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The relationship between *Schistosoma haematobium* infection and school performance and attendance in Bamako, Mali

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Schistosomiasis due to *Schistosoma haematobium* was the most common helminth infection in school-age children from a poor area in Bamako, Mali. Almost half (47%) of the boys and 40% of the girls were infected, 18% of the children being heavily infected. There was a significant decline in academic performance and in school attendance with increasing intensity of infection. When all sources of variation were taken into consideration, absenteeism was the main factor explaining the variation in academic performance, although a significant effect of infection remained. School-based delivery of chemotherapeutic interventions is currently promoted by several international organizations. However, rates of school attendance are low in some areas and it is the absentees who appear to be at relatively high risk of ill health. Novel ways of reaching this elusive subset of the population are required.

The most intense infections with the commonest species of helminths occur in school-age children (Bundy *et al.*, 1992; Savioli *et al.*, 1992) and there is growing concern that helminth infections may affect children's cognitive functions (Halloran *et al.*, 1989). Recent studies indicate that even moderate nematode burdens have an adverse effect on the mental development of children (Nokes *et al.*, 1991, 1992; Bundy, 1994; Nokes and Bundy, 1994). Although the effects of schistosomiasis on cognitive function and educational achievement have received relatively more attention than the effects of nematodes, the conclusions of the investigators have not been consistent. The results of some studies indicate that schistosomiasis has no effect on the school performance of children, whereas those of other studies indicate a limited detrimental effect or even a beneficial effect (Nokes and Bundy, 1994).

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There do not appear to have been any previous studies on the impact of schistosomiasis and/or geohelminths on the educational outcomes of the children in Mali. The most widespread helminth infection in this West African country is schistosomiasis, with *Schistosoma haematobium* and *S. mansoni* both being present. In 1986, surveys by the Malian National Schistosomiasis Control Programme of children attending four schools in the capital, Bamako, found that 30%–82% of the pupils carried *S. haematobium* and 9%–13% carried *S. mansoni* (M. Traoré, unpubl. obs.).

There have only been a few reports published on the distribution of geohelminths in Bamako (Rougemont *et al.*, 1974; Boukenem *et al.*, 1976; Doumbia, 1977, 1989; Kanouté, 1977; De Clercq *et al.*, 1995). The prevalences of *Ascaris lumbricoides* and *Trichuris trichiura* in the city have always been found to be $<1\%$ but hookworm infection (mostly *Necator americanus*) has been seen in 2.4%–5.1% of subjects.

The present study was carried out to determine the distribution of helminth infections in primary schoolchildren in Bamako, and to examine the impact of these infections on educational parameters such as school performance and school attendance.

SUBJECTS AND METHODS

Study Area

The study was carried out in two primary schools in the Baco-Djicoroni area of south–western Bamako. The schoolchildren (mostly aged 6–11 years, with a few older subjects) came principally from two areas, Baco-Djicoroni and Sabalibougou, where social and hygienic conditions are poor and no regular water and electricity supplies exist. Water is provided by wells, fountains, small streams or the Niger river. The survey took place in June, the last month of the academic year, in 1993.

Study Design

Overall, 580 children (51% male, 49% female) were registered for examination. One stool and one urine sample were collected from each child and examined using the Kato technique and urine filtration (through Nuclepore® filters), respectively. Eggs were counted so that heavy infections (>50 *S. haematobium* eggs/10 ml urine, >100 *S. mansoni* eggs/g stool or >2000 hookworm eggs/g stool; Stephenson, 1987; Feldmeier and Poggensee, 1993) could be identified. School performance was graded by the teachers on a descending scale from 1 (very good) to 3 (bad), and absenteeism was similarly graded 1 (rarely absent), 2 (absent from time to time) or 3 (often absent). All positive cases of schistosomiasis (and cestode infection) were treated with a single dose of 40 mg praziquantel (Bayer)/kg and the geohelminth infections were treated with a single, 500-mg dose of mebendazole (Global Pharmaceuticals, London, U.K.).

Statistical Analysis

The data were analysed using general linear interactive models (Crawley, 1993; Behnke *et al.*, 1994). The exact model used was determined by which dependent variable was being analysed. For infection intensity, a model with negative-binomial errors and raw, untransformed egg counts was used. For academic performance and absenteeism, models with normal errors were employed, but infection intensity was transformed $\log(x+1)$ and entered as a covariate. In models examining the effects of infection on academic performance, absenteeism was entered as a factor. Host age and gender were always entered as factors. The statistical analysis of each model was two-fold. First, step-wise deletion models of the various proposed sources of variation were carried out. Each procedure started with the deletion of the most complex interactions and ended with the principal components. Complex interactions (four-, three- and two-way interactions) were deleted in turn and the change in deviance and scale parameter noted. These were left out of the model before proceeding to the next interaction. When only the main effects remained, these were deleted in turn in order to obtain the change in deviance and scale parameter and were then replaced before deletion of the next main effect. From the changes in deviance obtained, the scaled deviance (the measure of how much variation in a particular dependent variable can be attributed to a particular factor) was calculated for each interaction and the main effects. For the models of absenteeism and academic performance, the scaled deviance was calculated by dividing the change in deviance by the degrees of freedom (error) followed by division by the scale parameter. This gave an F-value which was used to calculate a probability value. For the intensity of infection models, the scaled deviance was calculated by dividing the change in deviance by the scale parameter. The resulting values were distributed as χ^2, from which significance values were obtained. In all models a probability (P) value of <0.05 was taken to denote that a particular effect was associated with significant variation in the dependent variable. In the text below, F-, χ^2 and P-values are given as appropriate.

In the second stage of the analysis of each model, all the effects that were not associated with significant variation in the dependent variable were removed from that model (a minimum-sufficient model). The mean intensity of infection/absenteeism/academic performance (depending on the model) for the first subset of the first main effect entered into the model (e.g. 6-year-old boys) was then estimated. The numerical difference (+ or −) between this value and the mean values of all the other subsets within the first main effect was also calculated, together with the standard error of the difference. Student's t-tests were then used to evaluate the significance of each change. For covariates, a regression of the covariate on the dependent variable for each subset was carried out, with the differences between the relationship obtained for the first subset and the other subsets again being compared using Student's t-tests. In all cases, a P-value of <0.05 indicated the existence of a significant difference between the regression within a particular subset compared with that within the reference cell (e.g. 6-year-old boys).

RESULTS

Prevalence and Intensity of Infection

Initially, 580 children were enrolled for the study and their distribution across age-stratified cohorts, together with the mean age of each cohort, is given in the Table. Single urine and stool samples were returned by 99% and 77% of the children, respectively. Infection with *S. haematobium* was, by far, the most common helminth infection, with a prevalence of 46.6% among boys and 39.9% among girls, and 18% of the children heavily infected. Prevalences of *S. mansoni* infection (2.7%) and geohelminth infection (6.5%) were relatively low. Most (80%) of the geohelminth infections were of hookworms (*Necator americanus*) but *Enterobius vermicularis*, *Trichuris trichiura* and *Hymenolepis nana* were occasionally detected. All of the intestinal infections, except a few cases of *S. mansoni*, were light infections. Only *S. haematobium* was sufficiently widespread in the community to make further statistical analysis feasible.

Figure 1 illustrates the age–intensity and age–prevalence profiles of *S. haematobium* infection by host gender. Prevalence differed among the age-cohorts, increasing in both sexes from the 6-year age-group to the 11-year age-group. The mean intensity of infection also increased, although a marked fall in egg counts was apparent by 12 years in girls and 13 years among the boys. As the sample size of those aged >11 years was small and some data for this sample were missing, only the 6–11-year age-cohorts were subjected to statistical analysis. The overall mean (S.E.) egg count/10 ml urine was 43.07 (5.52). There was no significant difference in intensity of infection between genders, but there was a highly significant difference between age-groups [$\chi^2=94.633$; five degrees of freedom (df); $N=540$; $P<0.001$]: 10- and 11-year-old children had significantly higher egg counts than the 6-year-old children [Fig. 1(a)]. There was also a significant interaction between gender and age ($\chi^2=20.602$; df$=5$; $N=540$; $P<0.001$) arising from the fall in egg count among 9-year-old boys relative to that in the 8-year-old boys, and the magnitude of the

TABLE
The distribution of children in the study, across age-stratified cohorts

	Males		*Females*		
Age-group (year)	*No.*	*Mean age (years)*	*No.*	*Mean age (years)*	*Total no. of subjects*
6	11	6.6	9	6.6	20
7	31	7.5	39	7.5	70
8	68	8.5	71	8.4	139
9	72	9.3	74	9.5	146
10	59	10.3	48	10.4	107
11	35	11.2	26	11.3	61
12	8	12.4	13	12.3	21
13	9	13.3	3	13.6	12
14	0		2	14.1	2
15	1	15	0		1
16	0		1	16.7	1
All	294		286		580

difference in egg counts between the genders in the 9-year-old cohort [Fig. 1(a)].

Academic Performance

Overall, 537 children (275 boys and 262 girls) provided data on both intensity of *S. haematobium* infection and academic performance [Fig. 2(a)]. There was a positive, but non-significant, increase in mean grade with age [Fig. 2(b)]. There was no significant difference in academic performance between the genders, nor was there any significant interaction between age and gender, despite the apparently steeper slope for mean grade in female subjects in relation to increasing age [Fig. 2(b)]. There was, however, a significant decline in academic performance (mean grade increased) with increasing infection intensity

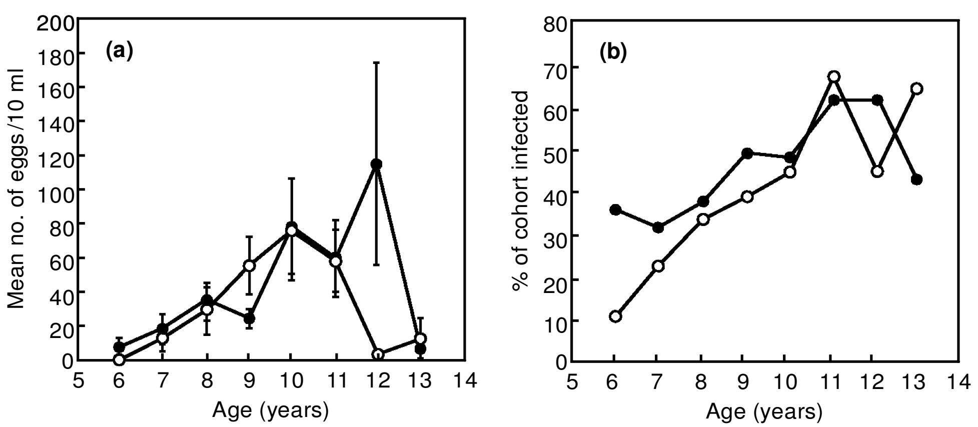

Fig. 1. Age-stratified profiles of the mean intensity (a) and prevalence of infection (b) with *Schistosoma haematobium* among the male (●) and female (○) subjects. Vertical lines indicate S.E.

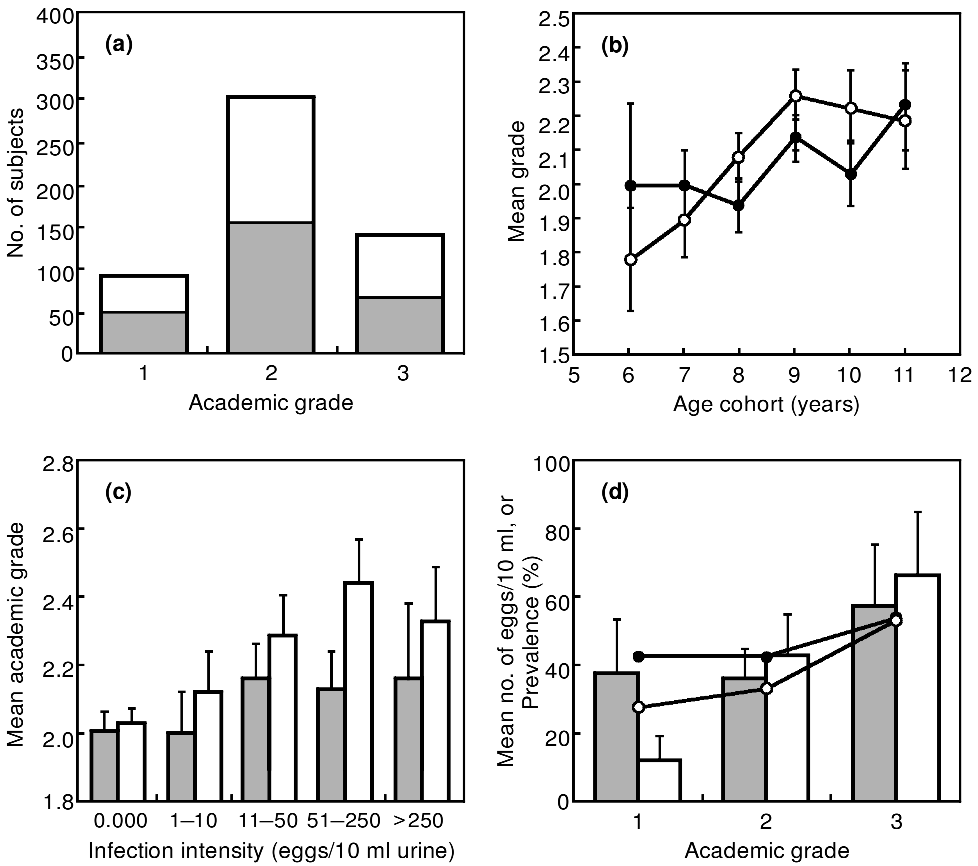

Fig. 2. (a) Frequency distribution of academic grades among the male (▦) and female (□) subjects. (b) Age-related changes in academic performance among the male (●) and female (○) subjects. (c) Mean academic grade by category of infection intensity among the male (▦) and female (□) subjects. (d) Mean intensity by academic grade (▦, males; □, females) and prevalence of infection by academic grade (●, males; ○, females). Vertical lines indicate S.E.

[$F_{1,530} = 8.099$; $P < 0.005$; Fig. 2(c)]. As shown in Figure 2(d), the mean intensity and prevalence of infection in those children whose academic performance was graded 3 (bad) were higher than in the children graded 1 (very good or good) or 2 (average). There was a significant interaction between age and infection, indicating that the relationship between infection and academic performance differed between the age-groups ($F_{5,529} = 3.024$; $P < 0.01$). The significant interaction can be ascribed to the increasing infection intensity with declining academic performance in the 6-, 8-, 9-, and 10-year age-cohorts compared with the increasing infection intensity with increasing academic performance in the 7- and 11-year cohorts.

Absenteeism

Data on both absenteeism from school and infection with *S. haematobium* were available for 466 of the children [Fig. 3(a)]. There were significant increases in absenteeism with increasing age [$F_{5,\ 463} = 6.197$; $P < 0.001$; Fig. 3(b)], and intensity of infection [$F_{1,459} = 5.583$; $P < 0.001$; Fig. 3(c)], but there

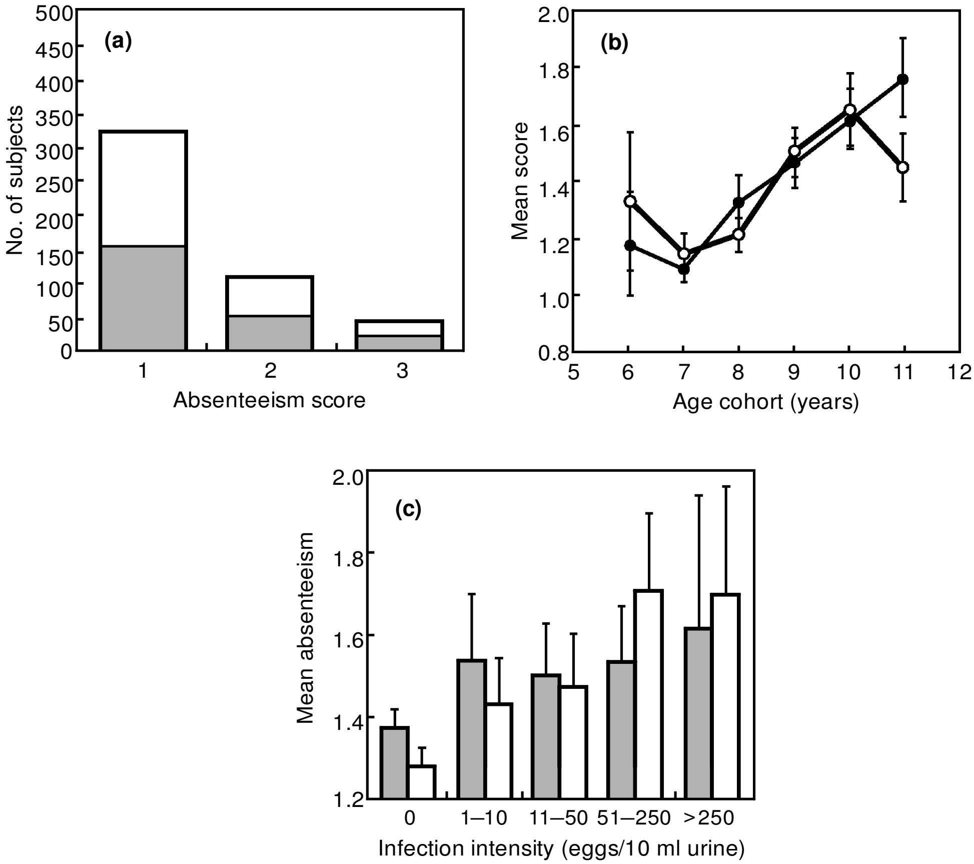

Fig. 3. (a) Frequency distribution of absenteeism among the male (▦) and female (□) subjects. (b) Age-related changes in absenteeism among the male (●) and female (○) subjects. (c) Mean absenteeism grade by category of infection intensity among the male (▦) and female (□) subjects. Vertical lines indicate S.E.

was no significant interaction between the latter two factors. There was also no significant difference in absenteeism between the genders. Figure 4 presents the relationship between academic grade and absenteeism. As might be expected, there was a reduction in academic performance with increased absenteeism. Statistical analysis of academic performance with consideration of absenteeism in addition to age, gender and intensity of infection showed that, whilst the main effects of gender and intensity of infection were significant ($F_{1,457} = 4.071$ and 4.074, respectively; $P < 0.05$ for each), absenteeism accounted for the largest proportion of the variation in academic performance ($F_{2,458} = 40.349$; $P < 0.001$). There was also a significant interaction between the effects of absenteeism, gender and intensity of infection on academic performance ($F_{2,431} = 4.55$; $P < 0.025$), indicating that the reduction in academic performance with increasing intensity of infection cannot be dissociated from that of absenteeism.

DISCUSSION

The objectives of the present study were to determine the distribution of helminth infections in schoolchildren in Bamako and the relationship between infection intensity and

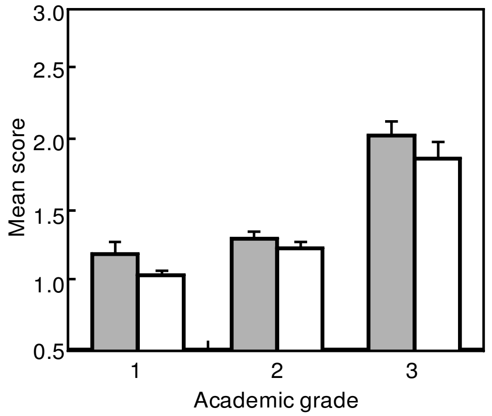

Fig. 4. Relationship between academic grade and score for absenteeism among the male (▦) and female (☐) subjects. Vertical lines indicate S.E.

educational outcomes such as school performance and school attendance. The results indicate that the most prevalent helminth infections in these schoolchildren were of *S. haematobium* and hookworm. However, the study was constrained by its dependence on only single stool samples from each subject because of the local reluctance to provide stools for analysis. Hence the true prevalences of hookworm and intestinal schistosomiasis in the present study group were probably underestimated.

Only *S. haematobium* was sufficiently widespread to make further statistical analysis feasible. As expected, the intensity of infection with *S. haematobium* increased with age across the 6–11-year groups. The analysis showed that there was a significant decline in academic performance with increasing infection intensity (although some age-groups did not conform to this general pattern). This agrees well with the results of a previous study in Jamaica, in which the children judged to be the least academically able were the most likely to harbour geohelminth infection and above-average worm burdens (Nokes *et al.*, 1991). It was also shown in Jamaica that the level of school absenteeism was related to infection in the children: the most heavily infected individuals were absent almost twice as often as were their uninfected counterparts (Nokes and Bundy, 1993). In a more recent study, in Egypt, children who were not enrolled in school had higher prevalences and intensities of schistosomiasis infection than children who attended school (Husein *et al.*, 1996).

In the present study, where absenteeism was found to increase with age and where the children with relatively high parasite burdens showed relatively high absenteeism from school, age and intensity of infection affected absenteeism in distinct ways, with the age effect being slightly stronger than that of infection. As might be expected, academic performance was linked with absenteeism, so that children showing higher absenteeism had poorer academic grades. When all sources of variation were taken into consideration, absenteeism was the principal factor explaining the variation in academic performance, although a significant effect of infection remained.

School health programmes have been identified as among the most cost–effective of public-health interventions (World Bank, 1993) and school-based delivery of drugs is currently promoted by several international organizations (WHO, 1995). However, school attendance rates are low in some areas. In Mali, for example, only 23% of the children have access to schooling and many of those enrolled do not attend school regularly. Children are required by their families to be economically active and consequently start school late, or have interruptions in their schooling because of seasonal agricultural activities (Kvalsvig, 1988). The present results, as well those of others, indicate that the absentees are more at risk of ill health than those who attend regularly. Thus, ultimately, the success of school-based programmes will depend on the level of school attendance and school enrolment (Nokes and Bundy, 1993). Equally, improvement in the health of the children who do not attend school regularly, and who generally carry heavier infections than the school attenders, will depend on novel ways of reaching this elusive subset of the population and ensuring compliance with treatment programmes (Bundy and Guyatt, 1996).

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