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Full Length Research Paper

Prevalence of malaria and soil-transmitted helminth infections in healthy school children in Cameroon

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Malaria and soil-transmitted helminths are common parasitic diseases found in school children in sub-Saharan Africa. We determined the prevalence and intensities of these infections in apparently healthy schoolchildren living in Mfou health district, where malaria and intestinal infections are among the first causes of morbidity. In a cross-sectional study involving 503 schoolchildren, anthropometric parameters were measured. Finger-prick blood and fresh stool samples were collected for malaria parasites determination, assessment of anaemia and detection of helminths' eggs. Logistic regression analysis was used to investigate the association between these infections and other factors. Overall, 40.6 and 29.6% of children harboured malaria parasites and worms respectively. Prevalences of mild, moderate and severe undernutrition were respectively 22.2, 2.3 and 0.5% for underweight, and 21.9, 7.6 and 2.0% for stunting. In logistic regression analysis, anaemia (OR=2.64, 95% CI: 1.71-4.07) and infection with *Ascaris lumbricoides* (OR=1.72, 95% CI: 1.01-2.91) were significantly associated with malaria infection. Infection with *Trichuris trichiura* was significantly associated with increased risks of underweight (OR=2.11, 95% CI: 1.11-4.01). Moreover, rural schoolchildren showed increased chances of carrying worms, compared to their urban counterparts (OR=2.60, 95% CI: 1.75-3.86). Malaria prevention and school-based deworming activities should be re-enforced in Mfou health district to reduce the burden of these infections in children.

Key words: Malaria, soil-transmitted helminths, undernutrition, schoolchildren, Mfou, Cameroon.

INTRODUCTION

Malaria infection and soil-transmitted helminths (STHs) are among the most prevalent endemic parasitic diseases in sub-saharan Africa, where both diseases have similar geographical distribution and co-infections are common (Snow et al., 2005; Mwangi et al., 2006; Brooker et al., 2007; Brooker, 2010). In Cameroon, both infections are prevalent and responsible for increased morbidities and associated consequences in vulnerable populations, including young children, pregnant women and school-age children (Quakyi et al., 2000; Brooker et al., 2000; Kimbi et al., 2005a,b; Tchuem and N'Goran, 2009; Leke et al., 2010). Schoolchildren living in an environment with inadequate sanitation (Ziegelbauer et al., 2012), usually in deprived communities in rural areas, are likely to be infected with at least one of the three main

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STHs (*Ascaris lumbricoides*, *Trichuris trichiura* and hookworms [*Ancylostoma duodenale* and *Necator americanus*]), as well as other helminths species (Tchuem et al., 2003; Bethony et al., 2006; Mupfasoni et al., 2009; Ayalew et al., 2011). Infections by intestinal helminths have been shown to result in abdominal pain, diarrhea, anaemia, malnutrition, ulcers, intellectual retardation, cognitive and educational deficits, intestinal obstruction and, in severe chronic and untreated infections, could even lead to death (Crampton and Nesheim, 2002; Hotez et al., 2008; Hall et al., 2008; Brooker et al., 2010). In the context of continuous exposure to *Anopheles* mosquitoes, these conditions are further exacerbated with asymptomatic malaria parasites, often resulting in co-infections with *Plasmodium*, and thus, putting these children at enhanced risk of clinical disease (Mwangi et al., 2006; Nkuo-Akenji et al., 2006; Achidi et al., 2008).

Current preventive strategies adopted by the Ministry of Public Health for malaria in Cameroon are based on the use of insecticide-treated nets in households and intermittent preventive treatment with sulphadoxine-pyrimethamine for pregnant women (Ministry of health/National Malaria Control Programme, 2011). On the other hand, activities aiming at reducing the burden of helminths infections in children are based on annual distribution of anthelminthics in primary schools (Tchuem and N'Goran, 2009), as well as other deworming activities which are integrated to immunization in pre-school children (1-5 years) within the community.

Regular update on the prevalence and intensities of these infections are important in order to assess the impact of these control interventions on the burden of the infections, especially in children. However, there is currently a scarcity of such information in Mfou health district where malaria and intestinal infections are ranked respectively among the first and third cause of morbidities within this rural district. Therefore, our study was designed to determine the prevalences of malaria and STHs and their association with undernutrition in primary schoolchildren residing in this study locality.

MATERIALS AND METHODS

Study area

The study was conducted in 4 primary schools of Mfou health district, a forest area located in the Mefou and Afamba division, in the centre region of Cameroon. Two of the schools were situated in the district headquarter (Mfou urban), an emerging semi-urban area located at ~25 km of Yaoundé, the Capital of Cameroon; while the two others were found in the rural area (Mfou rural). The population of the district was over 71 000 inhabitants, who were mainly farmers (District Health Management Team, 2011). Most households in Mfou urban and nearly all in the rural area have no access to potable water and appropriate sanitation, but the socio-economic conditions are relatively improved in Mfou urban. Mfou is hyperendemic for malaria; transmission occurs all year round, with peaks during the rainy season and transition to the dry season. Malaria morbidity ranked the first position among the top ten causes of morbidity in the district, while intestinal infections ranked the third position (District Health Management Team, 2011).

Study population

The study involved apparently healthy primary schoolchildren of both sexes aged between 3 and 16 years. This population also included children from the nursery section of one of the rural primary schools. Each participant was clinically examined for febrile symptoms (fever) or any other clinical conditions (headache, abdominal discomforts, etc.). Sick children were referred to Mfou district hospital for appropriate management.

Anthropometric measurements and assessment of undernutrition

The age, sex, height and weight of children were measured to determine their anthropometric indices. Age of each child was obtained from school records, while weight was measured to the nearest 100 g using an electronic personal scale (Geepas®). Height was measured to the nearest 1 mm, using a height measuring board (Innotech International, 7-9 avenue F.V. Raspail-94110-France). Weight-for-age Z-score (WAZ) and height-for-age Z-score (HAZ) were calculated to assess underweight and stunting status respectively, as indicators of undernutrition. WAZ is easily available and can capture both stunting, associated with long-term undernutrition and wasting, a manifestation of recent and acute undernutrition (Caulfield et al., 2004). These calculations took into account children' weight and height, as well as the median weight and height of healthy children of the same age and sex (WHO, 1983). WAZ and HAZ scores were classified as mild (-1.01 to -2.00 Standard Deviation [SD]); moderate (-2.01 to -3SD) or severe (<-3SD) undernutrition, and normal (WAZ≥-1SD) (Caulfield et al., 2004; Crookston et al., 2010; Mfonkeu et al., 2010).

Sample collection and laboratory analyses

Finger prick blood samples were collected directly onto a clean glass slide to prepare thick and thin blood films. Heparinised micro capillary blood was collected at the same time for assessment of anaemia. Additionally, fresh stool samples were collected from each child, in a clean plastic container. The samples were immediately transported in the laboratory for processing and analysis.

For malaria parasite detection, thin blood films were first fixed in methanol, stained with 50% May-Grunwald, and both thin and thick films were stained with 10% Giemsa stain. Slides were examined under a microscope (x100 objective). A slide was considered negative if malaria parasites were not detected after examination of 200-oil immersion fields of thick smear. For positive samples, the number of parasites per 200 white blood cells (WBCs) was counted and the parasite density estimated based on an average of 8000 WBCs/µl of blood. All slides were read independently by two microscopists, and when discrepancy occurred, the slide was read by a third person. *Plasmodium* species was determined in thin films. Children with malaria parasites were treated with a fixed combination of Arthemether-Lumefantrine for three consecutive days, as recommended as one of the first line treatment for uncomplicated malaria in Cameroon.

For assessment of anaemia, heparinised micro capillary tubes containing fresh blood were centrifuged at 15,000 rpm for 5 min (IEC Micro-MB centrifuge). The parked cell volume or hematocrit level was determined using a micro hematocrit reader. Anaemia was defined as hematocrit level <33% (Quakyi et al., 2000).

Fresh stool samples were immediately processed using the Kato-

Katz thick smear method. Two slides were prepared per child, kept refrigerated overnight and egg-counts were performed within 15-24 h after slides preparation. The number of eggs counted in 41.7 mg of faeces was extrapolated as eggs per gram (epg) of faeces. Infected children were treated with a standard oral dose of Mebendazole, 2×100 mg per day for three consecutive days.

Statistical analysis

All statistical analyses were performed using SPSS version 18.0 and threshold for statistical significance was set at p<0.05. Overall descriptive statistics were carried out to select variables for consideration in multivariate regression models, using malaria infection or helminths status as dependent variable. Independent variables that were significant at p<0.10 were included in the models.

Ethical considerations

The study was approved by the National Ethics Committee of Cameroon. Participation was dependent on a written consent given by the parents/guardian of the children.

RESULTS

Description of the study population

A total of 503 children participated in the study which included 269 (53.5%) males and 234 (46.5%) females. About 55.5% resided in the urban area of Mfou, while 44.5% lived in the rural area. Age ranged from 3 to 16 years, with a mean of 8.4±2.7 years. Children from urban Mfou were significantly younger (mean age=7.9±2.0 years; p=0.001) than their rural counterparts (mean age=9.1±3.3 years). A total of 40 children (8.0%) were feverish (axillary temperature>37.5°C) at the time of the survey and the prevalence of fever was significantly elevated in children residing in Mfou urban (22.2%; p=0.024), compared to those from Mfou rural (17.8%).

Prevalence of malnutrition and anaemia in the study children

Table 1 shows the prevalence of the different categories of undernutrition according to WAZ and HAZ scores' classification, as well as in relation to the sex of children. Overall, mild undernutrition (-1.01≤Z-score≥-2SD) was more prevalent in these children, while the prevalences of moderate (-2.01≤Z-scores≥-3SD) and severe (Z-scores<-3SD) undernutrition were relatively low. Children residing in the rural area had significant increased chances of being underweight compared to their urban counterparts (OR=1.63, 95% CI: 1.02-2.61; p=0.040). Likewise, male schoolchildren relative to females, showed increased chances of been underweight (OR=1.66, 95% CI: 1.04-2.66; p=0.033). There was a significant age-related increase in the prevalence of underweight (p=0.041). Similarly, rural schoolchildren had more than two-fold increased chances of being stunted than those living in urban Mfou (OR=2.33, 95% CI: 1.59-3.42; p=0.000). Also, male schoolchildren showed increased chances of been stunted compared to females (OR=1.59, 95% CI: 1.09-2.34; p=0.016). There was no significant age-related change in the prevalence of stunting (p=0.210). The overall prevalence of anaemia was 33.5% (168 children) and there was no significant difference between the proportion of anaemic children residing in the rural area (33%, n=74) and that from urban Mfou (33.6%, n=94). Likewise, no significant difference was observed in the prevalence of anaemia between male and female schoolchildren. However, there was a significant age-related decrease (p=0.000) in the prevalence of anaemia; ranging from 66.7 to 37.7% and 17.3%, respectively in under 5, 5-9 and 10-16 years old children. Additionally, children with mild to severe underweight showed increased prevalence of anaemia (43.3%) compared to healthy ones (36.7%), but the difference was not statistically significant (p=0.246). Likewise, those with mild to severe stunting were also more likely to be anaemic (36.9%) compared to healthy ones (31.9%). The difference also did not reach statistical significance (p=0.156).

Prevalence and intensities of malaria and soil-transmitted helminths in children

Overall, 204 children (40.6%) were infected with malaria parasites, among whom, 182 (89.2%) were asymptomatic carriers and 22 (10.8%) were symptomatic cases (axillary temperature>37.5°C). *Plasmodium falciparum* was the predominant species (96.6%) with parasite density ranging from 0-792,000 parasites/ μl of blood. There was no significant difference in the prevalence and geometric mean parasite density in relation to sex of children and the area of residence; however, an age-related decrease in the geometric mean parasite density was observed (Table 2).

A total of 149 children (29.6%) were infected with STHs. They included: 113 cases of *A. lumbricoides* (75.8%), 79 cases of *T. trichiura* (53%) and 45 cases of co-infections with both species (30.2%). No infection with hookworm was detected. The prevalence of STHs was significantly higher in rural schoolchildren (40.6%; p=0.000) compared to those living in Mfou urban (20.8%). However, geometric mean density of *T. trichiura* was significantly elevated in children from urban Mfou (mean=307 epg; p=0.039) compared to rural school children (mean=130 epg). Children infected with *T. trichiura* had more than two fold increased chances of been underweight compared to uninfected ones (OR=2.33, 95% CI: 1.25-4.36; p=0.008). There was no significant association between the prevalence of anaemia and presence of STHs. However, children co-infected infected with malaria parasites and STHs showed increased

Table 1. Prevalence of malnutrition and anaemia in relation to sex of children.

Characteristic	Male		Female		Total population		P- value
	n	Prevalence (%)	n	Prevalence (%)	n	Prevalence (%)	
Underweight category							
Mild (-1.01≤WAZ≥-2)	50	24.6	36	19.6	86	22.2	0.015
Moderate (-2<WAZ≥-3)	9	4.4	0	0.0	9	2.3	
Severe (-3<WAZ)	1	0.5	1	0.5	2	0.5	
Normal (WAZ≥-1.0)	143	70.4	147	79.9	290	74.9	
Total population	203	52.5	184	47.5	387	100	/
Stunting category							
Mild (-1.01≤HAZ≥-2)	68	25.3	42	17.9	110	21.9	0.051
Moderate (-2<HAZ≥-3)	21	7.8	17	7.3	38	7.6	
Severe (-3<HAZ)	8	3.0	2	0.9	10	2.0	
Normal (HAZ≥-1.0)	172	63.9	173	79.3	345	68.6	
Total population	269	53.5	234	46.5	503	100	
Anaemia status							
Anaemia (hematocrit<33%)	88	32.7	80	34.3	168	33.5	0.701
*Mean hematocrit	269	37.1±4.9	233	36.8±4.7	502	36.9±4.9	0.544

WAZ=W eight-for-age Z-scores; HAZ=Height-for-age Z-scores; WAZ indices were calculated for children aged 3-10 years, while HAZ indices were calculated for those aged 3-16 years; * values are arithmetic means ± standard deviation.

Table 2. Prevalence of malaria and geo-helminths in relation to age of children.

Characteristic	Age category (years)			Total population	P value
	3-4	5-9	10-16		
Total number of children surveyed	45	290	168	503	/
Prevalence of malaria, % (n)	42.2 (19)	40.7 (118)	39.9 (67)	40.6 (204)	0.958
Light parasiteamia*, %	26.3	50.8	74.6	56.4	
Moderate parasiteamia, %	42.1	33.1	19.4	29.4	
Heavy parasiteamia, %	10.5	15.3	4.5	11.3	0.000
Very heavy parasiteamia, %	21.1	0.8	1.5	2.9	
Geometric mean parasiteamia, % (parasites/μl of blood)	1394 (120, 792000)	508 (40, 10400)	238 (40, 10440)	435 (40, 792000)	0.004
Prevalence of STHs**, % (n)	15.6 (7)	23.8 (69)	43.5 (73)	29.6 (149)	0.000

Table 2. Contd.

Prevalence of *Ascaris lumbricoides*, %	13.3 (6)	18.6 (54)	31.5 (53)	22.5 (113)	0.002
Light density (1-4999 epg†), %	66.7	74.1	58.5	66.4	
Moderate density (5000-49999 epg) , %	33.3	25.9	39.6	32.7	0.456
Heavy density (≥50000 epg) , %	0.0	0.0	1.9	0.9	
Geometric mean parasite density, % (epg)	4301 (1248-34464)	1628 (96-48192)	2373 (96, 50496)	2045 (96, 50496)	0.307
Prevalence of *Trichuris trichiura*	6.7 (3)	11.7 (34)	25.0 (42)	15.7 (79)	0.000
Light density (1-999 epg)	100	79.4	83.3	82.3	
Moderate density (1000-9999 epg)	0.0	20.6	16.7	17.7	0.647
Heavy density (≥10000 epg)	0.0	0.0	0.0	0.0	
Geometric mean parasite density (epg)	76 (48, 96)	191 (24, 3792)	169 (24, 6408)	173 (24, 6408)	0.738
Prevalence of co-infections‡	8.9 (4)	10.7 (31)	20.2 (34)	13.7 (69)	0.010

*Classification of malaria parasiteamia: light parasiteamia (1-499 parasites/µl of blood), moderate parasiteamia (500-1999 parasites/µl of blood); heavy parasiteamia (2000-9999 parasites/µl of blood) and very heavy parasiteamia (≥10000 parasites/ µl of blood); **Stool were examined using the Kato-Katz thick smear technique; †epg=egg per gram of faeces; ‡Co-infections= concomitant presence of malaria parasites and worms eggs.

Table 3. Univariate and multivariate logistic regression analyses of the association between malaria infection and independent factors.

Variable		Malaria positive (n=204)	Malaria negative (n=299)	Univariate analysis (OR***, 95% CI)	p-value	Multivariate analysis (Adjusted OR, 95% CI)	p-value	p-value for trend‡
Fever*	No	182 (39.3)	281 (60.7)	1				
	Yes	22 (55.0)	18 (45.0)	1.88 (0.98-3.61)	0.056	1.80 (0.86-3.78)	0.118	
Anaemia**	No	195 (39.9)	294 (60.1)	1				
	Yes	9 (69.2)	4 (30.8)	3.38 (2.29-4.97)	0.000	2.64 (1.71-4.07)	0.000	
Underweight categories†	Normal	119 (41.0)	171 (59.0)	1				
	Mild	45 (52.3)	41 (47.7)	1.57 (0.97-2.55)	0.065	1.49 (0.90-2.48)	0.117	
	Moderate to severe	1 (9.1)	10 (90.9)	0.14 (0.01 (1.13)	0.066	0.13 (0.01-1.12)	0.064	0.046
Ascaris lumbricoides	No	148 (37.9)	242 (62.1)	1				
	Yes	56 (49.6)	57 (50.4)	1.61 (1.05-2.44)	0.028	1.72 (1.01-2.91)	0.043	

*Fever: Temperature>37.5°C, **anaemia: Parked cell volume or hematocrit<33%, ***OR: Odds ratio; †Mild underweight:-1.01SD≤WAZ score≥-2SD and moderate to severe underweight: WAZ<-2 SD in children aged 3-10 years; SD: standard deviation; ‡ p-value for trend for n>2 modalities.

increased chances of been anaemic, although this did not reach statistical significance (OR=1.64, 95% CI: 0.98-2.75; p=0.059). But, mean level of haematocrit was significantly lower (mean=35.4±4.7%; p=0.000) in the latter compared to children with single *Ascaris* or *Trichuris* infections (mean=39.7±4.1%). Table 3 shows the prevalence and intensities of malaria and STHs in relation to age of children.

infection, soil-transmitted helminths and undernutrition (underweight and stunting) in a total of 503 school children, aged 3-16 years, residing in Mfou health district, a forest area with perennial transmission of malaria, in Cameroon. Overall, malaria infection and soil-transmitted helminths (*A. lumbricoides* and *T. trichiura*) detected in these schoolchildren were associated with anaemia (malaria infection and to a certain extent malaria-helminth co-infections), undernutrition (underweight and stunting), and the area of residence (STHs).

The prevalence of malaria infection and STHs observed in these children are similar or lower compared to previous figures recorded in schoolchildren in Cameroon and elsewhere in Africa (Quakyi et al., 2000; Kimbi et al., 2005a, b; Egwunyenga and Ataikiru, 2005; Nkuo-Akenji et al., 2006; Achidi et al., 2008; Ayalew et al., 2011). In fact, in many areas where malaria infection and helminthiases are co-endemic, schoolchildren usually harbour the heaviest burden of the infections, with associated morbidity, especially when co-infected (Mwangi et al., 2006; Achidi et al., 2008). The survey was conducted at the beginning of the rainy season when malaria transmission was more likely to be elevated. However, over the past years, there have been some fluctuations in climate, often resulting in prolonged dry season periods in the study locality, as well as elsewhere in the country.

No significant difference was observed in the prevalence of malaria infection between rural schoolchildren and those residing in the urban area of Mfou; thus, suggesting probably a similar rate of transmission between the two localities. In fact, the environment in Mfou urban (an emerging semi-urban area) is closely related to that of Mfou rural, with stagnant water bodies, streams and swampy areas that are pre-sent year round and provide breeding sites for *Anopheles* mosquitoes. Factors significantly associated with increased risk of malaria infection included: Anaemia and infection with *A. lumbricoides*; while association with mild underweight did not reach statistical significance. In fact, association between malaria infection and anaemia is well recognized as malaria parasite, *P. falciparum* lives inside the red cell, and requires haemoglobin for its development. Thus, completion of the parasite life cycle is associated with the break-down of red blood cells leading to anaemia. However, the cause of anaemia has been shown to be multifactorial, and we found a significant low mean level of haematocrit in children co-infected with malaria parasites and STHs compared to those with a single helminth infection. It is also possible that in these children with prevalent undernutrition, low dietary intake in iron, or malabsorption of iron could also contribute to anaemia. In fact, increased prevalence of anaemia was observed in undernourished children (underweight and stunted), compared to normal children, however, the difference did not reach statistical significance.

Looking at the association between malaria infection and STHs, particularly, infection with *A. lumbricoides*, our data suggests increased susceptibility to asymptomatic malaria infection with concomitant *Ascaris* infection. In fact, there have been conflicting reports on the association between these two infections (Mwangi et al., 2006). Some studies conducted in patients with severe clinical forms of malaria (Nacher et al., 2002) or in schoolchildren (Murray et al., 1978) or children living in rural areas (Brutus et al., 2007) have suggested a protective effect of *A. lumbricoides* on malaria, while other studies have suggested a negative effect of this parasite or other worm infections on malaria (Spiegel et al., 2003; Sokhna et al., 2004; Le Hesran et al., 2004; Druilhe et al. 2005). As intensity of infection with *A. lumbricoides* seems to be important in this association as cited in these studies, we observed an increasing prevalence of malaria infection with increasing *Ascaris* load (moderate or heavy intensities), but this association was not statistically significant.

On the other hand, after adjusting for other factors, association between asymptomatic malaria infection and underweight (an indicator of both acute and chronic undernutrition) did not reach statistical significance (p=0.117). In fact, mild underweight (-1.01≤WAZ≥-2SD) was associated with increased risk of malaria infection (p=0.065), while moderate to severe underweight (WAZ<-2SD) was instead associated with a reduced risk of mala-ria infection (p=0.066). However, the limited sample size of this latter category (n=13) did not allow us to make an interpretation of the observations. Previous studies on the relationship between undernutrition and asymptomatic malaria have often lead to controversial findings. Some studies have shown a positive association while others did not. For example, in a study conducted in Equatorial Guinean children, stunting was positively related to mala-ria infection, while no significant association was found with wasting and underweight (Custodio et al., 2009). Additionally, in another study conducted in Ghanaian children, Crookston et al. (2010), found no significant association between chronic undernutrition and asymptomatic malaria detected by polymerase chain reaction (PCR).

However, it should be noted that most of these studies were conducted in children aged less than 5 years, while our study included children up to 16 years, as late school entrance is common in rural primary schools in Mfou. Other factors that could explain differences observed could be the level of transmission, the study design, including the diagnostic method used for malaria (microscopy or PCR), childrens' diets and also intercurrent infections.

Moreover, infection with STHs, particularly *T. trichiura* was significantly associated with increased risk of underweight, but this did not reach statistical significance after adjusting for area of residence and age of the children (p=0.073). Previous studies have suggested that intestinal helminthiasis compromise healthy nutrition and growth in infected children. The variety of mechanisms used include reduced food intake due to malabsorption and/or reduced appetite, which result in higher levels of stunting (Stoltzfus et al., 1997; Stephenson et al., 2000; Crampton and Nesheim, 2002; Hotez et al., 2008; Hall et al., 2008; Brooker et al., 2010).

On the other hand, prevalence of STHs was significantly elevated in rural schoolchildren, with more than twofold increase in chance of being infected compared to children residing in urban Mfou. This is likely due to the sanitation conditions in rural areas where the majority of households do not have access to good potable water, and this offers the possibility for the spread and maintenance of these infections.

No infection with hookworm was detected in our study population and this is probably due to the low prevalence in the study area based on statistics of the clinical laboratory of Mfou district hospital, which is the referral hospital in the district. This could also be related to the fact that the Kato-Katz slides were not read immediately after preparation. It is likely that hookworm eggs deteriorate during the 15-24 h incubation period before slides reading. This likely lead to underestimation, as it has been suggested that hookworm eggs collapsed and disappeared shortly after the thick smear had cleared (Santos et al., 2005).

On the other hand, mild to severe underweight (WAZ≤-1.01SD) was significantly associated with the area of residence, sex and age of children. A sex-related increase in the prevalence of undernutrition was observed, with boys significantly more likely to be underweight or stunted, than girls. This observation has already been noted in previous studies (Stoltzfus et al., 1997; Genton et al., 1998; Wamani et al., 2007); and it has been suggested that the daily energy and micronutrients intakes of the study population could be different by sex. Also, malaria infection and geo-helminths could act as cofounders in this association, but we did not find any sex-related association with these two infections.

Conclusion

The cross-sectional nature of our study limits the interpretation of some of the observations, but the data provide additional support to the fact that malaria infection and STHs exacerbate anaemia and undernutrition in schoolchildren of the study locality. Also, concomitant *Ascaris* infection increases the risk of malaria infection in these schoolchildren. Thus, current preventive strategies including use of long lasting insecticide treated bed nets in households and annual school-based deworming programs coupled with a nutritional component should be reinforced in this age group.

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