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EPIDEMIOLOGY OF *SCHISTOSOMA MANSONI* INFECTION IN A RECENTLY EXPOSED COMMUNITY IN NORTHERN SENEGAL

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Abstract. The epidemiology of *Schistosoma mansoni* infection was investigated in Ndombo, a village in the epicenter of a very recent outbreak of schistosomiasis in northern Senegal. Repeated fecal egg counts and antigen detection in urine and serum were carried out in a random population sample (n = 422). Eggs were found in 91% of the subjects, with 41% excreting > 1,000 eggs per gram of feces (epg) (mean egg load of 646 epg). The prevalence was almost 100% in groups greater than five years of age. In spite of the supposed absence of acquired immunity, intensities of infection decreased strongly in adults. Antigen detection confirmed the high prevalence and intensity of infection and the age-related distribution of worm loads. The emergence of this new focus is probably due to the ecologic impact of newly built dams and the extension of irrigation projects in the Senegal basin.

Recently, the emergence of a new focus of *Schistosoma mansoni* has been described in Northern Senegal. The first case was diagnosed in 1988 in the city of Richard-Toll; since then, the number of cases has increased explosively.[1,2] This outbreak appears to be due to a series of ecologic changes and the subsequent spread of *Biomphalaria pfeifferi* from an inland lake (Lac de Guiers) to the canals of a sugar cane plantation and the Senegal river. The situation is a serious new public health problem, but provides a unique opportunity to study the epidemiology of schistosomiasis in a recently exposed, supposedly nonimmune community. Of particular interest are the age-related distribution of the prevalences and intensities of infection. Usually in endemic situations, egg counts decrease in adults, a phenomenon that is at least partially attributed to the development of acquired resistance.[3] In recently exposed communities, this resistance would not yet have developed, and atypical distributions may be expected. In preliminary studies, Talla and others reported high prevalences in adults as well as in children.[2] However, due to the high frequency of diarrhea, they were not able to assess intensities of infection with common quantitative techniques. In the study reported in this paper, we used a modified Kato-Katz method and circulating antigen detection assays to investigate a community near Richard-Toll.

SUBJECTS AND METHODS

Study population

Richard-Toll is a rapidly expanding town situated along the Senegal River, 100 km from its mouth in St. Louis (Figure 1). The sugar cane company located here attracts labor from the surrounding arid, rural areas. The actual number of inhabitants is estimated approximately 50,000. The present study was carried out in Ndombo, a village 4 km south of Richard-Toll, situated along the main canal of the sugar cane plantation (Figure 1). This canal connects Lac de Guiers with the Senegal River and by cutting through an old, meandering river, it has created a series of marshy creeks. The populations of both Richard-Toll and Ndombo depend largely on the canal and the creeks for its water supply.

Ndombo has approximately 4,000 inhabitants, mostly ethnic Woloffs. Unlike the urban population of Richard-Toll, it has a traditional structure and customs, and almost all inhabitants have lived in the village for their entire life. Rice culture, subsistence farming, and fishing are the main activities of men; some find additional work at the sugar company in Richard-Toll. Most women are involved in domestic duties and small-scale vegetable farming.

The study took place in July–August 1991. Before the investigation began, extensive information on its objectives and methods was provided to the community. A map of the village

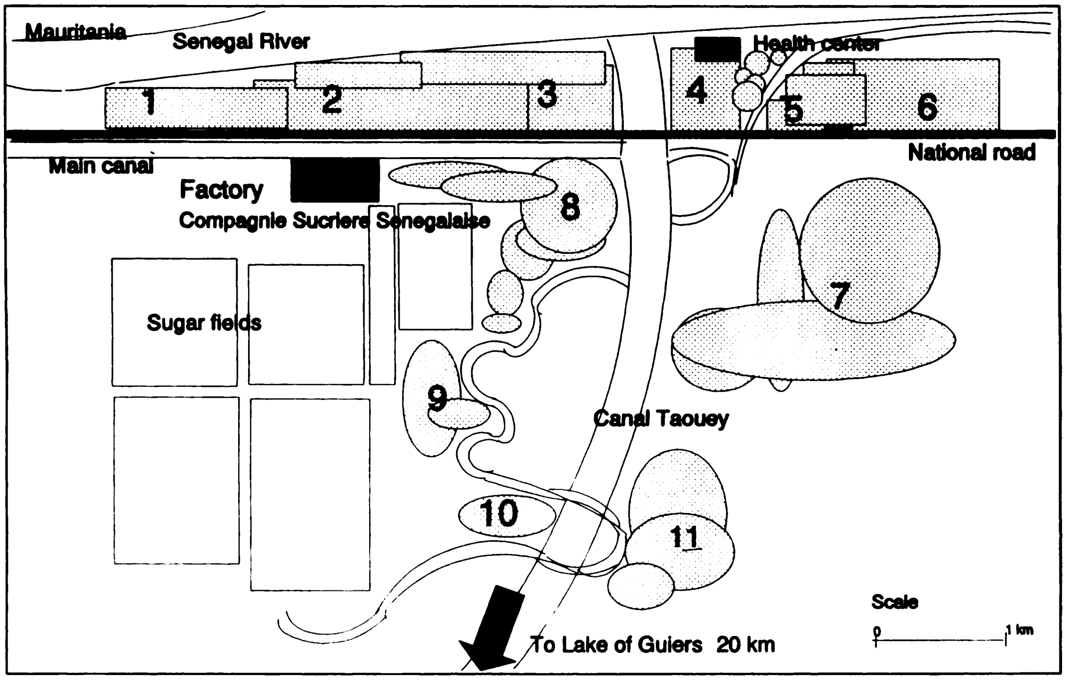

FIGURE 1. Map of Richard-Toll. Ndombo, the study village, is situated approximately 4 km south of the town center along the Taouey canal. 1 = Ndiaw; 2 = Ndiangu; 3 = Richard-Toll; 4 = Gaya II; 5 = Khouma; 6 = Gallo Malick; 7 = Thiabakh; 8 = Gadal Khout; 9 = Campement; 10 = Ndombo Al Arba; 11 = Ndombo.

was drawn and each family compound was given a number. With this base, a 10% random sample of households was then selected.

All invited families agreed to participate in the study. Families presented as a unit to a clinic that had been established in house in the village. Each person submitted to two stool examinations within an interval of two weeks, each one consisting of duplicate, 25-mg Kato slides.[4, 5] The appearance and consistency of each stool sample was recorded. The slides were prepared on the spot and examined within 24–48 hr. Mean egg counts were calculated as the geometric mean of the number of eggs per gram of feces (epg) of positive individuals. A standardized interview in Woloff language was conducted concerning age, sex, occupation, and previous treatment. One urine sample and one (venous or capillary) blood sample were collected; serum samples were stored frozen and transported to Leiden for detection of circulating anodic antigen in serum and circulating cathodic antigen in urine according to methods described by Deelder and others[6] and De Jonge and others.[7] All persons found to be infected received treatment with praziquantel (40 mg/kg).

RESULTS

Parasitology

The population sample included 422 subjects, 234 females and 188 males, with an age range of 0 to 77 years (Table 1). The predominance of adult females probably reflects the migration of men to the cities. Of 406 subjects who completed the interview satisfactorily, 73 (18%) reported at least one treatment with praziquantel since 1988. Of the 422 subjects, 383 (91%) had at least one positive egg stool specimen. Many infections were very intense: 41% of the population excreted more than 1,000 epg and 9% more than 4,000 epg. The geometric mean was 646 epg, and individual counts were as high as 24,160 epg.

Figure 2 shows the prevalence and egg distribution by age. Of those negative for eggs, 77% (30 of 39) were less than five years of age; in older age groups, almost everyone was infected.

TABLE 1

Age and sex distribution of the study population in Ndombo

Age group (years)	Total no.	(%)	Males No.	Males (%)	Females No.	Females (%)
1–4	75	(18)	37	(20)	38	(16)
5–9	71	(17)	29	(15)	42	(18)
10–14	63	(15)	31	(16)	32	(14)
15–19	48	(11)	23	(12)	25	(11)
20–29	68	(16)	30	(16)	38	(16)
30–39	42	(10)	16	(9)	26	(11)
>40	55	(13)	22	(12)	33	(14)
Total	422	(100)	188	(100)	234	(100)

The most intense infections were found in subjects between five and 20 years of age; 80% of those excreted more than 400 epg, 60% more than 1,000 epg, and the geometric mean egg count was 1,178 epg. Although the prevalence did not decrease in adults, the frequency of intense infections and mean egg counts decreased from the age of 20 years (Figure 2). In those over 30 years of age, 52% had egg counts greater than 400 epg, 25% had counts greater than 1,000 epg, and the mean egg count was 336 epg. The overall prevalence was 90% in males and 92% in females; with mean egg counts of 652 epg and 643 epg, respectively. These differences were not statistically significant. The sex-related differences appear more important in children and young adults between five and 20 years of age (Figure 3), but they were statistically significant only in the group 5–9 years of age ($P = 0.0097$).

Of those with a history of schistosomiasis treatment, 68 of 73 (93%) were infected, and 27

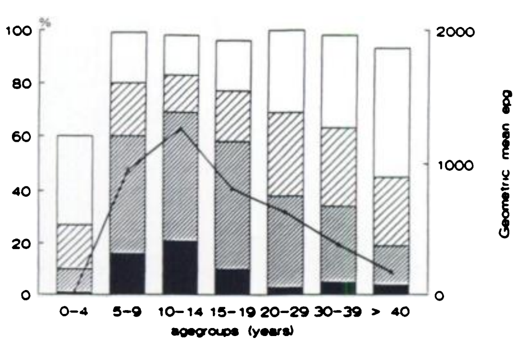

FIGURE 2. Prevalence and egg count distribution relative to age (n = 422). Solid bars = eggs per gram of feces (epg) > 4,000; narrow-hatched bars = epg > 1,000; wide-hatched bars = epg > 400; open bars = epg > 0. The line shows the geometric mean epg (Δ).

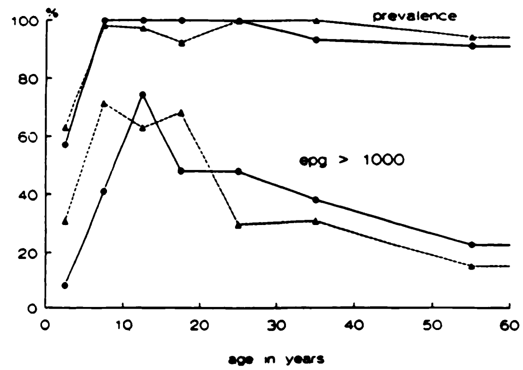

FIGURE 3. Prevalence and intensity of infection relative to sex. ● = males; ▲ = females. epg = eggs per gram of feces.

(37%) had egg counts greater than 1,000 epg; there was no significant difference between the treated and the untreated populations.

Antigen detection

Circulating cathodic antigen was detected in 96% (307 of 371) of the urine samples examined and circulating anodic antigen was detected in 87% (335 of 360) of the serum samples examined. Of those with no eggs in their stools from which urine (29 subjects) or serum (24 subjects) samples were also examined, 22 persons were positive in one or both antigen detection assays. The combined data from egg counts and antigen

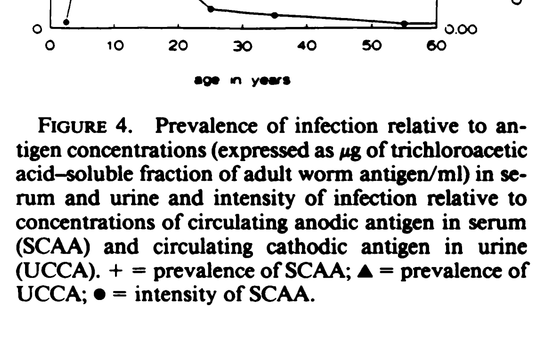

FIGURE 4. Prevalence of infection relative to antigen concentrations (expressed as μg of trichloroacetic acid–soluble fraction of adult worm antigen/ml) in serum and urine and intensity of infection relative to concentrations of circulating anodic antigen in serum (SCAA) and circulating cathodic antigen in urine (UCCA). + = prevalence of SCAA; ▲ = prevalence of UCCA; ● = intensity of SCAA.

detection resulted in a prevalence of 96%. Serum antigen levels peaked strongly in children 10–19 years old, and decreased substantially in adults (Figure 4).

DISCUSSION

This study in the village of Ndombo confirms the preliminary observations, based on direct stool examinations in Richard-Toll,[1,2] that the prevalence of infection with *S. mansoni* in the Richard-Toll area has, indeed, reached very high levels in a few years. By applying the more sensitive and quantitative Kato-Katz method, we have shown that virtually everyone greater than five years of age is infected, and also that intensities of infection are extremely high. This focus is actually one of the most intense in the world, comparable only to those described in Maniema, Zaire and West Nile, Uganda.[8,9] The parasitologic results were not only confirmed, but even strengthened by those of the antigen detection assays, which picked up additional infections among those with negative results on stool examinations.

Although the exact point at which *S. mansoni* was introduced into the area cannot be determined, all evidence indicates that transmission has been established in recent years. During the past decades, several investigators have reported only foci of *S. haematobium* in the Senegal River basin.[10–12] This species, however, has not been reported in the Richard-Toll area so far. A survey in 1989 revealed this parasite in only one (migrant) girl of 1,032 subjects from Richard-Toll and surroundings, including 191 from Ndombo (Diallo S, Department of Parasitology, University of Dakar, Dakar, Senegal, unpublished data). In local health centers, only sporadic, imported cases of urinary schistosomiasis are seen.

The presence of *B. pfeifferi* in the river delta near St. Louis and in Lac de Guiers has been described before.[11] However, the first case of infection with *S. mansoni* in the area was found only in January 1988, and the number of diagnosed cases increased very rapidly in the following months and years.[1,2] Our data indicate that in four years, virtually everyone has become infected, and often with heavy worm burdens.

The outbreak can be linked to several human-made ecologic changes in the past decade. In 1976, the main supply canal for the sugar cane estate was constructed, linking Lac de Guiers with the Senegal River, and creating the marshy creeks noted above. In 1986, a dam was completed near St. Louis that prevents salt water intrusion into the Senegal River basin; another new dam, 1,200 km upstream in Manantali, Mali, regulates the water flow. Consequently, the water in the Senegal River basin and in the irrigation system in Richard-Toll has become permanently fresh and water levels have been stabilized. These modifications of the aquatic environment have apparently led to a massive invasion of the canal system by *B. pfeifferi*.[13] During the same period, the explosive population growth in Richard-Toll has led to increased water contact and contamination. The introduction of *S. mansoni*, possibly by immigrant workers from endemic areas in southern Senegal or neighboring countries, was only a matter of time. Recently, up to 45% of the snails collected in this area were shown to be infected.[13] The intense transmission has enabled the parasite to spread very rapidly in the non-immune population, creating an important new health problem in this area. Hepatosplenic morbidity in this community is still limited: only 7% of the subjects, mainly children, showed mild hepatomegaly (Stelma FF and others, unpublished data). However, recent outbreaks of diarrhea in children as well as adults have been linked to the rapid spread of schistosomiasis.[1,2] In the present survey, only 17% of the stool samples were diarrheic, which allowed the use of the Kato-Katz technique without major problems.

Extension of the focus along the Senegal River, to which *B. pfeifferi* now, at least seasonally, has spread (Diaw OT, Sturrock RF, unpublished data) is to be expected, particularly in the areas where irrigation projects are planned or underway. Further upstream, e.g., around the Manantali dam in Mali, schistosomiasis has not yet become a major problem, but this situation may change rapidly.[14,15] Obviously, problems may also arise (and probably already have) in southern Mauritania, across the Senegal River. In addition, urinary schistosomiasis, focally endemic for many years, may become much more widespread in all these areas if the ecologic changes would also lead to further spreading of the bulinus snails. Schistosomiasis in the Senegal River basin is thus once more a cross-frontier problem that should be addressed through international cooperation. The unexpected outbreak of *S. mansoni*, rather than the predicted extension of the urinary form,[11] illustrates the difficulty in predicting the consequences of water-related development projects.

The emergence and early detection of this new focus provides a unique opportunity to investigate the impact of immunity on the epidemiology of *S. mansoni.* In most endemic areas, rates and intensities of infection or reinfection are higher in children than in adults. The relative contribution of age-related water contact patterns and of acquired immunity to this pattern has long been a subject of debate.[16, 17] Although, exposure to transmission is obviously an important factor, recent work in Kenya and the Gambia strongly supports a predominant role of acquired immunity.[3]

Earlier studies on schistosomiasis in noninfected migrants moving to endemic areas has produced conflicting results. In Brazil, prevalences decreased in adult migrants a few decades after their settlement in the endemic area.[18] In Burundi, prevalences and intensities of infection continued to increase with duration of exposure, even 20 years after settlement. In recently settled communities, prevalences and intensities decreased in adults.[19, 20] These data, however, have been obtained retrospectively by comparing infection rates in migrants who settled in different periods. In our study population, we had the opportunity to investigate the epidemiology of schistosomiasis in the very early phases of endemicity. Prevalences increased rapidly in children and remained nearly 100% in adults, indicating that transmission is very intense indeed, and that virtually everyone is susceptible to infection. However, intensities of infection, as determined by egg counts, are much lower in age groups greater than 20 years of age. As shown by the parallel decrease in levels of adult worm antigen, this reduction genuinely reflects changes in worm burdens. Neither acquired immunity, which would develop only after 5–10 years nor a reduction of worm fecundity, can thus explain the decrease in egg counts in adults in this recently exposed population.[3] Although several possible explanations exist, age-related water contact patterns probably still play the most important role in this population. However, it may be that in later stages of the development of the focus, the role of acquired immunity in the distribution of the infection will become more important. An analysis of humoral immune responses and careful epidemiologic studies, including exposure and reinfection studies, are now underway. Hopefully, these studies will further contribute to our understanding of the development of acquired immunity in human schistosomiasis, as well as to rational control strategies in epidemic situations.

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