MALARIA AND GEO-HELMINTH CO-INFECTIONS AND SYNDEMICS AMONG PREGNANT WOMEN AT NANDI-HILLS SUB-COUNTY HOSPITAL, KENYA

BY

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DECLARATION

DECLARATION BY THE CANDIDATE

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DEDICATION

To my husband Mr. C.N. Jumbe for his moral support and to my precious children Kibet, Cherono and Osoro for being with me to the end of the course.

ABSTRACT

This study was carried out in Nandi Hills Sub-county Hospital to investigate malaria and geo-helminth co-infections and associated syndemic factors among pregnant women. A cross sectional study was used to collect data from three hundred (300) randomly selected pregnant women who attended antenatal care (ANC) and did not show any disease symptoms from March to December 2015. Stool samples were collected for geohelminth detection and blood samples for malaria parasite detection and haemoglobin (Hb) levels measurements. Collection of socio-demographics of the participants was also done using questionnaire survey. Stool samples were subjected to formal-ether concentration technique and microscopy for detection and identification of geo-helminths ova. Blood samples for malaria parasites detection and identification were processed using Field's stain and microscopy whereas for haemoglobin (Hb) measurements, blood was subjected to diaspect haemoglobin test machine. Pearson chi square, Phi test and logistic regression were used to analyse the data. Probabilities of < 0.05 were considered significant. Geo-helminth prevalence was 30%, 15% and 1% for *Ascaris lumbricoides*, hookworm (*Ancylostoma duodenale*) and *Trichuris trichiura* respectively. *A. lumbricoides* and *T. trichiura* infections were of light intensity whereas *A. duodenale* infections were of light (12%) and moderate (3.7%) intensities. Asymptomatic *P. falciparum* infection prevalence was 8% and of low intensity. Malaria-geohelminth co-infections were not significant for *P. falciparum-A. lumbricoides* (13%) (*P=0.07*) but significant for *P. falciparum-A. duodenale* (30%) (*P=0.04*). Socio-demographic confounders that significantly affected malaria-*A. duodenale* co-infection were marital status, small family size (≤ 2) and being in the middle income category (ksh 10,000-20,000). *P. falciparum-A. lumbricoides* and *P. falciparum-A. duodenale* co-infections were not affected by wet and dry seasons (*P=0.06* and *P=0.21* respectively). *P. falciparum* and *A. lumbricoides* were negatively associated with each other (r^{φ}=-0.105) whereas *P. falciparum* and *A. duodenale* were positively associated (r^{φ}=0.121). Obstetric and socio-demographic/economic factors that were considered in the study maintained the trend of association for *P. falciparum-A. lumbricoides* and *P. falciparum-A. duodenale* parasites but the strength of association became variable. Antagonistic relationship for *P. falciparum-A. lumbricoides* co-infection was however upturned with being single, having secondary education and staying in urban rental type of settlement while the synergism for *P. falciparum-A. duodenale* co-infection was upturned by being single, large family size and residing in the estate camp. *P. falciparum* and *A. duodenale* infections had significant ($P= 0.00$) effect on Hb levels and co-infection with the two parasites having negative impact on the anaemic category, that is, Hb<11 (r^{φ}=-0.105). The outcome of this study showed that there is need to diagnose and treat pregnant women for both malaria and geohelminth parasites since the parasites can co-exist. Pregnant women should be encouraged to practice early attendance of ANC to improve their health and their unborn babies. This study provides baseline information that can be exploited in prevention and control strategies of malaria and geohelminth parasites with the aim of improving the health of pregnant women as we strive to achieve millennium development goals (MDG).

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LIST OF ABBREVIATIONS

ANC- Antenatal Care

CIDP- County Integrated Development Plan

Hb- Haemoglobin

ICF- Informed Consent Form

IPT-Intermittent Preventive Treatment

MCH- Mother Child Health

MDGs- Millennium Development Goals

NE DDP- Nandi East District Development Plan

OR- Odds Ratio

RR- Rate of Risk

SP- Sulfadoxine-Pyrimethamine

SSA- Sub-Saharan Africa

STH- Soil Transmitted Helminths

WHO- World Health Organization

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CHAPTER ONE

INTRODUCTION

1. 1: Background Information

Geohelminths and malaria are both endemic in both rural and urban areas of sub-Saharan Africa (SSA) and their overlapping distribution results in high rate of co-infection (Petney and Andrews, 1998). Pregnant women in malaria endemic areas are highly susceptible to malaria (Mwangi *et al*., 2006). *Plasmodium* protozoa that cause malaria coexist alongside other pathogens and parasites many of which are also infectious to humans and that research and control of helminthiases is under-prioritized and under-funded and this has earned many parasitic worms a place among the World Health Organization (WHO) list of 'neglected tropical diseases' (Standley, 2011). Adding to the global morbidity that results from human helminth infections are the observations that they have both direct and indirect effects on malaria and HIV/AIDS in developing countries (Hotez *et al.,* 2008).

Parasitic diseases pose a major obstacle to health, growth and socio-economic development in developing countries (Brooker *et al.,* 2007). They are life threatening as well as leading cause of mortality in endemic countries more especially among those at risk such as pregnant mothers (Rosenfield and Maine, 1985). In pregnancy, there is transient depression of cell mediated immunity that allows foetal allograft retention which in other hand interferes with resistance to other diseases such as malaria (Getachew *et al.,* 2013)

There are still controversies concerning biological association between helminths and protozoa parasites. It has been estimated that over a third of world's population, mainly in the tropics and sub-tropics is co-infected with parasitic helminths and

protozoa parasites (Snow *et al*., 2005). Research is beginning to show some interesting and conflicting findings regarding the clinical and control implications of malaria co-infections with helminths (Standley, 2011).

Co-infections of malaria with helminths have additive effects such as severe anaemia and even increased transmission of malaria causing parasite (Hotez *et al*., 2008). Helminth infection may alter susceptibility to clinical malaria or malaria may alter clinical consequences of helminth infections (Brooker *et al*., 2007)

Pregnant women are immunologically compromised therefore highly susceptible to parasitic infections such as malaria (Strickland *et al.,* 2000) and geohelminths which have been categorized as infectious syndemics of pregnancy in Africa by Singer (2013). There is a poor understanding of the association between malaria and helminth infections and the basic factors for their co-occurrence in pregnant women. According to Metz *et al.,* (1970) and Egwunyenga *et al*., (2001), *Plasmodium* and intestinal helminth co-infection anaemia in pregnancy is aggravated by low nutritional status of the subjects mainly due to consumption of foods which are poor sources of iron and folate.

Helminth infections such as hookworm, trichiuriasis and schistosomiasis have been shown to directly contribute to severe anaemia in patients through blood loss where hookworm is the leading cause of pathologic blood loss in endemic areas (Brooker *et al.,* 2008, Muhangi *et al* ., 2007 and Gyorkos *et al.,* 2012). Helminth infected pregnant women are typically found with protein energy malnutrition and deficiencies of micronutrients such as iron and zinc and this can have devastating effects on both mother and foetus (Weatherhead and Woc-Colburn, 2014).

Malaria causes anaemia among other mechanisms through haemolysis and increased splenic clearance of infected and uninfected red blood cells and cytokine induced dyserythropoiesis (McDevitt *et al*., 2004). *Plasmodium falciparum* malaria induced anaemia in tropical Africa lowers the mean haemoglobin level by 2g/dl causing profound anaemia in some cases (Strickland *et al.*, 2000). Increased risk of premature delivery, low birth weight, foetal abnormalities and foetal death is directly related to the degree of maternal anaemia (Fleming, 1982).

Intestinal helminth causes anaemia as a result of direct blood loss, nutritional theft and impairment of appetite due to immunological factors (Kelkar and Kelkar, 1993). Pregnant women with *Plasmodium* and helminth co-infection especially primigravids have been found to have lower haemoglobin levels than those who suffer malaria or helminth infections only (Egwunyenga *et al.*, 2001).

Reduced mean haemoglobin level is attributed to chronic loss of blood and iron. Most important cause of pathological chronic loss of blood and iron in the tropics is hookworm and other soil transmitted helminths (Migasena and Gilles, 1987).

Occurrence of helminth infection at a high rate among pregnant women is indicative of faecal pollution of soil and domestic water supply around homes due to poor sanitation and improper sewage disposal (Egwunyenga *et al.*, 2001).

Occurrence of malaria and helminth parasites in poorer regions of SSA could be dependent on variations in socio-economic status that are wide enough for significant parasite associations to occur within individual populations, poorer homesteads are less likely to invest funds in buying nets, mosquito repellents or even obtain adequate clean water and sanitation (Worrall *et al.*, 2003).

1.2: Problem statement and justification

There has been continued spread of malaria parasites among different groups of vulnerable individuals such as the pregnant women despite global efforts to eradicate the parasite. Overlapping distribution of malaria and geohelminth parasites lead to high rates of co-infection in developing tropical countries and they have a significant and additive problem against the host (Degarege *et al*., 2010).

According to Singer (2013), there is limited literature on helminth and malaria syndemics and that pregnant women in sub-Saharan Africa are an understudied group but are more vulnerable to infections because of suppression of immune system during pregnancy. While amplified vulnerability is recognized, epidemiological, biomedical and social sciences of health research about pregnant women have tended to be characterised by a single disease approach. This research is therefore geared towards examining the nature of the relationship(s) between malaria infection and geohelminth infection during pregnancy in Nandi-Hills Sub County.

There could be an interaction in infections caused by helminths and by the malaria parasite (Hartgers and Yazdanbakhsh, 2006). Worldwide, many people are co-infected with malaria and helminths (Maizels *et al.,* 2009) and the influence of helminth infections on the course of malaria infection needs more careful investigation in vulnerable populations such as children and pregnant women.

It has increasingly been speculated that helminth infections may alter susceptibility to clinical malaria (Nacher, 2001) and there is now increasing interest in investigating the consequences of this co-infection (LeHesran *et al*., 2004). This research therefore explored whether malaria and geohelminth co-infection were counter syndemics or whether they interacted to enhance or exacerbate ill health among pregnant women attending ante-natal care at Nandi-Hills Sub-County hospital.

In the current study, parasite interaction was evaluated against other factors which were considered such as trimester, gravidity, socio-demographic/economic factors as well as wet and dry seasons of the year 2015.

According to Gorman (2013), maternal health has been recalcitrant to progress in Sub-Saharan Africa and this has proved to be a formidable challenge in achieving millennium development goals (MDGs). Maternal survival has been a comparatively neglected area in global health with more focus in foetuses and children (Rosenfield and Maine, 1985). This study therefore was important in testing the possibility that geohelminth infected pregnant women in Nandi-Hills Sub County could constitute a transmission hub for malaria parasites hence exacerbating their negative effects on the health of the pregnant women.

Malaria and helminth infections are known etiological factors in tropical anaemia, it is not clear how their combined presence might interact to further enhance the risk of anaemia in affected individuals (Brooker *et al*., 2007). The current study therefore explored the syndemic effect of co-infection of malaria and geo-helminths on anaemia in pregnant women attending ANC at Nandi Hills Sub County hospital.

Available studies of malaria and geohelminths in Kenya have mainly concentrated in the endemic regions such as Nyanza and there are no available information on the epidemic regions such as the highland areas including Nandi-Hills. The area has attracted many occupants including those from high transmission areas who come to seek labour in the tea plantations and factories. This study therefore provides information which can be utilised in preventing malaria and geo-helminth infection outbreaks in highland areas in the foreseeable future given that there has been no known vaccine for malaria and helminth parasites to the present time. With rising

global temperatures and changing hydrological cycles, it is likely that malaria infections will increase in areas where infections have been very low.

It is therefore imperative to understand the syndemics of geo-helminth/malaria co-infections in this part of the country (Nandi-Hills Sub County) and come up with ways of preventing the infections. Co-infected pregnant women were followed up to undertake treatment so as to reduce or eliminate the ill effects on themselves and on their developing foetuses. Iron supplements were recommended for all pregnant women who participated in the study.

1.3 General objective

To investigate geohelminths and malaria parasites infections, co-infections and syndemics among pregnant women attending antenatal care at Nandi-Hills Sub-County hospital.

1.4 Specific objectives

1. To determine the prevalence and intensity of geo-helminth and malaria parasite single infections.
2. To determine the prevalence and intensity of geo-helminth and malaria co-infections
3. To evaluate syndemic effects of malaria and geohelminth parasites on each other.
4. To compare malaria and geo-helminth co-infection and syndemics of different gravid groups.
5. To compare malaria and geo-helminth co-infection and syndemics of different trimester groups.

6. To assess the effects of socio-economic status of the pregnant women to geo-helminth and malaria co-infections and syndemics.
7. To compare malaria and geo-helminth/malaria co-infections and syndemics during two different seasons (wet and dry) in the year, (2015).

1.5 Hypotheses.

1. **H_O.** Prevalence and intensity of geohelminth and malaria single parasite infection in pregnant women attending ANC at Nandi-Hills Sub County hospital is low
2. **H_O.** Co-infection prevalence of geohelminth and malaria parasites in pregnant women is low.
3. **H_O.** Geohelminths and malaria parasites infecting pregnant women attending ANC at Nandi-Hills sub-County Hospital have no syndemic effect on each other.
4. **H_O.** Geo-helminth and Malaria co-infections and syndemics prevalence in different gravid groups among pregnant women attending pre-natal care at Nandi-Hills sub-county hospital are not significant.
5. **H_O.** Geo-helminth and Malaria co-infections and syndemics prevalence in different trimester groups among pregnant women attending pre-natal care at Nandi-Hills sub-county hospital are not significant.
6. **H_O.** Socio- demographic and economic status of pregnant women attending ANC at Nandi Hills Sub-County hospital has no effect on co-infection and syndemics by geo-helminths and malaria parasites
7. **H_O.** Wet and dry seasons of the year 2015 have no significant effect on co-infection and syndemics of geo-helminth and malaria parasites among pregnant women attending ANC at Nandi-Hills Sub-County hospital

CHAPTER TWO

LITERATURE REVIEW

2.1 Prevalence of geohelminth and malaria co-infections

Globally most common nematode species that cause soil transmitted helminthiases (STHs) diseases are *Ascaris lumbricoides, Trichuris trichiura* and hookworm *(Ancylostoma duodenale* and *Necator americanus).* The rates of co-infection may depend not only on chance, but also on the spatial distribution of environmental conditions that favour the transmission of multiple species (Booth, 2006), as well as on immunological interactions and common factors that affect genetic susceptibility or host behaviour.

It has been estimated that over a third of the world's population, mainly in the tropics and sub-tropics, is infected with parasitic helminths and *Plasmodium* species (Snow *et al*., 2005) and an estimated 40 million pregnant women were infected with STHs and schistosomes globally (Hotez, 2001).

Helminths and *P. falciparum* infection are endemic throughout most of Africa and populations often endure infections with a number of different parasite species (Petney and Andrews, 1998). Individuals are often co-infected with combinations of helminths and malaria parasites (Booth *et al*., 1998). Largest clinical disease burden due to infections with both *P. falciparum* and helminth species is carried by populations living in sub-Saharan Africa (SSA) (deSilva *et al.,* 2003; Snow *et al.*,2005).

Hospital based studies conducted among Nigerian pregnant women by Egwunyenga *et al*., (2001) showed that out of the 2,104 near-term pregnant women examined, 816

(38.8%) were found to be infected with malaria parasites. Among the 816 parasitaemic subjects, 394 (48.3%) were also infected with intestinal helminths, 102 (12.5%) had mixed helminth infections. The prevalence of the helminth species found in stool samples of parasitaemic subjects was, *A. lumbricoides* (19.1%), hookworm (14.2%), *T. trichiura* (7%) *Schistosoma mansoni* (3.4%), *Enterobius vermicularis* (2%), *Hymenolepis species* (1.6%) and *Taenia species* (1%). In a similar study done in Ghana, prevalence of co-infection was found to be 16.6% and women with intestinal helminth infection(s) were 4.8 times more likely to have malaria infection (Yatich *et al*., 2009).

A study in Kumasi Ghana showed a high prevalence of malaria, intestinal helminths and co-infection among pregnant. Pregnant women who tested positive for *P. falciparum* only was 19.7%, while those who tested positive for helminth parasites only was 9.1%. (Asundep *et al.*, 2014).

In Ethiopia, Getachew *et al.*, (2013) reported an overall prevalence of STH and malaria among pregnant women in Southwest Ethiopia as 159 (41%) and 45 (11.6%) respectively. Hookworm was the most prevalent soil transmitted helminthiasis infection at 114 (29.4%) followed by *A. lumbricoides* at 58 (15%) and *T. trichiura* at 13 (3.4%). The prevalence of STH and malaria co- infection among the pregnant women was 30 (7.7%). Intestinal helminth and malaria parasite co-infection was therefore found to be a problem among pregnant women in south west Ethiopia.

A study by Hillier *et al*., (2008) among pregnant women of a semi-urban population in Uganda, found out that the prevalence of asymptomatic *P. falciparum* infection was 11% (268 out of 2459), and the geometric mean parasite count in infected individuals was 43 parasites per 200 white blood cells. Of 2498 pregnant women, 1693 (68%)

were infected with one or more species of helminth. The dominant helminth species were as follows: hookworm (recovered from 1112 of 2498 subjects [45%]), *Mansonella perstans* (531 of 2499 subjects [21%]), *Schistosoma mansoni* (458 of 2498 subjects [18%]), *Strongyloides stercoralis* (306 of 2485 subjects [12%]), *T. trichiura* (226 of 2498 subjects [9%]), and *A. lumbricoides* (58 of 2498 subjects [2%]). Among 1112 subjects with hookworm infection, the intensity of infection was low in 942 (85%), moderate in 127 (11%), and heavy in 43 (4%) individuals, while the geometric mean parasite count was 57 microfilariae per millilitre for subjects with *M. perstans* infection,

In Entebbe Uganda, Woodburn *et al*.,(2009) found hookworm to be the most prevalent helminth infecting pregnant women at 44.5%, *M. perstans* at 21.2%, *S. mansoni* at 18.3%, *S. stercoralis* at 12.3%, *T .trichiura* at 9.3%, *A. lumbricoides* at 2.3% and malaria parasite detected was *P. falciparum* at 10.9%

In Peru, pregnant women were found to be heavily infected with geohelminths. The overall prevalences were 47.22% for hookworm, 82.25% for *T. trichiura* and 63.92% for *A. lumbricoides*. Only 9.31% of the pregnant women were free of any parasite infection; 20.25% of the women had a single infection, 38.96% had two infections, and 31.48% were infected with all the three worm infections. The prevalence of *T. trichuris* and hookworm co-infections was 44.05% (Larocque *et al*., 2005). In Nepal Dreyfuss *et al*., (2000) found hookworm to be the most prevalent STH at 74.2%, followed by *A. lumbricoides* at 58.9% and *T. trichiura* was the least prevalent at 5.3%. Malaria parasite that infected pregnant women in Nepal was *P. vivax* at 19.8%

Among febrile patients in a Northwest health center, Ethiopia, malaria parasites detected were *P. vivax* and *P. falciparum*. Prevalence of malaria infection was 11.5%.

Ascaris. lumbricoides was the most predominant helminth (62.1%) and hookworm infection was 18.4% while co-infection with malaria and *A. lumbricoides* was 45% (Alemu *et al.*, 2012)

In Osogbo Nigeria, a study was done on malaria and geo-helminth co-infections in children and Ojurongbe *et al.* (2011), found out that 4.3% of the children were co-infected with *P. falciparum* malaria and intestinal helminthes. Prevalence of *P. falciparum* was 26.5% while that of intestinal helminthes was 40.2%. Single helminth parasite species prevalence was 34.2%- *A. lumbricoides*, 5.1%-hookworm, 2.6%- *T. trichiura*, 0.9%-*Diphyllobothrium latum* and 0.9%- *Trichostrongylus* species.

In another study that was done to determine the effect of malaria and geohelminth infection on birth outcome in Kumasi, Ghana by Asundep *et al*. (2014). It was found out that the prevalence of the infections were 5% and 9% for helminthes and malaria respectively. Helminths that were detected were *Dicrocoelium dendtriticum*, *Strongyloides stercoralis*, *S. mansoni* and *A. duodenale*.

In similar study at the Kenyan coast, McLure *et al*. (2014) carried out a cohort study and found that the parasite with the most prevalence was hookworm at 23.7%, and all the infections were of light intensities. *P. falciparum* infection prevalence was 10.8% whereas that of *T. trichiura* was 10.1%.

A cross sectional study that was done in Western Kenya on pregnant women by van Eijk *et al*. (2009) revealed that out of the 390 participants who provided stool samples, 76.2% were infected with at least one geohelminth: 52.3% with *A. lumbricoides*, 39.5% with hookworm, and 29.0% with *T. trichiura*. Malaria was

detected in the blood smear of 37.8% of the women and 95.9% of infections were *P. falciparum* only, with the remainder being mixed infections.

2.2 Malaria- geohelminth co-infections and syndemics

Syndemics are an aggression of two or more diseases or afflictions in a population where there is a synergistic relationship which enhances and exacerbates the negative health effects of any or all of the diseases. Disease co-occurrence without any interaction is known as comorbidity or co-infection as opposed to syndemics whereby co-occurring diseases additively increases negative ill health (Singer, 2013).

According to Brooker *et al. (*2007), if co-infection is either synergistic or antagonistic then occurrence of both parasites would be significantly different from that predicted by individual chance encounters with either infection. Such associations may arise due to biological associations, whereby the presence of one species promotes or inhibits the establishment and/or survival of the second species, potentially through immune modulation. There is also a possibility of an opposite kind of disease interaction known as counter-syndemic that tends to lower the burden of disease in a population below the sum effect of the individual disease involved (Singer, 2013).

Malaria and helminths have been classified as infectious syndemics of pregnancy in Africa and that vulnerability to syndemics involves factors that put groups in harm's way for cluster of diseases and those factors that contribute to the weakening of bodies or the degrading of the immune capacities (Singer, 2013). Other factors are the failing of the social support systems and the disruptions or inaccessibility of health care services. Social encumbrances have direct impact not only on disease development and progression but on deleterious disease interaction as well. Apart

from either the synergistic or antagonistic effects of the parasite on each other, a key symptom of both malaria and helminth infections and resultantly co-infections is anaemia in which pregnant women, children and immunocompromised people are at risk (Standley, 2011).

It is well documented that a woman's immune response during pregnancy and chronic helminth infection shift towards type 2 immunity and anti-inflammatory cytokines. During pregnancy activities of CD4+ T cells, T cell type 2 (Th2) and their inflammatory cytokines interleukines 4, 5 and 10 increase. Inversely, the activities of T helper 1 (Th1) cells and their inflammatory cytokines as well as inflammatory macrophages and natural killer (NK) cells decrease. Protective immune response therefore against a majority of intracellular pathogens during pregnancy is weakened. Infectious diseases including malaria during pregnancy are very common because Th1 immune response and their cytokines are down-regulated (Abdoli and Pirestani, 2014).

Mwangi *et al*. (2006) noted that there were several hypotheses that had been set forth to explain the observed (and potential) interactions between malaria and helminths. Most of the evidence points towards helminth infection as having a negative effect on the acquisition of immunity to malaria, but data from Asia suggest that, due to possible modulation of pro-inflammatory and anti-inflammatory cytokines responses, helminth infection might protect against cerebral malaria (Nacher *et al.,* 2002). Due to the limited availability of studies, the relative value of these hypotheses remains uncertain (Mwatha *et al.,* 2003).

So far, the emphasis has been on how helminths may affect the epidemiological and clinical patterns of malaria. However, malaria may also exacerbate the consequences

of helminth infection. An important consequence of both malaria and helminth infection is anaemia, (Hotez *et al.,* 2004) which is an important public health problem in the tropics. Anaemia is regarded worldwide as a medical condition whish deserves sustained public health intervention.

Anaemia in pregnant women is defined as haemoglobin levels less than 11 g/dL (Larocque *et al*., 2005). It is well recognized that malaria is a significant contributor to anaemia both among young children and pregnant mothers, operating through a number of mechanisms, including haemolysis and phagocytosis, while hookworm infection is an acknowledged significant cause of anaemia as a result of intestinal blood loss (Hotez *et al*., 2004).

In rural western Kenya, van Eijk *et al*. (2009), did not find any significant interaction between malaria and any geohelminth parasite on the haemoglobin concentration of pregnant women. A cross sectional study of febrile patients in a health center in the Northwest of Ethiopia found a significant association between *Plasmodium* and helminth co-infection with anaemia (Alemu *et al.*, 2012)

Since the mechanisms by which malaria and hookworm infections cause anaemia differ, it is possible that their impact on haemoglobin levels is additive (Mwangi *et al.,* 2006) and it has recently been demonstrated by Brooker *et al.* (2006) that hookworm and malaria interact additively in reducing haemoglobin concentrations among East African schoolchildren.

A study on the impact of anaemia arising from co-infections was provided by a hospital-based study in Nigeria which reported lower birth weights of babies from

women co-infected with *P. falciparum* and helminths when compared to those infected with *P. falciparum* only (Egwunyenga *et al.,* 2001).

Chronic and intense geohelminth infection can contribute to malnutrition and iron deficiency anaemia which adversely affects physical and mental growth in childhood (Brooker *et al.,* 2007). Anaemia affects a large number of pregnant women in developing countries and increases their chances of dying during pregnancies and delivering low birth weight babies who in turn are at a risk of dying (Steketee *et al.,* 2001).

Although malaria and helminth infections are known aetiological factors in tropical anaemia, the extent to which their combined presence might interact to further enhance the risk of anaemia is poorly understood. If co-infection is either synergistic or antagonistic then occurrence of both parasites would be significantly different from that predicted by individual chance encounters with either infection. Such associations may arise due to biological associations, whereby the presence of one species promotes or inhibits the establishment and/or survival of the second species, potentially through immune modulation. (Brooker *et al.,* 2007).

A cautious conclusion that can be drawn from the human studies conducted so far, is that helminth infections seem to increase the susceptibility to malaria infection (Hartgers and Yazdanbakhsh, 2006).

The conditions for a potential syndemic of malaria and geohelminth parasitic infections are created by the overlapping geographic distributions of mosquito vectors of malaria and the various species of intestinal helminthes (Singer, 2013). An assessment of over 1,000 febrile patients in southern Ethiopia, it was found out that

malaria infection was more common in patients co-infected with the helminthes *A. lumbricoides* (21.3%), *T. trichiura* (23.1%), and *S. mansoni* (23.1%) than those patients without a helminth infection (9.3%) (Degarege *et al.*, 2012). Co-infected individuals showed lower mean levels of hemoglobin than those with malaria infection alone.

The specific helminth species involved may be critical, as some findings suggest a protective or counter-syndemic effect with particular types of intestinal worms and a worsening syndemic effect with others (Adegnika and Kremsner, 2012). Hookworm, for example, falls into the latter group, which is consequential both because its prevalence in SSA among pregnant women is high and also because it may contribute significantly to the degree of anemia in pregnant women (Egwunyenga *et al*., 2001).

A review by Mwangi *et al.* (2006) highlights the possibility that helminth infection creates a cytokine milieu that is favorable to the production of non-cytophilic antibodies, making individuals more susceptible to clinical malaria. Alternately, Yazdanbakhsh *et al.* (2001) suggests that the presence of T-regulatory cells increase during helminth infection, which, if present in sufficient numbers, induce a non-specific immune suppression that facilitates malaria development upon exposure.

First described over 75 years ago, it is clear that dual infection of malaria and intestinal helminthes presents a serious threat to the health of pregnant women in SSA (Wickaramsuriya, 1937). Varying patterns of co-infection have been described. A cross-sectional study of women presenting for delivery at two hospitals in Kumasi, Ghana, found that 19.7% were positive for the malarial pathogen *P. falciparum*, 9.1% were positive for helminth infection without malaria, and 16.6% were co-infected (Yatich *et al.*, 2009). Several helminthes were identified, including hookworms, *A.*

lumbricoides, *T. trichiura*, and *S. stercoralis*, with the first two being the most common. Women with intestinal helminthes were almost five times as likely to be infected with malaria as women without a helminth infection.

The principal finding by Hillier, *et al*. (2008), was a strong association between asymptomatic infection with *P. falciparum* and infection with *M. perstans*. A weaker association was observed between hookworm infection and *P. falciparum* infection, and there was an interaction between infections with the two helminths, such that the effect of hookworm infection was only seen in the absence of the stronger association with *M. perstans* infection.

Egwunyenga *et al.* (2001) randomly selected over 2,000 near-term pregnant women who delivered at three hospitals in Nigeria for screening for malaria and helminth parasites. Their study revealed that over 45% of *Plasmodium* infected women also harboured intestinal helminths. Women, especially primigravids, with *Plasmodium*/intestinal helminth co-infections had lower hemoglobin levels than those who suffered from malaria infection alone. This condition was attributed to chronic loss of blood and iron due to both infections. Anemia was believed to be further aggravated by the poor nutritional status of study participants, especially due to limited access to folate and iron.

Hookworm and *P. vivax* infection intensities were found to be stronger predictors of moderate to severe anaemia among pregnant women in the plain of Nepal (Dreyfuss *et al*., 2000). Anaemia was prevalent at 78% and in bivariate analysis hookworm was the most important contributor, *P. vivax* was also associated with anaemia

A study in Senegal showed that the risk of clinical malaria was reduced in helminth free children compared to those infected with *A. lumbricoides, A. duodenale or T. trichiura.* It was also established that there was a positive association between infection with *A. lumbricoides* and the occurrence of severe malaria (Le Hesran *et al*., 2004). In Thailand a study showed a positive association of intestinal helminths and infection with *P. falciparum* in adults (Boel *et al*., 2010). In Zaire, association between ascariasis and *P. falciparum* was also found to be positive (Tshikuka *et al.,* 1996).

Assessment of disease interaction was done further to examine the interplay of malaria, helminthes, and HIV disease among 328 HIV-positive women attending antenatal centers in Rwanda (Ivan *et al.,* 2012). It was found that 38% tested positive for helminthes, 21% had malaria, and 10% had dual infection. The most prevalent helminth was *A. lumbricoides* (20.7%), followed by *T. trichiura* (9.2%). Pregnant women with helminth infections were characterized by low hemoglobin and CD4 counts cell. This study demonstrates the importance of assessing multi-disease syndemics among pregnant women.

Co-infections with *Plasmodia* and *Schistosoma species* may also have synergistic effects on the organ pathology due to infection, including hepatomegaly and splenomegaly. For example, malaria may exacerbate hepatosplenic morbidity associated with schistosome infection (Fulford *et al.,* 1991). Schistosome infection can also contribute to anaemia (Friedman *et al.,* 2005) potentially exacerbating anaemia arising from malaria.

Naing *et al*. (2013) carried out a meta-analysis which revealed that pregnant women with hookworm infections had 1.36 times (odds ratio (OR) =1.36, 95% CI -1.17-1.59)

higher risk of malaria infection than those mothers without hookworm. The risk of malaria in primigravid mothers was 1.6 times higher than multigravida mothers. Similarly, in Uganda, Hillier *et al.* (2008) found that pregnant mothers with hookworm infection were 1.5 times likely to have *P. falciparum* infection than those without hookworm.

The meta-analysis by Naing *et al*., 2013 also revealed that the OR of the association between malaria and anaemia alone was 1.53, while that of STH alone was 0.28. But, the OR of the association of anaemia and STH combined was 2.91. Asundep *et al.* (2014), found a similar outcome regarding malaria – helminth co-infection and haemoglobin. According to their study, a higher proportion of women with low haemoglobin (severe/moderate anaemia) were those infected with malaria and helminths as compared to those who had normal haemoglobin, but this trend was not statistically significant.

Brutus *et al*. (2006) carried out a randomized clinical trial to look at the effect of helminthic treatment on malaria infections. They noted that treatment of *A. lumbricoides* was associated with two-fold increase in malaria parasitaemia in adults, suggesting a protective effect of *A. lumbricoides* co-infection.

According to Strickland *et al.* (2000), malaria can potentiate the expected anaemia of pregnancy and acute renal insufficiency and hypoglycaemia can complicate *falciparum* malaria in pregnant women. Low birth weight has been associated with placental malaria infections especially primigravidae living in endemic areas, who have little or no immunity against *P. falciparum* strains that get sequestered in the placenta (Fried and Duffy, 1996).

The main ill effect of hookworm parasites is the sucking of blood using its stout buccal cavity (Strickland *et al.,* 2000). Anaemia develops only if the dietary intake of the affected individual is inadequate in iron. Hypoalbuminaemia may also result on account of loss of proteins due to blood loss. Besides anaemia which is the most important pathogenic effect of hookworm, there may be gastrointestinal symptoms which include epigastric pain and an abnormal appetite with a desire to eat mud or soil (Kelkar and Kelkar, 1993), and act of pica or geophagy common in pregnant women.

According to Abdoli and Pirestani (2014), the immune system during pregnancy or helminth infection gives a weaker response to the infection that require Th1 immune response. This then makes a pregnant woman with chronic helminth infections more susceptible to acquiring congenital infections due to synergic immunoregulatory effect from pregnancy and chronic helminth infections. Infectious diseases in pregnant women therefore are more common due to physiological immonoregulation that is required for a successful pregnancy.

2.3 Risk factors associated with malaria and geohelminth co-infections

In Western Kenya, van Eijk *et al*. (2009) found out that among gravidae 2 and 3, those with *A. lumbricoides* were less likely to have malaria (OR = 0.4, 95% CI 0.2–0.8) than were those without *A. lumbricoides*. Conversely, among gravidae 2 and 3, those with *T. trichiura* were more likely to have malaria (OR = 2.39, 95% CI 1.06–5.40) than those without *T. trichiura*. These relationships were not observed in other gravidity groups.

Malaria was not associated with either hookworm or *T. trichiura* infection however for *A. lumbricoides*, there was a trend towards decreased malaria risk (OR = 0.7, 95%

CI 0.4–1.0, *P* = 0.06, model adjusted for gravidity, marital status, and trimester of pregnancy).

A study carried out among school going children by Ojurongbe *et al*. (2011), in Osogbo Nigeria, showed that children who were infected with helminthes were equally likely to be infected with malaria as those without intestinal helminthes (RR=0.7295). Those with *A. lumbricoides* were as likely to be infected with *P. falciparum* as compared with uninfected children (RR=1.359).

According to Asundep *et al*. (2014), women who did not receive prophylaxis (anthelmintic drugs) had a higher prevalence of malaria (15.3%) than those who received whose prevalence was 8.4% and furthermore, those who did not receive prophylaxis were two times more likely to be infected with malaria (OR=2.1; 95% CI:1.06-4.17) than their counterparts who received prophylaxis. Prevalence of helminths was higher for those who had not been screened for helminths (8.6%) than those who had been screened and received chemopropylaxis (4.0%). Odds ratio for those who had not been screened was two times higher (OR=2.4) compared to those who had been screened. This implied that those who had not been screened and had not received any malaria prophylaxis or anthelminthic treatment were two times more likely to be infected as compared to those who had been treated. Lack of prophylaxis therefore was a risk factor for infection in Kumasi, Ghana.

In low-income settings in particular, pregnant women may be subject to complex syndemics involving more than two diseases in adverse interaction (Singer, 2013). In Ethiopia, presence of stagnant water, habit of eating soil and habit of using human feces as a fertilizer were associated risk factors for malaria and STH co-infection among pregnant women in Gilgel Gibe dam area in which pregnant women who lived

in houses which were near stagnant water were three times more likely to be co-infected (Getachew *et al.,* 2013).

Study done in Thailand (Boel *et al*., 2010) and Nigeria (Egwunyenga *et al*., 2008) however identified parity, low income, being of young age and marital status (being single) as possible factors associated with malaria and STH co-infection. In Entebbe Uganda, risk factors for helminth and malaria infection were young age, lack of education, tribe, region of origin and gravidity (Woodburn *et al.,* 2009).

In Ghana, young age at pregnancy was found to be strongly associated with dual infection, while heightened rates of dual infection also were found among single, low-income, short pregnancy interval and primigravid women (Yatich *et al.,* 2009). Similarly, McLure *et al*. (2014) in a study carried out among pregnant women at the Kenyan Coast found that young age (< 20 years) was associated with a higher risk of malaria (OR = 2.29; 95% CI: 1.38-3.79), hookworm (OR =1.42; 95% CI: 1.02-1.98) and urinary schistosomiasis infections (OR = 2.25; 95% CI: 1.66-3.07).

Wekesa *et al.* (2014), noted that socio-economic factors play an important role in the establishment and spread of helminthiases in communities. In a study carried out among pregnant women in Kitale District hospital, they found that high prevalence of intestinal helminth infections were found among those who were younger in age (< 29 years), those with primary basic education and living in mud/ semi-permanent houses and those living in rural areas due to poor environmental sanitation, low economic status and lack of appropriate methods of refuse disposal. In many agricultural communities, women often acquire helminths in the process of growing family food and through the process of eating soil which is common in pregnant women of many communities in developing countries.

Thigpen *et al.* (2010), noted that primigravid women were 2 to 3 times more likely to have peripheral and placental malaria than multigravida women and that hookworm infection remained associated with malaria. This was consistent with prior studies which suggested that hookworm infection exacerbated malaria in pregnant women, thus making hookworm a risk factor for malaria infection, but limited in determining the cause and effect between the co-infection.

A study that was done in an endemic area of Colombia by Fernandez-Nino *et al*. (2012) showed that hookworm was a risk factor for malaria infection (OR=4.21; 95% CI: 1.68-11.31) and *A. lumbricoides* had a protective effect on malaria infection (OR=0.43; 95% CI: 0.18-1.04). According to Ojurongbe *et al.* (2011), malaria and soil transmitted helminths are highly prevalent in rural communities as a result of poor sanitary conditions prevailing in these areas.

The large-scale geographical distributions of malaria and helminths are determined largely by climate, which determines mosquito and helminth free-living stage survival (Hay *et al*., 2000; Brooker and Michael, 2000). Thus, it is probable that the geographic congruence of malaria and geohelminthes, especially hookworm, reflect common climatic drivers of parasite geographic ranges. Among the geo-helminth species, hookworms appear to have a wider thermal tolerance than *A. lumbricoides* or *T. trichiura* occurring throughout most of SSA, congruently with malaria

Although they have distinct means of transmission, a variety of environmental and host-specific factors have been identified for each parasite that influences epidemiological and geographic patterns of infection and disease. Identifying common risk factors of malaria and helminth infection is important since apparent associations between the two infections may be due to common social or

environmental factors rather than a true biological interaction (Mwangi, *et al*., 2006). Valencia *et al*. (2010) found an ecological correlation between malaria incidence and soil transmitted prevalence in Colombia. Malaria and soil transmitted helminths were found to be eco-syndemic.

Brooker *et al.* (2013), found that environmental factors associated with *Plasmodium falciparum* and hookworm co-infection were generally the same as those associated with hookworm infections and those for *Plasmodium falciparum-Schistosoma* co-infections were the same as those for *Schistosoma* infections. The findings suggested that environmental factors associated with individual helminth species were also associated with large scale spatial patterns of co-infections.

CHAPTER THREE

MATERIALS AND METHODS

3.1. Study area

The study was carried out in Nandi Hills Sub-County Hospital in Nandi County (Plate 3.1). The hospital serves residents mainly from Nandi Hills Sub County. The Sub County is situated in Western part of Kenya and it covers an area of 938.2km^2. It borders Nyando to the south, Nandi south to the West, Nandi North to the north, Uasin Gishu County to the North East and Kericho County to the South East (Appendix 15). It lies within latitudes 0^0 and $0^0$34' North and Longitudes $34^0$45'' and $35^0$25'' East (District Development Plan, Nandi East 2008-2012, 2009).

According to the NE DDP 2008-2012 (2009), the Sub County is divided into three distinct features namely; the rolling hills to the west, the weeded highlands of Tinderet volcanic mass in the South East and the dissected Nyando escarpment at the Southern border. It lies at an altitude ranging between 1300 m to 2500 m above sea level. Most parts of the District are hilly with basement rock system and such topography is favourable for natural forests which serve as catchment areas for major rivers and streams in the district (NE DDP 2008-2012, 2009).

The Sub County has a cool and moderately humid climate with an average rainfall of between 1200 mm to 2000 mm in a year. Long rains start in early March and continue to end of June while short rains start in September to November. Dry spell is experienced between December and March. Most parts of the Sub County experience temperature ranging between 18^0C and 22^0C during rainy seasons while higher temperatures (23^0C) are recorded during the dry spell in the highlands. Temperatures

of 26^0C are experienced during the months of December and January in the lower side of Nandi escarpment (NE DDP 2008-2012, 2009). Access to economic resources is low for women owing to the traditional division of labour that places women at the household level for domestic chores. Cases of early marriages are high in the county and are the major cause of school dropouts among the girls. Common diseases within Nandi County are malaria, upper respiratory tract infection, skin diseases and diarrhea. Period with highest outpatient cases is March and October when the area experiences heavy rains (Nandi County-CIDP 2013-2017, 2013).

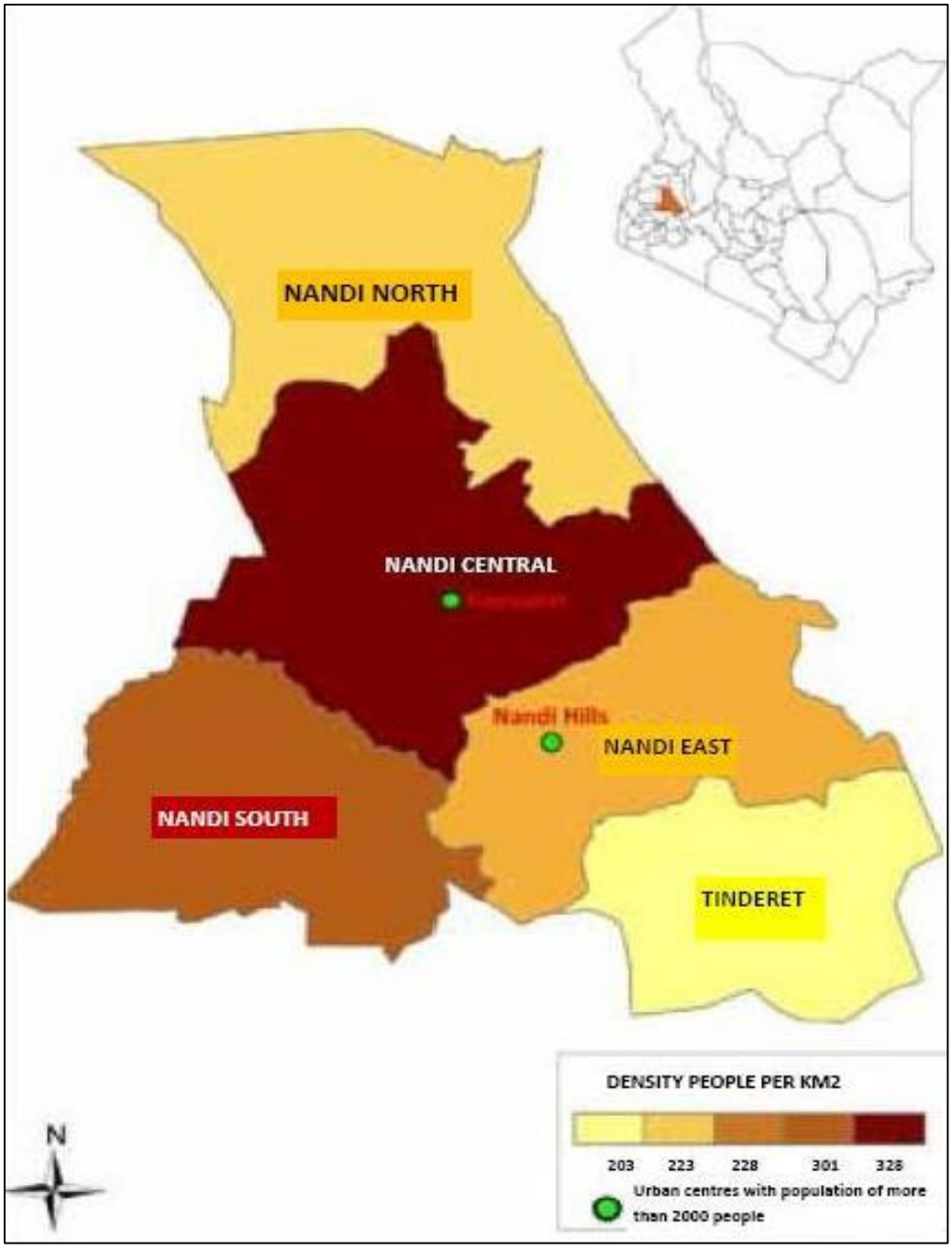


Plate 3.1: A map of Nandi County showing the study area

Source: County Integrated Development Plan 2013-2017 (2013)

3.2. Equipment and laboratory reagents

For malaria testing; a microscope (Olympus CX21®) from Olympus cooperation Tokyo Japan was used, alcohol swabs saturated in 70% isopropyl alcohol, Field's stains A and B, oil immersion, sterile lancets, cotton wool, microscope slides and cover slips were used.

For haemoglobin testing; cuvettes, diaspect haemoglobin machine, alcohol swabs saturated in 70% isopropyl alcohol, sterile lancets and cotton wool were used.

For geo-helminth testing centrifuge machine and tubes, stool container with a spatula attached to the cap were used (Plate 3.2). The container had a label on it which made it easier the identification of samples, beakers, disposable Pasteur pipettes, ceramic pestle and mortar, microscope and microscope slides, cover slips, di-ethyl ether, 40% formaldehyde, Lugol's iodine, wooden applicator sticks, gauze, plastic funnels, gloves and tissue papers.

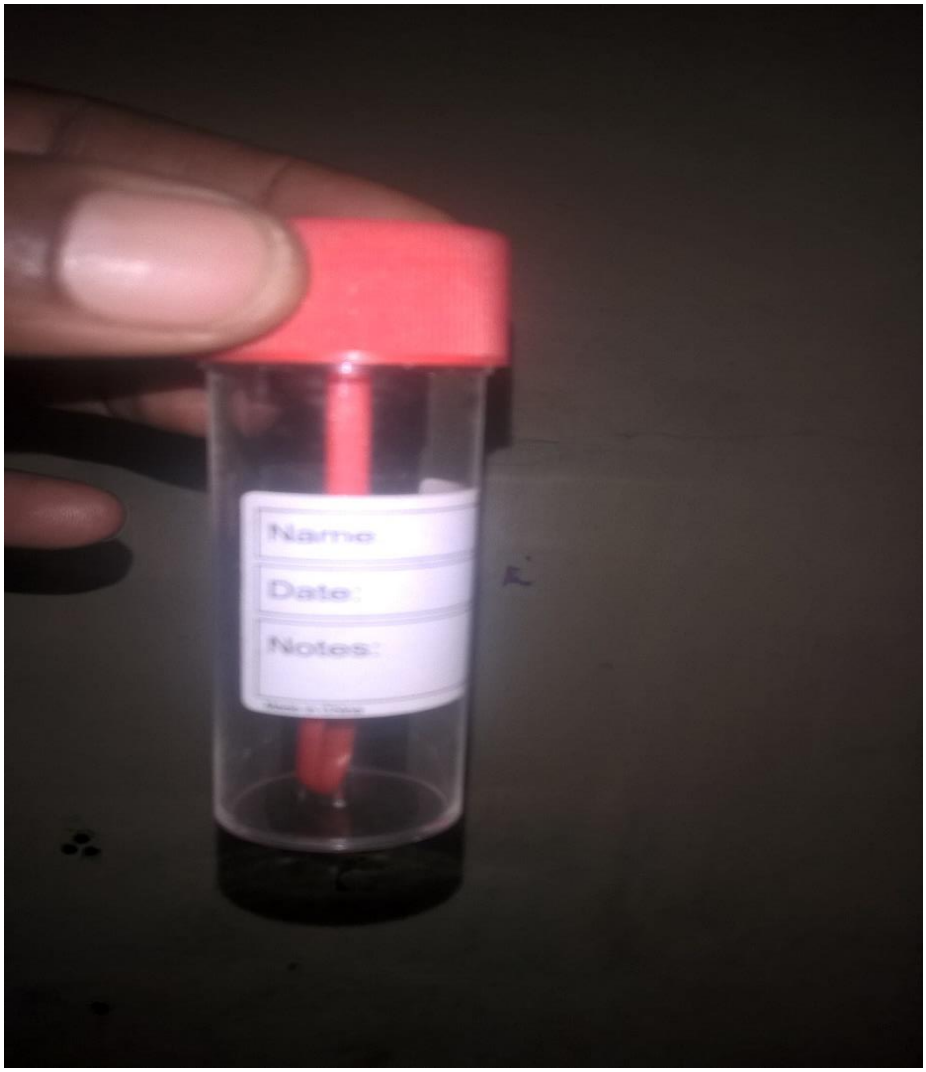


Plate 3.2: Stool container

Source: Author, 2015-2016

3.3. Study population and selection criteria

Study population constituted consenting pregnant women attending ANC at Nandi Hills Sub County hospital in the year, 2015. The selection in an inclusive criteria mode considered pregnant women irrespective of their parity and trimester or even their area of residence, there was no criteria for exclusion. Pregnant women were easily accessed from the clinic where they attended their regular ante-natal care. Incentives were provided to the pregnant women in form of a bottle of anti-septic

hand wash and a packet of anti-bacterial wipes. They were advised to use the soap and the wipes after collecting the stool specimen.

3.4. Study design, sample selection and sample size

The current study was a cross sectional survey study of pregnant women attending ANC at Nandi Hills Sub-County hospital. The data was collected from the month of March to December 2015 to obtain enough information that enabled drawing of inferences. Sample size was determined using Fisher's formula (Rosner, 1995);

$$\frac{N=Z^2p\,(100-p)}{d^2}$$

Where; Z=1.96, d= any value between 5 and 10 and p value was based on the average malaria and geo-helminth infection prevalence in Nandi-Hills Sub-County hospital which was 20%. Sample size therefore was found to be 245 individuals but it was expanded to 300 individuals because according to Montresor *et al*. (1998), a larger sample is used, when research is to evaluate other parameters other than prevalence and intensity.

Subjects were selected using random sampling whereby consenting pregnant women who attended ANC were recruited for the study until adequate samples were attained. Selected individuals were stratified based on their parity ranges. They were further stratified based on their trimesters.

Collection of data was done from March to December in the year 2015 and this period was stratified into two namely dry season and wet seasons.

3.5. Ethical approval and consent to participate

Consent to carry out the study in the hospital was obtained from the hospital management board through the hospital superintendent (appendix 3 b) after a formal request through the department of Biological Sciences, University of Eldoret (Appendix 3 a). Sampled pregnant women gave informed consent to participate in the study. Written consent was obtained whereby the pregnant women were asked to sign an informed consent form (ICF) after explaining the objectives and value of the study to them. ICF (appendix 2) written in English was explained in Swahili and sometimes in their mother tongue to enhance understanding. Ethical clearance was obtained from Jaramogi Oginga Odinga Teaching and Referral Hospital. Ethics of research were adhered to throughout the study period.

3.6. Stool samples collection and processing

Each participant was provided with a labeled screw caped stool container (Plate 3.1) and informed on how to collect about 5 grams of stool sample. Stool was processed immediately at the hospital using formal- ether concentration technique whereby 1 gm of faeces was mixed with formalin, sieved into a centrifuge tube and 3 ml of ether was then added. The mixture was centrifuged for a minute and the supernatant was discarded so that the remaining contents could be used in slide preparation as described by Cheesbrough, (2006). Microscopic examination was done using X10 objective magnification after staining with 1% lugol's iodine and results recorded in terms of presence or absence and intensity of geohelminth parasite ova in stool sample.

Quantification of worm burden was done by direct smear egg count (Chakraborty, 2004) in which 2mgs of the stool was mixed with a small drop of saline on a slide. A

coverslip was applied on the evenly mixed material without forming air bubbles. The preparation was examined systematically with low power microscope and eggs of the present geo-helminth species were counted. Quantification of worm burden was applicable to the stool samples which had been found to have geo-helminth ova. Number of eggs per gram of faeces (epg) was obtained using the following formula (Chakraborty, 2004);

No. of eggs per gram of faeces=N/2 × 1000, where N= number of eggs.

Intensity was then categorized into light, moderate and heavy infections using a threshold proposed by WHO (Montresor *et al.*, 1998). Light intensity is described to be 1-4,999 epg, 1-1,999 epg, and1-999 epg for *A. lumbricoides*, hookworm and *T. trichiura* respectively. Moderate intensity is estimated to be 5000-49000 epg, 2000-3999 epg and 1000-9,999 epg for *A. lumbricoides*, hookworm and *T. trichiura* respectively, while heavy intensity is estimated to be 50000 epg, 40000 epg and 10,000 epg for *A. lumbricoides*, hookworm and *T. trichiura*, respectively (Montresor *et al.*, 1998).

3.7. Blood sample collection and processing

Consenting participants donated capillary blood sample through a finger prick. The finger was cleansed with alcohol moistened swab then dried with a piece of cotton. It was then punctured with a disposable blood lancet. Thick and thin blood smears were prepared and stained using Field Stains A and B. Microscopic examination was done under oil immersion at x100 objective to determine the level of parasitaemia and identify parasite species following the method of Strickland *et al*. (2000).

Estimation of *P. falciparum* densities was done by counting the number of *P. falciparum* parasites in relation to standard number of leucocytes in the thick film. Parasite density was thus calculated using the formula;

Parasite /µl of blood = number of parasites counted x 8000 leucocytes/ 200 leucocytes

Where 8000 leucocytes represents total number of white blood cells (WBCs) in an individual and 200 leucocytes represents the number of WBCs against which the parasites are counted but if the parasites counted were less than 99 after counting 200 WBCs, the number was raised to 500 WBCs (WHO, 2010)

Haemoglobin concentration was determined by drawing blood into the cuvettes and tested using diaspect haemoglobin test machine. Haemoglobin levels were then recorded as either Hb<11 to represent the anaemic category or Hb≥11 to represent the non-anaemic category.

3.8. Questionnaires survey:

Semi structured questionnaires were developed and administered to obtain information regarding individual demographics and socio-economic status of the consenting pregnant women (Appendix 1). Information provided by the respondents was treated with confidentiality. Obstetric information (gravidity and trimester) was obtained from the ANC booklet of the respondents.

Each variable was coded and responses were accorded numerical values when recording the data in SPSS work sheet. Gravidity was categorized into (1) primigravidae and (2) multigravidae, whereas trimester was accorded values as (1) 1^{st} trimester, (2) 2^{nd} trimester and (3) 3^{rd} trimester. Age was categorized into five

numerical groups namely; 1 (16-20 years), 2 (21-25 years), 3 (26-30 years), 4 (31-35 years) and 5 (36-40 years). Marital status was coded as m.s and responses were numbered as 1(married), 2(single) 3(widowed) and 4(divorced). Categories in education level were numbered as (1) primary, (2) secondary and (3) tertiary. Settlement area was categorized as (1) own home, (2) urban rental and (3) estate camp. Family size was coded as F. Size and categorized as (1) ≤ 2, (2) 3-5 and (3) >5, water source was coded as W. source and categorized as (1) piped, (2) spring and (3) bore hole and mode of faecal disposal was coded as F. disposal and characterized as (1) pit latrine and (2) toilet. Income per month was determined by the occupation of the respondents for those who did not have formal employment and all the categories were recorded as (1) >ksh 20,000, (2) ksh 10,000-20,000 and (3) ksh<10,000. Variable whose responses were either (1) yes or (2) no were geophagy, chemoprophylaxis, use of ITN and residual house spray.

3.9. Data analyses

Data was recorded in a laboratory notebook and later transferred to excel spreadsheet protected by a pass word only accessible to the investigator**.** Data was processed using statistical package for social sciences (SPSS Version 16). Descriptive statistics was used to analyze demographic data. Comparison of prevalence of geohelminthes and malaria co-infection between different variables was done using chi-square test statistics. Synergistic and antagonistic relationships of parasites were determined using Phi and Cramer's V test of strength of association by mainly considering Phi (r^{ϕ}) value. The test was used to determine the interaction of geohelminth and malaria parasites before and after the introduction of other parameters. Variable that had significant association with parasite infection and co-infections were used to

determine the odds ratios (OR) with 95% confidence interval by logistic regression to show the risk factors of parasite infection and co-infection.

CHAPTER FOUR

RESULTS

4.1. Proportion and intensity of parasitic infections.

4.1.1 Geo-helminth infection rates and intensity.

Parasites that were detected among the pregnant women attending ante-natal care clinic at Nandi-Hills Sub - County hospital were *A. lumbricoides*, *A. duodenale* and *T. trichiura*. Out of the 300 pregnant women, 89 (30%) were infected with *A. lumbricoides,* 46 (15.3%) with *A. duodenale*, and only 3, (1%) were infected with *T. trichiura* (Figure 4.1**)**. Differences in infection with *A. lumbricoides*, *A. duodenale* and *T. trichiura* were statistically significant among the pregnant women (*P=0.00*) (Appendix 4a).

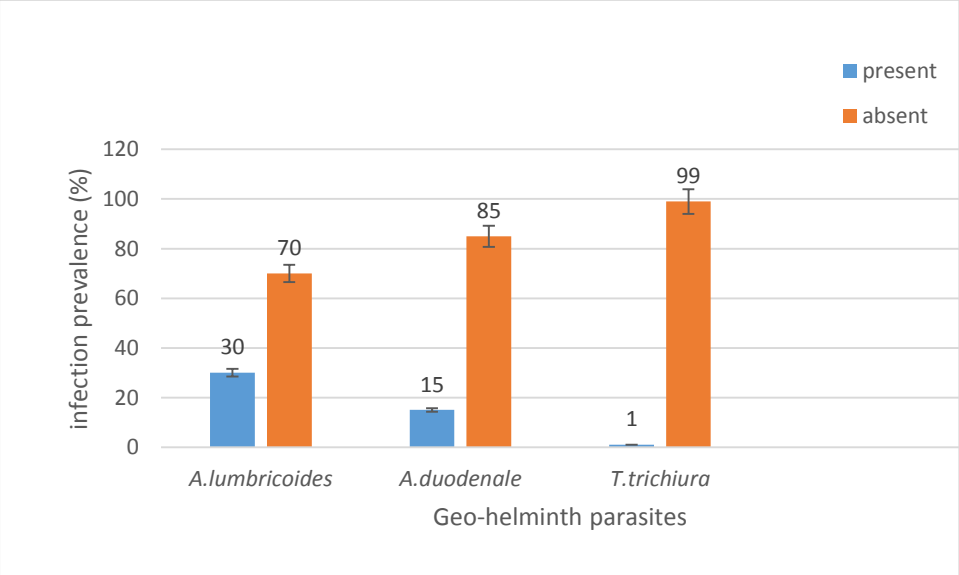


Figure 4.1: Proportion of pregnant women infected with geo-helminths by parasite species

The most prevalent geo-helminth was *A. lumbricoides* and 28% of the 89 pregnant women who had *A. lumbricoides* infection were also co-infected with *A. duodenale*.

All the three who had *T. trichiura* infection were co-infected with *A. lumbricoides* (Table 4.1). The difference in geohelminth co-infection was significant for both *A. lumbricoides-A. duodenale* and *A. lumbricoides- T. trichiura* parasites (*P=0.00* and *P=0.007* respectively; Table 4.1). There were no co-infections with *A. duodenale* and *T. trichiura* parasites.

Table 4.1: Prevalence rate of *A. lumbricoides-A. duodenale* and *A. lumbricoides-T. trichiura* co-infections.

		A. lumbricoides		Total	
		present	absent	(n)	P value
A. duodenale	present	25(28%)	21(10%)	46(15%)	0.000*
	absent	64(72%)	190(90%)	254(85%)	
Total		89(100%)	211(100%)	300(100%)	
T. trichiura	present	3(3%)	0(0%)	3(1%)	0.007*
	absent	86(97%)	211(100%)	297(99%)	
Total		89(100%)	211(100%)	300(100%)	

*(%) = percentage within A. lumbricoides; *= significant at 0.05;*

All infections with *A. lumbricoides* were light infections (1-4,999 epg) whereby 500 epg, 1000 epg and 1500 epg and 2000 epg of faeces was recorded in 43.8%, 29.2%, 18% and 9% respectively of the 89 *A. lumbricoides* infected individuals. With regard to *A. duodenale*, out of the 46 pregnant women infected, 12% were light infections (1-1999) while 3.7% were moderate infections (2000-3999). The difference in intensity of *A. duodenale* infection was statistically significant (*P=0.00*). All the three infections (1%) with *T. trichiura* were light infections (500 epg of faeces).

4.1.2 Malaria infection proportion.

Infection with *P. falciparum* was 8% representing 23 out of the total 300 pregnant women who participated in the study (Figure 4.2). All the cases of *P. falciparum* infection were asymptomatic. Those who did not harbour malaria parasites were 277 (92%).

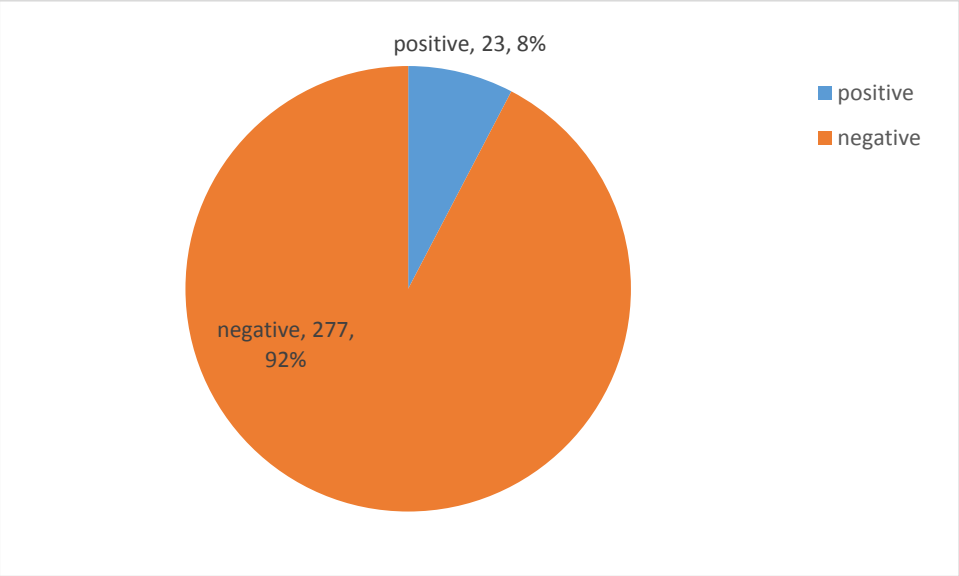


Figure 4.2: Percentage infection and non-infection by *P. falciparum*

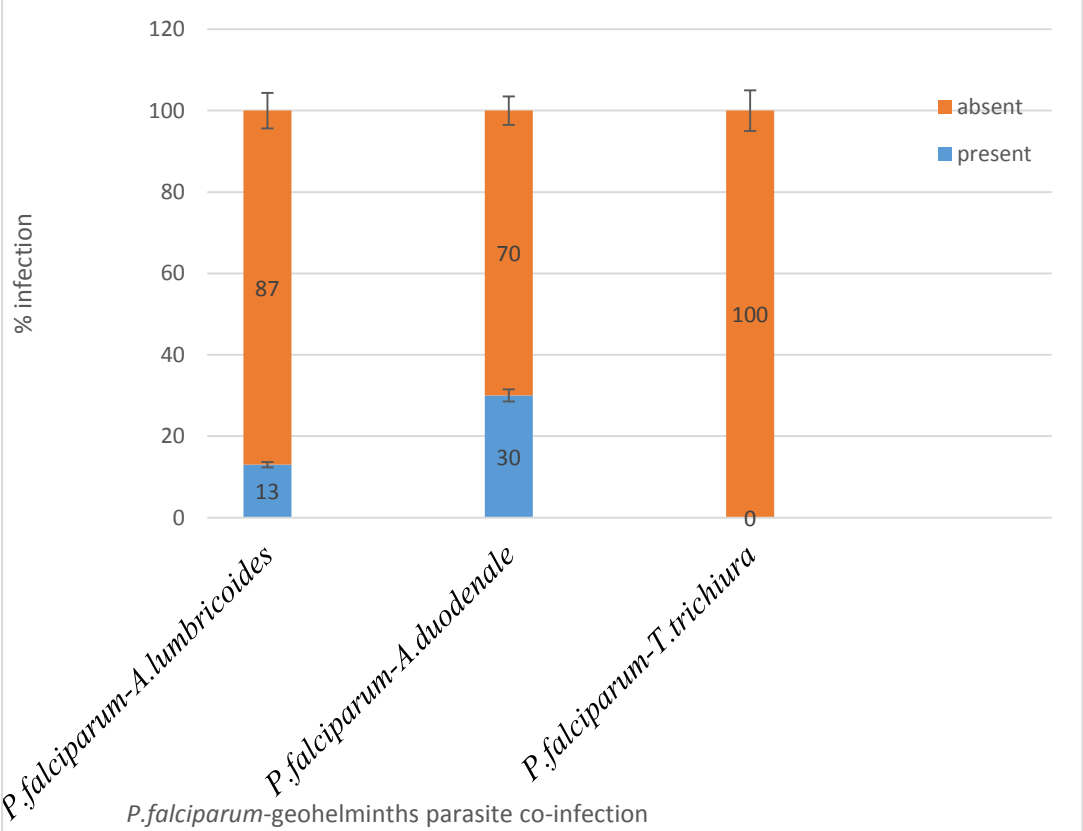
Parasite density for all *P. falciparum* infected individuals was low, that is; 1 X 8000/500 giving 16 parasites/µl of blood.

4.2. Malaria and geo-helminth co-infection and syndemics.

Out of the 300 pregnant women, only 2.7% were co-infected with malaria and either with *A. lumbricoides* or *A. duodenale* parasites. Pregnant women who were positive for *Plasmodium* parasites and were co-infected with *A. lumbricoides* were 3 (13%), while 7 (30%) of the malaria infected pregnant women were co-infected with *A. duodenale* parasites and none of them had *Plasmodium* and *T. trichiura* parasites (Figure 4.3). Malaria parasites and *A. lumbricoides* co-infection was not significant

(*P=0.07*) compared to malaria parasites and *A. duodenale* co-infection which was significant (*P=0.04*) (Appendix 4a).

There was however a weak negative association between malaria parasites and *A. lumbricoides* co-infection (r^{φ}=-0.105; Appendix 4b) and a strong positive association between malaria parasites and *A. duodenale* (r^{φ}=0.121; Appendix 4b).



Horizontal axis=malaria and geohelminth parasites co-infecting pregnant women; vertical axis=% prevalence with co-infection and without co-infection

Figure 4.3: *P. falciparum*-Geo-helminth co-infection rates

A. duodenale infection was a significant risk factor for malaria parasites infection with OR=3.926; 95% C.I: 1.425-10.814, while *A. lumbricoides* infection had odds ratio of less than one (OR=0.231; 95% C.I: 0.063-0.850) in relation to *P. falciparum* infection (Appendix 4c).

4.3. Malaria and geo-helminth infections among gravid groups.

4.3.1. Single parasite infections by gravid groups.

Primigravidae constituted 25% of the study population while multigravidae made up 75% of the study population. More of the primigravidae group had *Plasmodium falciparum* parasites. Eleven (15%) of all primigravidae group had malaria, whereas 12 (5%) of multigravidae group tested positive for malaria parasites (Table 4.2). The difference in malaria parasites infection prevalence between these parity groups was statistically significant whereby primigravidae had the highest prevalence (*P=0.01*; Appendix 5a). In regard to helminth infections there was no significant difference between those infected and the non-infected with any of the three geo-helminths by parity. Prevalence of *A. lumbricoides* was 29% and 30% for primigravidae and multigravidae respectively (*P=0.94*). For *A. duodenale* infections, 19%, primigravidae and 14%, multigravidae were infected (*P=0.36*). All the three pregnant women infected with *T. trichiura* were multigravidae (*P=0.32*; Table 4.2). Primigravidae was a risk factor for malaria parasites infection (OR=3.051; 95% C.I: 1.285-7.242; Table 4.12)

Table 4.2: Parasite infection rates by gravidity.

Parasites	Infection status	Primigravidae	Multigravidae	Total	P value
P. falciparum	Positive	11 (15%)	12(5%)	23(8%)	0.014*
A. lumbricoides	Present	22(29%)	67(30%)	89(30%)	0.942^{ns}
A.duodenale	Present	14(19%)	32(14%)	46(15%)	0.363^{ns}
T. trichiura	Present	0(0%)	3(1%)	3(1%)	0.32^{ns}

*(%) percentage within category total; *= significant at 0.05; ns= not significant at 0.05*

4.3.2 Malaria and geo-helminth co-infection and syndemics among different gravid groups.

Out of the total 11 primigravidae women who were positive for malaria parasites, 2 of them (18%) were co-infected with *A. lumbricoides* and 4 (36%) were co-infected with *A. duodenale* . In the multigravidae group, out of the total 12 women positive for malaria parasites, 1 (8%) was co-infected with *A. lumbricoides* and 3 (25%) were co-infected with *A. duodenale* parasites (Table 4.13).

However, the difference in co-infection proportions with malaria parasites -*A. lumbricoides* in the two groups (primigravida and multigravida) was not significant (*P=0.38* and *P=0.098* respectively). Similarly, the difference in malaria -*A. duodenale* co-infection proportions was not significant with either primigravidae or multigravidae (*P=0.103* and *P=272* respectively). There was no co-infection between malaria and *T. trichiura* parasites in any gravidity. There was an insignificant negative association between malaria parasites-*A. lumbricoides* (r_{φ}=-.102 and r_{φ}=-.111 for primigravidae and multigravidae respectively; Appendix 5c), and insignificant positive association in *P. falciparum- A. duodenale* co-infections by parity (r_{φ}=.188 and r_{φ}=.073 for primigravidae and multigravidae respectively; Appendix 5c). The counter syndemic effect of *P. falciparum -A. lumbricoides* and syndemic effect of *P. falciparum –A. duodenale* by parity was not strong.

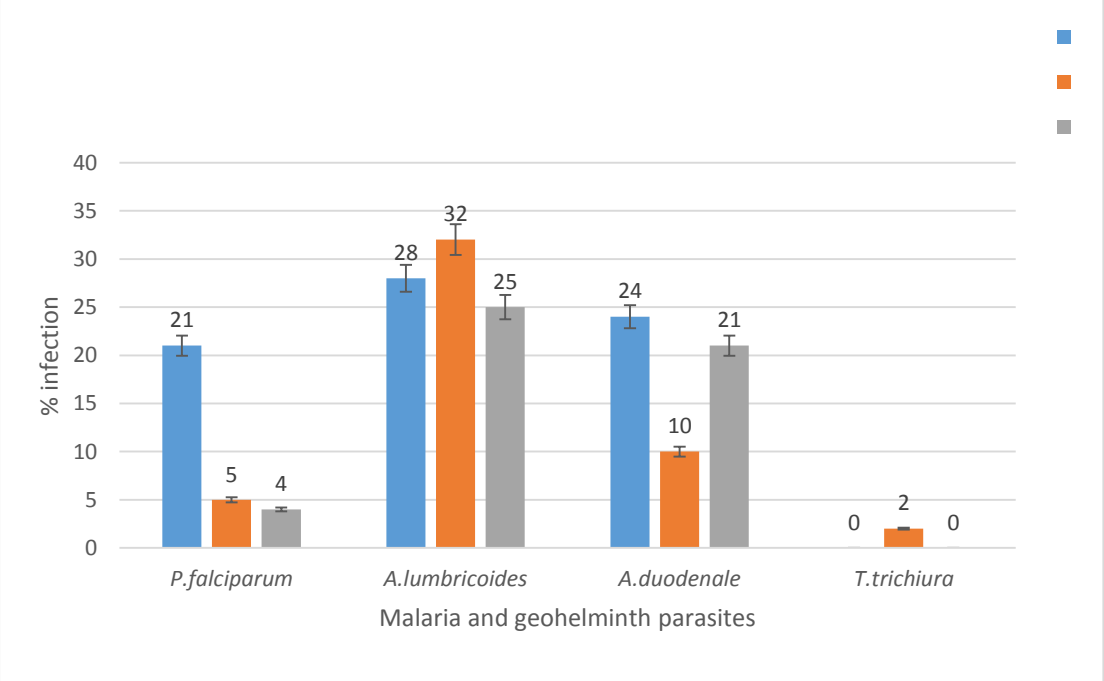
4.4. Infection among trimester groups.

4.4.1 Single parasite infection by trimester groups.

Most of the pregnant women (57%) in the study were in their 2nd trimester whereas 19.3% were in the 1st trimester and 23.7% were in 3rd trimester. Infection prevalence with *P. falciparum* was high among the 1st trimester group which was recorded at

21%, while in the 2nd and 3rd trimesters, infection prevalence was 5% and 4% respectively (Figure 4.4). There were significant differences in malaria infections by trimesters (*P=0.00*; Appendix 6a).

For *A. lumbricoides* infection, 28%, 32% and 25% of those in 1st, 2nd and 3rd trimesters respectively were infected, regarding *A. duodenale* infection prevalence was 24%, 10% and 21% of those in their 1st, 2nd, and 3rd trimesters respectively, while the three infections of *T. trichiura* were found among the 2nd trimester group (Figure 4.4). Differences in infection proportions by geohelminth parasites was insignificant for *A. lumbricoides* and *T. trichiura* (*P=0.53, P=0.32* respectively) but significant for *A. duodenale* (*P=0.01*) (Appendix 6a). 1st trimester was a significant risk factor for malaria parasites infection (OR=5.913; 95% C.I: 1.581-22.120) unlike 2nd trimester which was an insignificant risk factor (OR=1.112; 95% C.I.: .286-4.320; Table 4.12).



Horizontal axis= parasite infection in 1st, 2nd and 3rd trimesters; vertical axis= prevalence of infection by P.falciparum and geohelminth parasites

Figure 4.4: Parasite infection prevalence by trimester

4.4.2 Malaria and geo-helminth co-infection and syndemics by trimester

Out of the 12 *P. falciparum* infected individuals, 2(17%) were co-infected with *A. lumbricoides,* and 4(33%) of them were co-infected with *A. duodenale* in their 1st trimester. Among those in the 2nd trimester, there was only one case (12%) of malaria parasites and *A. lumbricoides* co-infection and 2(25%) cases of malaria parasites and *A. duodenale* co-infections out of 8 *P. falciparum* infected individuals. There was no *P. falciparum-A. lumbricoides* in the 3rd trimester but for *P. falciparum-A. duodenale* co-infection there was 1 case (33%) which as statistically insignificant. There were no cases of *P. falciparum- T. trichiura* co-infections in all the three trimesters (Table 4.13). Differences in co-infection proportions in all the trimester groups was not statistically significant for *P. falciparum-A. lumbricoides* (*P=.34, P=.22* and *P=.30)* for 1st, 2nd and 3rd trimester respectively. Similarly, differences in *P. falciparum-A. duodenale* co-infection proportions were not significant (*P=.40, P=.15* and *P=.60*) for 1st, 2nd and 3rd trimesters respectively (Appendix 6b).

Co-infection with *P. falciparum* and *A. lumbricoides* had a negative association in all the three trimester groups and the strength of association was r^{φ} =-.125, r^{φ}=-.093 and r^{φ}=-.122 for 1st, 2nd and 3rd trimesters respectively. Co-infection with *P. falciparum* and *A. duodenale* had a positive association in all the trimester groups (r^{φ}=.110, r^{φ}=.111 and r^{φ}=.063 for 1st, 2nd and 3rd trimesters respectively). With trimester, *P. falciparum- A. lumbricoides* remained counter syndemic whereas *P. falciparum*-hookworm remained syndemic (Appendix 6c).

4.5. Age related infections and co-infections.

4.5.1 Age related single parasitic infections.

Majority of the pregnant women were aged between 21-25 years (39%), those aged between 16-20 years, 26-30 years, 31-35 years and 36-40 years were 19%, 26%, 11% and 5% respectively as shown in Figure 4.5.

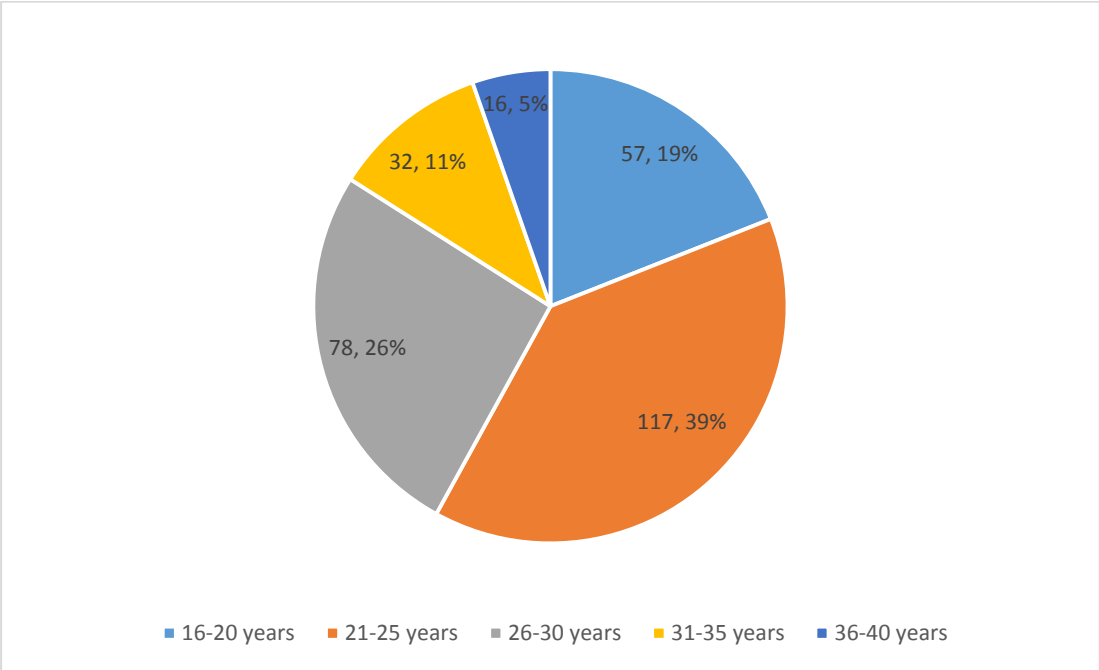


Figure 4.5: Age categories of the respondents.

Infection with *P. falciparum* among those aged between 16-20 years was 18% while infection prevalence among those aged between 21-25 years, 26-30 years, 31-35 years and 36-40 years was 8%, 8%, 6% and 0% respectively (Figure 4.6). Differences in infection prevalence with *P. falciparum* in relation to age was statistically significant (*P=0.025*) (Appendix 7a). All age categories became significant risk factors for *P. falciparum* infection (Table 4.12).

Older age 36-40 years had a higher *A. lumbricoides* infection prevalence of 50%. This represented 8 out of the total 16 individuals in the age category, infection prevalence in the young age group (16-20 years) was 33%, whereby among those aged 21-25 and 26-30 years, infection prevalence was 28% in both age categories and 35% in the age category of 31-35 years (Figure 4.6). Differences in infection prevalence with *A. lumbricoides* in relation to age was not significant (*P=0.32;* Appendix 7a).

Prevalence of *A. duodenale* infection was higher at 21% among the young age category followed by those aged 26-30 years where infection prevalence was 18%. Among those aged between 31-35 and 36-40 years, infection prevalence was 13% for each category and 12% among those aged between 21-25 years (Figure 4.6). The difference in infection prevalence with *A. duodenale* was not statistically significant (*P=0.53;* Appendix 7a).

Infection prevalence with *T. trichiura* was 2% representing only one out of the total 57 individuals in the young age category of 16-20 years, 1% among those aged between 21-25 years and 6% representing 1 out of 16 in the older age category of 36-40 years (Figure 4.6). The difference in infection prevalence with *T. trichiura* was not significant with age (*P=0.21;* Appendix 7a)

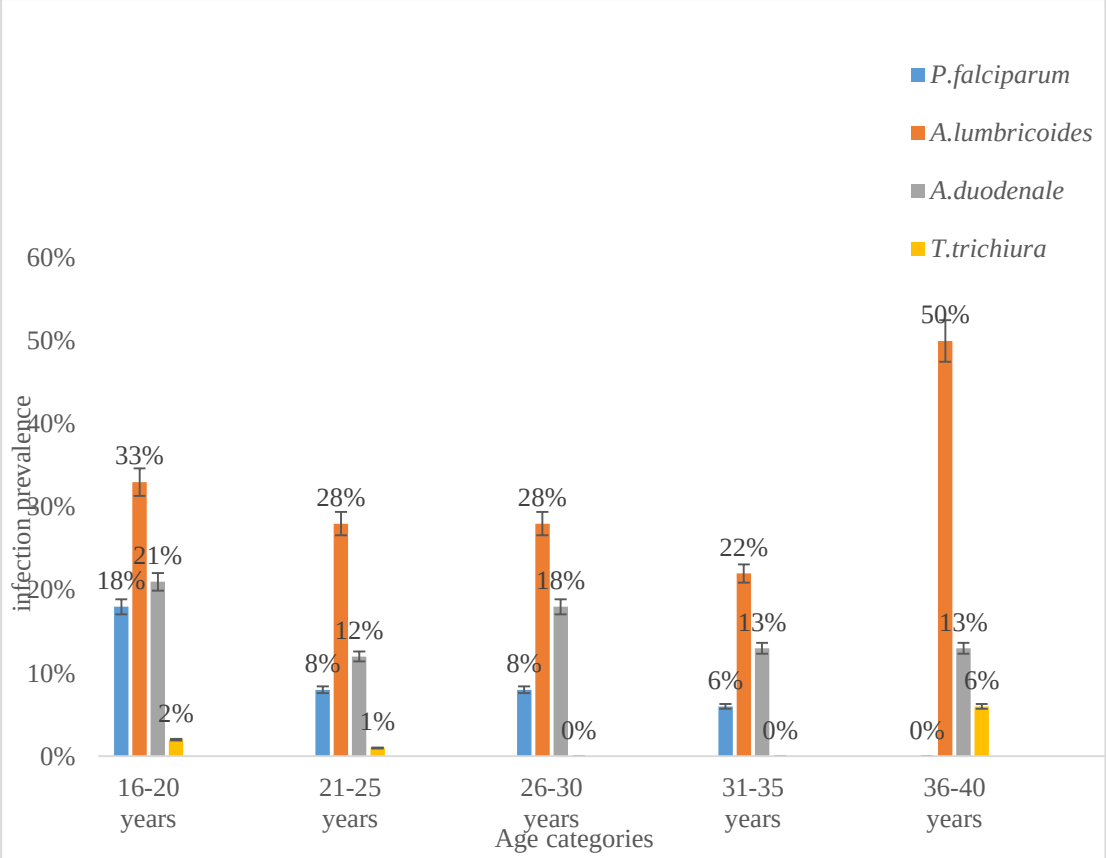


Figure 4.6: Parasitic infection prevalence in different age categories

4.5.2 Malaria and geo-helminth co-infection and syndemics in relation to age.

Thirty percent (30%; 3 out of 10) of the individuals in the young age category of 16-20 years who were positive for *P. falciparum* were co-infected with *A. lumbricoides* (Table 4.14). The proportion of those co-infected with *P. falciparum* and *A. lumbricoides* was not statistically significant in this age category (*P=0.81*) (Appendix 7b). None of the pregnant women in the subsequent age categories were co-infected with *P. falciparum* and A. *lumbricoides* (Table 4.14). There was a weak negative association between *P. falciparum* and *A. lumbricodes* co-infection in all the age categories (Appendix 7c).

Similarly, 30% of those in the young age category (16-20 years) were co-infected with *P. falciparum* and *A. duodenale* parasites. 40% in the 21-25 years category and

33.3% in the 26-30 years category had *P. falciparum* and *A. duodenale* co-infections (Table 4.14). Co-infection of *P. falciparum* and *A. duodenale* in relation to all age was not significant except among those aged between 21-25 years. (*P=0.45, P=0.048; P=0.31, P=0.58*) for 16-20 years, 21-25 years, 26-30 years and 31-36 years respectively (Appendix 7b).

Co-infection of *P. falciparum* and *A. duodenale* had a positive association in the first three age categories and the kind of association among those aged 21-25 years was significant (r^{φ}=0.183; *P=0.048*). The other age categories had insignificant positive association, (Appendix 7c). There were no *Plasmodium* and *T. trichiura* co-infections in all age categories.

4.6 Marital status of the pregnant women and parasitic infection.

The young aged pregnant women who were singles/not married constituted 12% of the study participants, while 88% were married. There were no widows or divorcees among the participants (Figure 4.7).

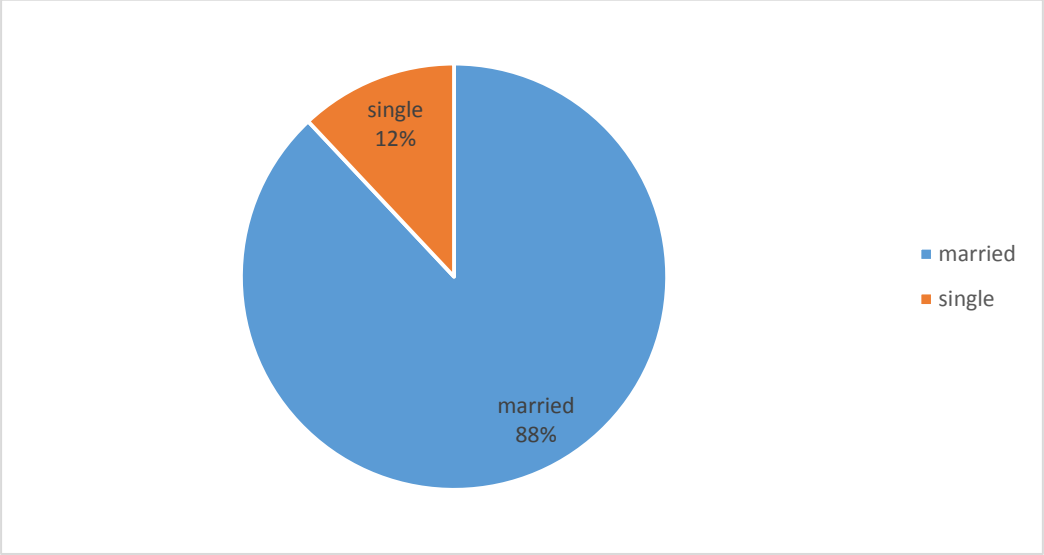


Figure 4.7: Proportion of pregnant women by their marital status

4.6.1 Single parasitic infection in relation to marital status.

Among the singles, 31% were infected with *A. lumbricoides*, 17% with *A. duodenale* and 17% with *P. falciparum*. Among those who were married, 29% were infected with *A. lumbricoides*, 15% with *A. duodenale* and 6% with *P. falciparum* (Figure 4.8).

Infection prevalence for *P. falciparum* were significantly different between the married and the single pregnant women (*P=0.025*) and being single became a significant risk factor for *P. falciparum* infection (OR=4.833; 95% CI=1.103-8.263; Table 4.12). Infection prevalence with any three of the geo-helminths were not significantly different between the married and the single pregnant women (*P=0.81* for *A. lumbricoides*, *P=0.75* for *A. duodenale* and *P=0.53* for *T. trichiura* infections) (Appendix 8a).

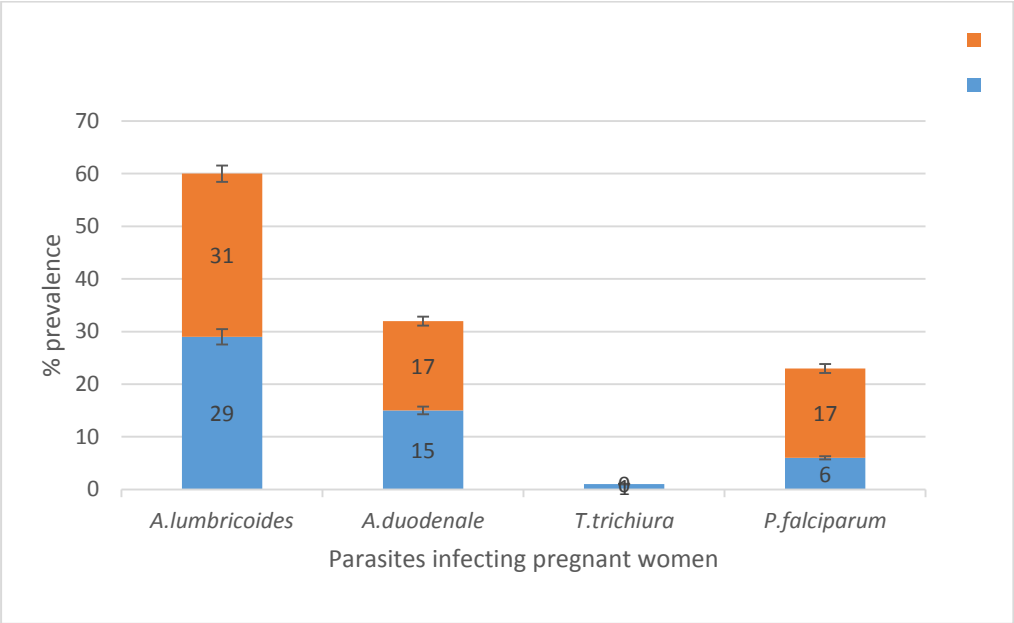


Figure 4.8: prevalence of pregnant women infected by *P. falciparum* and geohelminth parasites with respect to their marital status.

4.6.2. Malaria and geo-helminth co-infection and syndemics in relation to marital status of pregnant women attending ANC at Nandi-Hills Sub-County hospital.

Among the 17 married pregnant women who were positive for *P. falciparum*, only 1 (5.9%) was co-infected with *A. lumbricoides* while 16 (94.1%) were not co-infected (Table 4.14) and the difference in co-infection prevalence in this category was significant (*P=0.03*; Appendix 8b) whereby prevalence of *P. falciparum* alone was high. There was a significant negative association between *P. falciparum* and *A. lumbricoides* co-infection among the married pregnant women (r^{φ}=-.135; Appendix 8c). Out of the 6 pregnant women who were single and positive for *P. falciparum* 2 (33.3%) were co-infected with *A. lumbricoides* but the difference in co-infection proportions in this category was not significantly different (*P=0.91*) (Appendix 8b). There was a weak positive association for *P. falciparum-A. lumbricoides* co-infection among the single pregnant women (r^{φ}=.019).

Out of the 17 *P. falciparum* positive married pregnant women, 6 (35.3%) were co-infected with *A. duodenale* and, out of the 6 *P. falciparum* positive single pregnant women, only 1(16.7%) was co-infected with *A. duodenale* while a higher proportion of 5 (83.3%) had infection with *P. falciparum* only (Table 4.14). Difference in co-infection proportions between malaria parasites-*A. duodenale* and marital status of pregnant women was significant among the married (*P=0.02*) and insignificant among the singles (*P=0.97*; Appendix 8b). There was a significant positive association between malaria parasites-*A. duodenale* co-infection and being married (r^{φ}=0.148), and a very weak negative association between malaria-*A. duodenale* co-infection and being single (-.006; Appendix 8c).

4.7. Level of education of pregnant women and parasitic infection.

4.7.1 Single parasitic infection in relation to level of education.

Most of the pregnant women in this study had only primary education. Of the total 300 individuals, 191 (64%) had primary education, 82 (27%) had secondary education while only 27 (9%) had tertiary education (Figure 4.9).

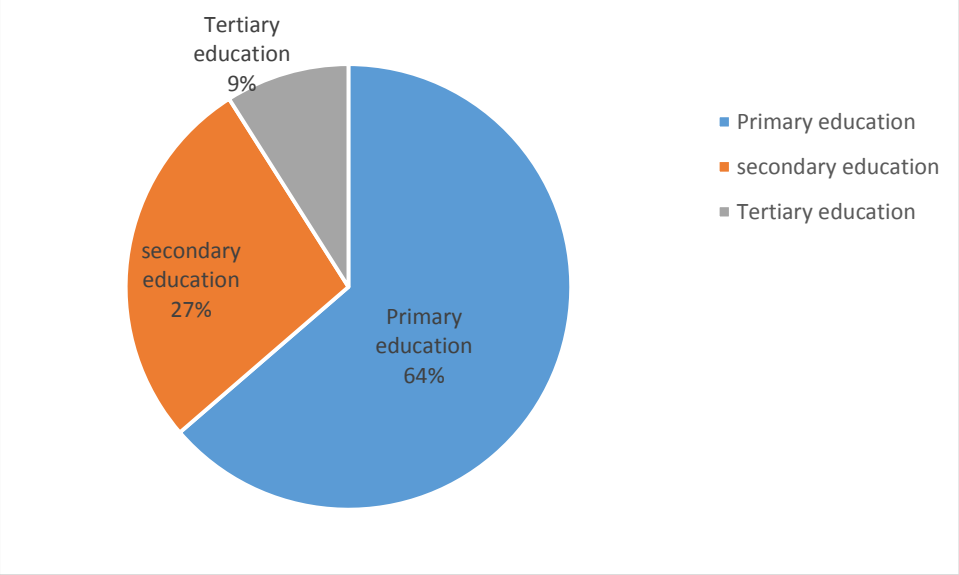


Figure 4.9: Proportion of pregnant women who took part in the study by their education levels

Prevalence of *P. falciparum* infection among those who had primary education was 7%, those who had secondary education was 11% and 4% among those who had tertiary education (Table 4.3). Difference in infection proportions with *P. falciparum* in relation to education levels was not statistically significant (*P=0.36;* Appendix 9a).

Infection prevalence for *A. lumbricoides* was 31% in pregnant women who had primary education as compared to 28% and 26% of those who had secondary and tertiary education respectively (Table 4.3). Difference in infection rates of *A.*

lumbricoides was not statistically significant in all the education level categories (*P=0.810;* Appendix 9a).

Infection with *A. duodenale* was high among those who had secondary education (21%) as opposed to those to those who had primary education (14%) and tertiary education (7%) (Table 4.3). The difference in infection proportions by *A. duodenale* was however insignificant (*P=0.19;* Appendix 9a). All the three cases of *T. trichiura* infections occurred in pregnant women who had primary education (Table 4.3).

Table 4.3: Parasitic infection proportions and education levels of the pregnant women

		Education levels of the respondents				
Parasite	Infection status	Primary education	Secondary education	Tertiary education	Total	P value
P. falciparum	Positive	13(6.8%)	9(11%)	1(4%)	23(8%)	0.356^{ns}
	negative	178(93.2%)	73(89%)	26(96%)	277(92%)	
total		191(100%)	82(100%)	27(100%)	300(100%)	
A. lumbricoides	Present	59(30.9%)	23(28%)	7(26%)	89(30%)	0.810^{ns}
	absent	132(69.1%)	59(72%)	20(74%)	211(70%)	
Total		191(100%)	82(100%)	27(100%)	300(100%)	
A.duodenale	Present	27(14%)	17(21%)	2(7%)	46(15%)	0.187^{ns}
	absent	164(86%)	65(79%)	25(93%)	254(85%)	
Total		191(100%)	82(100%)	27(100%)	300(100%)	
T. trichiura	present	3(1.6%)	0(0%)	0(0%)	3(1%)	0.421^{ns}
	absent	188(98.4%)	82(100%)	27(100%)	297(99%)	
Total		191(100%)	82(100%)	27(100%)	300(100%)	

(%) = percentage within category total; ns= not significant at 0.05

4.7.2 Malaria and geo-helminth co-infection and syndemics in relation to education levels of the pregnant women.

There was no co-infection of malaria parasites and *A. lumbricoides* among the pregnant women with primary education and among those with tertiary education (Table 4.14). Out of the 9 who had malaria parasites in the secondary school category, 3 (33.3%) were co-infected with *A. lumbricoides* and the difference in co-infection proportion in this category was statistically insignificant (*P=0.708*). There was a weak positive association in malaria-*A. lumbricoides* co-infection among those in secondary school category (r^{φ}=.04; Appendix 9c).

Among the 13 infected with malaria parasites in primary education category, 3 (23.1%) were co-infected with *A. duodenale* whereas 4(44.4%) was a co-infection of malaria parasites and *A. duodenale* among those who had secondary education (Table 4.14). Similarly, the difference in malaria and *A. duodenale* co-infection prevalence was insignificant (*P=0.34* and *P=0.06* for primary and secondary levels respectively as shown in appendix 9b). There was no *P. falciparum-A. duodenale* co-infections among those in the tertiary education level category.

Association of malaria parasites-*A. duodenale* co-infection was positive among those who were in either primary or secondary education categories but the strength of association was not strong (r^{φ}=0.07 and r^{φ}=0.21 for primary and secondary categories respectively; Appendix 9c).

4.8 Infection among pregnant women of different settlements

4.8.1 Single parasite infection in different settlement areas among pregnant women

Settlement areas where the participants came from were categorized as own home, urban rental and estate camp. 63% resided in their homes from the villages around Nandi-Hills town, 16.7% and 20.3% resided in urban rental and estate camps respectively (Figure 4.10).

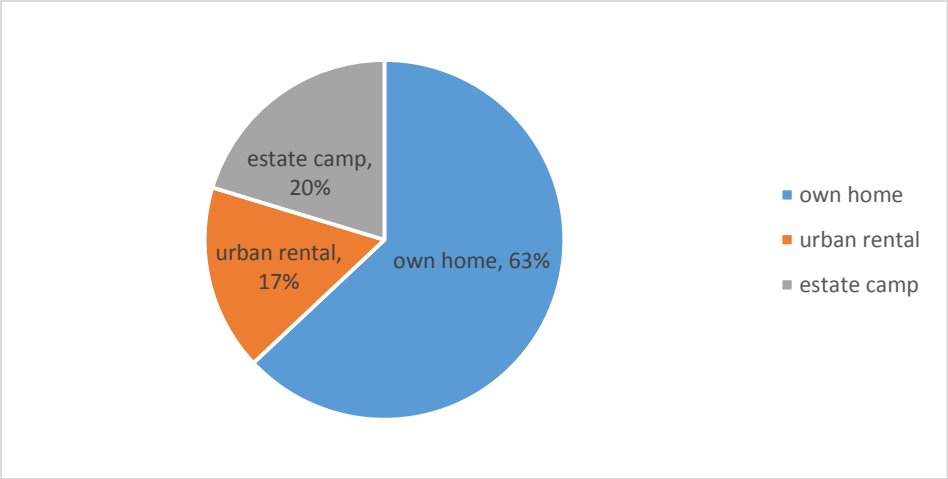


Figure 4.10: Proportions of the pregnant women by their settlement areas

Infection with *A. lumbricoides* was high among those who resided in the estate camps (39%), while those who resided in their own homes and urban rentals had 29% and 20% *A. lumbricoides* infections respectively. The difference in infection proportions by *A. lumbricoides* in the three settlement areas was not significant (*P=0.08;* Table 4.4)

Among the estate camp residents, 23% were infected with *A. duodenale* and 14% and 12% among those residing in their own homes and urban rentals respectively and the difference in infection proportion with *A. duodenale* was not significant (*P=0.17;* Table 4.4). There was one case of *T. trichiura* for each of the three settlement areas of Nandi-Hills and the difference in infection proportions was insignificant for all the settlement areas (*P=0.55;* Table 4.4).

Those residing in the estate camps had 13% *P. falciparum* infection which was high compared to the infections of those residing in their own homes and urban rentals with 6% prevalence for each settlement. There was however insignificant difference in infection proportions with *P. falciparum* in the three settlements (*P=0.2;* Table 4.4)

Table 4.4: Parasitic infection of the pregnant women in relation to settlement areas.

		Settlement areas of the respondents				
Parasite	Infection status	Own home	Urban rental	Estate camp	Total (n)	P value
A.lumbricoides	Present	55(29%)	10(20%)	24(39%)	89(30%)	0.08
	absent	134(71%)	40(80%)	37(61%)	211(70%)	
Total		189(100%)	50(100%)	61(100%)	300(100%)	
A.duodenale	Present	26(14%)	6(12%)	14(23%)	46(15%)	0.17
	absent	163(86%)	44(88%)	47(77%)	254(85%)	
Total		189(100%)	50(100%)	61(100%)	300(100%)	
T. trichiura	Present	1(1%)	1(2%)	1(2%)	3(1%)	0.55
	Absent	188(99%)	49(98%)	60(98%)	297(99%)	
Total		189(100%)	50(100%)	61(100%)	300(100%)	
P.falciparum	Positive	12(6%)	3(6%)	8(13%)	23(8%)	0.200
	Negative	177(94%)	47(94%)	53(87%)	277(92%)	
Total		189(100%)	50(100%)	61(100%)	300(100%)	

(%) = percentage within category total; ns= not significant at 0.05

4.8.2 Malaria and geo-helminth co-infection and syndemics among pregnant women in different settlement areas.

Out of the 12 malaria parasites infected pregnant women who resided in their own homes, 1 (8.3%; Table 4.14) was a co-infection with *A. lumbricoides* (*P=0.102*), whereas 1 (33.3%) of malaria parasites cases among those in urban rental was a co-infection with *A. lumbricoides* (*P=0.55*) and 1(12.5%) of malaria parasites infected

individuals in estate camp type of settlement were co-infected with *A. lumbricoides* (*P=0.095*). Difference in *P. falciparum-A. lumbricoides* co-infection was not significant in the three types of settlement (*P>0.05*; Table 4.13).

Co-infection with malaria parasites -*A. duodenale* was 41.7% among the pregnant women who resided in their own homes whereas those with *P. falciparum* single infections were 58.3% (Table 4.14). The difference in co-infection proportion in this type of settlement was significant (*P=0.004*). There was 33.3% and 12.5% malaria parasites- *A. duodenale* co-infections and 66.7% and 87.5% *P. falciparum* single infections among those who resides in urban rental and estate camps respectively (Table 4.14), and the difference in co-infection proportions in these settlement areas was insignificant (*P=0.24* and *P=0.45* for urban rental and estate camp respectively).

Association between malaria parasites- *A. lumbricoides* co-infection in relation to settlement was insignificantly negative among those who resided in their own homes (r^{φ}=-.119) and estate camps (r^{φ}= -.213; appendix 10). Association was insignificantly positive for malaria parasites-*A. lumbricoides* co-infection among those who resided in urban rentals (r^{φ}=0.08; Appendix 10).

Association between *P. falciparum -A. duodenale* and settlement was significantly positive among those who resided in their own homes (r^{φ}=.21; Appendix 10), insignificantly positive among the urban dwellers (r^{φ}=0.17) and insignificantly negative among the estate camp dwellers (-.09) (appendix 10).

4.9. Infection related to family size.

4.9.1 Single parasite infection in relation to family size.

Out of the 300 pregnant women, 70% had small family sizes (≤2), 27% had 3-5 (medium) family size while those who had more than 5 constituted only 3% (Figure 4.11).

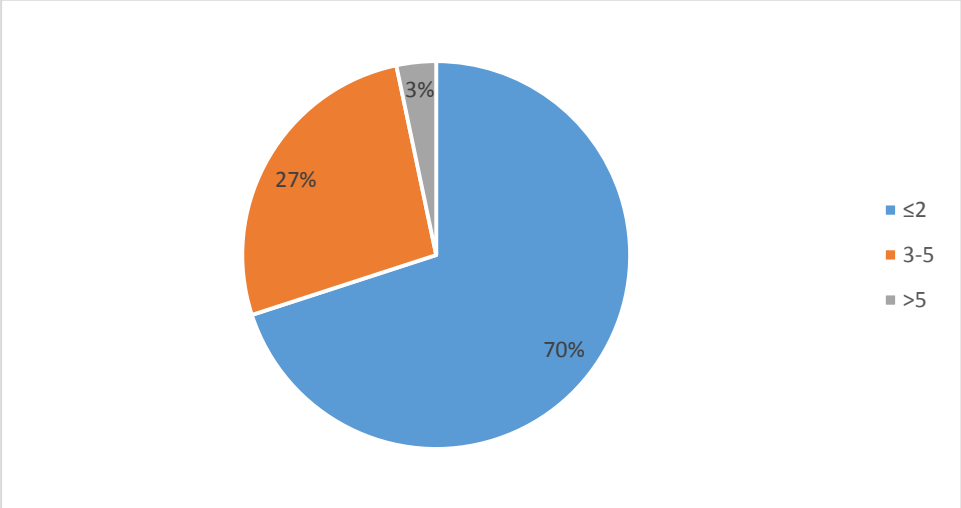


Figure 4.11: Proportion of the pregnant women by their family size categories

Infection with *A. lumbricoides* was at 30% among the small family size group, 31% among those of medium family size category and 20% among those of large family size category. The difference in infection proportions in relation to family size was not significant (*P=0.75*; Table 4.5).

Infection with *A. duodenale* was 14% in the small family size category, 19% in the category of 3-5 and 10% in the category of more than 5. The difference in infection proportion was however insignificant for *A. duodenale* (*P=0.58*; Table 4.5). There

was no *T. trichiura* infection in the category of more than 5 family size but there was 1% each for the other two categories (*P=0.88;* Table 4.5).

Infection with *P. falciparum* was 9% in the small family category and 4% and 10% for the 3-5 and >5 family categories respectively. Family size did not affect infection prevalence by *P. falciparum* parasites (*P=0.26*; Table 4.5).

Table 4.5: Infection proportion of the pregnant women in relation to their family size categories.

		Family size categories of the respondents				
Parasites	Infection status	≤2 (small)	3-5 (medium)	>5(large)	Total	P value
A. lumbricoides	Present	62(30%)	25(31%)	2(20%)	89(30%)	0.748
	Absent	148(70%	55(69%)	8(80%)	211(70%)	
Total		210(100	80(100%)	10(100%)	300(100%)	
A. duodenale	Present	30(14%)	15(19%)	1(10%)	46(15%)	0.575
	Absent	180(86%	65(81%)	9(90%)	254(85%)	
Total		210(100	80(100%)	10(100%)	300(100%)	
T. trichiura	Present	2(1%)	1(1%)	0(0%)	3(1%)	0.881
	absent	208(99%	79(99%)	10(100%)	297(99%)	
Total		210(100	80(100%)	10(100%)	300(100%)	
P. falciparum	Present	19(9%)	3(4%)	1(10%)	23(8%)	0.257
	Absent	191(91%	77(96%)	9(90%)	277(92%)	
Total		210(100	80(100%)	10(100%)	300(100%)	

(%) percentage within category total

4.9.2 Malaria-geohelminth co-infection and syndemics in relation to family size

Out of the 19 *P. falciparum* infections in the small family size category, 3(15.8%) were co-infections with *A. lumbricoides* (Table 4.14) and the difference in this co-infection prevalence was not significant (*P=0.17*). The other two family size categories did not record *P. falciparum-A. lumbricoides* co-infections (Table 4.14).

P. falciparum- A. duodenale co-infection prevalence was 31.6% (Table 4.14) in the small family size category and the difference in co-infection prevalence in this group was significant (*P=0.024*). Malaria parasites and *A. duodenale* co-infection in the medium family size category was 33.3% (3 out of three) while 2 out of three had *P. falciparum* single infections and the difference in co-infection proportion in this category was statistically insignificant (*P=0.51*). There were no *P. falciparum*-geohelminth co-infections in the family size of > 5.

There was a weak negative association between malaria parasites and *A. lumbricoides* co-infection in all three categories of family size, specifically (r^{φ}=-.095) in the small family size category where co-infection was recorded. Malaria parasites-*A. duodenale* co-infection association with small family size (≤ 2) and medium family size (3-5) was positive, though co-infection in the latter was insignificant (appendix 11).

4.10: Parasite infections in relation to sources of water.

The most utilized water source was the spring while the least utilised was the well/bore hole (Figure 4.12)

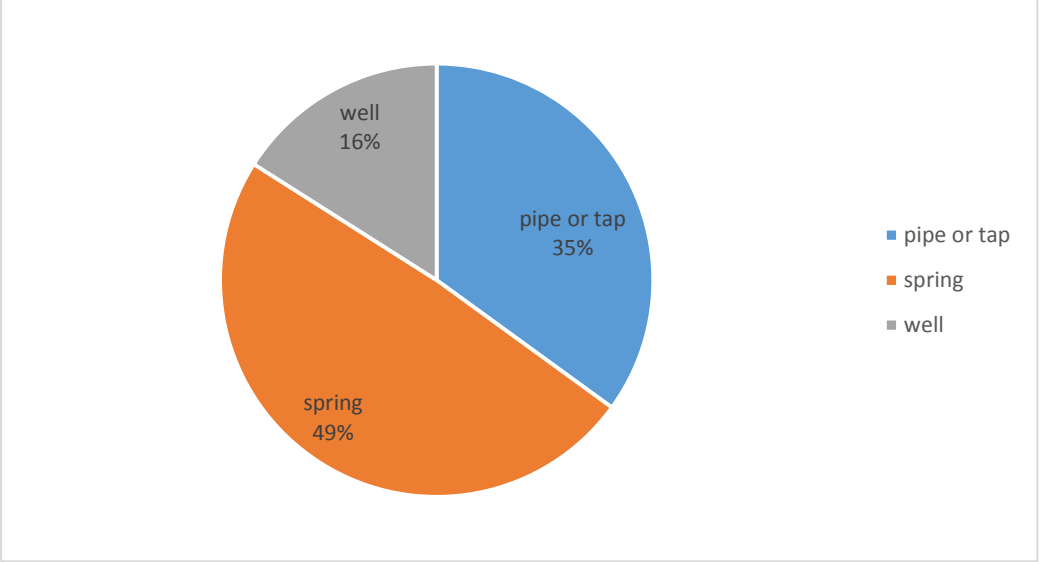


Figure 4.12: Different water source usage by pregnant women attending ANC at Nandi-Hills County Hospital.

4.10.1 Single parasite infection of pregnant women attending ANC at Nandi-Hills sub county hospital in relation to water sources.

Infection with *A. lumbricoides* was 32%, 31% and 20% among those who used piped/tap, springs and well water respectively. *A. duodenale* infection was 17%, 16% and 10% for those who used piped, spring and well water respectively. *T. trichiura* infection was 2% and 1% respectively for those using piped and spring water (Table 4.6).

Table 4.6: Proportion of pregnant women infected in relation to different water sources

Parasites	Infection status	Pipe/tap n=104	Spring n=147	Borehole/well n=49	P value
A. lumbricoides	Present	33(32%)	46(31%)	10(20%)	0.299^{ns}
	Absent	71(68%)	101(69%)	39(80%)	
Total		104(100%)	147(100%)	49(100%)	
A duodenale	Present	18(17%)	23(16%)	5(10%)	0.518^{ns}
Total	Absent	86(83%)	124(84%)	44(90%)	
		104(100%)	147(100%)	44(100%)	
T. trichiura	Present	2(2%)	1(1%)	0(0%)	0.463^{ns}
	Absent	102(98%)	146(99%)	49(100%)	
Total		104(100%)	147(100%)	44(100%)	

%=percentage within water source category; ns=not significant at 0.05

Differences in infection proportions of pregnant women with any of the three geohelminths in relation to water sources was statistically insignificant (*P=0.299, P=0.518* and *P=0.463* respectively for *A. lumbricoides*, *A. duodenale* and *T. trichiura* respectively as indicated in Table 4.6).

4.10.2 Geo-helminth co-infection among pregnant women attending ANC at Nandi-Hills sub county hospital in relation to water sources

Among 33 pregnant women using piped water and were infected with *A. lumbricoides*, 11(33.3%) were co-infected with *A. duodenale* and the difference in co-infection proportions in this category was significant (*P=0.003*). In the same category, 2 (6.1%) were *A. lumbricoides* and *T. trichiura* co-infections and the difference in co-infection prevalence was significant (*P=0.036*). Among the 46 who

used spring water and were parasitized with *A. lumbricoides*, 10 (21.7%) were co-infected with *A. duodenale* and 1 (2.2%) with *T. trichiura*. The differences in these co-infections were not significant (*P=0.14* and *P=0.17* respectively*)*. Among the individuals who used bore hole water 4(40%) out of ten *A. lumbricoides* infected pregnant women were co-infected with *A. duodenale* and the difference in co-infection proportions was significant (*P=0.00*)

There was a significant positive association between *A. lumbricoides-A. duodenale* co-infection and use of piped (r^{φ}=0.289) and well water (r^{φ}=0.498), and an insignificant positive association (r^{φ}=0.113) between *A. lumbricoides- A. duodenale* co-infection and use of spring water. *A. lumbricoides-T. trichiura* co-infections had a significant positive association with use of piped water (r^{φ}=0.205) and an insignificant positive association with the use of spring water (r^{φ}=0.123).

4.11 Parasite infections in relation to modes of faecal disposal

Pregnant women responded positively to the use of pit latrines as a mode of faecal disposal were 267 (89%) while the remaining 33 (11%) responded positively to the use of toilets (Figure 4.13).

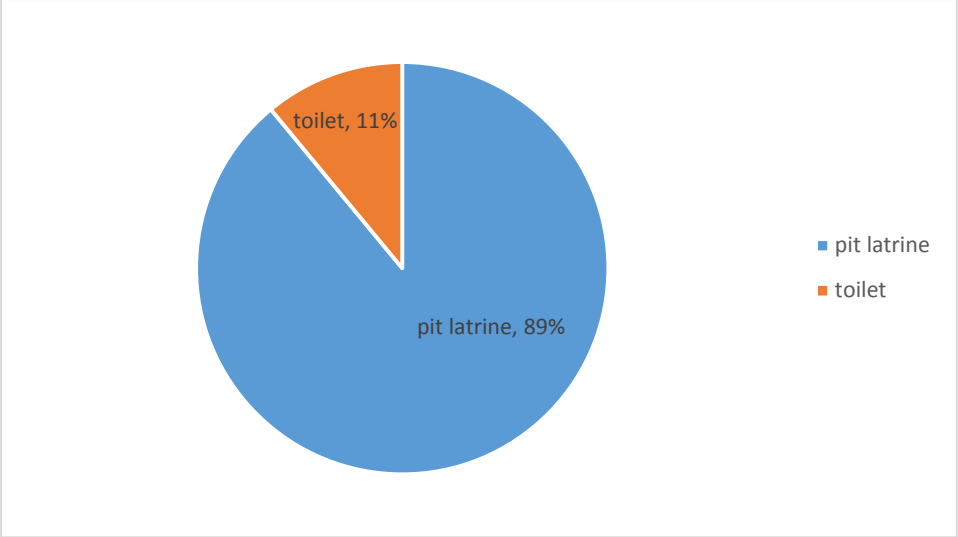


Figure 4.13: Proportion of pregnant women using different modes of faecal disposal

4.11.1 Single geo-helminth infection in relation to mode of faecal disposal

Pregnant women who responded yes to the use of the toilets and had *A. lumbricoides* infection were 45% and 12% had *A. duodenale* infections. With regard to the use of pit latrines, 28% were infected with *A. lumbricoides* whereas 16% had *A. duodenale* infections. All the three cases (1%) of *T. trichiura* infections were found among those using pit latrines for faecal disposal (Table 4.7).

Table 4.7: Proportion of pregnant women infected by geo-helminth parasites in relation to mode of faecal disposal.

Parasites	Infection status	Mode of faecal disposal				Total	%	P value
		pit latrine		toilet				
A.lumbricoides	present	74	28%	15	45%	89	30%	.035
	absent	193	72%	18	55%	211	70%	
Total		267	100%	33	100%	300	100%	
A.duodenale	present	42	16%	4	12%	46	15%	.587
	absent	225	84%	29	88%	254	85%	
Total		267	100%	33	100%	300	100%	
T.trichiura	present	3	1%	0	0%	3	1%	.541
	absent	264	99%	33	100%	297	99%	
Total		267	100%	33	100%	300	100%	

The difference in infection proportion of *A. lumbricoides* in relation to mode of faecal disposal was significant (*P=0.035*) whereas that of *A. duodenale* and *T. trichiura* were insignificant (*P=0.587* and *=0.541* respectively). Use of toilets became a risk factor for *A. lumbricoides* infection (OR=2.173; 95% C.I: 1.041-4.536).

4.11.2 Geo-helminth co-infection among pregnant women attending ANC at Nandi-Hills sub county hospital in relation to modes of faecal disposal

Out of the 74 pregnant women using pit latrines and were infected with *A. lumbricoides*, 21 (28.4%) were co-infected with *A. duodenale* and 3 (4.1%) were co-infected with *T. trichiura*. Differences in co-infection proportions in these categories were significant (*P=0.000* and *P=0.005* respectively). Among the 11 infected with *A. lumbricoides* and were using the toilets, 4 (26.7%) were co-infected with *A. duodenale* and the difference in co-infection proportion was also statistically significant (*P=0.019*)

A. lumbricoides - *A. duodenale* and *A. lumbricoides* - *T. trichiura* co-infections had significant positive associations with modes of faecal disposal. The strength of association between *A. lumbricoides*- *A. duodenale* co-infection and the use of pit latrine was strong (r^{φ}=0.215) and the association was much stronger with the use of toilets (r^{φ}=0.407). The strength of association between *A. lumbricoides* - *T. trichiura* and the use of pit latrine was not very strong (r^{φ}=0.172). That implied that the use of the different modes of faecal disposal increased the chances of geo-helminth co-infections among pregnant women attending ANC at Nandi-Hills sub county hospital.

4.12. Geo-helminth infection in relation to geophagy among pregnant women attending ANC at Nandi-Hills sub-county hospital

Proportion of the pregnant women who were geophagous was 59% while 41% were non-geophagous (Figure 4.14).

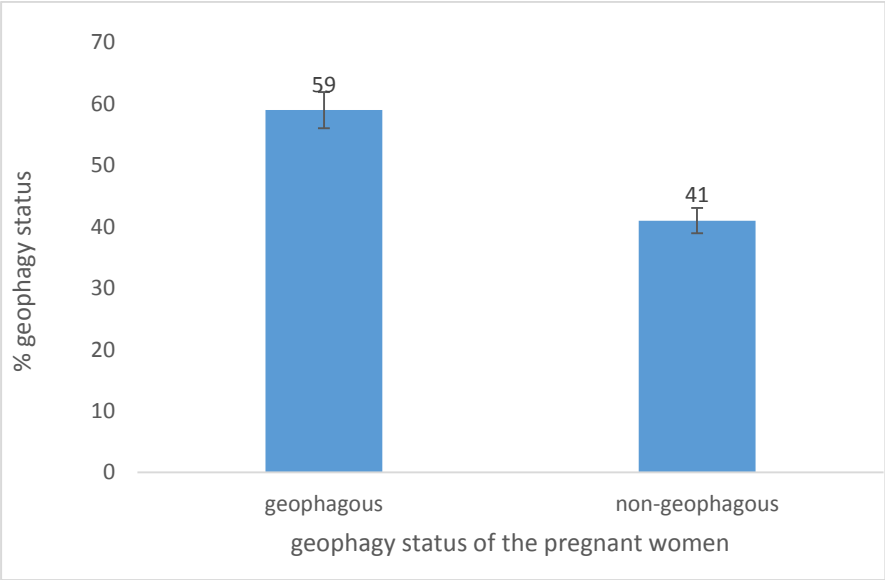


Figure 4.14: Proportion of geophagous and non-geophagous pregnant women.

4.12.1 Single geo-helminth infections in relation to geophagy

Infection with geo-helminths was 36%, 18% and 2% for *A. lumbricoides*, *A. duodenale* and *T. trichiura* respectively among the geophagous group. There was geo-helminth infection among the non-geophagous individuals at 20% and 11% respectively for *A. lumbricoides* and *A. duodenale* infections (Table 4.8).

Infection proportions between geophagous and non-geophagous pregnant women was significantly different for *A. lumbricoides* (*P=0.002*) but insignificant for *A. duodenale* and *T. trichiura* parasites (*P=0.103 and P=0.144* respectively).

Table 4.8: Geo-helminth infection prevalence of pregnant women in relation to geophagy

Parasites	Infection status	Geophagy status			
		Yes	No	Total(n)	P value
A. lumbricoides	Present	64(36%)	25(20%)	89(30%)	0.002*
	absent	112(64%)	99(80%)	211(70%)	
Total		176(100%)	124(100%)	300(100%)	
A. duodenale	Present	32(18%)	14(11%)	46(15%)	0.103^{ns}
	absent	144(82%)	110(89%)	256(85%)	
Total		176(100%)	124(100%)	300(100%)	
T. trichiura	Present	3(2%)	0(0%)	3(1%)	0.144^{ns}
	absent	173(98%)	124(100%)	297(99%)	
Total		176(100%)	124(100%)	300(100%)	

*(%) =percentage within group; *=significant at 0.05; ns= not significant at 0.05*

4.12.2 Geo-helminth co-infection in relation to geophagy.

Out of the 64 pregnant women who were geophagous and had *A. lumbricoides*, 20(30.2%) were co-infected with *A. duodenale* and 3(4.7%) were co-infected with *T. trichiura*. Differences in co-infection proportions were statistically significant (*P=0.001* and *P=0.021* respectively) in this category. Among those who were non-geophagous and were infected with *A. lumbricoides*, only 5(20%) were co-infected with *A. duodenale* and the difference in co-infection prevalence in this group was not significant (*P=0.124*).

Association of *A. lumbricoides-A.duodenale* co-infection among the geophagous pregnant women was significantly positive (r_{φ}=0.256) while that among the non-

geophagous was insignificantly positive (r^{φ}=0.138). Association of *A. lumbricoides-T. trichiura* among geophagous women was significantly positive (r^{φ}=174).

4.13 Infection in relation to recent anthelminthic treatment of pregnant women attending ANC at Nandi-hills sub county hospital

A large proportion (94.3%) of the pregnant women had not had recent anthelminthic treatment at the time of study. Only 5.7% responded to have had a recent treatment (Figure 4. 15).

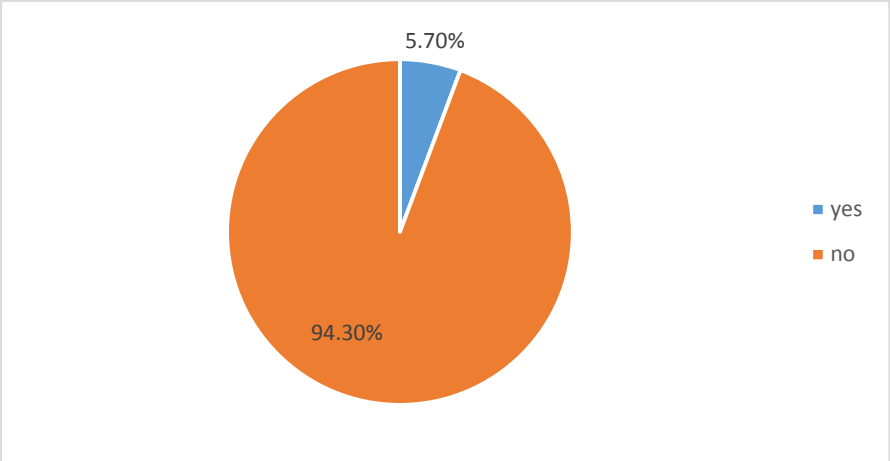


Figure 4.15: Proportions of the pregnant women by their recent anthelminthic treatment.

4.13.1 Single geo-helminth infection in relation to recent anthelminthic treatment.

There was geo-helminth infection among those who had had anthelminthic treatment at 18% for *A. lumbricoides* representing 3 out of 17 and 6% for *A. duodenale* but no infection with *T. trichiura* parasites. Geo-helminth infection for those who had not had anthelminthic treatment was 30%, 16% and 1% respectively for *A. lumbricoides, A. duodenale* and *T. trichiura* (Table 4.9). Infection proportions with *A. lumbricoides,*

A. duodenale and *T. trichiura* between those who had had recent anthelminthic treatment and those who had not was not statistically significant (*P=0.264, P=0.265* and *P=0.67* respectively).

Table 4.9: geo-helminth infection proportions of pregnant women in relation to previous anthelminthic treatment

Parasites	Infection	Recent treatment						
	status	yes	(%)	no	(%)	Total	(%)	P value
A.lumbricoides	present	3	18%	86	30%	89	30%	.242[ns]
	absent	14	82%	197	70%	211	70%	
Total		17	100%	283	100%	300	100%	
A.duodenale	present	1	6%	45	16%	46	15%	.215[ns]
	absent	16	94%	238	84%	254	85%	
Total		17	100%	283	100%	300	100%	
T.trichiura	present	0	0%	3	1%	3	1%	.553[ns]
	absent	17	100%	280	99%	297	99%	
Total		17	100%	283	100%	300	100%	

%=percentage within group; ns=not significant at 0.05

4.13.2 Geo-helminth co-infections in relation to recent anthelminthic treatment

There was no *A. lumbricoides* and *A. duodenale* co-infection among those who responded yes to previous anti-helminthic treatment. Among those who responded no to recent anthelminthic treatment and were infected with *A. lumbricoides*, 25 (29.1%) were co-infected with *A. duodenale* and the difference in co-infection proportions in this category was significant (*P=0.00*). All the three cases of *T. trichiura* infection were co-infections with *A. lumbricoides* among the no category. This represented 3.5% of the no category with *A. lumbricoides* infection. Difference in co-infection proportion in this group was significant (*P=0.008*).

Association of *A. lumbricoides-A. duodenale* co-infection and the yes category was insignificantly negative whereas in the no category it was significantly positive

(r^{φ}=0.238). Association of *A. lumbricoides* and *T. trichiura* co-infection in the no category was significantly positive (r^{φ}=0.157).

4.14 Malaria infection in relation to the use of ITN, residual house spray and previous anti-malarial treatment

Response of most of the pregnant women to the use of insecticide treated nets was 82%. Those who had had residual house sprays was 26% whereas those who had had antmalarial drugs was 12% (Figure 4.16).

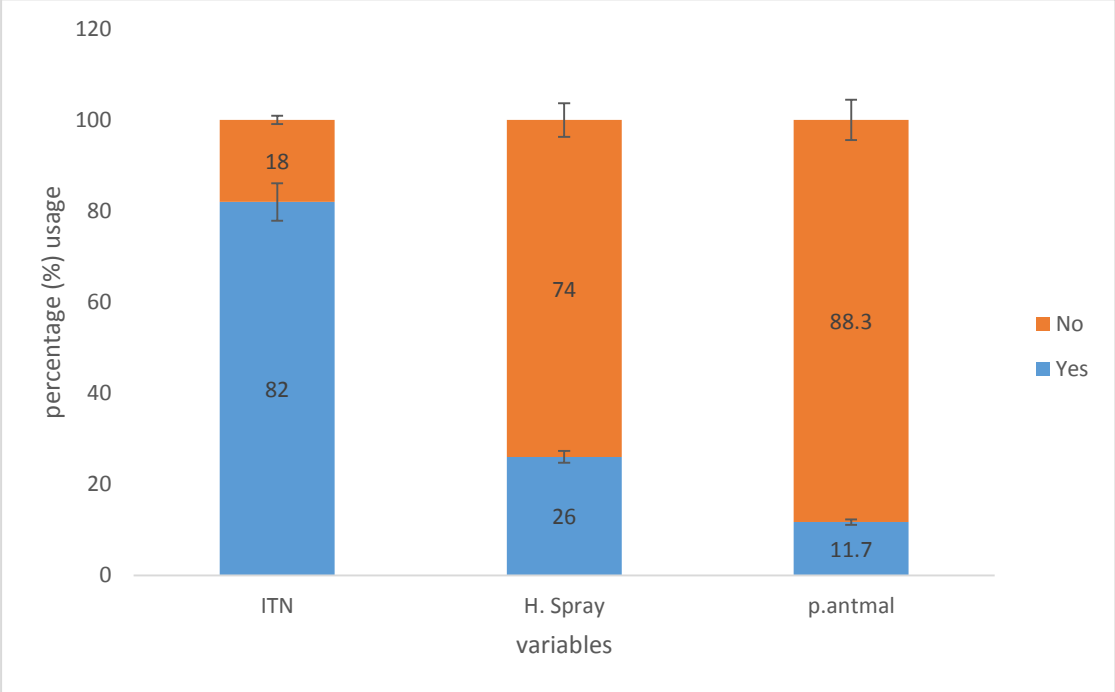


Figure 4.16: Proportion of pregnant women in relation to use of ITN, residual house spray and previous ant-malarial treatment

Pregnant women who tested positive for *P. falciparum* and who responded yes to use of ITN were 6.3%, while 1.3% of those who tested positive for *P. falciparum* responded no to the use of ITN. Among those who responded to have had residual house sprays and tested positive for malaria parasites were 3.0%, while 4.7% of the positive *P. falciparum* cases had not had residual house sprays. Malaria parasites

positive pregnant women and had had antimalarial drugs were 1.0%, while 6.7% of those who had not had any exposure to antimalarial drugs tested positive for *P. falciparum* parasites (Table 4.10).

Table 4.10: *P. falciparum* infection proportion of the pregnant women in relation to use of ITN, residual house spray and previous anti-malarial treatment

		P. falciparum						
Variable	Usage	Positive	(%)	Negative	(%)	Total	(%)	p value
ITN	yes	19	6.3%	227	75.7%	246	82%	.937^{ns}
	no	4	1.3%	50	16.7%	54	18%	
Total		23	7.7%	277	92.3%	300	100%	
H.spray	yes	9	3.0%	69	23.0%	78	26%	.135^{ns}
	no	14	4.7%	208	69.3%	222	74%	
Total		23	7.7%	277	92.3%	300	100%	
p.antmal	yes	3	1.0%	32	10.7%	35	12%	.831^{ns}
	no	20	6.7%	245	81.7%	265	88%	
Total		23	7.7%	277	92.3%	300	100%	

%=percentage of total (300); ITN=insecticide treated net; H.spray=house spray; p.antmal=previous antimalaral; ns=not significant at 0.05

The statistical difference the proportions of those infected and uninfected with *P. falciparum* in relation to either use of ITN, residual house spray or previous antimalarial treatment was not significant (*P=.94, P=.14* and *P=.83* respectively; Table 4.10). There was an insignificant positive association between *P. falciparum* infection and ITN use (r^{φ}=0.005), residual house spray (r^{φ}=0.086) or previous anti-malarial treatment (r^{φ}=0.012).

4.15: Parasite infection in relation to income per month of the pregnant women

Most of the respondents were those who earned less than ksh 10,000 representing 76.7% of all three hundred participants while the least were those earning > ksh 20,000 at 5%. (Figure 4.17).

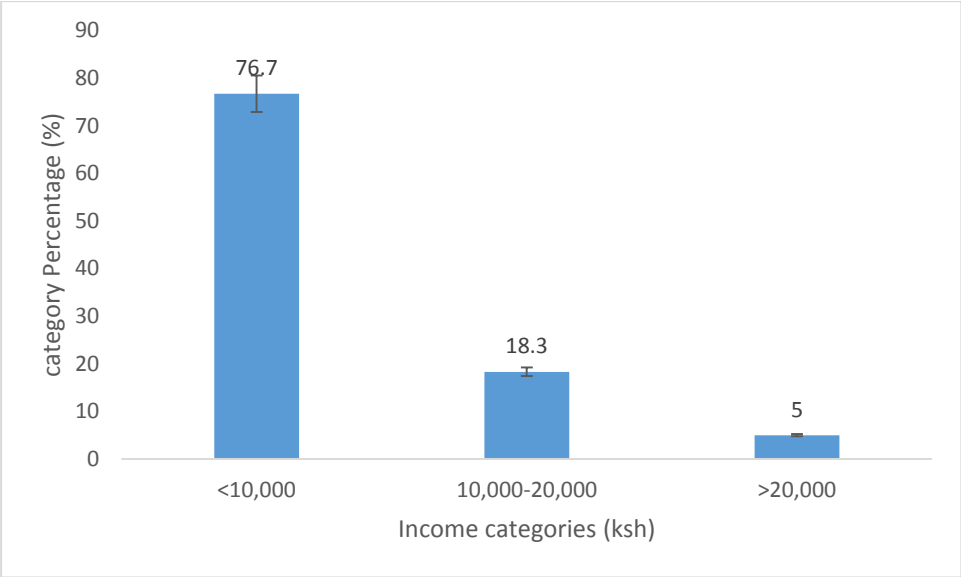


Figure 4.17: Percentage of the pregnant women attending ANC at Nandi Hills Sub County hospital in the year 2015 and their income per month

4.15.1 Single parasite infection in relation to income levels of pregnant women

Those in the high income category were not infected by *P. falciparum* and *T. trichiura* parasites (Table 4.11).

Table 4.11: Parasite infection of the pregnant women in relation to their income per month in ksh.

		Income per month (Ksh)			
Parasites	Infection status	>Ksh 20,000 (n=15)	Ksh 10,000 20,000 (n=55)	Ksh <10,000 (n=230)	P value
P. falciparum	Positive	0(0%)	3(1%)	20(6.7%)	0.208^{ns}
A.lumbricoides	Present	6(2%)	24(8%)	59(19.7%)	0.025*
A.duodenale	Present	1(0.3%)	12(4.0%)	33(11%)	0.240^{ns}
T. trichiura	Present	0(0%)	0(0%)	3(1%)	0.449^{ns}

**=significant at 0.05; ns=not significant at 0.05; n= total number of individuals in each income category; (%) = percentage of totals (300)*

Parasitic infection appeared to be increasing with decrease in income per month (Table 4.11). The difference in proportions of infection with *P. falciparum*, *A. duodenale* and *T. trichiura* was not significant with income categories of the respondents (*P=0.208*, *P=0.0240* and *P=0.449* respectively), while that of *A. lumbricoides* was significant (*P=0.025*).

4.15.2: Malaria-geohelminth co-infection and syndemics in relation to income status of the pregnant women.

There were no co-infections for *P. falciparum* and *A. lumbricoides* in the high and middle income categories while 3 out of the 20 malaria positive cases (15%) in the low income category were co-infected with *A. lumbricoides* (Table 4.14) but the difference in co-infection proportion was insignificant (*P=.254*). There was an insignificant negative association between malaria and *A. lumbricoides* parasites in the low income category (r_{φ}=-0.075; appendix 12).

There were no co-infections of *P. falciparum-A. duodenale* in the high income category while all the three *P. falciparum* positive cases (100%) representing 5.5% of all the participants in the middle income category were co-infected with *A. duodenale* (Table 4.14) and the difference in co-infection proportion in this category was significant (*P=0.001*). In the low income category, 4 (20%) were co-infections with of *P. falciparum-A. duodenale* but the difference in co-infection proportions in this category was insignificant (*P=0.450*). There was a significant positive association between *P. falciparum-A. duodenale* co-infection in the middle income group (r^{φ}=0.45) and an insignificant positive association in the low income category (r^{φ}=0.050; appendix 12).

4.16 Infection related to wet and dry seasons of 2015 among pregnant women attending ANC at Nandi-hills sub county hospital

The period for current study was stratified into dry and wet seasons. 100 (33.3%) of the pregnant women took part in the study during the wet season whereas 200 (66.7%) took part in the study during the dry season (Figure 4. 18)

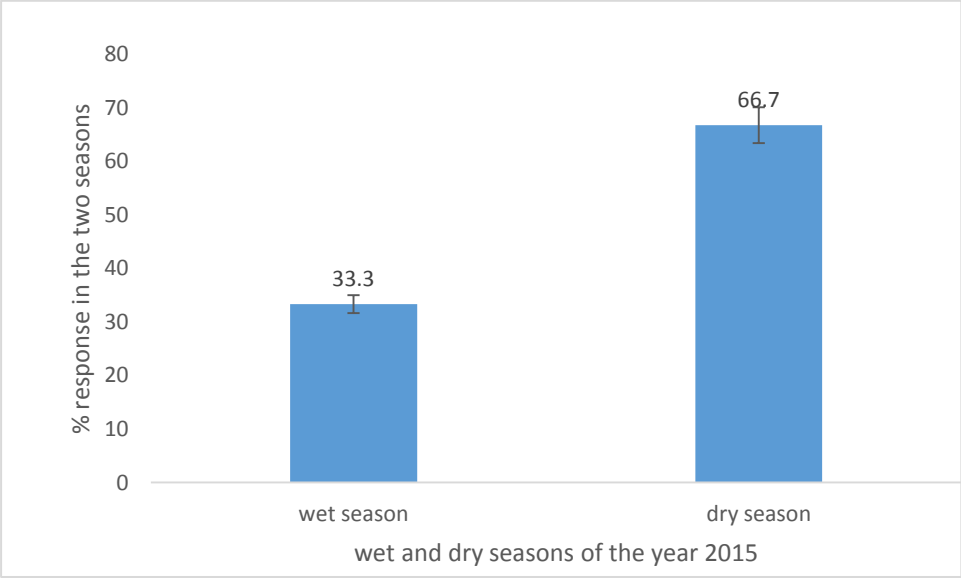


Figure 4 .18: Percentage of respondents in wet and dry season of the year 2015

4.16.1 Single parasite infection in relation to wet and dry season of the year 2015

Out of the total 23 (8%) *P. falciparum* cases, 16% were infections during the wet season, representing 5.3% of *P. falciparum* infection among all the study participants and only 4% during the dry season, representing 2.3% of *P. falciparum* infection among all the study participants (Fig 4.19). Differences in infection proportions with *P. falciparum* in wet and dry season was significant (*P=0.000*).

For geo-helminth infection, *A. lumbricoides*, A. *duodenale* and *T. trichiura*, 40%, 25%, and 1% infection prevalence were detected respectively during the wet season, and 24.5%, 10.5% and 1% respectively during the dry season. (Figure 4.19). Difference in infection proportions during the dry and wet season by malaria parasites, *A. lumbricoides* and *A. duodenale* was significant *(P=0.00, P=0.006* and *P=0.001* respectively*)* but there was no statistical significant difference in infection by *T. trichiura* parasites *(P=1.000)* between wet and dry seasons. Wet season of the year 2015 was a significant risk factor malaria parasites infection (OR=6.471; 95% C.I: 2.084-13.236; Table 4.12).

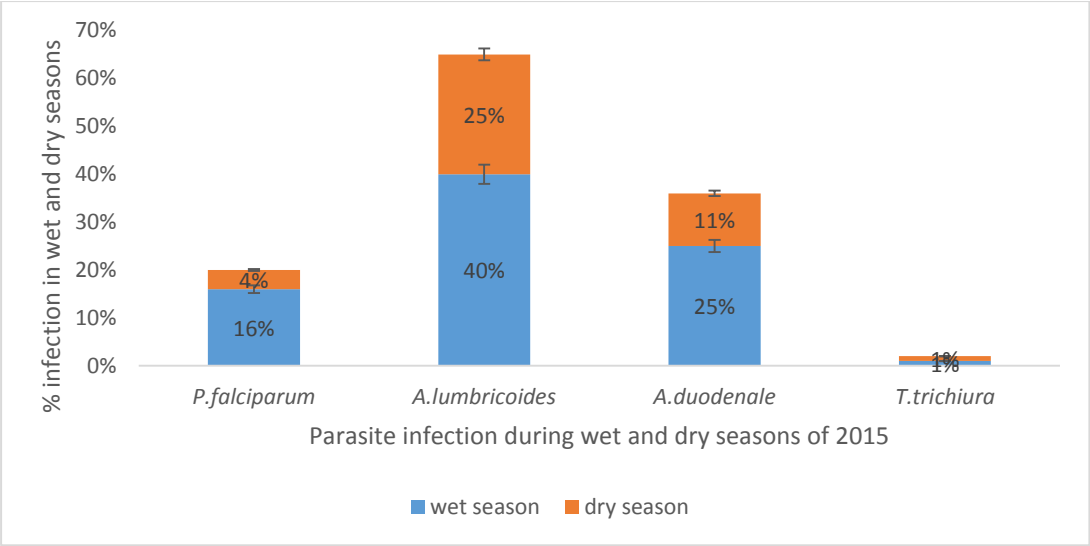


Figure 4.19: Parasite infection among pregnant women during the wet and dry seasons of the year 2015.

4.16.2 Malaria and geo-helminth co-infection and syndemics during dry and wet season of the year 2015.

During the wet season 19% pregnant women were co-infected with *P. falciparum* and *A. lumbricoides* and there were no co-infections of *Plasmodium* and *A. lumbricoides* during the dry season (Table 4.14). The difference in co-infection proportions with *P. falciparum* and *A. lumbricoides* during the wet season was insignificant (*P=0.058*). Pregnant women co-infected with *P. falciparum* and *A. duodenale* during the wet season were 37.5% whereas those co-infected during the dry season were 14% (Table 4.14). Co-infection of *Plasmodium* and *A. duodenale* during wet and dry seasons was not significant (*P=0.208*). There were no cases of malaria parasites and *T. trichiura* co-infections in both seasons of the year 2015.

Association between *P. falciparum* and *A. lumbricoides* co-infection during the wet season was insignificantly negative (r^{φ}=-0.189) and that of *P. falciparum* and *A. duodenale* co-infection in both wet and dry seasons was insignificantly positive (r^{φ}=0.126 and r^{φ}=0.024 respectively). *P. falciparum* and *A. lumbricoides* remained counter syndemic while *P. falciparum* and *A. duodenale* infection remained syndemic in both seasons of the year 2015 (Appendix 13).

Table 4.12: Characteristics/risk factors for malaria parasites infection among pregnant women attending ANC at Nandi Hills sub county hospital.

Characteristic	n	Positive	P value	OR	95% C.I for EXP (B) Lower limit	Upper limit
Gravidity						
Primigravidae	75	11	.012*	3.051	1.285	7.242
multigravidae	225	12		.		
Trimester						
1st	58	12	.000*	5.913	1.581	22.120
2nd	171	8		1.406		
3rd	71	3		.		
Age in years						
16-20	57	10		1.910E8	3.912E7	9.328E8
21-25	117	5		4.008E7	7406339	2.169E8
26-30	78	6	.025*	7.482E7	1.428E7	3.919E8
31-35	32	2		5.986E7	5.986E7	5.986E7
>36	16	0		.		
Season						
Wet	100	16	.000*	6.471	2.084	13.236
Dry	200	7		.		
Marital status	265	17	.038*	3.018		
Married	35	6		4.833	1.103	8.263
single						
A. duodenale						
Present	46	7	.044*	3.926	1.425	10.814
absent	254	16		.		

*Key: OR= odds ratio; *= significant at 0.05; n=total within group*

Table 4.13: Obstetric factors associated with *P. falciparum*-geohelminth co-infections and syndemics

		P. falciparum-A. lumbricoides			*P.falciparum-A. duodenale*		
Characteristics	n	present	P value	r^{φ}	present	P value	r^{φ}
Gravidity							
Primigravidae	11	2(18%)	.38	-.102	4(36%)	.10	.188
Multigravidae	12	1(8.3%)	.10	-.111	3(25%)	.27	.073
Trimester							
1st	12	2(17%)	.34	-.125	4(33%)	.40	.110
2nd	8	1(12%)	.22	-.093	2(25%)	.15	.111
3rd	3	0(0%)	.30	-.122	1(33%)	.60	.063

n= total P. falciparum within category; (%)= percentage co-infection within P. falciparum; association between P.falciparum-A.lumbricoides was insignificantly negative while that of P.falciparum-A.duodenale was insignificantly positive with obstetric factors of the participants

Table 4.14: Socio-demographic/economic factors associated with *P. falciparum*-geohelminth co-infections and syndemics.

	P.falciparum-A.lumbricoides				*P.falciparum-A.duodenale*		
Characteristics	n	present	P value	rᵠ	present	P value	rᵠ
Age (years)							
16-20	10	3(30%)	.805	-.033	3(30%)	.445	.101
21-25	5	0	.	.	2(40%)	**.048**	.183
26-30	6	0	.	.	2(33%)	.307	.116
31-35	2	0	.	.	0(0%)	.581	-.098
>36	0	0	.	.	.	.	
Marital status							
Married	17	1(6%)	**.028**	-.135	6(35%)	**.016**	.148
single	6	2(33%)	.912	.019	1(17%)	.973	-.006
Education							
Primary	13	0(0%)	**.013**	-.181	3(23%)	.338	.069
Secondary	9	3(33%)	.708	.041	4(44%)	.063	.205
tertiary	1	0(0%)	.547	-.118	0(0%)	.773	-.055
Settlement							
Own home	12	1(8%)	.102	-.119	5(42%)	**.004**	.211
Urban rental	3	1(33%)	.552	.084	1(33%)	.241	.166
Estate camp	8	1(13%)	.095	-.213	1(13%)	.451	-.097
Family size							
0-2(small)	19	3(16%)	.169	-.095	6(32%)	**.024**	.156
3-5(medium)	3	0(0%)	.234	-.133	1(33%)	.509	.074
>5(large)	1	0(0%)	.598	-.167	0(0%)	.725	-.111
Income per month							
>Ksh 20,000	0	0	.		.	.	.
Ksh10,000-20,000	3	0(0%)	.117	-.211	3(100%	**.001**	.455
Ksh <10,000	20	3(15%)	.254	-.075	4(20%)	.450	.050
Seasons of the year 2015							
Wet	16	3(19%)	**.058**	-.189	6(37.5%)	.208	.126
Dry	7	.	.	.	1(14%)	.739	.024

n= total P. falciparum in each category; (%)= percentage co-infection within P. falciparum in each category; values in bold are significant at .05; blanks= no co-infections recorded hence no statistics recorded.

4.17.1 Effect of geo-helminth and malaria co-infection on the haemoglobin level of pregnant women attending ANC at Nandi-Hills sub-county hospital.

Normal haemoglobin levels of the pregnant women was recorded to be ≥11mg/dl of blood while those with <11mg/dl of blood were categorized to be anaemic. A larger proportion of pregnant women (71.7%) had normal haemoglobin levels (Hb≥11mg/dl of blood) while only 28.3% were anaemic (Hb<11mg/dl of blood) representing mild and moderate anaemia (Figure 4.20). There were no cases of severe anaemia (Hb<7 mg/dl of blood) among the study participants.

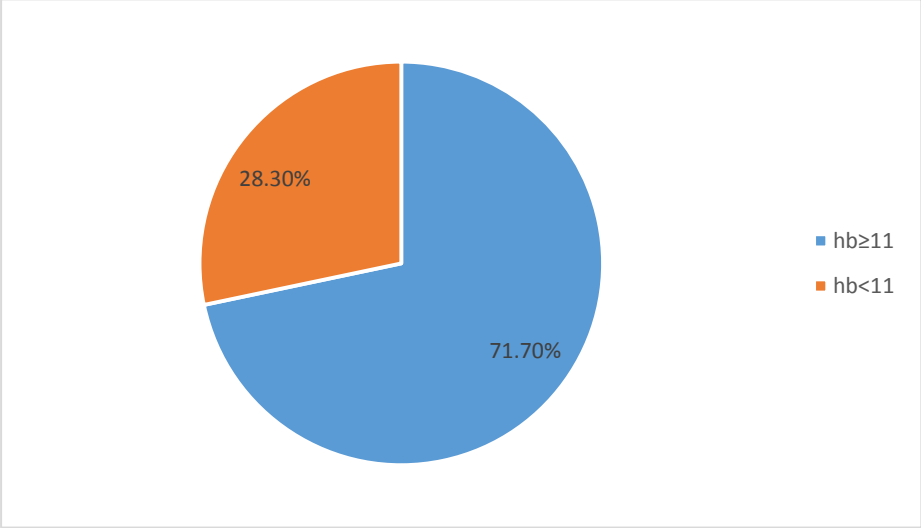


Figure 4.20: Proportion of pregnant women by their haemoglobin levels status

Only 4 (2%) of those who had normal haemoglobin levels (Hb≥11mg/dl of blood) were positive for malaria parasites while 19 (22%) of those who were anaemic tested positive for malaria parasites. Eleven (5%) of the pregnant women who had *A. duodenale* had normal haemoglobin levels, while 35 (41%) of the *A. duodenale*

infected participants had haemoglobin levels of less than 11, that is, they were anaemic (Table 4.15).

Table 4.15: Parasitic infection proportions of the pregnant women in relation to their haemoglobin levels

	Infection status	Hb≥11	(%)	Hb<11	(%)	Total	(%)
P.falciparum	positive	4	2%	19	22%	23	8%
	negative	211	98%	66	78%	277	92%
Total		215	100%	85	100%	300	100%
A.lumbricoide	present	64	30%	25	29%	89	30%
	absent	151	70%	60	71%	211	70%
Total		215	100%	85	100%	300	100%
A.duodenale	present	11	5%	35	41%	46	15%
	absent	204	95%	50	59%	254	85%
Total		215	100%	85	100%	300	100%
T.trichiura	present	2	1%	1	1%	3	1%
	absent	213	99%	84	99%	297	99%
Total		215	100%	85	100%	300	100%

(%) = percentage within haemoglobin level category

Infection with either *P. falciparum* or *A. duodenale* parasites in relation to haemoglobin levels of the pregnant women was significant (*P=.00*). Furthermore, there was significant negative association between either *P. falciparum* or *A. duodenale* infection and haemoglobin levels of the pregnant women (r^{φ}=.-347 and r^{φ}=.-451 respectively).

There was only one individual (25%) out of the 4 malaria parasites infected pregnant women in the non-anaemic category (Hb≥11) who was co-infected with *A. lumbricoides* but this was not statistically significant (*P=.83*). Among those in the anaemic category (Hb<11), 2(10.5%) out of 19 malaria parasites infected individuals

were co-infected with *A. lumbricoides* and the difference in co-infection proportion in this category was significant (*P=.04*) (Table 4.15).

Similarly, an insignificant proportion 1 (25%) out of 4 malaria parasites infected individual in the non-anaemic category was co-infected with *A. duodenale* (*P=.07*) and 6 (31.6%) out of 19 malaria parasites infected individuals in the anaemic category were co-infected with *A. duodenale* and the difference in co-infection proportions was insignificant (*P=.33*) (Table 4.14). *P. falciparum-A. lumbricoides and P. falciparum-A. duodenale* co-infection in relation to haemoglobin level of <11, that is, the anaemic category had a negative association (r^{φ}=-22 and r^{φ}=-0.105; Table 4.16).

Table 4.16: *P. falciparum* –geohelminth co-infections in relation to haemoglobin levels

	Haemoglobin levels	
	Hb≥11	Hb<11
	n=4	n=19
P.falciparum-A.	1(25%)	2(10.5%)
lumbricoides	*P=.83*	*P=.04*
p value	r^{φ}=-.01	r^{φ}=-.22
r^{φ}		
P. falciparum-A.duodenale	1(25%)	6(31.6%)
P value	*P=.07*	*P=.33*
r^{φ}	r^{φ}=.12	r^{φ}=-.11

n= number of P. falciparum infections in the anaemic and non-anaemic categories; p=level of significance at .05; r^{φ}= strength of association

4.17.2. *A. duodenale* intensity and anaemia among the pregnant women

Out of 35 light infections 12(34.3%) were non-anaemic while 23(65.7%) were anaemic. All the 11 moderate intensity infections were anaemic (Table 4.17). Anaemia proportions among the light and moderate intensity *A. duodenale* infected pregnant women was statistically significant (*P=.00*).

Table 4.17: Haemoglobin levels of the pregnant women by *A. duodenale* intensity

	Uninfected	light infection	moderate infection	total	p value	r^{φ}
Hb≥11	203(79.9%)	12(34.3%)	0(0)	215(71.3%)		
Hb<11	51(20.1%)	23(65.7%)	11(100%)	85(28.3%)	.000	.438
Total	254(100%)	35(100%)	11(100%)	300(100**%)**		

Pregnant women who were positive for malaria parasites with light *A. duodenale* infection were five and 1 (20.0%) of these was non anaemic while 4 (80%) were anaemic, however the difference was not statistically significant (Appendix 14). Only one individual who was positive for malaria parasites with moderate *A. duodenale* infection was anaemic.

CHAPTER FIVE:

DISCUSSION

Parasites detected in the pregnant women attending ANC at Nandi Hills sub county hospital were geo-helminths and *P. falciparum*. Geo-helminth species were *A. lumbricoides,* hookworm (*A. duodenale*) and *T. trichiura.* The three are the most common nematode species causing soil transmitted helminthiases (Booth *et al*., 2006 and Hotez *et al.,* 2008), and, the clinical burden due to infection with both *P. falciparum* and the helminth species is carried by populations living in sub-Saharan Africa (deSilva *et al*., 2003).

The most prevalent geo-helminth infecting pregnant women in Nandi Hills sub county hospital was *A. lumbricoides* (30%) and this high prevalence was close to the findings of another study done by vanEijk *et al*., 2009 (52.3%) in western Kenya and another one by Egwunyenga *et al*., 2001 (19.1%) in Nigeria. The current outcome differed with those of most studies whereby the most prevalent geohelminth was found to be hookworm (Getachew *et al*., 2013, Hillier *et al*., 2008, Woodburn *et al*., 2009, Larocque *et al*., 2005, Dreyfuss *et al*., 2000 and McLure *et al.,* 2014).

A. lumbricoides is a more prevalent helminth worldwide because the female worm produces prodigious number of eggs that are relatively resistant to drying and extreme temperature. Eggs in the soil can remain viable for some period to infect enormous number of people (Strickland *et al*., 2000). *A. duodenale* prevalence was at 15% (46 individuals out of 300) but this proportion was lower than that reported by McLure *et al*., (2014) in the Kenyan Coast which was at 23.7%. The two regions of the country vary greatly in terms of altitude, rainfall patterns and temperature which may determine differential development of hookworm stages in the out of host

environment. Hookworm eggs and juvenile stages cannot withstand undiluted faeces or waterlogged soils and for this reason, unfavourable conditions coupled with low basic reproductive number (Ro) (Brooker *et al*., 2006), can reduce *A. duodenale* transmission rate.

T. trichiura prevalence was found to be low at 1% though it is known to share the same distribution with *A. lumbricoides* (Strickland *et al.,* 2000). *T. trichiura* eggs unlike those of *A. lumbricoides* are less resistant to low temperatures and drying and can therefore be easily destroyed by unfavourable environmental conditions (Kelkar and Kelkar, 1993). This consequently would reduce its transmission resulting in low prevalence as observed in the current study.

Co-infections of both *A. lumbricoides* & *A. duodenale* and *A. lumbricoides* & *T. trichiura* as observed in this study is a common phenomenon in pregnant women. *A. lumbricoides* and *T. trichiura* infections were of light intensity but there was a significant difference among those with light and moderate intensity infections of *A. duodenale* parasites. Occurrence of infection that lead to high egg output determines the level of environmental contamination which partly contributes to transmission (Magalhaes *et al.,* 2011).

Some of the factors that favour the spread of hookworm include poor sanitary practices, shaded sandy or loamy soil, and a warm moist climate and that intensity of infection for helminths in communities is uneven with most individuals harbouring few worms (Strickland, 2000) as it was the case in the current study. There is a possibility that the slightly higher *A. duodenale* infection among those in the estate camp represented individuals who had moved in from areas with high transmission levels.

Proportion of pregnant women infected with *P. falciparum* was slightly lower in the current study compared to other co-infection studies in pregnancy within Kenya, McLure *et al*. (2014) and VanEijk *et al*. (2009). Co-infection studies in other countries indicated a slightly higher *P. falciparum* infection such as those reported by Yatich *et al*. (2009), Getachew *et al*. (2013), Hillier *et al*. (2008) and Woodburn *et al*. (2009). In Nepal, Dreyfuss *et al*. 2000 reported a 19.8% infection with *P.vivax* among pregnant women.

Nandi Hills sub county hospital located in the Western highland of Kenya serves women mostly from the villages around the town and the area is known to be a malaria epidemic zone with seasonal transmission and the whole population is vulnerable (Republic of Kenya, 2010). It is characterised by variable transmission rate from year to year (Strickland *et al*., 2000). The Kenyan coast and Western Kenya around the Lake Victoria region as reported by McLure *et al*., (2014) and Van Eijk *et al.*, (2009) experience perennial malaria transmission due to high survival rate of the vector as a result of suitable climatic conditions.

The method for determining parasite density was manual convention method which was set conveniently by WHO for use in facilities lacking the tools for determining parasite density especially in poor resource countries (WHO, 2010). *P. falciparum* density was low at 20-200 parasites per microliter of blood.

A statistically insignificant smaller proportion (13%) of pregnant women were co-infected with *P. falciparum* and *A. lumbricoides*, but a statistically significant proportion was co-infected with *P. falciparum* and *A. duodenale* parasites. Association between *P. falciparum* and *A. lumbricoides* was negative (that is, the two

parasites were counter syndemic or antagonistic) whereas that between *P. falciparum* and *A. duodenale* was positive, that is, they were synergistic or syndemic.

The outcome of the current study had similarities with a meta-analysis carried out by Naing *et al*. (2013) which showed that pregnant women with hookworm infections had 1.36 times higher risk for malaria infection than those mothers without hookworm and a randomized clinical trial done by Brutus *et al*. (2006) to look at the effect of helminthic treatment on malaria infections also found a similar trend. They noted that treatment of *A. lumbricoides* was associated with two-fold increase in malaria parasitaemia in adults, suggesting a protective effect of *A. lumbricoides* co-infection.

Boel *et al*. (2010) in their study like in the current study, found that *A. duodenale* and malaria parasites were syndemic whereas *A. lumbricoides* and malaria parasites were counter-syndemic. That is, pregnant women who had *A. duodenale* had more malaria parasites whereas those who had *A. lumbricoides* had a lower rate of malaria infection. In western Kenya, VanEijk *et al*. (2009) did not find any association between *A. duodenale* and malaria parasites but found that those with *A. lumbricoides* infection had decreased risk of malaria infection, an indication that *A. lumbricoides* and malaria parasites were counter-syndemic as observed in the current study. A study that was done in an endemic area of Colombia by Fernandez-Nino *et al*., (2012) showed that *A. duodenale* was a risk factor for malaria infection (OR=4.21) and *A. lumbricoides* had a protective effect on malaria infection (OR=0.43).

Only a quarter of the pregnant women who formed the study group in the current study were primigravidae while ¾ were multigravidae. However, there was a statistically significant difference in the proportion of malaria infection by gravidity with primigravidae having higher prevalence than the multigravidae. In pregnancy,

those with the highest risk of infection are particularly primigravidae (Schants-Dunn and Nour, 2009). Malaria parasites get sequestered in the placenta during pregnancy (Strickland *et al.,* 2000) and women may develop efficient mechanisms of resisting the parasite due to increased exposure with subsequent pregnancies hence a lower rate of infection in the multigravidae group (5%) as opposed to primigravids (12%) seen in the current study. Primigravidae was a risk factor for malaria infection but the level of risk was low (OR=1.356). Some previous studies have also shown that primigravidae women are more susceptible to *P. falciparum* infection (Thigpen, *et al*., 2010, Yatich *et al*., 2009)

There was an insignificant difference in the proportion of primigravidae and multigravidae infected with any of the geo-helminths. This suggested that irrespective of the number of pregnancies one had had, they were equally exposed to the same risk factors for geo-helminth infection.

Prevalence of those co-infected with *P. falciparum* and either *A. lumbricoides* or *A. doudenale* by gravidity did not show any significant difference. Presumably, geohelminth parasites (*A. lumbricoides* and *A. duodenale*) influenced the course of co-infection by gravidity. This could have contributed to the weak negative association between *P. falciparum* and *A. lumbricoides* (r_{φ} = -0.102 and r_{φ} = -0.111) in the primigravidae and multigravidae groups respectively and weak positive association between *P. falciparum* and *A. duodenale* (r_{φ} = 0.188 and r_{φ} = 0.073) for primigravidae and multigravidae respectively in relation to gravidity. Gravidity therefore weakens the synergy between *P. falciparum* and *A. duodenale* or the antagonism between *P. falciparum* and *A. lumbricoides*. This could have resulted from the insignificant effect of gravidity on parasite co-infection.

Most of the pregnant women were in their 2nd trimester, implying that in Nandi-Hills sub county pregnant women begin attending ANC when pregnancies have progressed. There was a significant difference in *P. falciparum* infection by trimester, with those in their 1st trimester bearing a higher proportion of infection (21%) as opposed to those in 2nd and 3rd trimesters. Malaria are frequent during the second half of pregnancy, probably because of immunosuppression associated with pregnancy (Strickland *et al*., 2000).

It is plausible to note that most women do not take their pregnant status seriously to even consider protecting themselves from malaria infections before the pregnancies begin to advance into second trimester, making 1st trimester a more risk factor to malaria infection as it was noted in this study. This is probably because they are not even aware of their pregnancy status or due to their inability to access protective measures such as chemoprophylaxis because in Nandi County generally women are lower resource owners (Nandi county-CIDP 2013-2017, 2013).

Infection with any of the three geo-helminths was not significantly different in the three trimester groups and the same applied to co-infection with *P. falciparum* and either *A. lumbricoides* or *A. duodenale*. Like in gravidity, geohelminth parasites (*A. lumbricoides* and *A. duodenale*) probably influenced the course of co-infection by trimester and contributed to a weak negative association between *P. falciparum* and *A. lumbricoides* by trimester (r_{φ} = -0.125, r_{φ} = -0.093 and r_{φ} = -0.122 for 1st, 2nd and 3rd trimesters respectively) and a weak positive association between *P. falciparum* and hookworm by trimester (r_{φ} = 0.110, r_{φ} = 0.111 and r_{φ} = 0.063 for 1st, 2nd and 3rd trimesters respectively).

Pregnant women aged 16-20 years had a significantly higher *P. falciparum* infection (18%) rate while those in other age categories had lower infections (below 10%). Young age which corresponds to primigravidae has been found in other studies to be a contributing factor to *P. falciparum* infection (McLure *et al.,* 2014, Yatich *et al.,* 2009, Woodburn *et al.,* 2009 and Egwunyenga *et al.,* 2001).

Age however did not show any significant effect on geohelminth infection although older pregnant women had a higher *A. lumbricoides* infection (50%). This could be due to the fact that most common helminthiases in developing countries (including Ascariasis) have minor clinical symptoms thus infections are left untreated and they remain chronic for multiple years (Abdoli and Pirestani, 2014). Young pregnant women in the current study were mainly those who had no adequate education hence had insufficient knowledge on preventive measures against parasitic infections.

Co-infection with *P. falciparum* and either *A. lumbricoides* or *A. duodenale* was not significant with age. Any of the pregnant women irrespective of their age could be co-infected. However, those aged 21-25 years were significantly co-infected with *P. falciparum* and *A. duodenale.* This age category is described in the Nandi County-CIDP (2013-2017) as a group with many diverse needs following their completion of secondary education. This probably makes the pregnant women in this age category to be more exposed to parasitic infections (*P. falciparum* and geohelminths).

P. falciparum and *A. lumbricoides* were negatively associated with age implying that age did not alter the counter-syndemic relationship between *A. lumbricoides* and *P. falciparum,* and similarly, the positive association between *P. falciparum* and *A. duodenale* co-infection was maintained with age. Significant effect of age category 21-25 years on *P. falciparum -A. duodenale* co-infection, resulted in a significant

positive association of the two parasites in relation to age as opposed to the weak association in the other age categories.

Pregnant women who were not married were mainly the young in age (16-20 years) and primigravids and they had slightly higher *P. falciparum* infection (17%) as opposed to their married counterparts (6%). Being single has been implicated in other studies to be a predisposing factor to infection with either malaria or intestinal helminths (Yatich *et al*., 2009, Boel *et al*., 2010 and Egwunyenga *et al.*, 2008). In the study area, a single pregnant woman is one who became pregnant without intention, and this group constitutes mainly the school dropouts who probably have no resources of taking good care of themselves during pregnancy.

Infection with any of the three geo-helminths was not statistically significant with the marital status of the pregnant women. All pregnant women whether married or single probably had the same exposure or protection from the helminth parasite infections.

Co-infection proportion with *P. falciparum* and *A. lumbricoides* was significantly different among the married pregnant women as compared to the single pregnant women. This was probably due to increased *P. falciparum* infection among the singles and increased *A. lumbricoides* infection among the married category. Marital status of the pregnant women consequently, did not alter the negative association between *P. falciparum* and *A. lumbricoides* co-infection. On the other hand the effect of *P. falciparum* infection among the single pregnant women could have resulted in insignificant positive association in *P. falciparum –A. lumbricoides* co-infection.

P. falciparum-A. duodenale co-infection was statistically significant among the married pregnant women. Married pregnant women get more exposed to infective

stages of *A. duodenale* as they work in farms. Being married did not alter the positive association of *P. falciparum-A. duodenale* co-infection. Married pregnant women could be too busy with household chores and responsibilities to even get time for their own wellbeing. There was a weak negative association between *P. falciparum- A. duodenale* co-infection and the single group of pregnant women. This could suggest that those who were single were less likely to be exposed to *A. duodenale* infective stages probably in the farms leading to low rates of co-infection as opposed to their married counterparts.

Majority of the pregnant women in the current study (64%) had just primary education as their higher qualification. Socio-economic status and education are intricately linked since those who are well educated are likely to achieve a higher socio-economic status. Education level of pregnant women did not show any significant effect on infection status of the pregnant women by either *P. falciparum* or any of the three geohelminths. However, high prevalence of intestinal helminth infection has been found among those who had only primary basic education (Wekesa *et al.,* 2014) and that parasite infestation is less in individuals with higher level of education and this may be related to knowledge of personal hygiene, better quality of life and proper food preparation (Shinondo and Mwikuma.2009). *P. falciparum* and geo-helminth co-infection was also insignificantly different among pregnant women of the three education categories.

Weak positive association between *P. falciparum-A. lumbricoides* co-infection among those with secondary level of education was suggestive of lack of protection from parasite infection by the pregnant women. *P. falciparum* and *A. duodenale* co-infection had positive association, though insignificant in relation to the education

levels of the pregnant women. This could be attributed to the syndemic effect of malaria parasites and *A. duodenale* parasites without considering other parameters. Education level of an individual has a bearing on one's ability to understand and access information regarding control of parasitic infections (Worrall *et al.,* 2003). The level of education of the subjects could not probably be relied upon as a factor to reduce parasite infection in the pregnant women and therefore other factors needed to be considered, for instance chemoprophylaxis, preventing exposure during wet seasons and avoiding geophagy.

Most of the pregnant women who formed the study population came from their own homes (63%). Infection proportion by any of the three geo-helminths and malaria parasites was not significant considering the type of settlement. However, *A. lumbricoides, A. duodenale* and *P. falciparum* infection proportions were higher among those who resided in the estate camps (39%, 23% and 13% respectively). It is worth to note that a majority of the estate camp dwellers are the casual labourers in the tea plantations and tea factories who according to the Nandi county-CIDP, 2013-2017 are the most vulnerable population.

Co-infection proportion of *P. falciparum* and *A. lumbricoides* was not significant among pregnant women of the three settlement types. *P. falciparum* and *A. duodenale* co-infection proportion was significant among those who came from their own homes in the rural areas. That is, 5 (41%) of the 12 *P. falciparum* positive cases in the own home category. Rural location can be associated with increased malaria risk for both epidemiologic and socio-economic reasons and that urban residence can be accompanied by potentially protective socio-economic factors against malaria (Rashed *et al.,* 2000).

Malaria and soil transmitted helminths are highly prevalent in the rural communities as a result of poor sanitary conditions prevailing there (Ojurongbe *et al*., 2011). *P. falciparum* and *A. duodenale* co-infection proportion was insignificant in the other two settlement categories. *P. falciparum* and *A. lumbricoides* co-infection remained counter-syndemic with own home and estate camp types of settlements.

Most of the pregnant women who attended ANC and took part in the study were those of small family size categories (≤2). There was insignificant parasite infection proportions in all family size categories. This was probably due to the fact that any pregnant woman irrespective of the number of children she had was predisposed to the conditions that led to infection and these factors were not associated in any way with the size of the family.

Co-infection with *P. falciparum* and *A. lumbricoides* maintained a negative association in relation to family size. *P. falciparum* and *A. duodenale* co-infection was however positive in the small and medium family size categories, or rather the two parasites had a syndemic (synergistic) effect on each other in the two family size categories. In large family size category *P. falciparum* and *A. duodenale* co-infection association was negative. Probably, those in this family size category are more cautious of their surrounding and are able to protect themselves. Presumably, a large family size comprises individuals who are grownups or who can understand basic hygiene practices that ensure a salubrious home environment and would probably decimate parasite transmission among the family members.

Infection proportion by any of the three geo-helminths in relation to types of water sources was not significant. According to Egwunyenga *et al*. (2001), faecal pollution of soil and domestic water supply could result in high helminth infections in pregnant

women and that maternal women are at high risk of infection because of their close association with children. The finding of the current study showed a positive association between geo-helminths and the type of water source.

Piped water as would have been expected did not reduce geo-helminth infection in pregnant women in the current study. Residents of Nandi County generally experience a challenge of inadequate clean and safe water which is aggravated by lack of solid waste disposal facility in the entire county. This has led to non-conventional ways of waste disposal like dumping garbage in rivers and streams and bush defaecation (Nandi county-CIDP 2013-2017, 2013).

Piped water is assumed by many users to be the cleanest and that it does not require alternative interventions to further ensure safety such as boiling of drinking water. There could be contamination of piped water by wastes from homes and farms at source which if consumed without treatment can lead to geohelminth infections. Tea plantations could contribute to contamination of water sources. Assumedly, workers in the plantations could be using the tea bushes for faecal disposal as they cannot go long distances to the camps to answer call of nature. Apart from the workers in the plantations, people passing along the plantations could find the tea bushes convenient for faecal disposal. This practice can probably lead to water source contamination by surface run-offs.

Pregnant women in the current study who responded yes to geophagy were 59%. Infection proportion difference of *A. lumbricoides* in relation to geophagy was significant but insignificant for *A. duodenale* and *T. trichiura*. Getachew *et al*. (2013), found the habit of eating soil had an associated risk factor for STH infection among pregnant women in Ethiopia. Eating of contaminated soil is among the major modes

of transmission of helminths particularly *A. lumbricoides* and *T. trichiura* (Shinondo and Mwikuma, 2009). There was a positive association between geo-helminth infection and geophagy in the current study though insignificant for *A. duodenale* and *T. trichiura*. *A. lumbricoides* infection was increased by the habit of eating soil which were likely to be contaminated with infective eggs.

Infective eggs of *A. lumbricoides* and *T. trichiura* specifically are acquired by ingestion through the mouth whereas *A. duodenale* infection occurs when filariform larvae burrow/penetrate through the skin (Kelkar and Kelkar, 1993). Co-infection with geo-helminths increased with the habit of eating soil. This signified the impact of *A .lumbricoides* parasite on the other two geo-helminths detected in the participants.

Pit latrines was the most commonly used mode of faecal disposal by pregnant women in the current study. Infection proportion by *A. lumbricoides* was significant in relation to mode of faecal disposal but insignificant for *A. duodenale* and *T. trichiura*. Pregnant women using toilets as would have been expected did not show a decrease in *A. lumbricoides* infection.

Increased *A. lumbricoides* infection in this group (those using toilets) of individuals could be explained by the possibility of polluted domestic water supply due to poor sanitation and improper sewage disposal (Egwunyenga *et al*., 2001). There was a strong positive association between geo-helminth co-infection and mode of faecal disposal, an indication that not even the use of toilets reduced the risk of infection with geo-helminths among pregnant women in the current study. There is a great possibility that those using the toilets in the current study probably do not use them properly or sometimes lack sufficient water that is normally required for proper use of the toilets.

Infection proportions with any of the three geohelminths was not significantly different with recent treatment. Despite having had recent anthelminthic drugs there was a possibility of being re-infected by geohelminths among those who responded yes to recent treatment and were infected because the prevailing conditions could have favoured infection. It has been found out that without improved water supply and proper environmental sanitation, the expected benefits of antenatal anthelminthic treatment cannot be relied upon for sustainable reduction of parasite infection (Shinondo and Mwikuma, 2009). According to this study, pregnant women in Nandi-Hills sub-county hospital however are neither diagnosed nor given anthelminthic chemoprophylaxis.

Co-infection with *A. lumbricoides* & *A. duodenale* or *A. lumbricoides* & *T. trichiura* was significant with recent treatment. Positive association between geohelminth co-infection and lack of previous treatment, showed that lack of recent treatment was associated with increased co-infection with geohelminth parasites and that anthelminthic drugs taken by the pregnant women on their own recently protected them from co-infections. This could explain the lack of *A. lumbricoides-A. doudenale* co-infection in the yes category. According to Asundep *et al*. (2014), prevalence of helminths was higher in pregnant women who had not been screened for helminths (8.6%) than those who had been screened and received chemopropylaxis (4.0%). Odds ratio for those who had not been screened was two times higher (OR=2.4) compared to those who had been screened.

Majority of the pregnant women (82%) responded yes to the use of ITN but this did not prove to protect them from *P. falciparum* infection. A smaller proportion of women (26%) responded to utilizing residual house sprays or to have had prophylaxis

(12%). In the current study, those who used ITNs recorded a higher rate of infection as compared to those who did not use ITNs. Other factors probably predisposed pregnant women to malaria infection aside from the use of ITN or the lack of it thereof. However, the use of ITNs have a well-documented beneficial impact on pregnancy outcomes (Gamble *et al.*, 2006). There is a possibility that those who had malaria infections were bitten by mosquitoes while outdoors or had moved recently from high transmission areas in search of casual labour in the tea estates and factories.

Residual house spray and recent antimalarial treatment was associated with a decreased prevalence of *P. falciparum* infection, however the difference was statistically insignificant. This suggests that if these practices were intensified it would lead to significant reduction in *P. falciparum* infection in pregnant women.

Control of malaria should be done to include IPTp-SP (Intermittent Preventive Treatment with Sulfadoxine-Pyrimethamine) given in the 2^{nd} and 3^{rd} trimester to reduce maternal anaemia and malaria morbidity. Other measures are use of ITNs and effective case management (diagnosis and treatment of illness) (Brooker *et al.*, 2007). It has been found out that there is poor uptake of preventive efforts against malaria by pregnant women and therefore further education should be carried out regarding bed net use (Schants-Dunn and Nour, 2009). In most homes presumably, bed net are reserved for the males/husbands who have beds and the women are left to sleep on the floors making the use of bed nets difficult or even impossible.

Infection proportion of geohelminths in relation to income categories of the pregnant women was significant only for *A. lumbricoides* but there appeared an increasing trend of parasite infection with decreasing income. However, prevalence was slightly high for *A. lumbricoides* and *A. duodenale* in the middle income category. There were

no co-infections of *P. falciparum* and *A. lumbricoides* in the middle and high income categories. This suggested that pregnant women in the low income category were not accessing preventive measures against parasitic infection due to limited resources. Low income can also make individuals not to use preventive measures in the most effective or appropriate manner due the seasonability of availability of financial resources (Worrall *et al.,* 2003).

Association between *P. falciparum* and *A. lumbricoides* in relation to low income remained negative whereas that between *P. falciparum* and *A. duodenale* in relation to income remained positive and strong for middle income (r_{φ} = 0.455) and weak for low income(r_{φ} = 0.050). The trend of malaria-geohelminth co-infection seemed not to be altered by income levels of pregnant women.

According to Yatich *et al.* (2009), low income heightened rates of dual infections. Low income in many homes deny pregnant women access to protective measures against malaria and helminth parasites infections as most of the resources are directed to more pressing needs such as food and education of the children. In Nandi County access to economic resources is low for women owing to the traditional division of labour that places women at the household level to address domestic chores Nandi County-CIDP 2013-2017, 2013).

According to Singer (2013), pregnant women with low income are subject to complex syndemics involving more than two diseases. In the current study, *P. falciparum* and *A. duodenale* infections were positively associated synergistically among the pregnant women. *P. falciparum-A. lumbricoides* parasites infection were counter syndemic.

Infections proportions with malaria parasites, *A. lumbricoides* and *A. duodenale* were significantly different in relation to the wet and dry seasons during the year 2015. Most infections occurred during the wet season according to the current study. Large scale geographical distribution of malaria and helminths are determined by climate which determines mosquito and helminth free living stage survival (Hay *et al.,* 2000). Infective stages of *A. duodenale* flourish in climates providing adequate rainfall and well drained soils but drying and direct sunlight are destructive (Reynolds *et al.,* 2008).

Differences in co-infections with *P. falciparum-A. duodenale* was statistically insignificant in both wet and dry seasons. *P. falciparum* and *A. duodenale* had an insignificant positive association in relation to wet and dry season of the year 2015. According to Brooker, *et al*. (2013), environmental factors associated with *P. falciparum* and hookworm co-infections were generally the same as those associated with hookworm infections. The findings suggested that environmental factors associated with individual helminth species were also associated with large scale spatial patterns of co-infection.

Co-infection proportions were insignificantly different for *P. falciparum-A. lumbricoides* during the wet season and there were no co-infection in the dry season. *P. falciparum* and *A. lumbricoides* had a negative association in both seasons during the year 2015 This was suggestive of decreased spread of *A. lumbricoides* infective eggs during dry season hence reduced contact and subsequent infection of the participants.

There were no cases of severe anaemia recorded in the current study. Proportion of anaemic versus non-anaemic pregnant women in relation to either *P. falciparum* or *A.*

duodenale infections was statistically significant. In Tanzania, pregnant women who had parasitic infections were more susceptible to anaemia as compared to their counter parts who were not infected (Mahande and Mahande, 2016).

An important consequence of both malaria and helminth infection is anaemia, (Hotez *et al.*, 2004) which is an important public health problem in the tropics. Anaemia though, develops only if the dietary intake of the affected individual is inadequate in iron (Kelkar and Kelkar, 1993). Due to the different mechanisms through which malaria parasites and helminths cause anaemia, their impact on haemoglobin levels could be additive (Mwangi *et al*., 2006). According to Strickland *et al*. (2000), malaria can potentiate the expected anaemia during pregnancy.

The outcome of the current study showed that *P. falciparum-A. duodenale* co-infection had a negative impact on the haemoglobin levels in the pregnant women, that is, co-infection with the two parasites tended to decrease haemoglobin levels. In a study done by van Eijk *et al*. (2009), there was interaction between malaria-helminth co-infection and the haemoglobin level of pregnant women in western Kenya.

Pregnant women with either light or moderate *A. duodenale* infection in the current study could become anaemic and *A. duodenale* intensity showed an unexpectedly positive association with anaemia. *A. duodenale* intensity did not reduce haemoglobin level in the pregnant women. However, malaria and helminth infection was associated with low haemoglobin levels among febrile patients in Ethiopia (Alemu *et al*., 2012). The extent to which malaria and helminth infections might interact to further enhance the risk of anaemia is poorly understood (Brooker *et al.,* 2007).

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Asymptomatic malaria by *P. falciparum* and geohelminth parasites (*A. lumbricoides, A. duodenale* and *T. trichiura*) were parasites found infecting pregnant women attending ANC at Nandi Hills Sub County hospital at significant levels. *A. lumbricoides-A. duodenale* and *A. lumbricoides-T. trichiura* co-infections were statistically significant. Malaria-*A. lumbricoides* co-infection was not statistically significant whereas, malaria-*A. duodenale* parasites co-infection was significant. Association between *P. falciparum-A. lumbricoides* was negative (counter-syndemic) while that between *P. falciparum-A. duodenale* was positive (syndemic). There were no co-infections between malaria and *T. trichiura* parasites.

All *A. lumbricoides* and *T. trichiura* infections were light infections (1-4,999 epg and 1-999 epg for *A. lumbricoides* and *T. trichiura* respectively) but for *A .duodenale* infections there were 12% light infection intensities and 3.7% moderate infection intensities. All the *P. falciparum* infections were of low intensity.

Gravidity and trimester significantly affected malaria infection. Fifteen percent (15%) of all malaria infections were in the primigravidae group. On the other hand, 1st trimester group recorded a higher *P. falciparum* infection. Primigravidae and trimester one were risk factors for malaria infection. Geohelminth infection was not significant with gravidity. *A. duodenale* infection was significant with trimester while infections with *A. lumbricoides* and *T. trichiura* were not significant with trimester. *P. falciparum-A. lumbricoides* co-infections and *P. falciparum- A. duodenale* co-

infections were not statistically significant with the pregnant women obstetrics and the association of *P. falciparum* and geohelminth parasites did not change with either gravidity or trimester.

Young age (16-20 years) was significantly associated with parasite infection and co-infection. Being married on the other hand did not reduce the chances of parasite infection and co-infection. Family size did not affect the course of infection for both malaria parasites of geohelminths. Association of malaria and geohelminth parasites in relation to socio-demographics of the pregnant women was variable.

Use of piped water did not significantly affect infection of any of the three geohelminths but had significant effect on *A. lumbricoides-A. duodenale* co-infection. Mode of faecal disposal significantly affected *A. lumbricoides* as well as the two other geohelminth co-infection (*A. duodenale* and *T. trichiura*). Being geophagous and lack of recent anthelminthic treatment significantly affected *A. lumbricoides- T trichiura* co-infection. Use of ITN, residual house sprays and prophylactic treatment did not protect against the malaria parasite.

Wet season of the year 2015 was associated increased cases of parasite infection and co-infection. Malaria parasites and *A. duodenale* co-infection had a negative association with haemoglobin levels of the respondents. The presence of the two individual parasites (*P. falciparum* and *A. duodenale*) had significant effect on haemoglobin levels of the respondents.

Risk factors for malaria parasites infection were primigravidity, 1st and 2nd trimesters, age, wet season and being married. Risk factor for *A. lumbricoides* was use of the

toilet as mode of faecal disposal. There were no risk factors recorded for *A. duodenale* and *T. trichiura* infections in the current study.

6.2. Recommendations

- Pregnant women should undergo diagnosis for both malaria and geohelminth parasites and they should be given anti-malarial and anthelminthic drugs in the course of their pregnancies to reduce the consequences of infection.
- Pregnant women attending ANC at Nandi-Hills sub county hospital require education on the appropriate usage and benefits of bed nets.
- There is need to encourage pregnant women to attend ANC early enough or as soon as they become pregnant so as to enhance benefits for their health and unborn babies.
- There is need for the county government of Nandi to improve on the supply of safe drinking water especially in the urban area and improve on environmental sanitation to prevent contamination of water sources.
- Owners of the tea estates/plantations should ensure the welfare of the tea pickers by providing/constructing latrines at appropriate distances within the plantations and ensure proper their use by the workers.
- Pregnant women within the study area should be diagnosed for other intestinal helminths (including *Taenia* spp) and protozoa (such as *Entamoeba histolytica*) and treated subsequently.

6.3 Further studies

- Further studies should be done to ascertain the immunological causes of syndemics or counter-syndemics of malaria-helminth co-infections in pregnancy.
- There is need to establish if the pregnant women in the study area use natural remedies (herbs) and the efficacy of such herbs in eliminating intestinal parasites and malaria causing parasites.
- Studies should be done on *P. falciparum*-HIV syndemics in pregnancy
- Studied should be done on geo-helminths & HIV syndemics in pregnancy

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APPENDICES

Appendix 1: Questionnaire

Introduction

Greetings to you all. I would like to take this opportunity to invite you to participate in this research by filling this questionnaire form. Kindly seek help where you don't understand.

Signature…….Date ……

Part one: Demographic information

i. Name/ANC No: …….

ii. Age……weight……

iii. Marital status…….

[ ] married [ ] single [ ] widowed [ ] divorced

iv. Number of children /family size……

v. Level of education…….

[ ] primary education [ ] secondary education [ ] college level

Any other level (specify)……

vi. Ethnicity…….

Part two: socio-economic information

1. Residence [ ] urban area [ ] rural area
2. Name of the residential area/ village……..
3. Settlement [ ] estate [ ] rental house [ ] own home
4. House type [ ] grass thatched [ ] corrugated iron sheet roofed
5. Occupation/income p.m……
6. Source of drinking water [ ] piped water [ ] bore hole/ well [ ] spring

7. Mode of faecal disposal [ ] pit latrine [ ] toilet
8. Is the pit latrine shared with other families/persons? [ ] yes [ ] no

Part three: other information

1. Do you sleep under insecticide treated net (ITN)? [ ] yes [ ] no
2. Do you occasionally have your house sprayed with insecticides? [ ] yes [ ]no
3. Do you have the habit of eating soil/ geophagy? [ ]yes [ ] no
4. Have you taken any deworming drugs before? [ ]yes [ ] no
5. Have you taken any anti-malarial drugs before? [ ]yes [ ] no
6. Is there a swamp near your home? [ ]yes [ ]no

Part four: Obstetric information

i. Parity [ ] primigravidae [ ] multigravidae

ii. Trimester [ ] 1st [ ] 2nd [ ] 3rd

Part five: for laboratory information

1. Malaria……

   ……

2. Geohelminth

   ……

3. Haemoglobin

   ……

   ……

4. Other clinical manifestations

   ……

APPENDIX 2: INFORMED CONSENT FORM

Informed consent form for pregnant women attending ante-natal care at Nandi Hills Sub County Hospital, Nandi County.

Name of investigator: Rael Jepkogei Masai

Institute: University of Eldoret

Proposal title: 'Malaria and Geohelminth Co-infection and Syndemics Among Pregnant Women Attending Ante-natal Care at Nandi-Hills Sub-county Hospital, Nandi County'.

PART1: INFORMATION SHEET

Introduction

I am Rael Jepkogei Masai from University of Eldoret doing a Doctor of Philosophy Degree Course in medical parasitology (like malaria and worms). I am inviting you to take part in this study. You can take time to decide or even talk to someone you feel comfortable with about this research before you can decide.

Purpose of research

This research will help us know if there is any relationship between malaria and the worms so that it can be possible to prevent the diseases in pregnant women. This will make them remain healthy throughout the pregnancy and give birth to healthy babies.

Type of research intervention

You will only be asked to give a stool sample in addition to the routine finger prick for blood sample. Stool (faeces) will be used to check for the presence of worms

(**tiong'ik/ magargarek)** while blood will be used to check for the presence of malaria (**cheptigonit)** as well as the amount of blood one has (hb).

You will also be asked to answer questions in the questionnaire and you are free to ask where you do not understand.

Participant selection

All pregnant women attending ANC at Nandi Hills sub-county hospital are invited to participate in the study

Voluntary participation/ Right to refuse

Your participation in this research is entirely voluntary. It is your choice whether to participate or not and if you do not participate, your services in the clinic will continue as usual nothing will change. It is your choice and all your rights will still be respected

Procedures and protocol

Small amount of blood will be taken from you by a finger prick. Blood taken will be very small indeed and it will only be used for this research. You will also be requested to provide a small amount of faeces (stool) in a clean stool container provided to you. You will be given a tissue paper and an anti-bacterial wipe to clean yourself. There will be no blood or stool (faeces) to be kept what is obtained from you will be used in research.

Duration

The research will take place from **May 2015 to May 2016**. If you choose to participate please visit the clinic at a day of your convenience so that samples can be obtained from you. This will happen only once.

Side effects/ risks

There are no side effects or risks at all associated with this research

Benefits

If you participate in the research you will not be asked to pay the usual routine fee for test of malaria and hb. If you decide to come back at a later time to participate, you will be paid your transport cost.

Confidentiality

Information that we collect from this research will be kept confidential. The information will be put away and no one but the researcher and the head of the hospital laboratory will be able to see it.

Sharing the results

The knowledge we get from doing this research will be shared with you through a community meeting before it is made widely available to the public. There will be a small meeting in the community to be announced through the chiefs. After the meeting the results will be published so that other interested people may learn from this research.

Who to contact

If you have any questions you may ask them now or later. If you wish to ask questions later, you may contact the following:

Rael Jepkogei Masai 0721 514998, 0708785049, Gmail *jjepkogei@gmail.com*

Mr. Philip Sang 0725812423

This proposal has been approved by board of post graduate studies, University of Eldoret, it has also been approved by hospital management board Nandi-Hills Sub-County Hospital and the National Council for Science Technology &Innovation which is funding the study.

Part II: Certificate of consent

I have read the foregoing information, or it has been read to me. I have had the opportunity to ask questions about it and any questions that I have asked have been answered to my satisfaction. I consent voluntarily to participate as a participant in this research.

Name of participant……..

Signature of participant…….

Date……

If illiterate (a literate witness will sign)

I have witnessed the accurate reading of the consent form to the potential participant, and the individual has had the opportunity to ask questions. I confirm that the individual has given consent freely.

Name of witness…… Thumb print of participant

Signature of witness……..

Date……..

I have accurately read out the information sheet to the potential participant, and to the best of my ability made sure that the participant understands that the following will be done:

1. Blood and stool samples will be collected from them
2. Questionnaires will be administered to them
3. Information obtained will be confidential.

I confirm that the participant was given an opportunity to ask questions about the study and all the questions asked by the participant have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily.

A copy of this informed consent form has been provided to the participant.

Name of researcher/ person taking the consent……..

Signature of the researcher…….

Date……..

APPENDICES 3 a, b Letters

Appendix 3 a : An introduction letter from department of Biological Sciences

University of Eldoret
flame of knowledge and innovation

P.O.Box 1125 - 30100, Eldoret, Kenya
Tel: +254 0208008143 Ext. 364/365/366
Fax: +254 53 2031299
E-mail: biolscdept@yahoo.com
Website: www.uoeld.ac.ke

DEPARTMENT OF BIOLOGICAL SCIENCES

REF: UOE/BIOLS/PG/88 **DATE:** 25th November, 2014

TO WHOM IT MAY CONCERN

Dear Sir/Madam,

RE: LETTER OF RECOMMENDATION FOR MASAI RAEL – SC/DPHIL.067/09

This is to certify that the above named is a bonafide student of the University of Eldoret in the Department of Biological Sciences, School of Science undertaking a D.Phil. course in Zoology (Parasitology).

Ms. Masai satisfactorily completed her coursework for the program named and is to start doing her research work in January, 2015 to December, 2015. The topic of her research is **'Malaria – Geohelminth Co-infection and Syndemics among Pregnant Women attending Ante-natal Care at Nandi Hills District Hospital, Nandi County'.**

Masai is a hardworking, honest and dedicated person and we request you to allow her carry out her research studies in your hospital.

Any assistance accorded to her will be highly appreciated.

Yours faithfully,

UNIVERSITY OF ELDORET HOD 25 NOV 2014 BIOLOGICAL SCIENCES P.O. BOX 1125-30100 ELDORET

Dr. J.A. Makwali,
AG. HEAD, DEPARTMENT OF BIOLOGICAL SCIENCES.

JAM/ear.

Appendix 3 b: Research approval letter from Nandi Hills Sub-County Hospital

REPUBLIC OF KENYA

MINISTRY OF HEALTH

Telegrams: "HEALTH",
Telephone: Nandi Hills (020) 2438821
Direct MOH/FAX (053) 643024
Email: nandihillschosp@yahoo.com

NANDI HILLS COUNTYHOSPITAL
P.O. BOX 84
NANDI HILLS.

REF: NHDH/GEN/1/14/5

DATE: 9TH DEC, 2014

TO

MASAI RAEL -SC/DPHIL.067/09

RE: RESEARCH APPROVAL

Following your request to conduct the research "Malaria –Geohelmimnth Co-infection and Syndemics among pregnant Women attending Ante-natal Care at Nandi Hills County Hospital, Nandi County" your request been approved by the management of this institution.

Kindly adhere to ethics of research.

MEDICAL SUPERINTENDENT
NANDI HILLS DISTRICT HOSPITAL
15 JAN 2015

Dr. S.K. Kemei
Medical Superintendent
Sign .....
Nandi Hills County Hospital

CCC:

1. MCH/FP IN CHARGE.

Appendix 4a: Chi square test for single parasitic infection, *P.falciprum- A. lumbricoides* co-infection and *P.falciparum*-hookworm co-infection

Test Statistics

	A.lumbricoides	*A.duodenale*	*T.trichiura*	*P.falciparum*
Chi-Square	49.613[a]	144.213[a]	2.881E2[a]	2.151E2[a]
df	1	1	1	1
Asymp. Sig.	.000	.000	.000	.000

Chi-Square Tests for *P.falciparum-A. lumricoides* co-infection

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	3.299[a]	1	.069		
Continuity Correction[b]	2.492	1	.114		
Likelihood Ratio	3.807	1	.051		
Fisher's Exact Test				.095	.051
Linear-by-Linear Association	3.288	1	.070		
N of Valid Cases[b]	300				

Chi-Square Tests for *P.falciparum* and *A.duodenale* co-infection

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	4.376[a]	1	.036		
Continuity Correction[b]	3.207	1	.073		
Likelihood Ratio	3.654	1	.056		
Fisher's Exact Test				.063	.044
Linear-by-Linear Association	4.361	1	.037		
N of Valid Cases[b]	300				

Appendix 4b: Test of association for *P.falciparum-A.lumbricoides* and *P.falciparum*-hookworm (*A. duodenale*) co-infections

Symmetric Measures for *P. falciparum- A.lumbricoides* co-infection

		Value	Approx. Sig.
Nominal by Nominal	Phi	-.105	.069
	Cramer's V	.105	.069
N of Valid Cases		300	

Symmetric Measures for *P. falciparum- A. duodenale* co-infection

		Value	Approx. Sig.
Nominal by Nominal	Phi	.121	.036
	Cramer's V	.121	.036
N of Valid Cases		300	

Appendix 4c: Logistic regression table for *P. falciparum*-geohelminth co-infections

	B	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
					Lower Bound	Upper Bound
Intercept	-2.473	1	.000			
[ascaris=1.00]	-1.465	1	.027	.231	.063	.850
[ascaris=2.00]	0[b]	0	.	.	.	.
[hookworm=1.00]	1.368	1	.008	3.926	1.425	10.814
[hookworm=2.00]	0[b]	0	.	.	.	.

Appendix 5a : chi square test for infection prevalence and gravidity

Chi-Square Tests for *P.falciparum* and gravidity

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	6.922[a]	1	.009		
Continuity Correction[b]	5.666	1	.017		
Likelihood Ratio	6.102	1	.014		
Fisher's Exact Test				.013	.012
Linear-by-Linear Association	6.899	1	.009		
N of Valid Cases[b]	300				

Chi square test for *A.lumbricoides* and gravidity

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.005[a]	1	.942		
Continuity Correction[b]	.000	1	1.000		
Likelihood Ratio	.005	1	.942		
Fisher's Exact Test				1.000	.533
Linear-by-Linear Association	.005	1	.942		
N of Valid Cases[b]	300				

Chi-Square Tests for hookworm (*A. duodenale*) and gravidity

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.856[a]	1	.355		
Continuity Correction[b]	.548	1	.459		
Likelihood Ratio	.826	1	.363		
Fisher's Exact Test				.359	.227
Linear-by-Linear Association	.853	1	.356		
N of Valid Cases[b]	300				

Chi square test for *T. trichiura* and gravidity

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	1.010[a]	1	.315		
Continuity Correction[b]	.112	1	.738		
Likelihood Ratio	1.736	1	.188		
Fisher's Exact Test				.576	.420
Linear-by-Linear Association	1.007	1	.316		
N of Valid Cases[b]	300				

Appendix 5b: chi square test for *P. falciparum*-geo-helminth co-infection by gravidity

Chi square test for *P. falciparum-A.lumbricoides* by gravidity

Gravidity		Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
primigravidae	Pearson Chi-Square	.773[a]	1	.379	
	Continuity Correction[b]	.271	1	.602	
	Likelihood Ratio	.836	1	.360	
	Fisher's Exact Test				.491
	Linear-by-Linear Association	.763	1	.382	
	N of Valid Cases[b]	75			
multigravidae	Pearson Chi-Square	2.788[c]	1	.095	
	Continuity Correction[b]	1.810	1	.179	
	Likelihood Ratio	3.463	1	.063	
	Fisher's Exact Test				.115
	Linear-by-Linear Association	2.775	1	.096	
	N of Valid Cases[b]	225			

Chi square test for *P. falciparum*-hookworm (*A. duodenale*) by gravidity

parity		Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
primigravidae	Pearson Chi-Square	2.659[a]	1	.103	
	Continuity Correction[b]	1.469	1	.226	
	Likelihood Ratio	2.307	1	.129	
	Fisher's Exact Test				.201
	Linear-by-Linear Association	2.624	1	.105	
	N of Valid Cases[b]	75			

multigravidae	Pearson Chi-Square	1.207[c]	1	.272	
	Continuity Correction[b]	.454	1	.500	
	Likelihood Ratio	1.033	1	.310	
	Fisher's Exact Test				.385
	Linear-by-Linear Association	1.202	1	.273	
	N of Valid Cases[b]	225			

Appendix 5c: test of association for *P. falciparum*-geo-helminth co-infection by gravidity

Symmetric Measures for *P. falciparum-A. lumbricoides* co-infection by gravidity

Gravidity			Value	Approx. Sig.
primigravidae	Nominal by Nominal	Phi	-.102	.379
		Cramer's V	.102	.379
	N of Valid Cases		75	
multigravidae	Nominal by Nominal	Phi	-.111	.095
		Cramer's V	.111	.095
	N of Valid Cases		225	

Symmetric Measures for *P. falciparum*-hookworm (*A. duodenale*) co-infection by gravidity

parity			Value	Approx. Sig.
primigravidae	Nominal by Nominal	Phi	.188	.103
		Cramer's V	.188	.103
	N of Valid Cases		75	
multigravidae	Nominal by Nominal	Phi	.073	.272
		Cramer's V	.073	.272
	N of Valid Cases		225	

Appendix 6a: chi-square tests for parasitic infections by trimester

Chi-Square Tests for *P.falciparum* by trimester

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	17.241[a]	2	.000
Likelihood Ratio	13.721	2	.001
Linear-by-Linear Association	10.955	1	.001
N of Valid Cases	300		

Chi square test for *A.lumbricoides* by trimester

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	1.265[a]	2	.531
Likelihood Ratio	1.278	2	.528
Linear-by-Linear Association	.128	1	.720
N of Valid Cases	300		

Chi-Square Tests for hookworm (*A. duodenale*) infection by trimester

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	9.128[a]	2	.010
Likelihood Ratio	9.002	2	.011
Linear-by-Linear Association	.059	1	.808
N of Valid Cases	300		

Chi-Square Tests for *T.trichiura* by trimester

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.286[a]	2	.319
Likelihood Ratio	3.396	2	.183
Linear-by-Linear Association	.013	1	.908
N of Valid Cases	300		

Appendix 6b: chi square test for malaria-geo-helminth co-infection by trimester

Chi square test for *P.falciparum-A. lumbricoides* co-infection by trimester

trimester		Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
1st trimester	Pearson Chi-Square	.903[a]	1	.342	
	Continuity Correction[b]	.345	1	.557	
	Likelihood Ratio	.977	1	.323	
	Fisher's Exact Test				.479
	Linear-by-Linear Association	.888	1	.346	
	N of Valid Cases[b]	58			
2nd trimester	Pearson Chi-Square	1.487[c]	1	.223	
	Continuity Correction[b]	.692	1	.405	
	Likelihood Ratio	1.743	1	.187	
	Fisher's Exact Test				.439
	Linear-by-Linear Association	1.479	1	.224	
	N of Valid Cases[b]	171			
3rd trimester	Pearson Chi-Square	1.064[d]	1	.302	
	Continuity Correction[b]	.125	1	.724	
	Likelihood Ratio	1.799	1	.180	
	Fisher's Exact Test				.566
	Linear-by-Linear Association	1.049	1	.306	
	N of Valid Cases[b]	71			

Chi square test for *P.falciparum-A. duodenale* co-infection by trimester

trimester		Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
1st trimester	Pearson Chi-Square	.699[a]	1	.403	
	Continuity Correction[b]	.209	1	.648	
	Likelihood Ratio	.663	1	.416	

	Fisher's Exact Test				.457
	Linear-by-Linear Association	.687	1	.407	
	N of Valid Cases[b]	58			
2nd trimester	Pearson Chi-Square	2.126[c]	1	.145	
	Continuity Correction[b]	.727	1	.394	
	Likelihood Ratio	1.595	1	.207	
	Fisher's Exact Test				.182
	Linear-by-Linear Association	2.113	1	.146	
	N of Valid Cases[b]	171			
3rd trimester	Pearson Chi-Square	.280[d]	1	.597	
	Continuity Correction[b]	.000	1	1.000	
	Likelihood Ratio	.251	1	.616	
	Fisher's Exact Test				.515
	Linear-by-Linear Association	.276	1	.599	
	N of Valid Cases[b]	71			

Appendix 6c: test of association for *P. falciparum*-geohelminth co-infection by trimester

Symmetric Measures for *P. falciparum-A.lumbricoides* co-infection by trimester

trimester			Value	Approx. Sig.
1st trimester	Nominal by Nominal	Phi	-.125	.342
		Cramer's V	.125	.342
	N of Valid Cases		58	
2nd trimester	Nominal by Nominal	Phi	-.093	.223
		Cramer's V	.093	.223
	N of Valid Cases		171	
3rd trimester	Nominal by Nominal	Phi	-.122	.302
		Cramer's V	.122	.302
	N of Valid Cases		71	

Symmetric Measures for *P. falciparum*- *A. duodenale* co-infection by trimester

trimester			Value	Approx. Sig.
1st trimester	Nominal by Nominal	Phi	.110	.403
		Cramer's V	.110	.403
	N of Valid Cases		58	
2nd trimester	Nominal by Nominal	Phi	.111	.145
		Cramer's V	.111	.145
	N of Valid Cases		171	
3rd trimester	Nominal by Nominal	Phi	.063	.597
		Cramer's V	.063	.597
	N of Valid Cases		71	

Appendix 7a: chi square tests for parasitic infections in relation to age.

Chi-Square Tests for *P.falciparum* in relation to age

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	11.178[a]	4	.025
Likelihood Ratio	10.810	4	.029
Linear-by-Linear Association	4.206	1	.040

Chi-Square Tests for *A.lumbricoides* infection in relation to age

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.668[a]	4	.323
Likelihood Ratio	4.441	4	.350
Linear-by-Linear Association	.033	1	.857
N of Valid Cases	300		
N of Valid Cases	300		

Chi-Square Tests for hookworm (*A. duodenale*) infection in relation to age

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	3.166[a]	4	.530

Likelihood Ratio	3.111	4	.539
Linear-by-Linear Association	.426	1	.514
N of Valid Cases	300		

Chi-Square Tests *T.trichiura* infection in relation to age

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	5.918[a]	4	.205
Likelihood Ratio	4.535	4	.338
Linear-by-Linear Association	.130	1	.719
N of Valid Cases	300		

Appendix 7b: chi square tests for *P. falciparum*-geohelminth co-infections in relation to age of the pregnant women

Chi-Square Tests for *P.falciparum-A.lumbricoides* co-infection in relation to age

age		Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
16-20	Pearson Chi-Square	.061[a]	1	.805		
	Continuity Correction[b]	.000	1	1.000		
	Likelihood Ratio	.062	1	.804		
	Fisher's Exact Test				1.000	.560
	Linear-by-Linear Association	.060	1	.807		
	N of Valid Cases[b]	57				
21-25	Pearson Chi-Square	2.052[c]	1	.152		
	Continuity Correction[b]	.855	1	.355		
	Likelihood Ratio	3.400	1	.065		
	Fisher's Exact Test				.320	.184
	Linear-by-Linear Association	2.034	1	.154		
	N of Valid Cases[b]	117				
26-30	Pearson Chi-Square	2.554[d]	1	.110		
	Continuity Correction[b]	1.268	1	.260		
	Likelihood Ratio	4.170	1	.041		
	Fisher's Exact Test				.176	.126
	Linear-by-Linear Association	2.521	1	.112		
	N of Valid Cases[b]	78				

31-35	Pearson Chi-Square	.597[e]	1	.440		
	Continuity Correction[b]	.000	1	1.000		
	Likelihood Ratio	1.024	1	.312		
	Fisher's Exact Test				1.000	.605
	Linear-by-Linear Association	.579	1	.447		
	N of Valid Cases[b]	32				
36-40	Pearson Chi-Square	.[f]				
	N of Valid Cases[b]	16				

Chi-Square Tests for *P.falciparum*-hookworm (*A. duodenale*) co-infection in relation to age

age		Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
16-20	Pearson Chi-Square	.584[a]	1	.445		
	Continuity Correction[b]	.114	1	.736		
	Likelihood Ratio	.546	1	.460		
	Fisher's Exact Test				.424	.350
	Linear-by-Linear Association	.574	1	.449		
	N of Valid Cases[b]	57				
21-25	Pearson Chi-Square	3.897[c]	1	.048		
	Continuity Correction[b]	1.613	1	.204		
	Likelihood Ratio	2.699	1	.100		
	Fisher's Exact Test				.108	.108
	Linear-by-Linear Association	3.864	1	.049		
	N of Valid Cases[b]	117				
26-30	Pearson Chi-Square	1.045[d]	1	.307		
	Continuity Correction[b]	.219	1	.639		
	Likelihood Ratio	.897	1	.344		
	Fisher's Exact Test				.293	.293
	Linear-by-Linear Association	1.031	1	.310		
	N of Valid Cases[b]	78				
31-35	Pearson Chi-Square	.305[e]	1	.581		
	Continuity Correction[b]	.000	1	1.000		
	Likelihood Ratio	.553	1	.457		
	Fisher's Exact Test				1.000	.762

	Linear-by-Linear Association	.295	1	.587		
	N of Valid Cases[b]	32				
36-40	Pearson Chi-Square	.[f]				
	N of Valid Cases[b]	16				

Appendix 7c: test of association for *P. falciparum*-geohelminth co-infections in relation to age

Symmetric Measures for *P. falciparum-A. lumbricoides* co-infection in relation to age

age			Value	Approx. Sig.
16-20	Nominal by Nominal	Phi	-.033	.805
		Cramer's V	.033	.805
	N of Valid Cases		57	
21-25	Nominal by Nominal	Phi	-.132	.152
		Cramer's V	.132	.152
	N of Valid Cases		117	
26-30	Nominal by Nominal	Phi	-.181	.110
		Cramer's V	.181	.110
	N of Valid Cases		78	
31-35	Nominal by Nominal	Phi	-.137	.440
		Cramer's V	.137	.440
	N of Valid Cases		32	
36-40	Nominal by Nominal	Phi	.[a]	
	N of Valid Cases		16	

Symmetric Measures for *P.falciparum*-hookworm (*A. duodenale*) co-infection in relation to age

age			Value	Approx. Sig.
16-20	Nominal by Nominal	Phi	.101	.445
		Cramer's V	.101	.445
	N of Valid Cases		57	
21-25	Nominal by Nominal	Phi	.183	.048
		Cramer's V	.183	.048
	N of Valid Cases		117	

26-30	Nominal by Nominal	Phi	.116	.307
		Cramer's V	.116	.307
	N of Valid Cases		78	
31-35	Nominal by Nominal	Phi	-.098	.581
		Cramer's V	.098	.581
	N of Valid Cases		32	
36-40	Nominal by Nominal	Phi	.[a]	
	N of Valid Cases		16	

a. No statistics are computed because *plasmodium* is a constant.

Appendix 8a: chi square test for parasitic infection in relation to marital status of pregnant women attending ANC at Nandi Hills County Hospital

Chi-Square Tests for *P. falciparum* infection in relation to marital status

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	5.026[a]	1	.025		
Continuity Correction[b]	3.625	1	.057		
Likelihood Ratio	3.994	1	.046		
Fisher's Exact Test				.038	.038
Linear-by-Linear Association	5.010	1	.025		
N of Valid Cases[b]	300				

Chi-Square Tests *A. lumbricoides* infection in relation to marital status

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.059[a]	1	.808		
Continuity Correction[b]	.002	1	.963		
Likelihood Ratio	.058	1	.809		
Fisher's Exact Test				.845	.473
Linear-by-Linear Association	.059	1	.808		
N of Valid Cases[b]	300				

Chi-Square Tests for hookworm (*A. duodenale*) in relation to marital status

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.100[a]	1	.752		
Continuity Correction[b]	.004	1	.947		
Likelihood Ratio	.097	1	.755		
Fisher's Exact Test				.803	.456
Linear-by-Linear Association	.100	1	.752		
N of Valid Cases[b]	300				

Chi-Square Tests for *T. trichiura* in relation to marital status

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.400[a]	1	.527		
Continuity Correction[b]	.000	1	1.000		
Likelihood Ratio	.748	1	.387		
Fisher's Exact Test				1.000	.688
Linear-by-Linear Association	.399	1	.528		
N of Valid Cases[b]	300				

Appendix 8b: chi square tests for *P.falciparum*-geohelminth co-infections in relation to marital status.

P. falciparum-A. lumbricoides co-infection in relation to marital status

m.s		Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
married	Pearson Chi-Square	4.851[a]	1	.028	
	Continuity Correction[b]	3.715	1	.054	
	Likelihood Ratio	6.304	1	.012	
	Fisher's Exact Test				.027
	Linear-by-Linear Association	4.833	1	.028	
	N of Valid Cases[b]	265			
single	Pearson Chi-Square	.012[c]	1	.912	
	Continuity Correction[b]	.000	1	1.000	
	Likelihood Ratio	.012	1	.912	
	Fisher's Exact Test				1.000
	Linear-by-Linear Association	.012	1	.913	
	N of Valid Cases[b]	35			

P. falciparum-A. duodenale co-infection in relation to marital status

m.s		Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
married	Pearson Chi-Square	5.783[a]	1	.016	
	Continuity Correction[b]	4.222	1	.040	
	Likelihood Ratio	4.596	1	.032	
	Fisher's Exact Test				.028
	Linear-by-Linear Association	5.762	1	.016	
	N of Valid Cases[b]	265			
single	Pearson Chi-Square	.001[c]	1	.973	
	Continuity Correction[b]	.000	1	1.000	
	Likelihood Ratio	.001	1	.973	
	Fisher's Exact Test				1.000
	Linear-by-Linear Association	.001	1	.973	
	N of Valid Cases[b]	35			

Appendix 8c: test of association for *P.falciparum*-geohelminth co-infections in relation to marital status.

Symmetric Measures for malaria-*A. lumbricoides* co-infection in relation to marital status

m.s			Value	Approx. Sig.
married	Nominal by Nominal	Phi	-.135	.028
		Cramer's V	.135	.028
	N of Valid Cases		265	
single	Nominal by Nominal	Phi	.019	.912
		Cramer's V	.019	.912
	N of Valid Cases		35	

Symmetric Measures for *P. falciparum*-hookworm (*A. duodenale*) co-infection in relation to marital status

m.s			Value	Approx. Sig.
married	Nominal by Nominal	Phi	.148	.016
		Cramer's V	.148	.016
	N of Valid Cases		265	
single	Nominal by Nominal	Phi	-.006	.973
		Cramer's V	.006	.973
	N of Valid Cases		35	

Appendix 9a: chi square tests for parasite infection in relation to education level of pregnant women

Chi-Square Tests for *P. falciparum* infection in relation to education level

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.067[a]	2	.356
Likelihood Ratio	2.067	2	.356
Linear-by-Linear Association	.036	1	.849
N of Valid Cases	300		

Chi-Square Tests for *A.lumbricoides* infection in relation education level

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	.421[a]	2	.810
Likelihood Ratio	.426	2	.808
Linear-by-Linear Association	.417	1	.519
N of Valid Cases	300		

Chi-Square Tests for hookworm (*A. duodenale*) infection in relation to education level

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	3.358[a]	2	.187
Likelihood Ratio	3.470	2	.176
Linear-by-Linear Association	.001	1	.971
N of Valid Cases	300		

Chi-Square Tests for *T.trichiura* in relation to education level

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	1.729[a]	2	.421
Likelihood Ratio	2.726	2	.256
Linear-by-Linear Association	1.451	1	.228
N of Valid Cases	300		

Appendix 9b: chi square test for *P. falciparum*-geohelminth co-infection in relation to education levels of pregnant women.

Education		Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Primary	Pearson Chi-Square	.919[a]	1	.338	
	Continuity Correction[b]	.298	1	.585	
	Likelihood Ratio	.805	1	.370	
	Fisher's Exact Test				.401
	Linear-by-Linear Association	.914	1	.339	
	N of Valid Cases[b]	191			
Secondary	Pearson Chi-Square	3.459[c]	1	.063	
	Continuity Correction[b]	2.028	1	.154	
	Likelihood Ratio	2.940	1	.086	
	Fisher's Exact Test				.083
	Linear-by-Linear Association	3.417	1	.065	
	N of Valid Cases[b]	82			
secondary and above	Pearson Chi-Square	.083[d]	1	.773	
	Continuity Correction[b]	.000	1	1.000	
	Likelihood Ratio	.157	1	.692	
	Fisher's Exact Test				1.000
	Linear-by-Linear Association	.080	1	.777	
	N of Valid Cases[b]	27			

Appendix 9c: test of association for *P. falciparum*-geohelminth co-infection in relation to education levels.

Symmetric Measures for *P. falciparum-A. lumbricoides* co-infection in relation to education levels of pregnant women

education			Value	Approx. Sig.
primary	Nominal by Nominal	Phi	-.181	.013
		Cramer's V	.181	.013
	N of Valid Cases		191	
secondary	Nominal by Nominal	Phi	.041	.708
		Cramer's V	.041	.708
	N of Valid Cases		82	
Tertiary	Nominal by Nominal	Phi	-.116	.547
		Cramer's V	.116	.547
	N of Valid Cases		27	

Symmetric Measures for *P. falciparum-A. duodenale* co-infection in relation to education level

education			Value	Approx. Sig.
primary	Nominal by Nominal	Phi	.069	.338
		Cramer's V	.069	.338
	N of Valid Cases		191	
secondary	Nominal by Nominal	Phi	.205	.063
		Cramer's V	.205	.063
	N of Valid Cases		82	
Tertiary	Nominal by Nominal	Phi	-.055	.773
		Cramer's V	.055	.773
	N of Valid Cases		27	

Appendix 10: test of association for *P. falciparum*-geohelminth co-infection in relation to settlement areas of pregnant women attending ANC at Nandi Hills Hospital

Symmetric Measures for *P. falciparum-A. lumbricoides* co-infection in relation to settlement areas of pregnant women

settlement			Value	Approx. Sig.
own home	Nominal by Nominal	Phi	-.119	.102
		Cramer's V	.119	.102
	N of Valid Cases		189	
urban rental	Nominal by Nominal	Phi	.084	.552
		Cramer's V	.084	.552
	N of Valid Cases		50	
estate camp	Nominal by Nominal	Phi	-.213	.095
		Cramer's V	.213	.095
	N of Valid Cases		61	

Symmetric Measures for *P. falciparum-A. duodenale* co-infection in relation to settlement areas of pregnant women

settlement			Value	Approx. Sig.
own home	Nominal by Nominal	Phi	.211	.004
		Cramer's V	.211	.004
	N of Valid Cases		189	
urban rental	Nominal by Nominal	Phi	.166	.241
		Cramer's V	.166	.241
	N of Valid Cases		50	
estate camp	Nominal by Nominal	Phi	-.097	.451
		Cramer's V	.097	.451
	N of Valid Cases		61	

Appendix 11: test of association for *P. falciparum*-geohelminth co-infection in relation to family size.

Symmetric Measures for *P. falciparum- A. lumbricoides* co-infection in relation to family size

f.size			Value	Approx. Sig.
≤2	Nominal by Nominal	Phi	-.095	.169
		Cramer's V	.095	.169
	N of Valid Cases		210	
3-5	Nominal by Nominal	Phi	-.133	.234
		Cramer's V	.133	.234
	N of Valid Cases		80	
>5	Nominal by Nominal	Phi	-.167	.598
		Cramer's V	.167	.598
	N of Valid Cases		10	

Symmetric Measures for *P.falciparum-A. duodenale* co-infection in relation to family size

f.size			Value	Approx. Sig.
≤2	Nominal by Nominal	Phi	.156	.024
		Cramer's V	.156	.024
	N of Valid Cases		210	
3-5	Nominal by Nominal	Phi	.074	.509
		Cramer's V	.074	.509
	N of Valid Cases		80	
>5	Nominal by Nominal	Phi	-.111	.725
		Cramer's V	.111	.725
	N of Valid Cases		10	

Appendix 12: test of association for *P. falciparum*-geohelminth co-infection in relation to income status of the pregnant women

Symmetric Measures for *P. falciparum-A. lumbricoides* co-infection in relation to income status of the pregnant women

income			Value	Approx. Sig.
>20,000	Nominal by Nominal	Phi	.[a]	
	N of Valid Cases		15	
10,000-20,000	Nominal by Nominal	Phi	-.211	.117
		Cramer's V	.211	.117
	N of Valid Cases		55	
<10,000	Nominal by Nominal	Phi	-.075	.254
		Cramer's V	.075	.254
	N of Valid Cases		230	

Symmetric Measures for *P. falciparum-A. duodenale* co-infection in relation to income status of the pregnant women

income			Value	Approx. Sig.
>20,000	Nominal by Nominal	Phi	.[a]	
	N of Valid Cases		15	
10,000-20,000	Nominal by Nominal	Phi	.455	.001
		Cramer's V	.455	.001
	N of Valid Cases		55	
<10,000	Nominal by Nominal	Phi	.050	.450
		Cramer's V	.050	.450
	N of Valid Cases		230	

Appendix 13: test of association for *P. falciparum*-geohelminth co-infection in relation to wet and dry seasons of the year 2015

Symmetric Measures for *P. falciparum-A. lumbricoides* co-infection in relation to wet and dry seasons of the year 2015

season			Value	Approx. Sig.
wet season	Nominal by Nominal	Phi	-.189	.058
		Cramer's V	.189	.058
	N of Valid Cases		100	
dry season	Nominal by Nominal	Phi	-.108	.125
		Cramer's V	.108	.125
	N of Valid Cases		200	

Symmetric Measures for *P. falciparum-A. duodenale* co-infection in relation to wet and dry seasons of the year 2015

season			Value	Approx. Sig.
wet season	Nominal by Nominal	Phi	.126	.208
		Cramer's V	.126	.208
	N of Valid Cases		100	
dry season	Nominal by Nominal	Phi	.024	.739
		Cramer's V	.024	.739
	N of Valid Cases		200	

Appendix 14: test of association for *P. falciparum-A. duodenale* co-infection and the haemoglobin levels of pregnant women

hb.level			Value	Approx. Sig.
hb≥11	Nominal by Nominal	Phi	.124	.068
		Cramer's V	.124	.068
	N of Valid Cases		215	
hb<11	Nominal by Nominal	Phi	-.105	.335
		Cramer's V	.105	.335
	N of Valid Cases		85	

Appendix 15: Map showing the location of Nandi-Hills Sub-County and its neighbours in the western part of Kenya.

Source: Google maps

Appendix 16: Pregnant women on the queue at the MCH section, Nandi Hills county hospital Nandi County

Source: Author; 2015-2016

Appendix 17: Section of laboratory showing specimen collection area and parasitology section.

Source: Author, 2015-2017

Appendix 18: University of Eldoret supervisor Dr. J.A. Makwali (center) and two technicians of Nandi-Hills hospital parasitology laboratory.

Source: Author, 2015-2016