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Prevalence of Co-infection with *Schistosoma mansoni* and Soil-Transmitted Helminths: Association with Cognitive Performance and Nutritional Status among School-Aged Children in Mbam and Inoubou Division, Cameroon

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ABSTRACT

Intestinal helminth infections, including schistosomiasis and soil-transmitted helminthiases, remain a significant health challenge among school-aged children in developing countries, such as Cameroon, where parasitic co-infections are common. In this study, we investigated the prevalence of intestinal helminth infections among school-aged children and assessed their association with cognitive performance and nutritional status. A cross-sectional study was conducted from May to June 2025 in three public primary schools in the Mbam and Inoubou Division, Cameroon. A total of 126 children (aged 7 to 14 years) were enrolled; each provided one stool sample that was examined using Mini-FLOTAC and formol-ether concentration techniques. Cognitive performance was assessed with neuropsychological tasks adapted for school-aged children, evaluating five core domains of cognitive function: (i) verbal fluency, (ii) attention, (iii) memory, (iv) calculation, (v) cognitive flexibility. Anthropometric measurements were obtained using standard procedures. Data were analyzed using appropriate statistical tests (Mann-Whitney U test, Kruskal–Wallis test, Chi-squared (x^2), Fisher's exact test, ANOVA), with significance set at $P < 0.05$. The overall prevalence of intestinal helminth infections was 36.51%. *Schistosoma mansoni* (mono- and co-infections) was the most prevalent species (20.63%), followed by *Ascaris lumbricoides* (mono- and co-infections) (19.84%), hookworms (mono- and co-infections) (6.35%), and *Strongyloides stercoralis* (mono- and co-infections) (0.79%). Co-infection with at least two species was observed in 8.73% of children, most frequently *A. lumbricoides* + *S. mansoni* (6.35%). Children infected with *A. lumbricoides* showed significantly lower cognitive performance than uninfected children. *Schistosoma mansoni* infection was significantly associated with poor school performance ($P = 0.02$) and with high exposure to transmission factors ($P = 0.009$). No significant difference in BMI was observed between infected and uninfected children ($P = 0.06$). These findings highlight the need for integrated control strategies combining mass drug administration, improved sanitation, health education, and nutritional support.

Key words: *Schistosoma mansoni*, soil-transmitted helminths, cognitive performance, nutritional status, school-aged children.

RÉSUMÉ

Les infections par les helminthes intestinaux, y compris la schistosomiase et les géohelminthiases, demeurent un important problème de santé chez les enfants d'âge scolaire dans les pays en développement tels que le Cameroun, où les co-infections parasitaires sont fréquentes. Cette étude avait pour objectif d'évaluer la prévalence des infections par les helminthes intestinaux chez les enfants d'âge scolaire ainsi que leur association avec les performances cognitives et l'état nutritionnel. Une étude transversale a été menée de mai à juin 2025 dans trois écoles primaires publiques du département du Mbam-et-Inoubou, au Cameroun. Au total, 126 enfants (âgés de 7 à 14 ans) ont été recrutés; chacun a fourni un échantillon de selles analysé à l'aide des techniques Mini-FLOTAC et de concentration formol-éther. Les performances cognitives ont été évaluées à l'aide de tests neuropsychologiques adaptés aux enfants d'âge scolaire, permettant d'évaluer cinq domaines fondamentaux de la fonction cognitive: (i)

la fluence verbale, (ii) l'attention, (iii) la mémoire, (iv) le calcul et (v) la flexibilité cognitive. Les mesures anthropométriques ont été réalisées selon les procédures standardisées. Les données ont été analysées à l'aide de tests statistiques appropriés (le test U de Mann-Whitney, le test K de Kruskal-Wallis, le chi carré (x^2), le test exact de Fisher et l'ANOVA), avec un seuil de significativité fixé à $P < 0,05$. La prévalence globale des infections par les helminthes intestinaux était de 36,51 %. *Schistosoma mansoni* (mono et co-infections) était l'espèce la plus fréquente (20,63 %), suivie d'*Ascaris lumbricoides* (mono et co-infections) (19,84 %), des Ankylostomes (mono et co-infections) (6,35 %) et de *Strongyloides stercoralis* (mono et co-infections) (0,79 %). Une co-infection impliquant au moins deux espèces a été observée chez 8,73 % des enfants, l'association la plus fréquente étant *A. lumbricoides* + *S. mansoni* (6,35 %). Les enfants infectés par *A. lumbricoides* présentaient des performances cognitives significativement plus faibles que les enfants non infectés. L'infection à *Schistosoma mansoni* était significativement associée à de mauvais résultats scolaires ($P = 0,02$) ainsi qu'à une forte exposition aux facteurs de transmission ($P = 0,009$). Aucune différence significative de l'IMC n'a été observée entre les enfants infectés et non infectés ($P = 0,06$). Ces résultats soulignent la nécessité de mettre en œuvre des stratégies intégrées de lutte combinant l'administration massive de médicaments, l'amélioration de l'assainissement, l'éducation sanitaire et le soutien nutritionnel.

Mots-clés : *Schistosoma mansoni*, géohelminthes, performances cognitives, état nutritionnel, enfants d'âge scolaire.

1. INTRODUCTION

Intestinal helminth infections remain among the most widespread neglected tropical diseases (NTDs) affecting vulnerable populations worldwide. Globally, more than 1 billion people are estimated to be infected with soil-transmitted helminths. Schistosomiasis affects over 251 million individuals, with the majority living in sub-Saharan Africa (Colley et *al*. 2014; WHO 2023b). School-aged children are particularly at risk because of frequent contact with contaminated soil and water, inadequate sanitation, and limited access to hygiene facilities (Hotez et *al*. 2020; WHO 2023a). In endemic regions, school-aged children harbour the highest infection burdens and frequently co-infect with multiple parasitic species. Co-infections involving *Schistosoma mansoni* and soil-transmitted helminths such as *Ascaris lumbricoides, Trichuris trichiura,* and hookworms are frequently reported in areas with poor sanitation and limited access to clean water (Pullan et *al*. 2014; Jourdan et *al*. 2018).

These parasitic infections are associated with a variety of health consequences, including anaemia, chronic inflammation, and impaired nutrient absorption, which may contribute to growth retardation and undernutrition in children (Stephenson et *al*. 2020; Hall et *al*. 2021). Mewamba et *al*. (2025) reported that children infected with *Schistosoma haematobium* had significantly lower body mass indices (BMIs) than uninfected children. Similarly, a systematic review demonstrated that *A. lumbricoides* infection is associated with lower serum ferritin, zinc, and vitamin C concentrations in school-aged children (García et *al*. 2025). *S. mansoni* infection may also alter the gut microbiome and metabolic profiles, thereby contributing to chronic undernutrition (Osakunor et *al*. 2025).

Beyond physical health, increasing evidence suggests that helminth infections negatively affect cognitive development and educational outcomes. Chronic infections can cause reduced attention, impaired memory, and decreased school performance through nutritional deficiencies, inflammatory processes, and increased absenteeism (Jardim-Botelho et *al*. 2008; Drake and Bundy 2020; Ezeamama et *al*. 2021). Several epidemiological studies conducted in Africa have reported associations between intestinal helminth infections and deficits in learning ability, school achievement, and psychomotor development (Ezeamama et *al*. 2020; Nokes et *al*. 2021). However, most prior studies focused on single-parasite infections, whereas co-infections are the norm in endemic settings and may exacerbate health consequences through additive or synergistic effects (Brooker et *al*. 2020).

Cameroon remains highly endemic for both schistosomiasis and soil-transmitted helminthiases, particularly in rural communities where sanitation infrastructure is limited and access to safe water is inadequate (Tchuem Tchuente et *al*. 2017; Matsinkou et *al*. 2021). Mbam and Inoubou Division was selected for this study for several reasons: (i) this area is known to be highly endemic for both schistosomiasis and soil-transmitted helminth infections, with previous studies reporting prevalence rates above 40% (Tchuem Tchuente et al. 2012; Moyou-Somo *et al*. 2003), (ii) the presence of numerous rivers, streams, and wetlands in the regions creates favourable ecological conditions for the transmission of *S. mansoni* through its intermediate host *Biomphalaria camerunensis*, (iii) the population is predominantly engaged in agriculture and fishing, with frequent contact with natural water sources, increasing their exposure to parasitic infections, (iv) despite the high burden of helminth infections in this area, no recent studies have examined the combined impact of these infections on

cognitive performance and nutritional status in school-aged children. Although several epidemiological surveys have described the distribution of helminth infections in the country, few studies have examined their combined potential impact on nutritional status and cognitive performance in rural school populations. Therefore, we aimed to investigate the prevalence of co-infection with *S. mansoni* and soil-transmitted helminths and to assess their associations with cognitive performance and nutritional status among school-aged children in rural communities of the Mbam and Inoubou Division, Cameroon.

2. MATERIALS AND METHODS

2.1. Consent and ethical approval

Ethical clearance was obtained from the Regional Committee for Research Ethics in Human Health of the Centre Region, Cameroon (reference CE N° 0014-/CRERSHC/2025). Administrative authorizations were obtained from the Basic Education Inspector of Bafia and the directors of the participating schools. Written informed consent was obtained from the parents or legal guardians. Participation was entirely voluntary, and withdrawal carried no consequences.

2.2. Study area and period

The study was conducted from May to June 2025 in the rural communities of Bafia Subdivision, Mbam and Inoubou Division, Centre Region of Cameroon (Figure 1). The locality lies in a forest–savanna transition zone with a humid tropical climate (Moyou-Somo et *al*. 2003). Rivers, streams, and wetlands, combined with limited potable water and poor sanitation, create favorable conditions for the transmission of *S. mansoni* and soil-transmitted helminths (Tchinda Fosso et *al*. 2025). Populations are predominantly engaged in agriculture and have frequent contact with natural water sources, increasing their exposure to parasitic infections (Efon-Ekangouo et *al*. 2024).

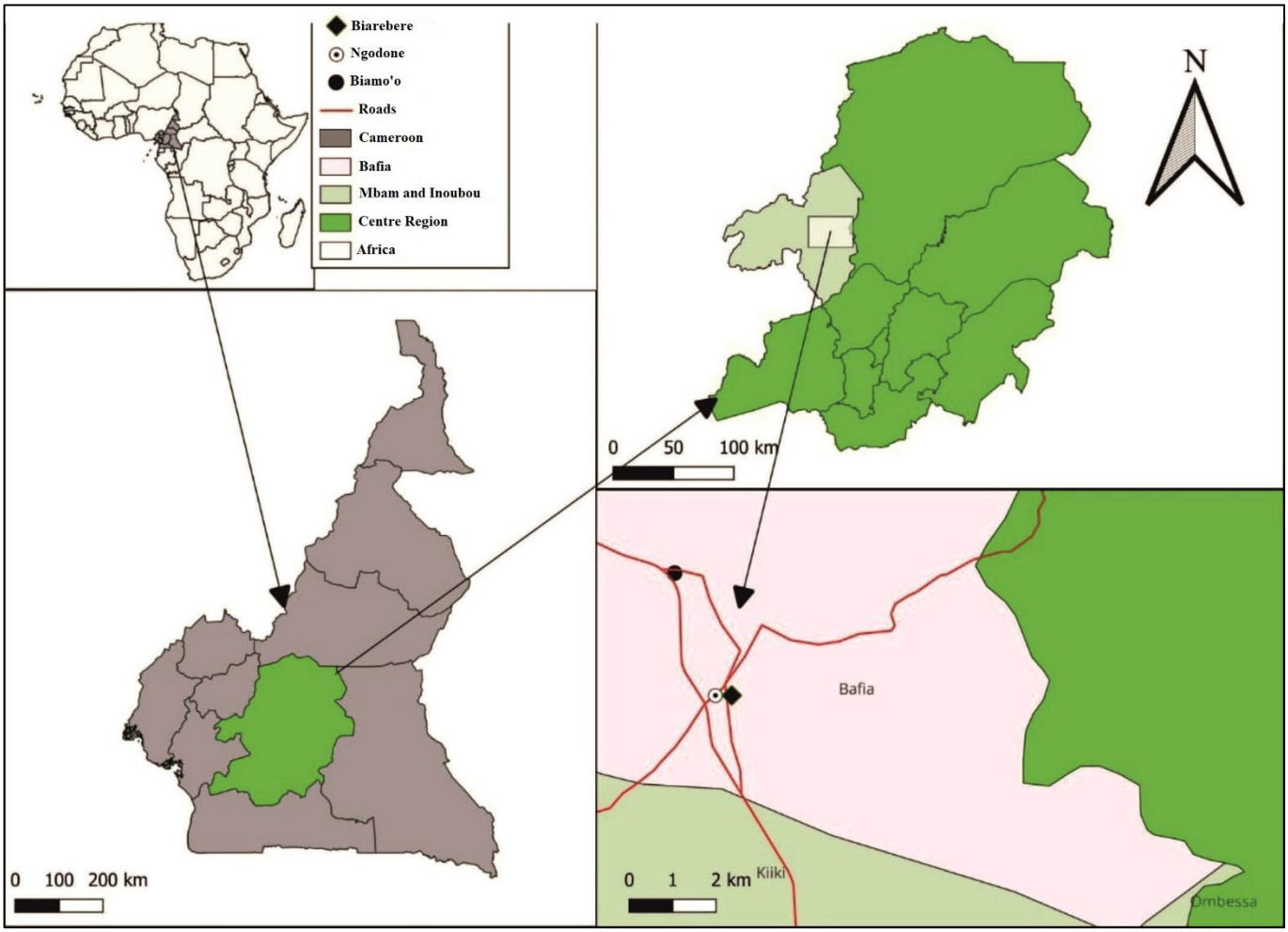

Figure 1: Map of Bafia Subdivision, Mbam and Inoubou Division, Centre Region of Cameroon showing the study area.

2.3. Study design and population

This was a descriptive cross-sectional study, as it described the health status of the study population by simultaneously assessing the prevalence of intestinal helminths and outcomes (cognitive performance and nutritional status) at a single point in time, providing a snapshot of the population's health status. The study population consisted of school-aged children attending public primary schools in the Bafia Subdivision, Mbam and Inoubou Division, Centre Region of Cameroon. Three public primary schools were randomly selected: Government Primary School (GPS) of Biamo'o (4°45'59.6"N 11°12'52.2" E), GPS of Ngodone (4°44'55.5"N 11°13'22.8" E), and GPS of Biarebere (4°44'28.1"N 11°13'35.0" E). These schools were chosen to reflect the diversity of the rural communities in the subdivision, spanning different geographical locations and levels of accessibility to health services.

2.4. Inclusion and exclusion criteria

Children were eligible if they were enrolled in the selected schools, aged between 6 and 15 years, had not been dewormed ≥1 month before enrolment, and parents or guardians had signed an informed consent form. Those who were absent during cognitive or anthropometric assessments, those who received anthelmintic treatment within the preceding month, and those who did not provide stool samples were excluded.

2.5. Sample size

The minimum sample size was determined using the Schwartz formula as described by Lwanga and Lemeshow (1991): $N = Z^2p(1-p) / d^2$, where N = required sample size, Z is the statistic that corresponds to the desired confidence level (95%), p is the estimated population proportion, and d is the margin of error (the desired precision of the estimate). Based on previously reported prevalence in Bafia, p = 48.5% (Tchuem Tchuente et *al*. 2012), a z-score of 1.96, a margin of error of 9%, and adding 5% for non-response, the formula yielded a minimum sample size of 125 children.

2.6. Stool sample collection and parasitological examination

An oral description and specific instructions on handling and avoiding contamination of stool specimens were provided to all the participants by the principal investigator. A structured questionnaire was used to collect data on socio-demographic characteristics. The questionnaire was prepared in English and French, and questions were answered by pupils in the presence of the teachers. Each participant received a labeled sterile container (with an identification number coded to name, age, and place of collection) and clean applicator sticks to collect a fresh first stool sample. Samples were transported to the Parasitology and Ecology Laboratory of the University of Yaoundé I for parasitological analysis using two techniques: Mini-FLOTAC and Formol-Ether concentration. The Mini-FLOTAC method was used for the quantitative detection of helminth eggs in stool samples. This flotation-based technique has been shown to provide reliable sensitivity for the diagnosis of soil-transmitted helminths and other intestinal parasites (Cringoli et *al*. 2017), whereas the formol-ether concentration technique improves parasite recovery by separating parasitic elements from faecal debris through centrifugation (Garcia 2016). Identification of the parasitic eggs was aided by photos and dimension ranges prepared by the World Health Organization (WHO) Bench Aid for the Diagnosis of Intestinal Parasites.

2.7. Anthropometric measurement

Standardized anthropometric measurements, weight and height, were taken from all study participants. Children were asked to remove their shoes, wear light clothes, and remove accessories. Then, data collectors measured children's weight using a calibrated portable scale (SALTER, UK) and recorded the value to the nearest 0.1 kilograms. For height measurement, children were instructed to stand upright against a vertical wall with their shoulders aligned, arms at their sides, thighs and heels touching comfortably; the buttocks, scapulae, and head were positioned against the vertical backboard with a sliding head bar. The height was then measured using a measuring tape (OKfort, China) and recorded to the nearest 0.1 centimeter.

BMI was calculated as weight (kg) divided by height squared (m^2) (Onis et *al*. 2007). Nutritional status was then classified according to the World Health Organization (WHO 2007) reference standards for children aged 5–19 years. BMI-for-age z-scores were calculated with WHO AnthroPlus software (version 1·0·4) and classified as underweight (z-score < −2 SD), normal weight (−2 SD to +1 SD), overweight (> +1 SD), or obese (> +2 SD) per WHO 2007 reference standards (WHO 2007).

2.8. Cognitive performance assessment

Children were eligible if they were enrolled in the selected schools, aged between 6 and 15 years, and attending classes from CE1 to CM2 (corresponding to the primary school cycle). The selection of these classes was based on the assumption that children in these grades (typically aged 7 to 14 years) have sufficient cognitive development to participate in neuropsychological assessments and are also at the highest risk of exposure to helminth infections due to their frequent contact with soil and water during school and recreational activities (Nokes et *al*. 2000; Ezeamama et *al*. 2005). Children had not been dewormed for ≥1 month before enrolment, and parents or guardians had signed an informed consent form.

Cognitive performance was assessed with neuropsychological tasks adapted for school-aged children, evaluating five core domains of cognitive function: (i) verbal fluency, (ii) attention, (iii) memory, (iv) calculation, (v) cognitive flexibility (Korkman et *al*. 2007):

(i) Verbal fluency: The "Semantic Fluency" task required children to name as many animals as possible in 60 s, assessing lexical access and semantic memory (Benton & Hamsher, 1976). The maximum score was 2 points;

(ii) Memory: The "Five-Word Recall" task (Dubois et *al*. 1999) assessed episodic memory. Children were presented with five words and asked to recall them immediately and after a 5-minute delay. The maximum score was 2 points;

(iii) Attention: The "Serial Sevens" task (Folstein et *al*. 1975) required children to subtract 7 sequentially from 100, assessing sustained attention and working memory. The maximum score was 2 points;

(iv) Calculation: Children were asked to perform simple mental arithmetic (addition and subtraction of two-digit numbers), assessing basic numerical processing. The maximum score was 2 points;

(v) Cognitive flexibility: The "Reverse Sequence" task required children to recite the days of the week in reverse order, assessing mental flexibility and working memory manipulation. The maximum score was 2 points.

Scores from the five tasks were summed to generate a global cognitive performance score ranging from 0 to 10 points for each child. The battery was administered individually by trained research assistants in a quiet room at the school and took approximately 20–25 minutes per child. All tasks were presented in the child's preferred language (French or English), and instructions were repeated as needed to ensure understanding. This assessment was adapted from validated tools used in similar studies in African school-aged populations (Ezeamama et *al*. 2005; Pabalan et *al*. 2018).

2.9. School Performance

School performance was assessed by teacher-rated academic achievement based on end-of-trimester grades in three core subjects (French, Mathematics, and Science/Health Education). These subjects were selected because they are the foundational disciplines of the primary school curriculum in Cameroon, evaluating reading comprehension and written expression (French), logical reasoning and numerical skills (Mathematics), and scientific inquiry and health knowledge (Science/Health Education), respectively. These subjects are also considered key indicators of academic success and cognitive development in school-aged children (Sunny et *al*. 2017; Ezeamama et *al*. 2018). Teachers classified overall performance as poor (average grade <5/10), average (5/10 to 7/10), or normal (>7/10). This classification was blinded to the child's parasitological status.

2.10. Statistical analysis

Data were entered into Microsoft Excel 2016 and analysed using GraphPad Prism software. Descriptive analysis was performed to summarize participants' sociodemographic characteristics, parasitic prevalence, nutritional status, and cognitive scores.

The normality of continuous variables was assessed using the Shapiro–Wilk test. As most variables were not normally distributed ($P < 0.05$), non-parametric tests were used for group comparisons: Mann–Whitney U test was used for two-group comparisons (e.g., infected vs. uninfected children for BMI and cognitive scores); Kruskal–Wallis test with Dunn's post-hoc correction was used for multiple-group comparisons (e.g., comparing cognitive scores across uninfected, mono-infected, and co-infected groups).

Associations between categorical variables (e.g., infection status and exposure to transmission factors, infection status and school performance) were assessed using: Chi-squared (x^2) test for large sample sizes with expected cell frequencies ≥ 5; Fisher's exact test when expected cell frequencies were below 5.

To compare means across multiple groups, a one-way analysis of variance (ANOVA) was performed, followed by Tukey's post-hoc test for pairwise comparisons when the ANOVA was significant.

To identify independent factors associated with the presence of at least one parasitic infection, a binary logistic regression was performed. Variables with $P < 0.20$ in the bivariate analysis were entered into the multivariate model. Results were expressed as adjusted odds ratios (ORa) with 95% confidence intervals.

All tests were two-tailed, and the significance threshold was set at $P < 0.05$.

3. RESULTS

3.1. Sociodemographic and clinical characteristics of the study population

A total of 126 children were enrolled across three primary schools: Government Primary School (GPS) Biamo'o (n = 70; 55.6%), GPS Ngodone (n = 47; 37.3%), and GPS Biarebere (n = 9; 7.1%), with a significant difference in enrolment across sites ($p < 0.001$; Table 1). The cohort was predominantly female (61.1%) and concentrated in the 10–11-year age group (48.4%). Nutritional status was largely normal, with 92.9% of children classified as normal weight by BMI; underweight and overweight children represented 0.8% and 6.3% of the sample, respectively. Regarding cognitive performance, approximately half of the children (49.2%) scored in the moderate range (5.0–5.4), while 24.6% scored low (3.0–4.9) and 24.6% achieved normal scores (5.5–6.0); very low scores were rare (1.6%). School performance was predominantly average (73.0%), with 16.7% performing well and 10.3% performing poorly. Regarding exposure to helminth transmission factors, 7.1% of children reported rare exposure, 86.5% reported frequent exposure (majority), and 6.5% reported high exposure.

Table 1: Sociodemographic and clinical characteristics of the study population

Characteristic	Category	N	%	95% CI (%)	P-value
School	GPS Biamo'o	70	55.6	[46.6–64.2]	
	GPS Ngodone	47	37.3	[28,9–46,3]	P < 0.001
	GPS Biarebere	9	7.1	[3.4–13.0]	
Sex	Male	49	38.9	[30.4–47.9]	
	Female	77	61.1	[52.1–69.6]	
Age (years)	[7–9]	28	22.2	[15.5–30.3]	
	[10–11]	61	48.4	[39.6–57.3]	
	[12–14]	37	29.4	[21.7–38.1]	
BMI	Underweight	1	0.8	[0.0–4.4]	
	Normal weight	117	92.9	[86.9–96.7]	
	Overweight	8	(6.3)	[2.8–12.1]	
Cognitive performance	Very low (0-2.9)	2	1.6	[0.2–5.6]	
	Low (3-4.9)	31	24.6	[17.6-33.0]	
	Moderate (5-5.4)	62	49.2	[40.3–58.1]	
	Normal (5.5-6)	31	24.6	[17.6-33.0]	
School performance	Poor	13	10.3	[5.7–17.0]	
	Average	92	73.0	[64.4–80.5]	
	Normal	21	16.7	[10.7–24.3]	
Exposure to Transmission factors	Rare	9	7.1	[3.4–13.0]	
	Frequent	109	86.5	[79.3–91.9]	
	High	8	6.3	[2.8–12.1]	

n, number of children; CI, confidence interval; BMI, body mass index. P-value for school distribution derived from chi-squared test. Cognitive performance scores range from 0 to 6.

3.2. Helminth infection prevalence and co-infection patterns

Of the 126 school-aged children enrolled in the study, 80 (63.49%) were uninfected and 46 (36.51%) harboured at least one helminth species (Table 2). The majority of infected children (35/46, or 76%) carried a single parasite. Among infected children (species-specific infection), *S. mansoni* was the most prevalent species infection (20.63%; n = 26), followed by *A. lumbricoides* (19.84%; n = 25) and hookworm (Ankylostomes; 6.35%; n = 8). *Strongyloides stercoralis* was rare (0.79%; n = 1). We also observed mutually exclusive infection patterns: *S. mansoni* only (12.70%; n = 16), *A. lumbricoides* only (11.11%; n = 14) and Ankylostomes only (3.97%; n = 5). Co-infection was identified in 11 children (8.73% of the total study population; 23.91% of infected children): eight harboured *A. lumbricoides* and *S. mansoni* concurrently (6.35%), one was co-infected with *A. lumbricoides* and hookworm (0.79%) and *A. lumbricoides*, *S. mansoni* and Ankylostomes (triple infection) (0.79%), and one child presented with a four-species infection (quadruple infection) comprising *A. lumbricoides*, *S. mansoni*, hookworm, and *S. stercoralis* (0.79%).

Table 2: Distribution of helminth infection patterns in the study population

Helminth infection pattern	n	Prevalence (%)	Classification
No helminth infection	80	63.49	overall
At least one helminth infection	46	36.51	overall
Species-specific infection			
S. mansoni	26	20.63	mono- and co-infections
A. lumbricoides	25	19.84	mono- and co-infections
Ankylostomes	8	6.35	mono- and co-infections
S. stercoralis	1	0.79	mono- and co-infections
Mutually exclusive infection patterns			
S. mansoni only	16	12.70	mono-infection
A. lumbricoides only	14	11.11	mono-infection
Ankylostomes only	5	3.97	mono-infection
S. stercoralis only	0	0.00	mono-infection
Co-infection			
A lumbricoides + *S. mansoni*	8	6.35	double-infection
A. lumbricoides + *Ankylostomes*	1	0.79	double-infection
A. lumbricoides + *S. mansoni* + Ankylostomes	1	0.79	triple infection
A. lumbricoides + *S. mansoni* + Ankylostomes + *S. stercoralis*	1	0.79	quadruple infection

n, number of children; prevalence calculated as proportion of total study population.

3.3. Association between Helminth infection and cognitive performance

To investigate the relationship between helminth infection and cognitive performance in school-aged children, we compared across four infection categories: any helminth infection, mono-infection with *A. lumbricoides*, mono-infection with *S. mansoni*, and co-infection with both parasites (Fig. 2a-d).

Children with any helminth infection showed lower median cognitive performance than non-infected children, approaching statistical significance (P = 0.05; Fig.2a). Species-specific analysis revealed that *A. lumbricoides* mono-infection was significantly associated with reduced cognition relative to uninfected control (P = 0.02; Fig. 2b). In contrast, mono-infection with *S. mansoni* was not significantly associated with difference in the cognitive performance compared to uninfected controls (P = 0.37; Fig. 2c). Pairwise comparisons among infected subgroups *A. lumbricoides* mono-infected, *S. mansoni* mono-infected, and co-infected revealed no significant differences in cognitive performance (P = 0.24, 0.46, and 0.16, respectively; Fig. 2d).

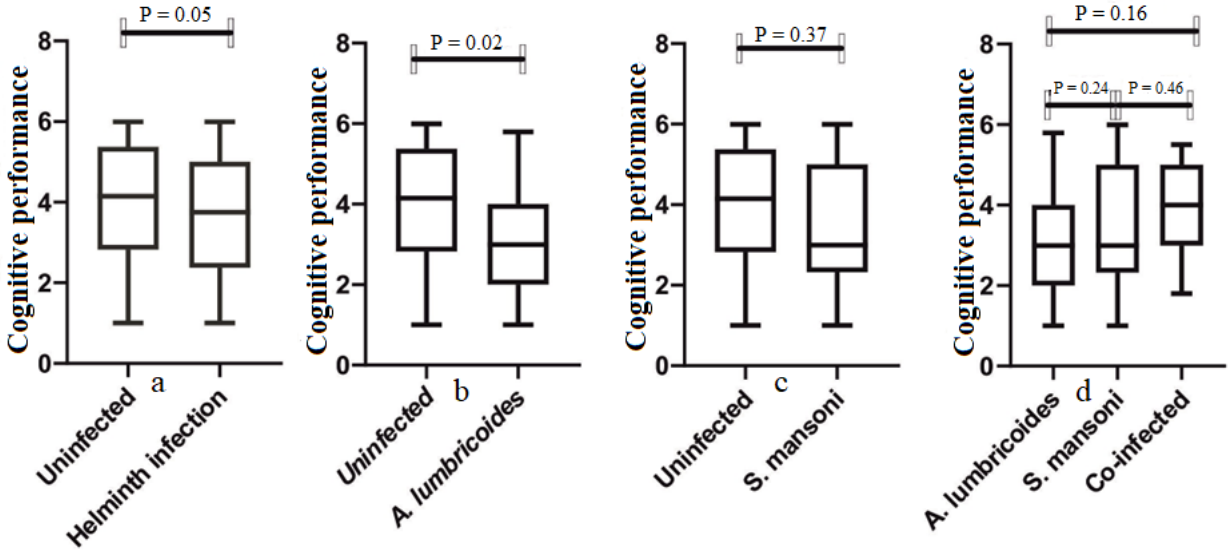

Figure 2: Mean cognitive scores (mean ± SD) according to infection status

3.4. Association between helminth infection and BMI

Next, we examined whether helminth infection was associated with differences in nutritional status, as measured by BMI (kg/m²). Children with any helminth infection showed a trend toward lower BMI compared to uninfected controls, narrowly missing statistical significance (P = 0.06; Fig. 3a). Species-specific analysis revealed a similar pattern for *A. lumbricoides* mono-infected children, who exhibited lower median BMI than uninfected controls, though this difference did not reach significance (P = 0.09; Fig. 3b). No appreciable difference in BMI was observed for *S. mansoni* mono-infected children relative to uninfected controls (P = 0.18; Fig. 3c). Pairwise comparisons among infected subgroups yielded no significant differences (P = 0.30–0.89; Fig. 3d); however, co-infected children displayed a notably narrow distribution concentrated at lower BMI values.

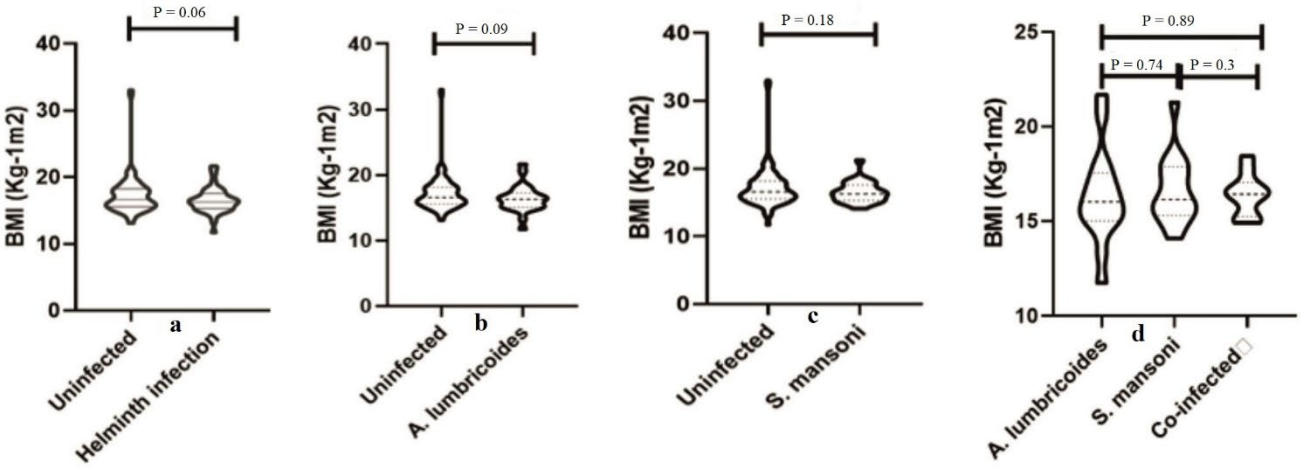

Figure 3: Body mass index (BMI) according to helminth infection status

3.5. Association of helminth infection with transmission exposure and school performance

We examined the association between helminth infection status and two key outcomes: high exposure to transmission factors and poor school performance (Table 3). Overall, any helminth infection was present in 46 children (36.51%) and was significantly associated with high transmission exposure (P = 0.05) and poor school performance (P = 0.05). Species-specific analyses revealed distinct association profiles. *S. mansoni* infection

showed the strongest and most consistent associations, with a significant relationship with both high transmission exposure (P = 0.009) and poor school performance (P = 0.02). *A. lumbricoides* infection was significantly associated with high transmission exposure (P = 0.03) but not with poor school performance (P = 0.11). Co-infection with two or more helminth species was also significantly associated with high transmission exposure (P = 0.008) but not with poor school performance (P = 0.23). Hookworm infection showed no significant association with either outcome (P = 0.61 and P = 0.93, respectively).

Table 3: Association between helminth infection, high transmission exposure, and poor school performance

Infection	N (%)	High exposure n(%)	P-value	Poor school performance n (%)	P-value
A. lumbricoides	25 (19.84)	4(50.0)	0.03	5(38.5)	0.11
S. mansoni	27 (21.42)	5(62.5)	0.009	2(15.4)	0.02
Ankylostomes	7 (5.55)	1(12.5)	0.61	1(7.7)	0.93
Co-infection (≥2 species)	11 (8.7)	3(37.5)	0.008	2(15.4)	0.23
Any helminth infection	46 (36.51)	6(75.0)	0.05	6/13 (46.2)	0.05

N, number of children. P-values derived from chi-squared or Fisher's exact test as appropriate. Bold P-values indicate statistical significance (P < 0.05). Poor school performance denominator: n = 13.

4. DISCUSSION

In this study, we evaluated the prevalence of helminth infections (*S. mansoni* and soil-transmitted helminths), as well as their association with cognition and nutritional status of school-aged children in the Mbam and Inoubou Division, Cameroon. The overall helminth prevalence of 36.51% found in this study is somewhat lower than that previously reported in the same study area by Tchuem Tchuente et *al*. (2012) and in the nearby locality of Makenene by Ntonifor et *al*. (2012). The reduction relative to earlier data is plausibly attributable to repeated mass drug administration campaigns conducted by the National Control Program against schistosomiasis and soil-transmitted helminthiasis, as well as potential differences in diagnostic sensitivity of the techniques used in the above studies. *S. mansoni* (species-specific infection) was the most prevalent (20.63%), followed by *A. lumbricoides* (19.84%), then Ankylostomes (6.35%) and *S. stercoralis* (0.79%). The dominance of *S. mansoni* over *A. lumbricoides* is unusual in Cameroon, where soil-transmitted helminths are usually predominant. This reversal is ecologically explicable: the study area encompasses the river systems (Biamo'o, Ngodone, Biarebere) and wetlands of the Mbam River, which sustain dense populations of *Biomphalaria camerunensis*, the obligate intermediate host of *S. mansoni* (Moyou-Somo et *al*. 2003). Comparable *S. mansoni* prevalences (15-30%) are documented in the lacustrine regions of Uganda and Tanzania (Ezeamama et *al*. 2018), reinforcing the importance of hydrological context in shaping local parasite assemblages. The very low prevalence of *S. stercoralis* (0.79%) almost certainly reflects the limited sensitivity of Mini-FLOTAC and formol-ether concentration for this parasite; Baermann technique or PCR would likely reveal a substantially higher burden (Garcia 2016), as recently demonstrated in Cameroonian school children by Efon-Ekangouo et *al*. (2024).

Co-infection with two or more species was present in 11 children (8.73% of all participants and 23.91% of infected children), the most common combination being *A. lumbricoides* + *S. mansoni* (6.35%). This rate is consistent with estimates from Gabon (6-8%) (Dejon-Agobé et *al*. 2020), but lower than those reported in Uganda (20-30%) of infected children (Ezeamama et *al*. 2018). This difference may reflect partial but effective coverage of Mass Drug Administration (MDA) in our area, temporal offsets in the peak transmission seasons of *S. mansoni* and *A. lumbricoides*, or the relatively modest sample size. Crucially, co-infection was significantly associated with high transmission exposure, confirming that polyparasitism is concentrated among children with the greatest cumulative environmental risk, a pattern consistent with prior observations across sub-Saharan Africa and identifying a targetable high-risk subgroup for intensified intervention (Brooker et *al*. 2020).

Taken together, these findings indicate that the cognitive consequences of helminth infection are species-specific rather than uniformly distributed across parasite types. The significant association observed for *A. lumbricoides* underscores the importance of targeted soil-transmitted helminth control as a strategy to protect

neurodevelopmental outcomes in endemic populations and motivates further investigation into the mechanistic pathways by which this parasite affects cognitive function. The significant association between *A. lumbricoides* infection and reduced cognitive performance is consistent with a substantial body of evidence implicating this nematode in neurodevelopmental impairment. Ezeamama et *al.* (2005) demonstrated in a longitudinal Philippine cohort that *A. lumbricoides*-infected children exhibited memory and sustained attention deficits, findings replicated by Jardim-Botelho et *al.* (2008), who reported reduced executive function in *A. lumbricoides*-infected children in Brazil. A meta-analysis by Pabalan et *al.* (2018) subsequently confirmed *A. lumbricoides* as the helminth most consistently associated with cognitive impairment across diverse settings. The probable mechanistic basis encompasses malabsorption of iron, zinc, and vitamin A, micronutrients critical to myelination and synaptic function, compounded by low-grade systemic inflammation that impairs neuroplasticity (García et *al*. 2026). The absence of a significant association between *S. mansoni* and direct cognitive score contrasts with findings from Uganda, where Ezeamama *et al.* (2018) observed a clear relationship between schistosomiasis and standardized neurocognitive outcome. Three non-exclusive explanations merit consideration. First, our cognitive instrument, although validated, was brief and may lack sensitivity to the specific attentional deficits associated with schistosomiasis. Second, we did not quantify infection intensity, and the neurocognitive impact of *S. mansoni* is primarily documented at moderate-to-heavy intensities that may not have predominated in our cohort. Third, the cognitive effects of *S. mansoni* may be more accurately captured by school achievement metrics than by global cognitive scores, consistent with its primary pathological manifestations of chronic anaemia, fatigue, and absenteeism rather than direct neurological impairment.

The significant association of *S. mansoni* with poor school performance, in the absence of a corresponding cognitive signal, points to a pathway mediated by absenteeism, fatigue, and somatic morbidity rather than neurocognitive impairment (Ezeamama *et al.*, 2018). This interpretation is supported by a growing literature: children with schistosomiasis in Tanzania faced a 1.5-fold higher risk of academic delay relative to uninfected peers, and treatment in Uganda improved standardized scores in mathematics and reading (Ezeamama et *al*. 2018). Drake and Bundy (2020) have further synthetized evidence that the indirect pathways of helminth-associated anaemia and school absence are at least as educationally significant as direct impairment. Conversely, the significant association of *A. lumbricoides* with cognitive performance but not with teacher-rated school achievement likely reflects the different constructs being measured: standardized cognitive testing captures attention and working memory, which are sensitive to nutritional deficits mediated by this nematode, whereas teacher ratings integrate attendance and behaviour, which are more strongly influenced by the somatic morbidity of schistosomiasis. The modest sample size (particularly the poor school performance denominator of n = 13) may additionally have limited power to detect a weak *A. lumbricoides*–school performance association. These findings suggest that *S. mansoni* infection may represent a particularly relevant determinant of academic outcomes in this cohort, while the association of *A. lumbricoides* and co-infection with transmission exposure underscores the role of environmental and behavioural risk factors in driving polyparasitism.

There were no significant differences in BMI between infected and uninfected children; pairwise comparisons among infected subgroups yielded no significant differences; however, co-infected children displayed a notably narrow distribution concentrated at lower BMI values, suggesting a more homogeneously undernourished subgroup, though this pattern was not significant, likely reflecting limited power in this subgroup. Collectively, the BMI trends parallel the cognitive performance findings, with *A. lumbricoides* showing the most consistent nutritional signal across both outcomes, and raising the possibility that impaired nutritional status may partially mediate the cognitive effects of this parasite. In contrast to studies reporting faltering helminth-associated growth in Cameroon (Mezajou Mewamba et *al*. 2025) and a meta-analysis by Hall et *al.* (2021) that documented modest but real reductions in anthropometric indices with helminth infection. Several factors likely account for this discrepancy. First, undernutrition was extremely rare in our cohort (0.8% underweight, 92.9% normal weight), leaving minimal distributional room to detect a parasitic effect on BMI. Second, the nutritional impact of helminths scales with infection intensity, and light infections are unlikely to impair intestinal absorption sufficiently to alter BMI. Third, the cross-sectional design captures BMI at a single time point, whereas longitudinal studies demonstrate that growth benefits of deworming accrue over months (Ezeamama et *al*. 2016). Fourth, adequate dietary intake may partially compensate for parasite-induced losses at low infection intensity. Importantly, the absence of a BMI effect does not rule out clinically significant micronutrient deficiencies, particularly iron, zinc, and vitamin A, that independently impair cognition and deserve direct measurement in future work (García et *al*. 2026).

The predominance of frequent transmission exposure (86.5% of children) and its significant association with *S. mansoni*, *A. lumbricoides*, and co-infection underscores that acquisition of helminthiasis in this population is driven primarily by environmental and behavioural determinants rather than host susceptibility. These findings echo studies from Cameroon (Matsinkou et *al*. 2021; Tchinda Fosso et *al*. 2025) and Uganda (Ezeamama *et al*. 2018) identifying river contact for bathing, washing, and agricultural activities as primary transmission routes. Sustainable reduction in helminth burden in such settings will therefore require interventions that extend beyond periodic MDA to encompass safe water access, sanitation infrastructure, and health education.

Key limitations of this study include the cross-sectional design (precluding causal inference), absence of infection intensity quantification, a brief cognitive battery that may under-detect schistosomiasis-specific attentional deficits, a small poor-school-performance subsample (n = 13) limiting statistical power, suboptimal sensitivity for *S. stercoralis*, and unmeasured confounders including anaemia, household income, and dietary diversity. Additionally, the lack of quantitative data on infection intensity may have obscured dose-response relationships, particularly for parasites whose cognitive effects are known to be intensity-dependent (Ezeamama et *al*., 2005; Pabalan et *al*., 2018).

5. CONCLUSION

In this cross-sectional study involving 126 school-aged children in rural Cameroon, we demonstrate that helminth infections are prevalent and exert species-specific effects on cognitive performance and school achievement. This study provides evidence that helminth infections in rural Cameroonian schoolchildren exert species-specific and outcome-specific effects on child development: *A. lumbricoides* impairs cognitive performance through pathways likely related to micronutrient deficiency, whereas *S. mansoni* predominantly degrades school achievement through somatic morbidity and absenteeism. These distinct impacts argue against a one-size-fits-all approach to helminth control and underscore the value of species-level diagnosis to target interventions. Integrated programmes combining MDA with water, sanitation, and hygiene improvements, micronutrient supplementation, and school-based absenteeism monitoring offer the most promising pathway to protect neurodevelopmental and educational outcomes in helminth-endemic communities across sub-Saharan Africa.

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DATA SHARING STATEMENT. The data generated and analyzed as part of this study, including data collected through questionnaires and laboratory analysis results, are available from the corresponding author upon reasonable request. Access to this data is subject to applicable ethical requirements and confidentiality regulations to ensure the protection of participants and sensitive information.

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