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MODERATE- AND LOW-INTENSITY CO-INFECTIONS BY INTESTINAL HELMINTHS AND *SCHISTOSOMA MANSONI*, DIETARY IRON INTAKE, AND ANEMIA IN BRAZILIAN CHILDREN

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Abstract. To determine the role of moderate- and low-intensity infections with *Schistosoma mansoni* and intestinal helminths (hookworm, *Trichuris trichiura, Ascaris lumbricoides*) on the prevalence of anemia and their relationship to iron consumption, a cross-section of 1,709 children in rural Brazil was studied. All participants were selected for infection with one or multiple helminthic parasites, and demographic, anthropometric, and dietary intake were surveyed. The prevalence and intensity were as follows: hookworm infection, 15.7% and 8.6 eggs/g; *T. trichiura,* 74.8% and 190.5 eggs/g; *A. lumbricoides,* 63% and 1,905.5 eggs/g; *S. mansoni,* 44.5% and 60.3 eggs/g. There was no increase in odds ratio for anemia with any combination of intestinal helminths without *S. mansoni* infection. By logistic regression, the odds ratio for having anemia when infected with *S. mansoni* and two intestinal helminths was 1.7 (95% CI, 1.1–2.5) and for *S. mansoni* and three intestinal helminths was 2.4 (95% CI, 1.2–4.6) compared with children with a single parasite species. Children with an adequate intake of iron had no increased odds of anemia independent of the combination of parasite infections.

INTRODUCTION

The anemia caused by iron deficiency constitutes one of the biggest nutritional problems in the world, relevant not only in developing but also in highly industrialized countries. Stoltzfus,[1] in a recent review of published data, estimated the number of those affected at two billion. This corresponds to one third of the world's population. It is estimated that one half of schoolchildren in developing countries are anemic,[2] while in tropical South America, the prevalence of anemia among children 6–12 years of age is estimated at 24%.[3] Iron deficiency anemia has been associated with negative effects on cognitive development, school performance,[4] infant growth,[5] resistance to infection,[6] infant birth weight, and infant and maternal morbidity and mortality.[7] In developing countries, inadequate consumption of good sources of iron is pointed to as the major reason for the high prevalence of iron deficiency anemia, but another important factor for consideration is infection by helminths such as *Schistosoma mansoni*, hookworm, *Trichuris trichiura*, and *Ascaris lumbricoides*. The mechanisms by which these parasites can compromise iron status include anorexia, competition for nutrients, chronic micro-hemorrhages caused by mucosal lesions, and decreased iron absorption. Some studies have shown that severe infection with *S. mansoni* has an important role in the development of anemia.[8] Other authors found similar results for hookworm infection[9] and for infection with *T. trichiura*.[10] Few studies have explored the joint effect of multiple simultaneous helminth infection and inadequate iron consumption on anemia. Fewer still have looked at light or moderate infections, despite these representing > 90% of all infections,[11] or the fact that a significant percentage are infected by two or more species. The need for treatment of most heavy infections is fairly clear-cut, but there is less certain support for treatment of the much more common light- or moderate-intensity infections. This study was performed to assess the role of concurrent infections by *S. mansoni* and intestinal helminths (hookworm, *T. trichiura*, and *A. lumbricoides*) of low or moderate intensity and inadequate dietary iron consumption on the prevalence of anemia in children.

MATERIALS AND METHODS

The study was conducted in the urban municipal district of Jequié, located in the southwest region of the Brazilian state of Bahia, 380 km from the state capital, Salvador. Stool examinations were performed on 13,771 boys and girls between 7 and 17 years of age who attended public school. A subsample of 1,709 (12.4%) individuals was selected for this study according to the following scheme: 1) all students infected with low- to moderate-intensity *S. mansoni* (< 400 eggs/g of feces) associated with any intestinal helminth were included, because there was a small number; 2) for those with isolated or associated low- to moderate-intensity infection caused by hookworm (< 2,000 eggs/g of feces), *A. lumbricoides* (< 50,000 eggs/g of feces), or *T. trichiura* (< 20,000 eggs/g of feces), 14.5% were selected at random.

For each individual, two fecal samples were collected, and two slides were examined for each sample, totaling four slides per child. Slide preparation was by the method of Katz and others.[12] By this method, hookworm species cannot be distinguished, because their eggs have similar microscopic appearance. Slides were examined 2 hours after preparation to allow for identification of hookworm eggs for each child examined. The estimate of the number of eggs per gram was obtained by multiplying the mean number of eggs for the two slides by 24.

Hemoglobin concentrations were measured using the Hemocue photometer (Hemocue, Laguna Hills, CA). Finger stick blood was collected using disposable sterile lancets.

Trained nutritionists obtained dietary information. Dietary intake was determined by a 24-hour dietary recall.[13] Bioavailable iron was quantified through an equation developed by Monsen and Balintfy.[14] For this measurement, the total iron,

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heme iron, nonheme iron, and the quantity of ascorbic acid and meat composition at each meal was considered. To adjust for bioavailability, the iron content of each food was first separated into its heme and nonheme components. The assumed proportion of total iron in each food that was nonheme was 60% for meats and 100% for non-meats. Heme iron availability was assumed to be 23%. Nonheme iron availability for each eating occasion was adjusted for meat and vitamin C based on equations developed by Monsen and Balintfy[14] and ranged from 3% to 8%.

Data on environmental sanitation (water supply, sewer system, presence of toilet,) and living conditions were obtained by observations of trained interviewers, supervised by field researchers. Level of income and other socio-economic variables such as education of the head of household were obtained through a standardized questionnaire administered to the person responsible for meals in the household. An indicator of the environmental and household conditions was constructed from these variables. Variables describing household conditions and sanitation were dichotomized as favorable (0) or unfavorable (1) and tested for statistically significant associations with each of the infecting species. Those variables found to be significant were included in a logistic regression model for multivariable analysis. Those that remained significant ($P < 0.15$) were included in the index (Table 1). Sex, age, and education of the head of household were included in the models as covariates. Thirteen variables were found to be significant, and the sum of these for each of the variables was used as the index of environmental and living conditions. The index included the following variables: pavement of the street, type of dwelling, adequacy of floor of the dwelling, adequacy of the wall of the dwelling, frequency of the water supply, piped water system in the dwelling, water storage facility, treatment of drinking water, method of garbage disposal, availability of garbage collection, presence of sewer system, reported site of defecation, and presence of toilet in the dwelling. The distribution of the scores in the community was used to define better (those with a score of 0–6) or worse (score 7–13) living conditions based on the 50th percentile of the index.

TABLE 1

Selected characteristics of household conditions and their association with helminth infections in children in Jequié, Bahia, Brazil, 1997

Household conditions and sanitation	Helminth infections			
	Hookroom	*T. trichiura*	*A. lumbricoides*	*S. mansoni*
Unpaved street*	1.7 (0.04)	0.8 (0.04)	1.0 (0.86)	1.1 (0.47)
No sewer system	1.1 (0.74)	1.4 (0.56)	1.1 (0.90)	0.9 (0.40)
Wooden or adobe construction*	0.4 (0.30)	2.9 (0.8)	0.3 (0.12)	1.0 (0.93)
Poor quality floor*	1.7 (0.15)	1.1 (0.85)	0.9 (0.81)	1.0 (0.91)
Poor quality wall construction*	2.2 (0.00)	1.0 (0.90)	1.3 (0.11)	1.4 (0.83)
Irregular water supply*	1.0 (0.90)	1.3 (0.18)	0.8 (0.23)	1.4 (0.03)
No piped water supply*	1.6 (0.05)	1.2 (0.20)	1.1 (0.62)	1.1 (0.44)
Inadequate water storage facility*	0.9 (0.53)	1.3 (0.10)	1.0 (0.89)	1.1 (0.63)
Untreated drinking water*	1.0 (0.52)	0.9 (0.70)	1.5 (0.00)	1.4 (0.01)
Garbage present in area	1.1 (0.79)	1.0 (0.80)	0.9 (0.70)	0.9 (0.30)
Inadequate garbage disposal*	0.8 (0.30)	1.4 (0.02)	1.0 (0.80)	1.0 (0.77)
Irregular garbage collection	0.9 (0.60)	1.2 (0.23)	1.0 (0.70)	1.2 (0.14)
Open sewer in the area*	0.9 (0.89)	1.1 (0.70)	1.2 (0.33)	1.7 (0.00)
Defecates in the area*	0.8 (0.65)	0.8 (0.69)	1.4 (0.50)	3.3 (0.01)
No toilet in dwelling*	0.9 (0.61)	0.9 (0.62)	1.2 (0.47)	1.7 (0.02)

Values are OR (*P*). All odds ratios adjusted for education of the head of household, sex, age, environmental and household conditions.
* Only those variables that remained significant ($P < 0.15$) were included in the index of the environmental and household conditions.

For statistical analysis, the geometric mean of egg counts per gram of feces was used. The geometric mean is less affected by extreme values than the arithmetic mean and is useful for some positively skewed distributions. The mean egg count was obtained by considering only positive cases. Analysis of covariance (ANCOVA) was chosen along with the Scheffé correction to compare the mean egg counts, stratified by the number of different infecting species. This test is often more conservative than other tests, which means that a larger difference between means is required for significance. Procedures for comparing all possible pairs of group means must adjust for the fact that many comparisons are being made. When many non-independent comparisons are being made, the possibility of finding significant differences by chance increases as the number of comparisons increases. The χ^2 test was used to evaluate the differences between the categorical variables and ANCOVA for the differences between mean hemoglobin concentrations.

For the simultaneous evaluation of confounders (income, sex, age, environmental, and household conditions) and effect modifier (consumption of bio-available iron), multivariable analyses were carried out using the logistical regression model and ANCOVA. A significance level of 0.05 was defined for this study. The statistical packages used were Epinfo (version 6.0)[15] and Stata (version 7.0).[16]

The study was approved by the ethics committees of the Gonçalo Moniz Research Center and Case Western Reserve University. Detailed information about the project and study protocols was provided to the community. All parents or persons responsible for each participating child provided written consent for inclusion in the study. Parasitologic and hemoglobin concentration results were provided to persons responsible for each participant. Children with anemia and/or infected with parasites received treatment. Additionally, an explanatory note about the prevention of anemia and parasitic infections was provided. Individuals infected with intestinal helminths were treated with albendazole (400 mg). Individuals infected with *S. mansoni* were treated with oxamniquine (40 mg/kg in a single dose).

RESULTS

Characteristics of the study population. The geometric mean egg count and the frequency of infection by hookworm, *T. trichiura, A. lumbricoides*, and *S. mansoni* were statistically significantly higher in the subsample compared with the total population of children (Table 2).

Table 3 shows that cases of single infection by *T. trichiura* (15.0%) were most prevalent, followed by *A. lumbricoides* (10.0%). More than one parasite was observed in 74% of the subjects. The greatest prevalences were observed in co-

TABLE 2

Geometric mean egg count and prevalence of helminth infections in subsample and total population of children. Jequié, Bahia, Brazil, 1997

Helminth	Prevalence* Subsample (1,709) (%)	Prevalence* Population (13,771) (%)	Geometric mean intensity Subsample (1,709) [epg† (SD)]	Geometric mean intensity Population (13,771) [epg (SD)]
Hookworm	15.7	8.6	128.8 (4.3)	147.8 (4.6)
T. trichiura	74.8	35.8	190.5 (4.1)	189.1 (4.3)
A. lumbricoides	63.0	31.8	1905.5 (6.0)	2511.9 (6.5)
S. mansoni	44.5	18.9	60.3 (2.5)	91.3 (4.0)

* χ^2 test was used to test the differences of prevalences of parasite species between the subsample and the population: hookworm, $P < 0.01$; *A. lumbricoides,* $P < 0.01$; *T. trichiura,* $P < 0.01$; *S. mansoni,* $P < 0.01$.

† Egg per gram.

infections for *S. mansoni* and *A. lumbricoides* (15.4%), *T. trichiura* and *A. lumbricoides* (14.6%), *S. mansoni* and ascaria (11.2%), *S. mansoni, T. trichiura*, and *A. lumbricoides* (18.1%), and *S. mansoni,* hookworm, *T. trichiura*, and *A. lumbricoides* (5.0%).

Table 4 shows the geometric mean and the frequency of infections by hookworm, *T. trichiura, A. lumbricoides*, and *S. mansoni* among individuals with single or multiple helminths infections. The average number of hookworm eggs per gram of feces was not significantly different among the groups with multiple helminth infections compared with the single helminth group. The average number of *A. lumbricoides* was higher in the *S. mansoni* group infected with two or three intestinal helminths compared with those with single species infections. For *T. trichiura*, the average number of eggs per gram of feces was significantly higher in the groups with multiple infections compared with the number of eggs in those infected with a single intestinal helminth. The prevalence of *A. lumbricoides, T. trichiura,* and hookworm was significantly higher in the groups that showed multiple infections by two or three intestinal helminths compared with the prevalence in those infected with one intestinal helminth. It is striking that, in general, the intensity of infection increases concomitantly with the increase in the number of intestinal helminth species,

TABLE 3

Number and prevalence of single and multiple infecting species in children in Jesquié, Bahia, Brazil, 1997

Infecting species	Helminths	Number (%)
1	Hookworm	15 (0.9)
	T. trichiura	258 (15.1)
	A. lumbricoides	170 (10.0)
2	*S. mansoni* + hookworm	23 (1.4)
	S. mansoni + *T. trichiura*	263 (15.4)
	S. mansoni + *A. lumbricoides*	191 (11.2)
	Hookworm + *T. trichiura*	19 (1.1)
	Hookworm + *A. lumbricoides*	8 (0.5)
	T. trichiura + *A. lumbricoides*	250 (14.6)
3	*S. mansoni* + hookworm + *T. trichiura*	54 (3.2)
	S. mansoni + hookworm + *A. lumbricoides*	23 (1.4)
	S. mansoni + *T. trichiura* + *A. lumbricoides*	309 (18.1)
	Hookworm + *T. trichiura* + *A. lumbricoides*	40 (2.3)
4	*S. mansoni* + hookworm + *A. lumbricoides* + *T. trichiura*	86 (5.0)

independent of the presence of *S. mansoni* infection. Infection with *S. mansoni* was not a marker for susceptibility to other parasites. This is consistent with their differing modes of transmission.

Table 5 stratifies individuals according to the number of intestinal helminth infections and socio-demographic and environmental conditions. Children infected with multiple helminth species had significantly less favorable environmental and living conditions than those infected with a single species. Income level was also significantly lower ($P < 0.01$, χ^2 test) for those with infected with two or three intestinal helminths, whether *S. mansoni* was present, compared with the group infected with one intestinal helminth. When adjusted for sex and age, only children infected with *S. mansoni* plus one, two, or three intestinal helminths were significantly different from those infected with only one parasite ($P < 0.05$, χ^2 test). Men and children 10 years and older presented with higher prevalences of infection than women and younger children ($P < 0.01$ and $P < 0.05$, respectively, χ^2 test). Only individuals infected with *S. mansoni* and three intestinal helminths had significantly lower iron intake than those infected with one intestinal helminth (Table 6; $P < 0.05$, χ^2 test).

Multiple infections by helminths and anemia. A strong interaction was detected between the consumption of bioavailable iron and the helminth infection groups ($P = 0.02$). Individuals with inadequate dietary iron consumption and *S. mansoni* infection associated with two or more intestinal helminths showed lower serum hemoglobin concentrations and a significantly higher prevalence of anemia compared with the group infected with one intestinal helminth. However, in the group of individuals with adequate iron intake, there were no statistically significant differences relative to mean serum hemoglobin and the prevalence of anemia regardless of infection status (Table 6).

In children with adequate iron consumption, multiple infections were not significantly associated with anemia, even after adjustments for potential confounders (household income, environmental and household conditions, age, and sex). However, among those with inadequate iron consumption, positive associations between anemia and multiple infections were observed, when *S. mansoni* infection was accompanied by two (OR, 1.7; 95% CI, 1.1–2.5) or three (OR, 2.4; 95% CI, 1.2–4.6) helminthic infections, even after adjusting for the same confounding variables (Table 7).

DISCUSSION

This study showed that concurrent infections with *S. mansoni* and two or more intestinal helminths, even in low to moderate intensities, constitute an important factor of anemia in schoolchildren with inadequate dietary iron. From these data, it seems that, in individuals with borderline iron consumption, helminth infection may be the final biologic insult that results in anemia. This effect persists even after controlling for social, environmental, and household effects.

In this study, anemia was not associated with inadequate iron consumption and multiple intestinal helminth infections in the absence of *S. mansoni* infection. However, this group of individuals exhibited lower intensities of intestinal helminths compared with those who were also infected with *S. mansoni*. Furthermore, the majority of this group (87.4%) was infected

TABLE 4

Geometric mean and prevalence of helminth infections by number and type of infecting species in children in Jequié, Bahia, Brazil, 1997

Helminth infections		Single or multiple helminth infection				
		1 IH* (a) (N = 443)	2 or 3 IH (b) (N = 317)	*S. m*† + 1 IH (c) (N = 477)	*S. m* + 2 IH (d) (N = 386)	*S. m* + 3 IH (e) (N = 86)
Hookworm	GM (±SD)‡§	130.5 (5.2)	161.2 (4.7)	89.3 (2.9)	178.8 (4.1)	188.7 (4.6)
	Percent infected¶	3.4	21.1	4.0	20.0	100.0
T. trichiura	GM (±SD)‡	150.2 (3.5)	219.7 (6.1)	200.4 (3.5)	301.4 (4.4)	487.7 (4.6)
	Percent infected¶	58.2	97.5	55.1	94.1	100.0
A. lumbricoides	GM (±SD)‡	1221.9 (5.2)	2534 (6.6)	1473.2 (5.7)	3730.8 (5.5)	4461.1 (4.9)
	Percent infected¶	38.4	94.0	40.0	86.0	100.0
S. mansoni	GM (±SD)‡	–	–	66.8 (2.4)	63.6 (2.5)	70.8 (2.5)
	Percent infected¶	–	–	100.0	100.0	100.0

* IH = intestinal helminth.
† *S. m* = *S. mansoni.*
‡ GM = geomeric mean.
§ Scheffé test was used to test the differences geometric mean of eggs of parasite species: hookworm $P > 0.05$ (a/b, a/c, a/d, a/e) (ANOVA F = 2,52 df = 3 P = 0.06); *A. lumbricoides* $P < 0.01$ (a/b, a/d, and a/e) $P > 0.05$ (a/c) (ANOVA F = 3,06 df = 3 P = 0.02); *T. trichiura* $P < 0.01$ (a/b, a/c, a/d, a/e) (ANOVA F = 6,34 df = 3 P = 0.00).
¶ χ^2 test was used to compare prevalences of parasite species between the groups with multiple helminth infections and the group infected with only one intestinal helminth species: hookworm $P < 0.01$ (a/b, a/d, and a/e) $P > 0.05$ (a/c); *A. lumbricoides* $P < 0.01$ (a/b, a/d, and a/e) $P > 0.05$ (a/c); *T. trichiura* $P < 0.01$ (a/b, a/d, and a/e) $P > 0.05$ (a/c).

with two intestinal helminths (87.4%). As a result, blood losses may not have been sufficient for the development of anemia. Some authors suggest that the presence and persistence of anemia are probably dependent on severe intestinal helminth infections.[9,10] Studies that analyzed the relationship between anemia and hookworm infection concluded that infection intensities > 2,000 eggs/g of feces could probably to cause a significant decrease in hemoglobin concentrations,[10] because 38.0% to 68.0% of blood leaked by the hookworm is reabsorbed by the intestine itself.[17] This explains in part the seeming resistance of parasitized individuals to developing anemia.[17] In addition, in this area, the prevalent species is *Necator americanus,* a species associated with lower capacity per worm for sucking blood.[18] For *T. trichiura* infection, Ramdath and others[10] studied the association between infection intensity and iron concentrations in children and adolescents and concluded that iron deficiency anemia was associated with high intensity infection, but not with low- or moderate-intensity *T. trichiura* infections.

Although an association between anemia and multiple low- and moderate-intensity infections caused by different intestinal helminths alone was not found in this study, other studies have concluded that lesser-intensity infections can be associated with anemia.[19] The differences between these studies could probably be resolved if co-factors including other helminth infections were known. Curtale and others[19] found that the low-intensity infection caused by hookworm was associated with anemia. The authors attribute this finding to the fact that the individuals infected with hookworm were also infected with *A. lumbricoides*. Robertson and others[20] observed that children and adolescents with multiple infections caused by hookworm and *T. trichiura* show significantly lower concentrations of hemoglobin than those not infected or who presented infection by just one of these intestinal helminths.

In this analysis, *S. mansoni* infections were treated separately from intestinal helminth infections, because of the fact that they differ in their mode of infection (skin penetration in contaminated water versus ingestion or skin penetration from contaminated soil) and their lifestyle (residence in the blood stream of mesenteric veins versus dwelling in the intestinal lumen). The host response to these two classes of parasites is likewise different as are their major morbidities. In the development of anemia, schistosome infection seems to be a necessary but not sufficient condition for intestinal helminth contribution to risk. In *S. mansoni* infection, blood losses are caused by lesions, which can occur throughout the whole intestine, caused by immune complexes and toxic factors released by the eggs of *S. mansoni.*[21] These blood losses are probably aggravated by co-infection with *T. trichiura* and hookworms, because these are also responsible for the loss of host's blood. Therefore, the occurrence of chronic hemorrhage caused by these parasites would increase the demand for iron, making this group more disposed toward anemia. Besides the blood losses, there are other mechanisms by which parasitic intestinal infections can compromise iron nu-

TABLE 5

Sociodemographic and environmental data by number and type of infecting species in children in Jequié, Bahia, Brazil, 1997

Variables	Prevalence of single or multiple helminth infections*				
	1 IH† (a) (N = 443)	2 or 3 IH (b) (N = 317)	*S. m*‡ + 1 IH (c) (N = 477)	*S. m* + 2 IH (d) (N = 386)	*S. m* + 3 IH (e) (N = 86)
Age					
7–9 years	37.5	40.7	21.2	25.6	18.1
10–14 years	54.4	53.3	59.3	60.1	58.1
15–17 years	8.1	6.0	19.5	14.2	23.3
Sex					
Female	51.2	54.9	43.0	40.2	31.4
Male	48.8	45.1	57.0	59.8	68.6
Family income					
< ¼ MW§	47.2	61.2	52.4	56.0	60.2
¼–½ MW	27.9	26.0	29.1	29.6	33.7
≥ ½ MW	24.9	12.8	18.5	14.4	6.0
Environmental and household conditions					
Adequate	64.9	57.9	58.6	45.9	38.5
Inadequate	35.1	42.1	41.4	54.1	61.5
Bioavailable iron intake					
Adequate	47.9	44.4	43.0	42.4	33.7
Inadequate	52.1	55.6	57.0	57.6	66.3

* χ^2 test was used to test the differences of sociodemographic and environmental features between the groups with multiple helminth infections and the group infected with only one intestinal helminth species: age $P < 0.01$ (a/c, a/d, and a/e) $P > 0.05$ (a/b); sex $P < 0.05$ (a/c, a/d, and a/e) $P > 0.05$ (a/b); per capita family income $P < 0.01$ (a/b, a/d, and a/e) $P > 0.05$ (a/c); environmental and household conditions $P < 0.05$ (a/b, a/c, a/d, a/e); adequacy of bioavailable iron $P > 0.05$ (a/b, a/c, a/d) and $P < 0.05$ (a/e).
† *S. m* = *S. mansoni.*
§ MW, minimum wage calculated as monthly minimum equivalent to ~$100 at the time of the study.

TABLE 6

Hemoglobin concentration and prevalence of anemia in children by single or multiple infecting helminth species and adequacy of dietary intake of bioavailable iron

	Bioavailable iron consumption			
	Adequate		Inadequate	
Infection status	Mean hemoglobin (SE)*†	Prevalence of anemia‡ [% (95% CI)]	Mean hemoglobin (SE)	Prevalence of anemia [% (95% CI)]
One intestinal helminth (a)	12.4 (1.3)	27.6 (21.5–33.7)	12.3 (1.3)	29.8 (23.8–35.8)
Two or three intestinal helminths (b)	12.2 (1.2)	31.4 (23.6–39.2)	12.4 (1.2)	28.0 (21.3–34.7)
S. mansoni + 1 intestinal helminth (c)	12.5 (1.3)	30.4 (24.0–36.8)	12.4 (1.3)	32.6 (27.0–38.2)
S. mansoni + 2 intestinal helminths (d)	12.5 (1.3)	27.8 (20.8–34.7)	12.1 (1.3)	43.2 (36.6–49.8)
S. mansoni + 3 intestinal helminths (e)	12.3 (1.2)	31.0 (13.1–48.9)	11.9 (1.2)	50.9 (37.4–64.3)

* Mean hemoglobin concentrations adjusted for income, sex, age, environmental, and household conditions.
† ANCOVA used to test the differences of the average of hemoglobin between groups. In the group with adequate iron consumption $P > 0.05$ (a/b, a/c, a/d, a/e) and in the group with inadequate iron consumption: $P < 0.05$ (a/e); $P = 0.05$ (a/d) e $P > 0.05$ (a/b, a/c). Linearity test $P = 0.39$.
‡ χ^2 test was used to test the differences of the prevalence of anemia between the groups. In the group with adequate iron consumption $P > 0.05$ (a/b, a/c, a/d, a/e) and in the group with inadequate iron consumption: $P < 0.05$ (a/d and a/e); $P > 0.05$ (a/b and a/c). χ^2 trend test $P < 0.01$.

trition, such as anorexia, competition for nutrients, and decrease in absorptive capacity.

There are few studies of the role *S. mansoni* and intestinal helminth co-infection at low to moderate intensities for developing anemia. This makes the comparative analysis of the findings difficult. Some studies suggest an inverse relationship between the degree of infection caused by *S. mansoni* and concentrations of hemoglobin.[8,22] However, in studies involving schoolchildren, significant reductions in the concentration of hemoglobin related to the increase in the degree of infection were not observed.[23] Friis and others,[24] also studying schoolchildren, showed that intensity of *S. mansoni* infection was not predictive of ferritin concentrations. These results are similar to those found by Latham and others,[25] in which there was no association found between hemoglobin concentrations and infection by *S. mansoni* in rural workers from Kenya. In these studies that failed to observe an association between anemia and *S. mansoni* infection, however, either intestinal helminths were not factored into the analysis or the study was conducted on adult men. There are few data on the impact of deworming in subjects with differing initial levels of infection and hemoglobin. Treatment was shown to be of hematological benefit to children who were both anemic and co-infected with schistosomes and geohelminths.[26]

There is probably a complex interaction of environment, diet, parasites, sex, and socio-economic status that ultimately produces anemia. The examination of these factors in isolation may lead to an erroneous conc1usion that one factor or another makes no contribution to this condition. When analyzed as intensity of individual species, associations have been difficult to observe except for schistosome or *T. trichiura* or heavy hookworm infections. However, in our data, even after adjusting for socio-economic factors and sex, one intestinal helminth infection in combination with schistosomiasis does exacerbate the effects of inadequate iron intake. This effect was not significant, unless there were two or more infecting species of intestinal helminths. Previous studies have suggested that there is a substantial genetic component to susceptibility to *Ascaris* infection in humans; the quantitative trait loci on chromosomes 1 and 13 provide strong evidence for the influence of at least two discrete genes on *Ascaris* burden.[11] Although intestinal helminth infection is mutually correlated with other factors to some degree, this infection does contribute a portion of risk for the development of anemia conditioned on the presence of other risk factors. For this reason, when analyzed alone or when independent of other risk factors, intestinal helminths may not seem to be a major factor in nutritional deficits, as has been the conclusion of this group in some previous studies.[27,28]

TABLE 7

Association between anemia and helminth infections in schoolchildren according to adequacy of dietary intake of bioavailable iron

	Bioavailable iron consumption	
Helminth infections	Adequate OR* (95% CI)	Inadequate OR (95% CI)
One geohelminth	1.0	1.0
Two or 3 geohelminths	1.3 (0.8–2.1)	0.8 (0.6–1.4)
S. mansoni + 1 geohelminth	1.1 (0.7–1.7)	1.1 (0.7–1.6)
S. mansoni + 2 geohelminths	0.9 (0.5–1.5)	1.7 (1.1–2.5)
S. mansoni + 3 geohelminths	1.0 (0.4–2.5)	2.4 (1.2–4.6)

* All odds ratios adjusted for income, sex, age, environmental, and household conditions.

A limitation of our cross-sectional study is that it is impossible to determine if polyparasitism proceeds or follows anemia. Therefore, causation cannot be attributed to polyparasitism. Clearly the role of these infections in anemia would be better assessed by means of prospective studies. These types of studies would allow for comparison of the coefficient of anemia incidence and the degree of exposure to the infections, establishing risk differentials.

Our findings and other evidence from the literature support the idea that the strategies to be adopted to control anemia in childhood and adolescence should include the control of helminth infections, especially infection caused by *S. mansoni*. This should be integrated with specific nutritional interventions and the promotion of nutrition education, iron supplements, and fortification of foods with this mineral.[29]

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