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An economic evaluation of the national schistosomiasis control programme in China from 1992 to 2000

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Abstract

The World Bank Loan Project, by far the largest effort in China for schistosomiasis control since control activities were initiated in the mid 1950s, was carried out for a 9-year period commencing in 1992 in the 8 provinces where *Schistosoma japonicum* remained endemic when the project started. To evaluate its impact, a retrospective economic evaluation was done in 2001. Six representative counties, i.e. Huarong in Hunan province, Qianjiang in Hubei province, Yugan in Jiangxi province, Tongling in Anhui province, Xichang in Sichuan province and Dali in Yunnan province, were selected for the study. The total financial input in these counties from 1992 to 2000 was RMB Yuan 90.334 million with the World Bank loan accounting for 40.9%. Control efforts resulted in reduction of human prevalence rates in the six counties from 0.7–9.0% in 1992 to 0.1–2.7% in 2000. With regard to *S. japonicum* infection in bovines, a high reduction was observed in Qianjiang, and smaller decreases were noted in four counties, while there was an increase in Dali. In general, the areas infested by the intermediate host snail fluctuated around the initial level. The net benefit-cost ratio was 6.20, which means that this project gained US$ 6.20 for every dollar spent. The correlation coefficients of the net benefit-cost ratio to the human and bovine infection rates at the beginning of the project were 0.55 and 0.66, respectively. It is conceivable that further progress in schistosomiasis control is an important feature for sustained growth of the local economy, particularly in areas where control of the disease has been most challenging.

Keywords: *Schistosoma japonicum*; Schistosomiasis; Control programme; World Bank; Economic evaluation; Cost-effectiveness analysis; Cost-benefit analysis; China

1. Introduction

Schistosomiasis japonica is a serious parasitic disease threatening millions of people in the southern part of China. The disease remains of considerable

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public health concern and its transmission continues despite 50 years of intensive control efforts (Zhou et al., 2005). Based on a national survey carried out in the late 1990s it was extrapolated that 865,000 people and 100,250 bovines were infected with *Schistosoma japonicum* (Expert Advisory Committee on Schistosomiasis, Ministry of Health, 1998). This parasite differs from other schistosome species in that it is a zoonotic organism capable of infecting more than 40 mammalian species besides the human final host (Chen and Feng, 1999). The wide spectrum of reservoir hosts adds to the difficulty of controlling the disease. The clinical features of schistosomiasis japonica range from fever, headache and lethargy to severe fibro-obstructive pathology leading to portal hypertension, ascites and hepatosplenomegaly and sometimes premature death (Chen, 2005). Severely infected children are often stunted with impaired memory and decreased learning ability (Guo et al., 2001; Ross et al., 2001; Zhou et al., 2002).

In 1992, a special programme on schistosomiasis control, the World Bank Loan Project (WBLP), was initiated in all 8 provinces of China where the disease remained endemic at the time of project initiation, i.e. in the lake and mountainous regions. The integrated control approaches, based on community chemotherapy but also emphasizing health education and snail control by means of environmental management and mollusciciding, substantially decreased the public health significance of the disease in most areas (Yuan et al., 2000; Zhang and Wong, 2003). The WBLP was requested by the Chinese government to address the problem of continuing (in some areas even increasing) human/bovine schistosome infection in the face of increased efforts and investments to control it. This is the first time that substantial international funding and advanced management were introduced into the schistosomiasis control programme in China (Yuan et al., 2000; Chen, 2002), and it was felt to be essential to analyze its impact for future reference.

Here, we present a retrospective economic evaluation, including both cost-effectiveness and cost-benefit analysis. We focus on six project counties that are representative for the different eco-epidemiological settings of schistosomiasis in China. The outcomes of this economic evaluation should inform policy and decision-making for efficient and cost-effective allocation of available resources for disease control.

2. Materials and methods

2.1. Study area and baseline information

At the beginning of the project, using the county as a unit, a number of study areas were selected based on intensity of schistosome transmission and type of endemicity, i.e. lake marshland, river marshland and mountainous areas. Fig. 1 shows the geographic location of the six study counties. Three counties are situated in the lake marshlands (i.e. Huarong, Qianjiang and Yugang), one in the river marshland (i.e. Tongling), and two in the mountainous areas (i.e. Dali and Xichang).

Table 1 summarises the baseline situation in each study county with regard to the extent of schistosomiasis endemicity, human and bovine infection rates and the area infested with intermediate host snails. Based on the human infection rate, the areas were divided into high (>5%), medium (3–5%) and low prevalence (<3%). At the beginning of the project the prevalence rate was at a high level, as was the intensity of transmission, in Tongling and Yugang, at a medium level in Huarong, Qianjiang and Xichang, while it was at a low level in Dali.

2.2. Project financial input

Support through the WBLP plus counterpart funding from the Chinese government and allocations from the Provincial Departments of Finance, and funds raised from local residents were considered for the period 1992–2000 as the total financial input. On the debit side, costs regarding the different aspects of control, such as case detection and treatment, snail survey and mollusciciding, health education, individual protective measures, control activities in livestock, project management and training, were calculated. The final figure for the period included also the weighted participation of manpower, costs related to personal needs in the schistosomiasis institutions at county level, construction fees related to molluscicide engineering, as well as running costs for use of buildings, communication tools, general equipment and supplies.

2.3. Data collection

The retrospective economic evaluation was performed by collecting the relevant data from the

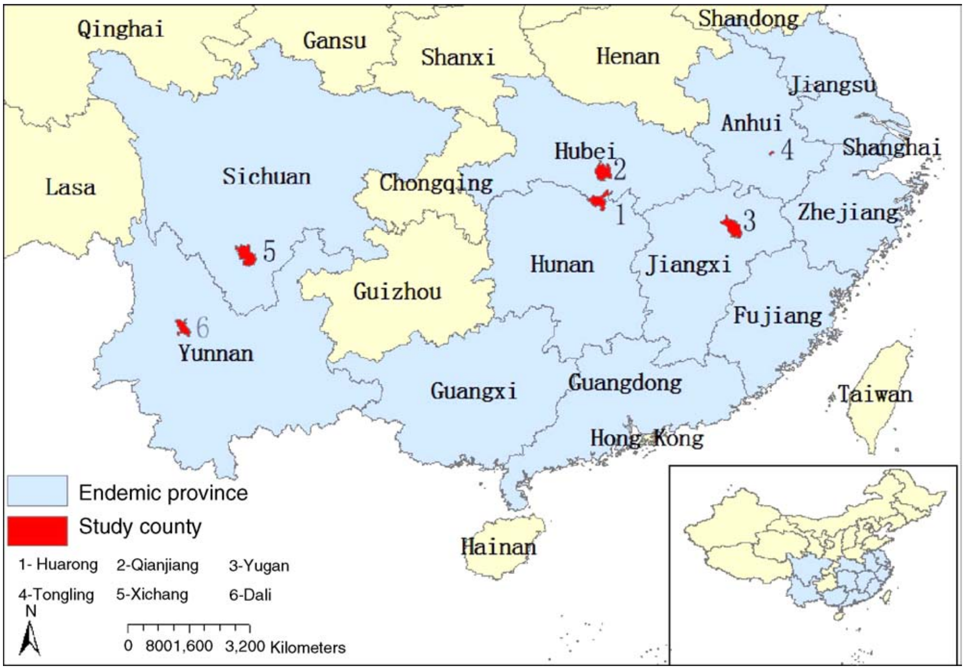

Fig. 1. Map of southern China showing the historic endemicity of *S. japonicum* (provinces marked with blue colour) and the six study counties (marked in red) where the present economic evaluation was carried out.

available records and databases of the study counties. These records and databases were kept under the guidance of senior scientists and managers, with the original data being assembled by professionals of anti-schistosomiasis control stations from 1992 to 2000. There was an exception in Xichang county, Sichuan province, where data collection ceased in 1998, in parallel with the completion of the WBLP in this province.

Control activities were implemented throughout the study and information regarding the number of townships/towns, population and numbers of cattle and

Table 1
Baseline information for the six study counties at the beginning of the WBLP on schistosomiasis control in China

Feature	Study county					
	Huarong	Qianjiang	Yugan	Tongling	Xichang	Dali
Province	Hunan	Hubei	Jiangxi	Anhui	Sichuan	Yunnan
Type of endemic area	Lake	Lake	Lake	River	Mountain	Mountain
No. of endemic townships/towns	23	13	22	18	36	10
No. of endemic villages	191	213	241	133	221	81
Population size in endemic areas	279642	549048	404729	225823	362527	365107
Human infection rate (%)	3.5	4.6	8.8	7.4	4.2	0.6
No. of cattle in endemic areas	19163	24473	31909	6684	40510	23689
Bovine infection rate (%)	7.9	8.5	11.6	15.7	21.0	1.3
Snail-infested areas (km^2)	86.29	28.62	117.44	37.26	6.52	4.09
Areas with infected snails (km^2)	1.36	15.93	82.21	5.32	1.88	0.72
Percent of infected snail areas among snail-infested areas (%)	1.6	55.7	70.0	14.3	1.88	17.6

water buffaloes in the endemic areas studied, were regularly collected.

2.4. Indicators

Data related to the reduction of disease burdens were collected in all study counties during the 9-year period and used as effectiveness indicators. This included parameters such as the annual infection rates in both humans and cattle, the infection rate of intermediate host snails and the density of infected snails, as assessed during field surveys.

Benefits were estimated on the basis of money gained for every dollar spent during the project period, and quantified by several indicators. The overall benefit was estimated using information on the reduction of losses due to infection and disease through successful mollusciciding and engineering and other control activities, as well as socio-economic data in the study counties during 1992–2000. The local hospitals and clinics were visited by specialists to estimate the expenses for treating acute, chronic, and advanced cases of schistosomiasis. Treatment costs for cattle were estimated on the basis of existing veterinary records.

The economic benefit due to mollusciciding and engineering supported by the WBLP was calculated from changes in income, for example, increased grain, water products, fruits and woods, increased income of livestock, decreased input of anti-flood engineering and increased access to local markets due to improvement and new constructions of road networks. The following data were assembled from the local anti-schistosomiasis control stations: annual number of people found with a *S. japonicum* infection and number of cases treated, the number of infected cattle and number of cattle treated, areas subjected to mollusciciding and snail areas eliminated. Socio-economic data, i.e. gross domestic product (GDP), price indexes, value of day-manpower and annual average income in the study counties during the evaluation period from 1992–2000, were collected from the relevant departments of the local governments.

2.5. Data analysis

Cost-effectiveness was estimated by various indices, e.g. the cost for reducing the *S. japonicum* infection rate per 100 persons by 1% or the cost for reducing the infection rate per 100 cattle by 1%. Three indices were calculated for cost-benefit analysis, i.e. the net benefit-cost ratio, the net benefit (net value), and annual average benefit of mollusciciding engineering (Udvarhelyi et al., 1992; Department of Disease Control, Ministry of Health, 1999).

As the WBLP on schistosomiasis control in China covered a relatively long period of 10 years, inflation and other variations of costs incurred could introduce biases threatening the usefulness of comparisons of input and output from one time point to another. Potential limitations of study results were overcome by utilizing the formuli specified below, where i the number of years the project was implemented (max. 9 years), r the discount rate based on the index of price increase, B_i the benefit in year i, and C_i the input in year i, thus:

$$\text{cost} = \sum C_i/(1+r)^i$$

$$\text{benefit} = \sum B_i/(1+r)^i$$

$$\text{gross benefit-cost ratio} = \left[\sum B_i/(1+r)^i\right] / \left[\sum C_i/(1+r)^i\right]$$

$$\text{net benefit-cost ratio} = \sum[(B_i - C_i)/(1+r)^i]/ \left[\sum C_i/(1+r)^i\right]$$

$$\text{net benefit(net value)} = \sum B_i/(1+r)^i - \sum C_i/(1+r)^i$$

The benefits gained from prevention and control, such as reduced treatment costs for acute, chronic, and advanced cases in humans, reduced treatment costs in cattle and the general saving of resources, were calculated by the following formuli:

(1) Benefits from schistosomiasis control in a year = health benefits + resources benefits.
(2) Health benefits = treatment benefits both in humans and in cattle + prevention benefits.
(3) Treatment benefits = the number of cured cases + the improved degree of manpower after treat-

ment × the daily value of manpower + the number of cattle cured × the value of the cattle.

(4) Prevention benefits = the reduced number of cases due to schistosomiasis control × (the economic loss due to disability caused by schistosome infection + the average individual cost of treatment of schistosomiasis) + the reduced number of infected cattle × (the economic loss due to cattle disability caused from schistosome infection + the average individual cost of cattle treatment).

(5) Resource benefits = the reduced number of schistosomiasis cases × the average individual cost of treatment.

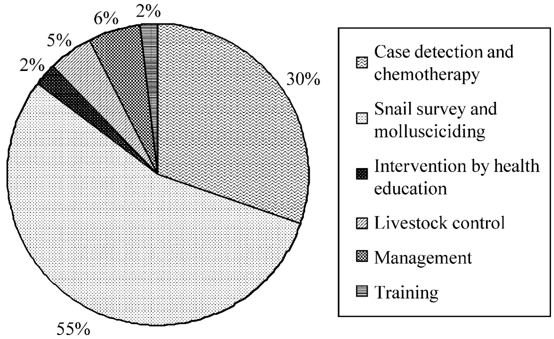

Fig. 2. The relative share of the different control interventions to the total costs incurred for the 9-year schistosomiasis control programme.

3. Results

3.1. Costs

Table 2 summarises total costs for the period 1992–2000, stratified by cost position and county. Total input in the six counties during the 9-year period was RMB Yuan 90.334 million. Among them, input from World Bank loan was RMB Yuan 36.932 million, which accounted for 40.9%. Counterpart input, which amounted to RMB Yuan 53.402 million, accounted for the remaining 59.1%. In accordance with the value index in 2000, the direct input for schistosomiasis control was RMB Yuan 97.170 million.

Fig. 2 shows the relative share of the different schistosomiasis control interventions. RMB Yuan 29.334 million were spent for case detection and chemotherapy (30.2% of total direct input). Snail surveys and mollusciciding required RMB Yuan 53.586 million (55.2%) and RMB Yuan 14.250 million was used for other control activities (14.7%).

3.2. Effectiveness

Fig. 3 depicts the human prevalence rate of *S. japonicum* over time in each of the six study counties. In all counties, the prevalence rates decreased significantly over time, i.e. from 9.0% during the baseline survey carried out in Yugan in 1992 to 2.7% in 2000, from 7.6% to 1.9% in Tongling, from 4.7% to 2.2% in Qianjiang, from 4.2% to 1.7% in Xichang, from 3.7% to 2.6% in Huarong and from 0.7% to 0.1% in Dali. These data show that the overall reductions in human infection prevalences varied considerably from one county to another, with the lowest impact recorded in Huarong. Here, the prevalence rates varied between 2.6% and 5.4% over the 9-year project period.

Table 2
Direct project input for schistosomiasis control in the six study counties from 1992 to 2000 (year 2000 considered as value index; unit used = RMB Yuan)

Item	Huarong	Qianjiang	Yugan	Tongling	Xichang	Dali	Total
Cases detection	1519944	2931304	2159218	4045850	878942	1295620	12830878
Chemotherapy	1592170	6372216	2009045	2371943	2156169	2000936	16502478
Snail survey	1075153	875772	225466	1287997	208879	1540530	5213797
Mollusciciding	9743387	11840174	5759814	4628713	6164274	10236020	48372383
Health education	112724	441440	296840	454693	337677	7716483	2415022
Livestock control	690535	802476	1021726	396507	242774	1478349	4632367
Management	703704	239054	541791	1983452	123307	1824243	5415551
Training	213004	137480	90853	681440	41979	6224009	1787157
Total	15650620	23639915	12104753	15850594	10154002	19769750	97169632

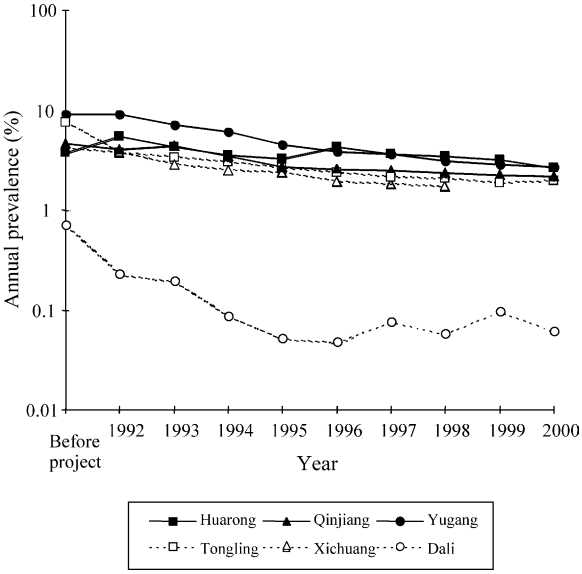

Fig. 3. Semi-log curve of the annual human infection prevalence with *S. japonicum* in each of the six study counties.

Fig. 4 shows the annual bovine infection rates from 1992 through 2000 in each of the six study counties. The highest reduction over time was observed in Qianjiang, whereas in Huarong, Tongling, Xichuang and

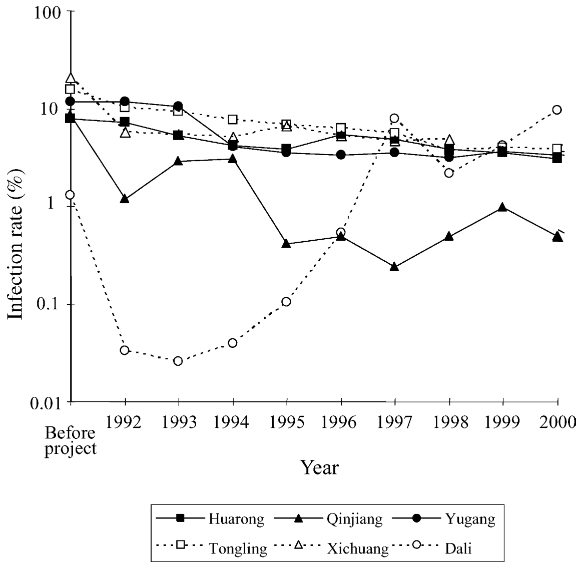

Fig. 4. Semi-log curve of the annual bovine infection prevalence of *S. japonicum* in each of the six study counties.

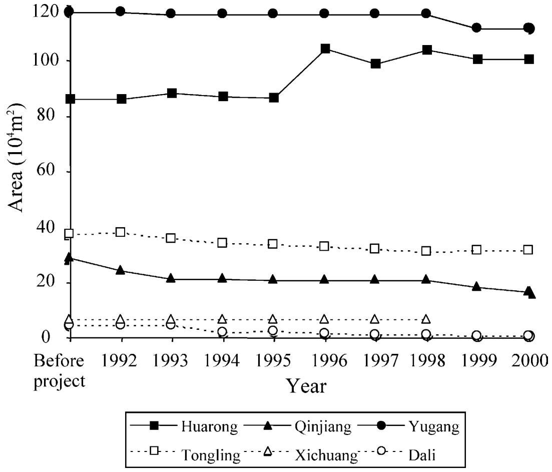

Fig. 5. Snail-infested areas in each of the six study counties from 1992 to 2000, as assessed by field surveys.

Yugang, the impact was less pronounced. In contrast, in Dali, a significant increase occurred over time in the infection prevalence of *S. japonicum* in bovines.

In most counties, the intermediate host snail infested areas and the rate of infected snails fluctuated around the original level throughout the study, as shown in Figs. 5 and 6. In general, the extent of snail-infested areas increased slightly, with the exception of Yugang, where a significant decline occurred.

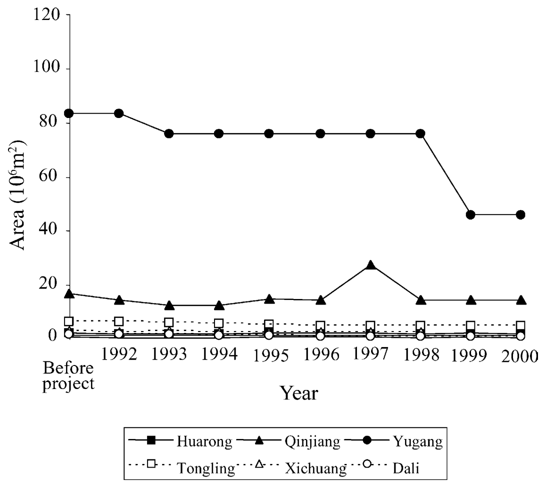

Fig. 6. Areas where infected intermediate host snails were recorded from 1992 to 2000 in each of the six study counties.

Table 3
An analysis of cost-effectiveness in the six study counties (unit used = RMB Yuan)

Item of cost	Huarong	Qianjiang	Yugan	Tongling	Xichang	Dali	Average
Cost for case detection per person	10.78	11.51	9.26	28.09	7.50	7.73	12.48
Overall cost of project per person	54.21	29.24	26.88	69.38	25.10	46.33	41.86
Cost for case detection to reduce 1% human infection rate per 100 people	3634.10	2190.01	1327.52	3780.44	1282.76	845.51	2176.72
Overall cost of project to reduce 1% human infection rate per 100 people	18275.65	5564.74	3855.16	9336.89	4291.49	5070.62	7732.42
Cost for mollusciciding to reduce 1000 m^2 of snail infested areas	704.31	967.33	1009.99	506.35	15359.58	2891.53	3573.18
Cost to reduce 1% bovine infection rate per 100 cattle	243264.52	93751.91	93006.79	350736.34	33695.94	–	162891.10

3.3. *Cost-effectiveness analysis*

Examination of the data derived from the six study counties found that the average cost for case detection was RMB Yuan 12.48 per person, with an average cost for all control measures of 41.86 per capita. The average cost to reduce the human infection rate of *S. japonicum* per 100 persons by 1% amounted to RMB Yuan 7732.42, whereas the average cost for case detection and treatment alone was RMB Yuan 2176.72. The average cost of reducing 1% of the bovine *S. japonicum* infection rate per 100 cattle was RMB Yuan 162891.10. Reducing the snail-infested areas by 1000 m^2 by means of mollusciciding costed RMB Yuan 3573.18 (Table 3).

3.4. *Cost-benefit analysis*

The analysis in the six counties showed that the average losses due to a case of acute, chronic, or advanced schistosomiasis japonica were RMB Yuan 992.62, 640.47 and 3807.80, respectively. The average costs for treatment of an acute, chronic or advanced case of schistosomiasis japonica were RMB Yuan 447.04, 347.95 and 1619.85, respectively (Table 4). In accordance with the value index of the year 2000, the total benefit of the WBLP in the six counties during the 9-year evaluation period was RMB Yuan 699.512 million and the direct benefit of schistosomiasis control was RMB Yuan 650.676 million, with the benefit from mollusciciding engineering project amounting to RMB Yuan 48.835 million.

In summary, the total per capita benefit was RMB Yuan 1804, the gross benefit-cost ratio 7.20, the net benefit-cost ratio 6.20 and the net benefit value RMB Yuan 602.34 million (Fig. 7). The correlation coefficient of the net benefit-cost ratio to the human and bovine infection rates with *S. japonicum* at the beginning of the project were 0.55 and 0.66, respectively.

Table 4
Losses due to schistosomiasis in humans and cost for human treatment in the six study counties (unit used = RMB Yuan)

County	Losses due to schistosomiasis			Cost for treatment		
	Acute cases	Chronic cases	Advanced cases	Acute cases	Chronic cases	Advanced cases
Huarong	800.25	1443.20	2761.40	432.15	968.75	1917.45
Qianjiang	795.80	1215.40	3675.00	490.00	930.50	1792.90
Yugan	630.12	103.49	6434.20	211.76	20.89	2790.56
Tongling	1436.90	559.79	5037.70	286.37	153.86	780.41
Xichuang	326.55	57.29	843.08	270.20	17.10	720.56
Dali	1966.10	463.62	4095.20	991.78	158.62	1717.20
Average	992.62	640.47	3807.80	447.04	374.95	1619.85

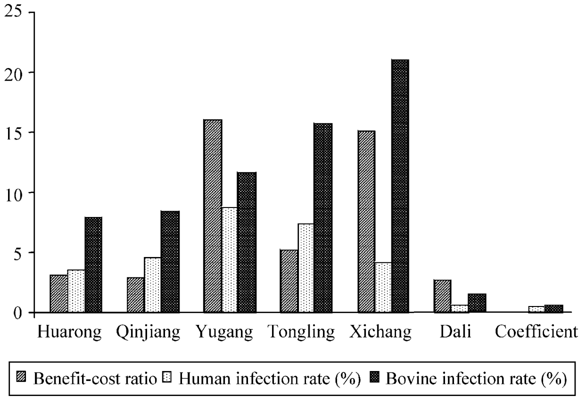

Fig. 7. Comparison of the net benefit-cost ratio to human or bovine infection rate with *S. japonicum*.

4. Discussion

In the current cost-benefit analysis, benefits were divided into two parts, namely (i) benefits obtained from reduction of schistosomiasis cases and (ii) benefits due to molluscicide engineering. The former included treatment benefit, prevention benefit and resources benefit, which provided the scientific information to allocate inputting structure and scale by comparison of the cost-benefit. The latter is able to balance the investment for the short- or long-term effectiveness of the control programme. This investigation was performed in a retrospective manner after experience from a pilot study carried out in one of the counties had been gained. Based on this knowledge-base, a detailed working plan was formulated. Since the six study counties represented the three different types of schistosomiasis transmission in China (Chen and Feng, 1999; Zhou et al., 2005), and had different degrees of endemicity at baseline and varied with regard to snail infested areas and geographic distribution, it was felt that the counties were representative for the schistosomiasis situation in China as a whole. All data and established databases were re-examined by scientists and schistosomiasis control experts from the local institutions to guarantee that the databases used were reliable and suitable for subsequent economic evaluation.

The main objective of the WBLP on schistosomiasis control in China was to significantly reduce and control morbidity, but interruption of transmission of the infection in highly endemic areas was also attempted (Chen et al., 2005). This was done by, in addition to praziquantel administration to humans, health education, implementing chemotherapy for cattle and focal mollusciciding. At a later stage of the project, an intervention strategy based on engineered environmental management with the aim of snail control was added. It is widely acknowledged that the annual human prevalence rates decreased from 1992 to 2001 when the WBLP was implemented (Chen et al., 2005). Our results obtained from six representative study counties confirm the overall achievements of the WBLP, as there was a gradual decrease in the human infection prevalence with *S. japonicum*. The average cost for reducing the infection prevalence per 100 persons by 1% was RMB Yuan 2176.72. This figure indicates that the control programme with its strong emphasis on praziquantel-based chemotherapy paid off well during the project period (Li et al., 2002). In this regard, it is important to note that less than one-third of the total funds available were used for case detection and chemotherapy.

The cost-benefit analysis revealed that a total of RMB Yuan 60.2 million was achieved in the six study counties during the 9-year evaluation period, as a net benefit from WBLP. Hence, the average benefit-cost ratio was 7.20, which means that each US$ spent achieved US$ 6.20 worth of net benefit. By comparison of the benefit-cost to the infection rate at the beginning of the project, it was found that the benefit-cost ratio ranged between 3.71 and 17.05 among study counties. Interestingly, the benefit-cost ratio was positively correlated with the *S. japonicum* infection rate in humans (correlation coefficient = 0.55) and in bovines (correlation coefficient = 0.66). These figures suggest that the outcome of the WBLP was highly dependent on the prevalence and intensity of transmission at the beginning of the project meaning that the higher the frequency and transmission dynamics of *S. japonicum* at the beginning of the project, the more the benefit per unit of input. The results reported here confirm that local residents benefited from this health project through governmental channelling of resources and that there was a particularly high benefit in relation to the input provided.

A considerable body of literature is available with regard to cost-effectiveness analyses of schistosomiasis control programmes (Korte et al., 1986; Brinkmann et al., 1988; Guyatt et al., 1994; Guyatt and Tanner, 1996; Guyatt, 1998; Ansell and Guyatt, 2002). However, only few cost-benefit analyses have been carried out to evaluate schistosomiasis control programmes (Talaat and Evans, 1996; Kirigia, 1997). This relative lack of cost-benefit analyses of schistosomiasis control programmes may be explained by the complexities in identification and quantification of health benefits due to schistosomiasis control. For example, it is not possible to simply use an index to estimate the benefit from a strategy for schistosomiasis control, which is basically an investment for the welfare of people in a specific location (Guyatt, 1998). Results from a separate project, focused on case-studies, demonstrated that the index improved with the labour productivity among cured cases (Jiang et al., 2002a,b; Sun et al., 2002), in which more than 30 cases of acute, chronic or advanced cases, respectively, were investigated by questionnaire. It was found that labour productivity improved among cured cases, i.e. 0.9 for acute cases, 0.8 for chronic cases, and 0.6 for advanced cases (Jiang et al., 2002a,b; Sun et al., 2002). However, the overall benefit is a likely underestimation, as some indirect benefits, as well as the social benefits, were not included because of the lack of standard methods and respective formuli to calculate them.

When comparing cost-effectiveness in different eco-epidemiological settings, it was found that the cost of mollusciciding in a unit of land was higher in the mountainous areas (i.e. provinces of Sichuan and Yunnan) than in lake or river marshlands. These observations indicate that more efforts are required in implementing mollusciciding in a mountainous region and that environmental management may be more suitable for snail control there. The cost-effectiveness analysis revealed that, on average, mollusciciding cost for reduction of 1000 m^2 snail habitats was RMB Yuan 3573.2. It ranged between RMB Yuan 506.4 and 15359.6. The higher cost is partially governed by the additional implementation of environmental management in the later phases of the WBLP. It will be interesting to evaluate the long-term effectiveness of this strategy, including economic appraisal. Although environmental management interventions are costly, mainly due to high capital investments at the beginning of a project, such measures are necessary for sustainable schistosomiasis control. Experiences made with environmental management for malaria control showed that this strategy becomes cost-effective in the longer run (Bos and Mills, 1987; Utzinger et al., 2001). We therefore suggest that both short-term effectiveness/benefit during the project period and long-term effectiveness/benefit after project support has ceased should be taken into account at the design stage of a project.

The best results are achieved when design and management are based on the different types of environment and endemicity encountered. For instance, in places where less benefit can be expected by mollusccicide engineering and where transmission is mainly governed by natural environmental factors, countermeasures in the form of mass chemotherapy would be preferable. On the other hand, in places where the prevalence is already low, more attention should be paid to long-term effectiveness and integrated benefit methods should be adopted to further reduce prevalence (Zhang and Lin, 2002).

In spite of the success and great achievement of the national schistosomiasis control programme in China during the last decades, biological and environmental factors, coupled with technological limitations and uneven socio-economic development in schistosome-endemic areas, pose considerable challenges for future control (Chen et al., 1999; Davis et al., 2002; Zhou et al., 2005). For example, water resources development and management projects to meet future food and energy requirements, the potential impact of climate change, and population movements between endemic and previously non-endemic areas are likely to enhance the frequency and transmission dynamics of schistosomiasis (Chitsulo et al., 2000; Spear et al., 2002; Yang et al., 2005). These developments require continued vigilance and increased support for the schistosomiasis control programme, particularly in the most severely endemic areas, such as the marshlands along the Yangtze River. However, this economic evaluation shows that significant control effectiveness has been gained from the implementation of the WBLP and that remarkably high benefits were achieved. In addition, the results support the notion that schistosomiasis control programme can promote local economic development provided that the control strategy is adapted to the local settings and implemented in a sustainable way.

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References

Ansell, J., Guyatt, H.L., 2002. Comparative cost-effectiveness of diagnostic tests for urinary schistosomiasis and the implications for school health programmes. Ann. Trop. Med. Parasitol. 96, 145–153.

Bos, R., Mills, A., 1987. Financial and economic aspects of environmental management for vector control. Parasitol. Today 3, 160–163.

Brinkmann, U.K., Werler, C., Traoré, M., Korte, R., 1988. The costs of schistosomiasis control in a Sahelian country. Trop. Med. Parasitol. 39, 175–181.

Chen, M.G., 2005. Use of praziquantel for clinical treatment and morbidity control of schistosomiasis japonica in China: a review of 30 years' experience. Acta Trop. 96, 168–176.

Chen, M.G., Feng, Z., 1999. Schistosomiasis control in China. Parasitol. Int. 48, 11–19.

Chen, M.G., Zhou, X.N., Wang, T.P., Ge, J.H., Zhang, S.J., 1999. Investigation report on the transmission status and control measures after heavy floods in Anhui and Jiangxi. Chin. J. Schisto. Contr. 11, 361–363.

Chen, X.Y., 2002. The challenges and strategies in schistosomiasis control program in China. Acta Trop. 82, 279–282.

Chen, X.Y., Wang, L.Y., Cai, J.M., Zhou, X.N., Zheng, J., Guo, J.G., Wu, X.H., Engels, D., Chen, M.G., 2005. Schistosomiasis control in China: the impact of a 10-year World Bank Loan Project (1992–2001). Bull. World Health Organ. 83, 43–48.

Chitsulo, L., Engels, D., Montresor, A., Savioli, L., 2000. The global status of schistosomiasis and its control. Acta Trop. 77, 41–51.

Davis, G.M., Wu, W.P., Chen, H.G., Liu, H.Y., Guo, J.G., Lin, D.D., Lu, S.B., Williams, G., Sleigh, A., Feng, Z., McManus, D.P., 2002. A baseline study of importance of bovine for human *Schistosoma japonicum* infections around Poyang Lake, China: villages studied and snail sampling strategy. Am. J. Trop. Med. Hyg. 66, 359–371.

Department of Disease Control, Ministry of Health, 1999. A Handbook for Schistosomiasis Control. Shanghai Press on Science and Technology, Shanghai, pp. 262–269.

Expert Advisory Committee on Schistosomiasis, Ministry of Health, 1998. An introduction of a nationwide sampling survey on schistosomiasis in China. Chin. J. Parasitol. Parasitic Dis. 16, 84–88.

Guo, J.G., Ross, A.G.P., Lin, D.D., Williams, G.M., Chen, H.G., Li, Y., Davis, G.M., Feng, Z., McManus, D.P., Sleigh, A.C., 2001. A baseline study on the importance of bovines for human *Schistosoma japonicum* infection around Poyang Lake, China. Am. J. Trop. Med. Hyg. 65, 272–278.

Guyatt, H., 1998. Different approaches to modelling the cost-effectiveness of schistosomiasis control. Mem. Inst. Oswaldo Cruz 93 (Suppl. 1), 75–84.

Guyatt, H., Evans, D., Lengeler, C., Tanner, M., 1994. Controlling schistosomiasis: the cost-effectiveness of alternative delivery strategies. Health Policy Plan. 9, 385–395.

Guyatt, H.L., Tanner, M., 1996. Different approaches to modeling the cost-effectiveness of schistosomiasis control. Am. J. Trop. Med. Hyg. 55 (Suppl. 5), 159–164.

Jiang, Q.W., Wang, L.Y., Guo, J.G., Chen, M.G., Zhou, X.N., Engels, D., 2002a. Morbidity control of schistosomiasis in China. Acta Trop. 82, 115–125.

Jiang, S.D., Gao, P., Huang, X.H., Sangguan, C.L., 2002b. Cost-effectiveness analysis on the project of schistosomiasis control in marshland regions. Chin. J. Schisto. Contr. 14, 385–387.

Kirigia, J.M., 1997. Economic evaluation in schistosomiasis: using the Delphi technique to assess effectiveness. Acta Trop. 64, 175–190.

Korte, R., Schmidt-Ehry, B., Kielmann, A.A., Brinkmann, U.K., 1986. Cost and effectiveness of different approaches to schistosomiasis control in Africa. Trop. Med. Parasitol. 37, 149–152.

Li, Y.S., Sleigh, A.C., Li, Y., Tanner, M., Dessein, A., Williams, G.M., McManus, D.P., 2002. Five-year impact of repeated praziquantel treatment on subclinical morbidity due to *Schistosoma japonicum* in China. Trans. R. Soc. Trop. Med. Hyg. 96, 438–443.

Ross, A.G.P., Sleigh, A.C., Li, Y.S., Davis, G.M., Williams, G.M., Jiang, Z., McManus, D.P., 2001. Schistosomiasis in the People's Republic of China: prospects and challenges for the 21st century. Clin. Microbiol. Rev. 14, 270–295.

Spear, R.C., Hubbard, A., Liang, S., Seto, E., 2002. Disease transmission models for public health decision-making: toward an approach for designing intervention strategies for schistosomiasis japonica. Environ. Health Perspect. 110, 907–915.

Sun, L.P., Zhou, X.N., Rong, G.R., Wang, Y.X., Cai, G., Hong, Q.B., Peng, H., Song, H.T., Zhang, X.P., Gao, Y., Zhang, L.H., 2002. Cost-effectiveness analysis on the project of schistosomiasis control by concreting banks of rivers connecting with the Yangtze River. Chin. J. Schisto. Cont. 14, 38–43.

Talaat, M., Evans, D.B., 1996. Costs, benefits and operational implications of using quantitative techniques to screen for schistosomiasis haematobium in Egypt. Southeast Asian J. Trop. Med. Public Health 27, 29–35.

Udvarhelyi, I.S., Colditz, G.A., Rai, A., Epstein, A.M., 1992. Cost-effectiveness and cost-benefit analyses in the medical literature. Are the methods being used correctly? Ann. Intern. Med. 116, 238–244.

Utzinger, J., Tozan, Y., Singer, B.H., 2001. Efficacy and cost-effectiveness of environmental management for malaria control. Trop. Med. Int. Health 6, 677–687.

Yang, G.J., Vounatsou, P., Zhou, X.N., Tanner, M., Utzinger, J., 2005. A potential impact of climate change and water resource development on the transmission of *Schistosoma japonicum* in China. Parassitologia 47, 127–134.

Yuan, H.C., Guo, J.G., Bergquist, R., Tanner, M., Chen, X.Y., Wang, H.Z., 2000. The 1992–1999 World Bank schistosomiasis research initiative in China: outcome and perspectives. Parasitol. Int. 49, 195–207.

Zhang, S.J., Lin, D.D., 2002. The potential risk and control strategy in low endemic area of schistosomiasis in China. Acta Trop. 82, 289–293.

Zhang, W., Wong, C.M., 2003. Evaluation of the 1992–1999 World Bank schistosomiasis control project in China. Acta Trop. 85, 303–313.

Zhou, X.N., Acosta, L., Willingham III, A.L., Leonardo, L.R., Chen, M.G., Aligui, G., Zheng, F., Olveda, R., 2002. Regional network for research, surveillance and control of Asian schistosomiasis (RNAS). Acta Trop. 82, 305–311.

Zhou, X.N., Wang, L.Y., Chen, M.G., Wu, X.H., Jiang, Q.W., Chen, X.Y., Zheng, J., Utzinger, J., 2005. The public health significance and control of schistosomiasis in China – then and now. Acta Trop. 96, 97–105.