THE EFFECT OF A COMBINED APPROACH TO SCHISTOSOMIASIS CONTROL ON THE TRANSMISSION OF *SCHISTOSOMA JAPONICUM* IN XINGZI OF POYANG LAKE AREA, CHINA

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Abstract. The impact of a combined approach to schistosomiasis control from 1987 to 1989 and mass chemotherapy from 1992 to 1994 was studied in a rural community in Xingzi county in the northwest corner of Poyang Lake in Jiangxi Province, China. Humans, cattle, buffalo and pigs were known potential reservoirs of *Schistosoma japonicum*. Transmission occurs during water contact on and around seasonally flooded marshes that are used for grazing, the harvesting of grass and fishing. Humans and livestock underwent yearly selective mass chemotherapy, and snails were eliminated through ploughing and compacting of the marshland in the spring of 1988. Transmission was monitored through the determination of annual re-infection rates in samples of the human population, the annual examination of piles of feces from animals and humans in the marshland, the annual collection and examination of intermediate snail hosts, and the exposure to potentially polluted water and subsequent examination of sentinel mice. Schistosomiasis prevalence among humans and animals declined sharply as soon as mass chemotherapy was implemented. Snail density decreased even before mollusc control was started, possibly indicating a high variability of this indicator. The infection rates of snails and sentinel mice reached zero after a single application of mollusc control. The results underline the importance of single infected water buffalo for the transmission of schistosomiasis. Since the impact stopped for two years (1990-1991), the schistosomiasis prevalence rose quickly. Mass chemotherapy was an effective means to curb the prevalence of schistosomiasis in this area, but the effects were only maintained for one or two years in the marsh zone.

INTRODUCTION

For centuries, schistosomiasis has caused suffering and premature death among people living along the Changjiang (Yangtze River) and in other endemic areas of China. People spoke of "villages without villagers" because so many had left or were dead (Chen, 1989). More than 100 million people were at risk before schistosomiasis control started in 1955. Continued efforts over four decades have led to a 90% reduction in the number of infected persons. *Schistosoma japonicum* was eradicated from one third of the original endemic area, it was controlled in another third, but remains an important public health risk in the remaining area (Chen, 1989). The integration of control measures and parallel, complimentary coordinated scientific research have been cited among the major elements that contributed to success of the program (WHO, 1988; Zhang, 1990). The strategies used in the eradication campaign have been described in detail by Zhang (1982) and Zhang *et al* (1990). They consisted of the eradication of intermediate snail hosts through environmental modification and molluscidiing, combined with large scale chemotherapy for humans and cattle as well as the provision of safe water, sanitation, personal protectior and health education.

Recently (WHO, 1988), there has been mountin evidence that schistosomiasis is expanding again This is especially true for epidemic areas consistin of marshlands along the shore of the lakes in th middle-lower Yangtzi River region of China. Control of schistosomiasis was known to be particularly difficult in relation to this type of ecolog (Zhang, 1982). Water contact is an occupationa hazard for farmers as well as for fishermen. Cattle and buffalo act as main reservoirs of the parasite and infected migrant fishermen may reintroduce the parasite into places where it had been controlled or eradicated (Chen, 1989). This requires a renewed effort to eradicate or control schistosomiasis in the remaining endemic areas. In order to make control effective as well as cost efficient, the im-

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pact of strategies and in combination has to be evaluated. The objective of the present study was to measure the impact of a combination of snail control with mass chemotherapy of humans and animals on schistosomiasis if applied locally in a lake area. A settlement in the prefecture of Jujiang on the northern end of Lake Poyang was chosen as study site. While control measures were carried out from 1987 to 1989, transmission of *S. japonicum* was measured.

MATERIALS AND METHODS

Study area

The Poyang Lake area is a vast plain in the north of Jiangxi Province in central China. It is a conduit for the rivers from the surrounding mountain ranges. The lake consists largely of a mass of broad, shallow waterways separating low lying marshes that are flooded during the wet season. Through a narrow gap the lake empties into the Yangtzi River to the north, close to Jujiang city. Humans and livestock are the main reservoirs of *S. japonicum*. Miracidia hatching from eggs that reach the water of the lake in the feces of humans, cattle and buffalo infect the amphibious intermediate host snail *Oncomelania hupensis*. The transmission cycle is completed when carceriae emerging from the snails infect humans and reservoir animals entering contaminated water.

The study area belongs to the county of Xingzi situated at the northwest corner of Poyang Lake where the northern shore turns into the outlet towards the Yangtzi River. In the 1958 more than four fifths of the population (86%) were at risk of schistosomiasis. Schistosomiasis was a serious health problem. 53.3% of the persons infected developed clinical symptoms which included hepatosplenomegaly, ascites and dwarfism. Through the application 717,246 person days of labor in snail control and 35,152 treatments the overall incidence of schistosomiasis dropped from 17.8% in 1957 to 1.1% in 1980. At the same time agricultural production in terms of quantity as well as yield per unit of land increased substantially. For example, the production of grains increased 4.6 times and the yield per area 2.2 times. However, in 1980 still 75,681 of the 177,517 inhabitants (42.6%) were at risk of schistosomiasis (Antischistosomiasis Office, Xingzi, 1981).

Liaonan, a rural settlement of about 2,000 inhabitants on a sandy cliff overlooking the northern shore of Poyang Lake in the county of Xingzi was chosen as the site of the study. The marshes that are a part of the lake are used for the grazing of cattle, water buffalo and pigs. They are also a source of thatch for the roofs of farm houses and grass harvested as winter fodder. The population consists of farmers, some of whom are part-time fishermen. There is also a group of migrant fishermen who live entirely on small boats moored along the main canal leading to Liaonan from the lake. They come and go as they please. The closer farmers live to the shore the higher is the probability that they have occupational or other water contact. For this reason the settlement was divided into three zones according to the distance from the shore. Each zone consists of strip of land parallel to the shore. The villages of zone 1 are within 500 meters from the lake, the villages of zone 2 are from 500-1,000 meters from the lake.

The wet season starts in April and lasts through October. During this time the marshland is gradually flooded. It starts to reemerge in September. Some cattle and buffalo remain in the marshes throughout the year. From March to December cattle and buffalo are also driven to the marshes from further inland. Pigs belonging to the inhabitants of zone 1 roam the marshes from March to December.

Schistosomiasis control

Every year in the spring stool samples were collected from the inhabitants of Liaonan. The samples were examined according to the Kato-Katz method (using 50 mg of stool) for the presence of schistosomiasis eggs. All persons found infected were treated with a single dose of praziquantel (40 mg per kg body weight). Cattle and buffalo were examined and treated on a yearly basis in a similar fashion. Pigs, although a potential reservoir of schistosomiasis, were not treated because they were usually slaughtered after one year. In the spring of 1988, after the malacological survey the marshland in front of Liaonan was ploughed and compacted. This fixes the snails underground and prevents them from mating. The technique is less harmful to the environment than the use of molluscicides and also less expensive (Zhang, 1982). All the control stopped from 1990 to 1991 because of budget constraints; in 1992 we received other support to continue to give mass chemotherapy in this area.

The measurement of transmission

Each year in the spring the research team collected stool specimens from a sample of about 500 villagers in each zone. Using a 50 mg template, stools were processed according to the Kato-Katz method. Eggs were counted and the number of eggs/g was calculated. Assuming that the mass treatment with praziquantel has led to a cure in 95% of the infected persons, one can approximate the incidence of schistosomiasis by reference to the infection rates found in 1988 and 1989.

Maps of the marshes in front of Liaonan were and overlaid with a grid. Corresponding to the intersections of the gridlines, circles of one square cm (0.11 m^2) were staked. Every year in spring and in the autumn these circles were used as collection points for snails. All snails within in a circle were taken to the laboratory. There they were crushed and microscopically examined for the presence of cercariae. The method has been described in detail by Zhang *et al* (1988).

At the same time, snails were collected, all piles of feces found in the marshes were examined. They were weighed and it was noted whether they came from buffalo, cattle, pigs or humans. A sample of 50g was taken from each of them to the field laboratory. After passing the samples through a mesh of 60 threads per inch, the suppressant was discarded after 20 minutes. Then the sediment was covered with clear water again. This procedure was repeated three time until the suppressant remained clear. Keeping the samples at 20 to 24°C they were examined for the presence of miracidia after 3, 6, 9, 12 and 24 hours. A sample of 50 mg was taken and examined after Kato Katz from each fiftieth specimen before the hatching teat was started.

Water contact of humans and reservoir animals was assessed through locally trained volunteers. On days 1, 11 and 21 of each month these volunteers spent the entire day in the marshland. They recorded the numbers, activities, and whether they originated from for the humans, buffalo, cattle or pigs they observed in the marshes.

The degree to which the water on the edge of the marshland was contained with cercariae was measured through the exposure of mice. On one occasion in the spring and in the autumn 50 mice were put into wire cages which were floated on the water surface with the help of inflated plastic balloon attached to their sides. These cages were dragged slowly along the main canal for fifteen hours for each of in three days. Forty days later the mice were killed and dissected. The number of adult schistosome worms were counted. This technique has been described and evaluated by Hu *et al* (1989).

RESULTS

Table 1 shows the results of schistosomiasis surveillance in the human population. At the beginning of study, schistosomiasis was endemic in the two zones of Liaonan. High prevalence rates of 39.9% and 34% were observed in zones 1 and 2. Reinfection was still relatively high after one application of mass chemotherapy. It dropped sharply after chemotherapy was combined with mollusc control.

If the chemotherapy stops, the prevalence will be soon rise again in this area: we stopped chemotherapy for two years and the prevalence rose from 7.0% (1989) to 22.5% (1992) in first zone and from 3.4% (1989) to 6.1% (1992) in zone 2.

Snail density (Table 3) shows dropped to one sixth of its initial value before any snail control was undertaken. Then it dropped to only about half of the value immediately before ploughing and compacting the soil decimated the number of *O. hupensis*. The density of infected snails dropped to a fourth of its initial value after mass chemotherapy had been applied for the first time. No infected snails were found after mollusc control in the spring of 1988. The density of snails rose slightly in 1992 and 1993, but in 1994 year the density of snail rose to its original level. The density of infected snails also increased.

The results of the examination of feces piles in the marshland are summarized in Table 2. Overall buffalo were the most important sources of viable schistosomiasis eggs, being responsible for 78.9%, 35.1 and 75.1 respectively of the total number schistosome eggs in 1987, 1988 and 1989. Humans contributed only 3.3% of the eggs found in the

Table 1

Prevalence of schistosomiasis in human in three zones of Liaonan which reflect the distance from the lake.

Zone	1987	1988	1989	1992	1993	1994
Zone 1						
examined	525	530	499	498	410	455
Infected%	39.9	26.1	7.0	22.5	11.2	13.4
Reduction%	0	34.4	82.5	43.6	71.9	66.4
EPG*	3.84	1.90	0.36	3.49	2.02	1.37
Zone 2						
examined	541	516	500	462	343	391
Infected%	34.0	12.2	3.4	6.1	1.8	2.3
Reduction%**		48.7	84.7	74.1	92.3	90.3
EPG*	1.48	0.60	0.18	0.33	0.09	0.09

* Geometric mean of n+1 eggs in per gram of stool
** (p1-p2)/p1

Table 2

Schistosomiasis eggs in feces collected on the marshes.

Year		Humans	Buffaloes	Cattle	Pigs
1987	Stools examined	2	452	100	0
	Propn infected%	0	3.3	6.0	0
	Eggs excreted*	0	382,202	102,095	0
	Proportion of all eggs%	0	78.9	21.1	0
1988	Stools examined	18	219	79	3
	Propn infected%	22.2	1.8	7.6	0
	Eggs excreted*	2,797	29,791	52,345	0
	Reduction eggs excreted%**	increase	92.2	48.7	0
	Proportion of all eggs%	3.3	35.1	61.6	0
1989	Stools examined	3	83	34	0
	Propn infected%	0	1.2	2.9	0
	Eggs excreted*	0	22,987	7,603	0
	Reduction eggs excreted%**	100	22.8	85.5	0
	Proportion of all eggs%	0	75.1	24.9	0

* Number of variable *S. japonicum* eggs in all stools collected
** (N1-N2)/N1

Table 3

The density and infection status of *Oncomelania hupensis* collected at fixed point in the marshes (Spring).

Year	Density/0.11 m^2		Infected %
	all	infected	
1987	3.84	0.0441	11
1988	0.97	0.0118	1.2
1989	0.83	0.0003	0.3
1992	0.39	0	0
1993	0.29	0.0028	1.0
1994	8.73	0.0013	0.01

marshes in 1988. None of the pig feces was found to be infected. After the first round of mass chemotherapy for humans and animals the egg output dropped sharpy in buffalo, but was much less pronounced in cattle. When chemotherapy was combined with snail control, the egg output of buffalo was only moderately affected but that of cattle dropped by a factor of seven. A pile of feces from a buffalo weighed on average about two to four times as much as that of cattle. In each case only a relative small number of snail was found infected, the changes in egg output were dependent on the infection status of relatively few animals.

Fig1 depicts the average number of farmers, fishermen or boat people, livestock and pigs observed per day through the year in the marshes. Water control is highest at the beginning and end of the wet season.

The results of exposing mice to the water along of the marshes are shown in Table 4. The average intensity of infections started to decrease immediately after the first mass chemotherapy of humans and cattle. It dropped by a factor of about four each season until it reached zero by the end of the study. Infection rates started to drop only after the first year. The sharpest drop occurred after mollusc control in the spring of 1988.

DISCUSSION

The drop in schistosomiasis prevalene in the study population was most pronounced among the population furthest from the lake. When snail

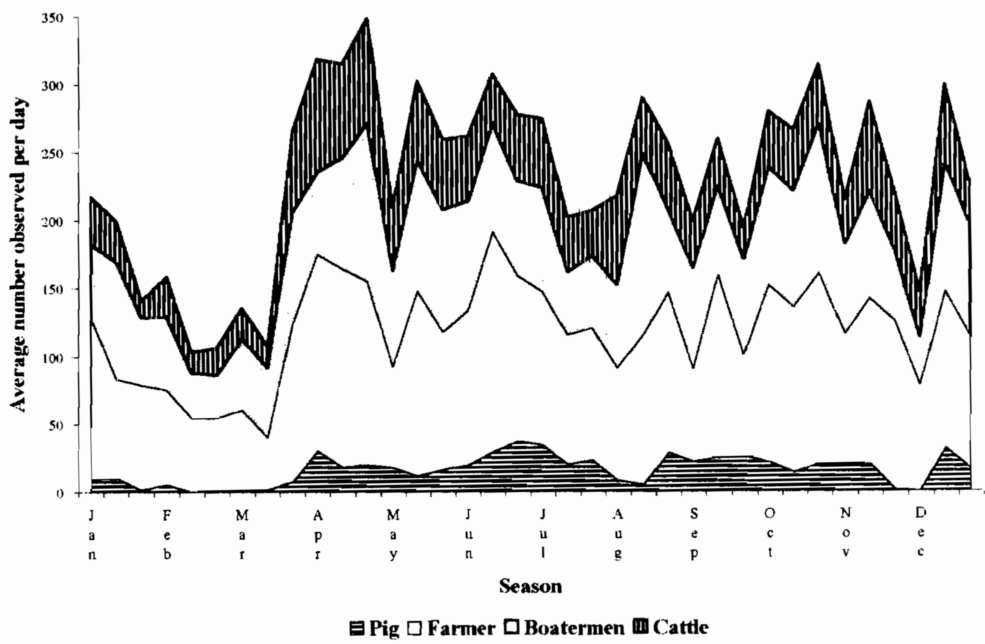

Fig 1–The average number of farmers, migrant fishermen, boatpeople, cattle (include buffalos) and pigs observed per day during the year in marshland in front of the study settlement. Observation are recorded in first, eleventh and 21st day of each-month for two years.

Table 4

Infections in mice exposed to water in the waterway surrounding the marshes (Spring).

Year	Examined	Infected%	Mean number of worms
1987	51	100.0	43.30
1988	53	76.9	4.08
1989	39	15.4	0.41
1992	30	100.0	9.16
1993	25	24.0	0.56
1994	52	11.5	0.27

control was added, the drop was sharpest in zones 1 and 2. The initial levels of prevalence differed significantly between the zones.

The study of piles of excreta in the marshes showed the importance of single infected animals for the transmission of schistosomiasis in the Poyang Lake area. Especially water buffalo which enjoy lying almost total submerged in water for hours and which are likely to defecate into water and marshlands are shown to be the most important source of viable schistosome eggs in this ecological situation. Further schistosomiasis control should place special emphasis on detecting infected domestic animals and treating them. In view of the openness of the marshland, modesty will prevent humans from defecating where they can be easily observed by others. It is not astonishing that relatively few human feces were found although the numbers of people exceed by far those of livestock (Fig 1).

Surprisingly, snail density changed more without than with control measures. This suggests that the duration of study may have been too short to obtain meaningful malacological results. Maps making the location there snails were found in subsequent surveys show a clustering close to places where people and animals ford waterways. The sometimes extreme focality of schistosomiasis transmission is well known for other species (Klumpp and Webbe, 1987). Perhaps it would be easier and yet more informative to concentrate the snail surveillance activities close to places where water contact of humans and animals is more frequent.

The exposure of sentinel mice to potentially polluted water is a direct and sensitive instrument to assess the risk of transmission. However mice can easily drown if the floats are dragged too fast through the water. If the mouse colonies are not well maintained during the following 40 days and mice die prematurely, the results can be difficult to interpret. In the present study a clear (and statistically significant) trend was observed. Both the mean number of worms per mouse and the infection rates declined as control measures continued.

By setting the initial infection rates equal to 100 and tracking the proportional declines among humans (in zone 1), cattle, snails and sentinel mice, the impact of control during the study period showed in Table 1. It shows that schistosomiasis transmission was significantly reduced during the study period. This was achieved despite the presence of migrant fishermen, among whom the prevalence of schistosomiasis is known to be high (Li and Yu, 1991), and who could not be included in the mass chemotherapy scheme on a regular basis. The study shows that the application of a combination of strategies will permit to control schistosomiasis effectively as Yuan (1985) has stressed.

The impact stopped for two years, the prevalence rose again form 7.0% (1989) to 22.5% (1992). The effects on schistosomiasis chemotherapy were evident in just one or two years in the first zone. But if mass chemotherapy was given again the prevalence would be decreased again. In this type epidemic area, schistosomiasis would reemerge yearly. Mass chemotherapy was given from 1992 to 1994, the prevalence of schistosomiasis decreased from 22.2% (1992) to 11.2% (1993) and 13.4% (1994). In the zone 1, the people live near the marshland and have high frequency to contact the infectious water. Although the population get the mass treatment, in this area the main infection sources are the infected livestock. The chemotherapy can decrease the prevalence of the disease in the population, but the intensity of transmission is still at high level. After mass treatment, yearly selective population treatment will still be recommended in this area.

In the secondary zone, when the impact stopped for two years, the schistosomiasis prevalence rose but more modestly from 3.4 (1989) to 6.1% (1992). Selective chemotherapy was given in this area, and the prevalence of schistosomiasis decreased from 6.1% (1992) to 1.8% (1993) and 2.3% (1994). In zone 2, the effects of chemotherapy can be expected to continue for long time but the disease would reemerge after 2-3 years. After mass chemotherapy, biannual the selective group treatment will be recommended in this areas.

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