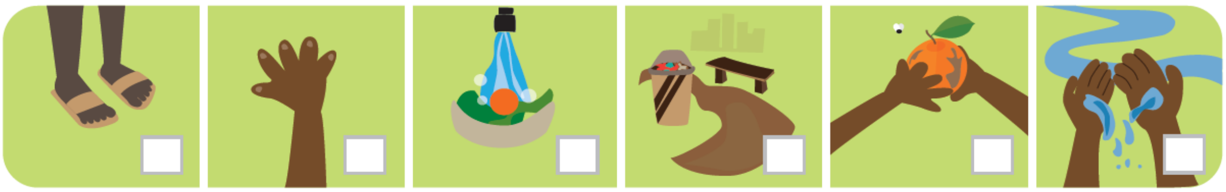
Tick (✓) what you ate at home this month



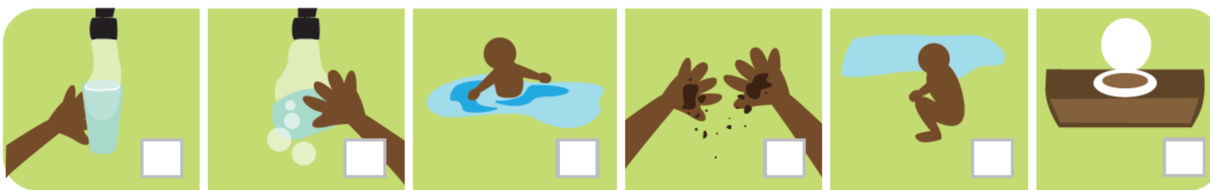
Include others in the boxes below

Homework
SANITATION RECORDS AT HOME

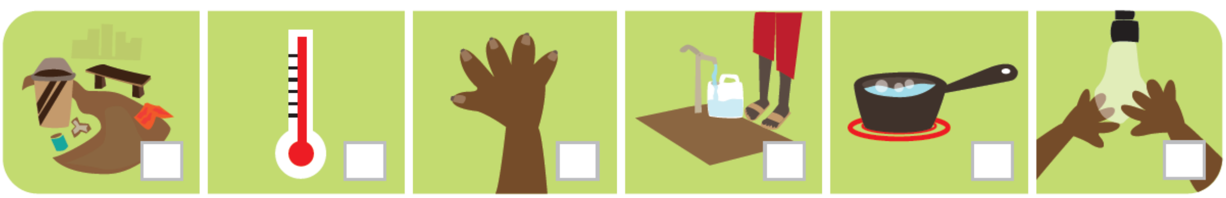
Tick (✓) what you did at home this month



Wore shoes | Kept nails clean | Washed fruits | Cleaned environment | Ate unwashed fruits | Drank dirty water



Drank tap water | Washed hands with soap and water | Bathed in rivers and ponds | Played with soil | Open defecated | Used designated toilet facilities



Kept surroundings dirty | Cooked food with adequate temperatures | Kept fingernails dirty | Fetched tap water for household use | Boiled water before drinking | Washed hands with water only

Include others in the boxes below