Surveillance on schistosomiasis in five provinces of the People's Republic of China in post-elimination era

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Abstract

Background: The People's Republic of China (P. R. China) had made significant progress on schistosomiasis control. Among the 12 provinces (municipality, autonomous region with schistosomiasis endemic) in P.R. China, Guangdong, Shanghai, Fujian, Guangxi and Zhejiang provinces (following called as five provinces) had successively eliminated schistosomiasis during 1985-1995. However, given the increasing mobilization of the population and goods, wetland protection, climate changes etc., consolidation of the schistosomiasis elimination in these five provinces remain challenges. In the current study, we sought to understand the epidemic situation in these post-elimination areas and their surveillance capabilities on schistosomiasis.

Methods: (□) Through the national schistosomiasis reporting system, annual data reflecting the interventions and surveillance on human beings, cattle and snails based on county level from 2005 to 2016 were collected and analyzed to understand the epidemic status of schistosomiasis in five provinces. (□) A standardized score sheet was designed to assess the surveillance capacity for schistosomiasis of selected disease control agencies in five provinces and ten counties. Assessment on surveillance capacity consisted of two parts: the first part focused on the capacity of testing skills including schistosomiasis diagnostic skills, identification of snails' living and infection status; the second part was to assess the knowledge level about schistosomiasis and its control.

Results: The comprehensive assessments showed that no local cases in humans and cattle or infected snail were found in these five provinces from 2005, and the surveillance abilities on schistosomiasis of the prevention and control institutions in five provinces were appropriate. However, from 2005 to 2016, a total of 221 imported cases were detected in Zhejiang, Shanghai and Fujian provinces, and 11.98 hm^2 of new snail habitats were found in Zhejiang, Shanghai and Guangxi provinces. In addition, snail infestation was reoccurred in 247.55 hm^2 of former snail habitats since 2011.

Conclusions: Elimination of schistosomiasis was consolidated successfully in five provinces of P.R. China due to effective and strong post-elimination surveillance. Comprehensive consolidation strategies should be focused on the elimination of residual snails and the prevention of imported infection sources among the five provinces to consolidate the achievements of schistosomiasis control.

1. Background

Schistosomiasis, caused by parasitical trematode blood-dwelling flukes called S*chistosoma*, is one of the most important neglected tropical diseases in the world in terms of public health impacts [1, 2]. According to the report of World Health Organization (WHO), schistosomiasis is transmitted in 78 countries around the world. In 2017, at least 220.8 million people needed prophylactic treatment for schistosomiasis [3]. In recent decade, with the increased quantity of donation of praziquantel by international organizations and companies and increased willingness to give priority for schistosomiasis control or elimination by governments of endemic countries, great progress had been obtained in multi countries. Meanwhile,

elimination of schistosomiasis is regarded as an achievable goal in endemic regions or countries if continuous interventions and adequate resources were provided.

Schistosomiasis japonica is the only disease caused by schistosomes for human beings and livestock in P. R. China, distributed in twelve provinces along and south of Yangtze River with a long history. Investigations conducted in the 1950's proved that there were 380 endemic counties within 12 provinces, with about 12 million people and 1.2 million cattle infected with schistosomes, and over 100 million people at risk of infection. In addition, the total habitat area of *Oncomelania hupensis*, the only intermediate host of *S. japonicum*, was approximately 14.5 billion m^2 [4–7]. Following three decades of unremitting efforts with control strategies shifted from snails control to morbidity control, Guangdong (1985), Shanghai (1985), Fujian (1987), Guangxi (1989) and Zhejiang (1995) provinces eliminated schistosomiasis successively.

Being a zoonotic parasitic disease, the transmission of schistosomiasis japonica is influenced by biological, natural and social factors. Multiple studies proved that schistosomiasis easily rebounded or spread to new areas due to weakened interventions, ecological changes caused by flooding, construction of water conservancy projects, increased migration of goods or human resources etc., without a sensitive surveillance and response system [8–11]. As Shanghai, Guangdong, Fujian, Guangxi and Zhejiang had eliminated schistosomiasis at least twenty years before, we evaluated the epidemic situation and the surveillance capabilities on schistosomiasis among the five provinces, to facilitate the consolidation of elimination achievements in post elimination era and provide reference for other regions where schistosomiasis had been eliminated or will be eliminated.

2. Materials And Methods

2.1 Study sites and research design

Among the five provinces, Shanghai and Zhejiang provinces are located in the Yangtze River Delta, in the east of China, Fujian, Guangdong and Guangxi provinces are located in the south of China. According to the epidemiological characteristics, the endemic areas in Shanghai belong to waterway-network regions, while the endemic areas in Zhejiang, Guangdong, Guangxi and Fujian provinces are mainly hilly and mountainous regions (Fig. 1).

The study consisted of two parts: (□) Data reflecting the schistosomiasis intervention and surveillance conducted in Shanghai, Guangdong, Fujian, Guangxi and Zhejiang provinces based on county level were collected and analyzed to understand the epidemic status of schistosomiasis. (□) A standardized score sheet was designed to assess the surveillance capacity for schistosomiasis of selected disease control agencies.

2.2 Retrospective data collections

A comprehensive surveillance strategy focused on clearing the internal snail habitats and infection source and preventing imported snails and cases from other provinces with schistosomiasis un-

eliminated was conducted in the five provinces. Annual data reflecting the interventions and surveillance on human beings, cattle and snails based on county level from 2005 to 2016 were collected through the national schistosomiasis reporting system. Variables could be split into three categories: variables reflecting serological tests and stool examination for schistosomiasis on humans; variables on serological tests and stool examinations for schistosomiasis on cattle, and variables reflecting the distribution of oncomelania snails including total habitats, new infested areas etc.

2.3 Assessment on surveillance capacity

A standardized score sheet was developed to assess the surveillance capacity after consulted experienced experts in the field of schistosomiasis control. The score sheet included two parts: the first part focused on the capacity of testing skills including schistosomiasis diagnostic skills, identification of snails' living and infection status among the professionals; the second part was to assess the knowledge level about schistosomiasis and its control among the professionals. The assessment was implemented during December 2015-March 2016 in a blind manner.

2.3.1 Assessment on schistosomiasis testing skills

Laboratory testing skills of schistosomiasis were performed at provincial and county level among laboratory professionals. Two counties were selected in each province. The assessed testing skills included: (1) Diagnostic skills included the indirect hameagglutination assay (IHA) and the miracidia hatching technique (MHT), which are most widely used in low endemic areas with light infection intensity for population screening and confirmation of schistosome infection respectively. (2) Snails dissection and microscopic method to identify the snails' living and infection status.

2.3.1.1 Preparation of reference panels for assessment

To ensure the consistence and comparability of the assessed results among different provinces, reference panels for testing methods were prepared and coded by National Institute of Parasitic Diseases, Chinese Center for Disease Prevention and Control. Each panel for IHA contained five serum samples (four from schistosomiasis cases and one from healthy persons), while panels for MHT included two samples containing mature eggs of schistosome obtained from the liver of infected rabbits and three negative samples with boiled-water treated eggs. Each snail panel consisted of three dead oncomelania snails and seven living snails, while three of living snails were infected by schistosomes confirmed by shedding method.

2.3.1.2 Laboratory testing and score

The technicians in selected agencies were asked to perform the IHA and MHT tests according to the protocol of each method [12–14] and judge the results. The results were documented and reported to NIPD, China CDC within the given time. The total score of testing skills was 20, five points for IHA and MHT respectively and 10 points for snail identification. The detailed evaluation rules is provided in Additional file 1: Table S1.

2.3.2 Assessment on basic knowledge on schistosomiasis control

A questionnaire was designed to assess the basic knowledge of medical staff responsible for schistosomiasis surveillance. Three professionals from CDC and two medical agencies at provincial level and county level attended the assessment respectively. The questionnaire was composed of three parts: knowledge of epidemiological and transmission characteristics of schistosomiasis japonica, diagnosis and treatment, case reporting and management. Each part consisted of five questions (The full questionnaire is provided in Additional file 2). The total score for the questionnaire was 10. One point would be deducted per error answer until the score was decreased to zero (Additional file 1: Table S1).

2.4 Data management and statistical analysis

All data were transferred to Microsoft Excel software for data compilation. The positive rate of serological test (No. antibody positives/No. serum samples examined) and the infection rate of cattle in different years and provinces, number of cases with stool examination positive, number of cattle with stool examination positive, and areas of newly detected snails in each county from 2005 to 2016 were calculated to analyze the epidemic situation. The results of assessments on diagnostic skills, snail identification and questionnaire survey were determined by the accuracy rate (NO. correctly tested samples/No. total samples or No. correct answers/No. questions). 95% confidence intervals (CI) were calculated using standard formulas based on the binomial distribution. Microsoft Excel software, version 2013 (Microsoft Office, CA, USA) and the statistical software SPSS, version 23.0 (SPSS Inc., Chicago, USA) were used to analyze the epidemic trend based on descriptive analysis.

3. Results

3.1 Epidemic situation of schistosomiasis

3.1.1 Surveillance results on population

From 2005 to 2016, a total of 3 569 509 serological tests were conducted for schistosomiasis screening and 24 978 blood samples were determined as antibody positives in the five provinces (Table 1). The annual positive rate of serological tests was 0.56–0.90%, with a slight fluctuation from 2005 to 2010, and a sustained downward trend from 2011.

Totally 45 997 stool examination were performed during the twelve years in five provinces and 221 stool positives were detected (Table 1). Among the stool positives, Zhejiang, Shanghai and Fujian provinces accounted for 87.33% (193/221), 11.31% (25/221) and 1.36% (3/221), respectively, while no stool positive cases were found in Guangdong or Guangxi province. All stool positives were imported cases who got infection from other endemic areas.

Table 1
Surveillance results of schistosomiasis on human beings in five provinces during 2005–2016

Year	Serological tests			Stool examination	
	No. serum samples examined	No. antibody positives	Positive rate (%, 95% CI)	No. fecal examinations	No. stool positives
2005	428 800	3479	0.81 (0.78–0.84)	4565	44
2006	475 182	2681	0.56 (0.54–0.59)	4740	36
2007	476 201	3348	0.70 (0.68–0.73)	5876	27
2008	391 047	2647	0.68 (0.65–0.70)	3549	17
2009	339 583	3062	0.90 (0.87–0.93)	4145	21
2010	345 645	3057	0.88 (0.85–0.92)	3993	12
2011	240 121	1488	0.62 (0.59–0.65)	5167	12
2012	223 487	1332	0.60 (0.56–0.63)	3720	9
2013	221 765	1324	0.60 (0.57–0.63)	2570	14
2014	150 182	973	0.65 (0.61–0.69)	3520	10
2015	143 617	842	0.59 (0.55–0.63)	2563	8
2016	133 879	745	0.56 (0.52–0.60)	1589	11

Year	Serological tests			Stool examination	
	No. serum samples examined	No. antibody positives	Positive rate (%, 95% CI)	No. fecal examinations	No. stool positives
Total	3 569 509	24 978	-	45 997	221

3.1.2 Surveillance results on cattle

From 2005 to 2016, a total of 82 858 serological tests were conducted for surveillance on cattle in the five provinces and 19 serological positives were found in Zhejiang province, with 11 and 8 positive in 2014 and 2015, respectively (Table 2). Meanwhile, a total of 42 645 stool examination were performed, and no infected cattle was detected.

Table 2
Surveillance data of cattle in the five provinces from 2005 to 2016.

Year	No. serological tests	No. positive serological tests	No. stool examinations	No. positive stool examinations
2005	12 869	0	4812	0
2006	8846	0	4231	0
2007	8827	0	4027	0
2008	7525	0	2700	0
2009	7601	0	2593	0
2010	5730	0	2362	0
2011	6706	0	3109	0
2012	6068	0	2882	0
2013	5917	0	3031	0
2014	4878	11	3299	0
2015	4859	8	4368	0
2016	3032	0	5231	0
Total	82 858	19	42 645	0

3.1.3 Data on snail survey

Snail survey was conducted in 126 837.75 hm^2 of areas from 2005 to 2016 in the five provinces. The area infested with living *Oncomelania hupensis* presented a descending trend, decreased from 112.70 hm^2 in 2005 to 52.81 hm^2 in 2016 (Table 3). Among the five provinces, Guangdong maintained the status without snails' infestation since 1992. The area of snail habitats in Zhejiang province always accounted for the largest percentage, but presented a decrease trend from 80.72 hm^2 in 2005 to 44.41 hm^2 in 2016. However, no infected snail was found through dissection method in the five provinces.

During the twelve years, 11.98 hm^2 of new snail habitats (environments with no snails initially) were found in Zhejiang (6.53 hm^2), Shanghai (4.19 hm^2) and Guangxi (1.26 hm^2). In addition, snail infestation reoccurred in 247.55 hm^2 of former snail habitats since 2011, mainly distributed in Zhejiang (224.62 hm^2), Guangxi (11.48 hm^2), Fujian (10.73 hm^2) and Shanghai (0.72 hm^2).

Table 3
Results of snail survey in the five provinces during 2005–2016

Year	Areas conducted snail survey (hm^2)	Areas found living snails (hm^2)	Area of new snail habitats (hm^2)	Area with recurrent snails (hm^2)
2005	13 181.83	112.70	1.26	*
2006	11 190.36	116.12	0.00	*
2007	11 059.95	126.90	4.66	*
2008	11 243.00	95.90	0.00	*
2009	10 735.92	100.26	0.00	*
2010	11 059.37	71.06	0.60	*
2011	10 046.77	58.52	0.82	51.74
2012	9161.18	79.15	0.61	61.52
2013	9326.08	62.52	0.43	35.64
2014	9441.76	48.46	1.18	28.90
2015	9833.01	47.52	0.43	32.60
2016	10 558.53	52.81	1.99	37.15
Total	126 837.75	-	11.98	247.55

*The data was not available.

3.2 Comprehensive assessments of surveillance capacity

3.2.1 Capacity for testing skills and snail detection.

Totally fifteen disease prevention and control agencies attended the assessment on testing skills and snails detection. For IHA, all professionals from the 15 agencies could perform and judge the results of 5 serum samples accurately, the accuracy rate was 100% (75/75). For MHT, the average accuracy rate was 89.33% (67/75, 95%CI: 82.18–96.48%), while eight wrong judgement results were all occurred in four CDC laboratories at county level.

For snail identification, all agencies preformed excellent capacity to identify the snails' living status with the accuracy rate of 100% (150/150) (Fig. 2). The average accuracy rate of identifying infection status of snails was 98.06% (103/105, 95%CI: 95.44-100.75%). And two wrong judgement results occurred in one CDC at county level.

3.2.2 Questionnaires survey on basic knowledge of schistosomiasis

Total of 108 medical staffs in fifteen disease prevention and control agencies attended the questionnaire survey (Table 4). The results showed that the average accuracy rate of all respondents was 97.96% (529/540, 95%CI: 96.77–99.16%). Among five provinces, respondents from Guangdong and Guangxi provinces answered all questions correctly. The wrong-answered questions were mainly about knowledge on national comprehensive schistosomiasis control strategies and diagnosis of schistosomiasis.

Table 4
Scores of questionnaires on schistosomiasis control knowledge among professionals from 15 institutions in 5 provinces and 10 counties.

Province	Agency level	No. respondents	No. questions	No. correct answers	Accuracy rate (%)
Guangdong	Province	9	45	45	100.00
	Qingcheng	9	45	45	100.00
	Qujiang	9	45	45	100.00
	Subtotal	27	135	135	100.00
Shanghai	Municipality	3	15	15	100.00
	Pudong	9	45	45	100.00
	Songjiang	9	45	39	86.67
	Subtotal	18	90	84	93.33
Fujian	Province	3	15	14	93.33
	Xiapu	9	45	45	100.00
	Fuqing	9	45	44	97.78
	Subtotal	21	105	103	98.10
Guangxi	Autonomous region	3	15	15	100.00
	Jingxi	9	45	45	100.00
	Yizhou	9	45	45	100.00
	Subtotal	21	105	105	100.00
Zhejiang	Province	3	15	15	100.00
	Jiahsan	9	45	45	100.00
	Changshan	9	45	42	93.33
	Subtotal	21	105	102	97.14
Total		108	540	529	97.96

3.2.3 The scores of the comprehensive assessment

Based on the results of testing skills and snail detection (3.2.1) and questionnaire surveys (3.2.2), except for Fujian scored 29 points, the scores of the other four provinces were all 30 points (Table 5 OR Fig. 3). In

ten counties, the scores ranged from 26 to 30 points.

Table 5
Comprehensive assessment scores of schistosomiasis surveillance capabilities in five provinces and ten counties.

Province	Agency level	Diagnostic skills	Snail identification	Questionnaire survey	Total
Guangdong	Province	10	10	10	30
	Qingcheng	9	10	10	29
	Qujiang	10	10	10	30
Shanghai	Municipality	10	10	10	30
	Pudong	10	9	10	29
	Songjiang	6	10	4	20
Fujian	Province	10	10	9	29
	Xiapu	10	10	10	30
	Fuqing	10	10	9	29
Guangxi	Autonomous region	10	10	10	30
	Jingxi	10	10	10	30
	Yizhou	10	10	10	30
Zhejiang	Province	10	10	10	30
	Jiahsan	8	10	10	28
	Changshan	9	10	7	26

4. Discussion

Although the definition of schistosomiasis elimination was announced by WHO in recent years and the debate of how to prove elimination is still going on, Guangdong (1985), Shanghai (1985), Fujian (1987), Guangxi (1988) and Zhejiang (1995) provinces were announced that schistosomiasis was eliminated successively according to the criteria issued by Chinese government at that time. Then the five provinces transferred to post-elimination surveillance with main tasks to find and eliminate local residual infectious sources and remained snail habitats, and prevent the import of infectious sources and snails from other endemic areas [15–17]. Before our study, except one foci with two new cases reemerged in a farm of Guangdong province in 1992 but rapidly was under controlled [17, 18], no new infections occurred in other provinces [19].

In our study, no local infection in reservoir hosts and intermediate host was detected in the five provinces during 2005–2016, proving the successful consolidation of schistosomiasis elimination. The comprehensive assessment results showed that the staffs have mastered the basic knowledge of schistosomiasis prevention and presented good capacity for schistosomiasis detection. All of these are elementary components of a sensitive and rapid surveillance platform. However, we noticed that there were some samples misdiagnosed and wrong answers for questionnaire answered by staff at county level. Capacity building should be strengthened focusing on schistosomiasis control and diagnosis through continued training and practices to consolidate local achievements on schistosomiasis control.

However, risks of the re-emergence and resurgence of schistosomiasis still existed in the five provinces through our study. Over the past 12 years, a total of 221 imported cases were found in the five provinces, mainly in Zhejiang province, neighbored with Jiangxi and Anhui provinces where the transmission of schistosomiasis is still going on. Studies showed that most of the imported cases in Zhejiang Province are farmers, migrant workers and merchants from schistosomiasis endemic areas, primarily from Anhui, Jiangxi, Hubei [20–22]. In recent years, owing to urbanization and economic development, the number of the floating population from domestic epidemic areas has an increasing trend. At the same time, with the escalation of international trade and entry-exit personnels, the risk of importing cases from abroad infected with *S. haematotium* or *S. mansoni* is also increasing [23–25]. In view of this situation, on the one hand, supervision and treatment should be strengthened for imported definite cases to eliminate the transmission potential; on the other hand, health education should be promoted for the floating population from schistosomiasis endemic areas to spread the knowledge of schistosomiasis prevention and control [26].

The surveillance data proved that the area of snail habitats kept a low level during 2005–2016, compared with 95 900.70 hm^2 reported by Wu [17]. The remained snail habitats mainly distributed in the places that the ecological environments are complicated or water level is unstable, where molluscaciding approach doesn't work well. In addition, several articles published also presented the evidence that the rebound or spread of snails habitats were occurred in Shanghai, Fujian, Guangxi and Zhejiang Provinces [17, 27–29]. It is worth noting that the connection of water systems or the transplanting of seedlings and aquatic plants from the snail habitat areas may also lead to the possibility of snail importation and spread [30, 31]. The development of new snail habitats and snails reappeared in former snail habitats in four provinces except Guangdong Province, providing evidence that eliminating oncomelanid snails completely was quiet difficult. Although Guangdong Province kept the achievement with no oncomelanid snails detected, a new challenge for Guangdong Province is the invasion and spread of *Biomphalaria Strami* [32].

Considering the potential risks of schistosomiasis still existed in five provinces, snail control through environmental modification and surveillance focused on eliminating remaining snails and preventing imported infection sources should be continued and strengthened, to prevent the re-emergence of schistosomiasis, and consolidate the achievements of schistosomiasis elimination. Risk assessment should be conducted timely if there were large water conservancy projects or importing plants or animals

from endemic areas etc [33, 34]. Specifically, the monitoring of the environments where snails infested previously or connected with snail habitats should be strengthened through multi ways [10, 35]. Meanwhile, the floating people and livestock from the areas where the transmission of schistosomiasis has not been interrupted or the epidemic situation of schistosomiasis is recovering should be inspected emphatically, and the patients should be treated in time if they are found [36–38].

5. Conclusion

Elimination of schistosomiasis was consolidated successfully in five provinces of P.R. China due to effective and strong post-elimination surveillance. Being a zoonotic parasitic diseases, challenges still exist to maintain the achievements as imported cases and snail habitats were detected during 2005–2016. Continuous surveillance should be strengthened through capacity building for staff responsible for schistosomiasis surveillance, providing adequate funding and resources etc.

Abbreviations

CDC: Center for Disease Control; CI: Confidence intervals; MHT: Miracidia Hatching technique; IHA: Indirect hemagglutination assay; NIPD: National Institute of Parasitic Diseases; P. R. China: People's Republic of China; WHO: World Health Organization.

Declarations

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Authors' contributions

Xiao-nong Zhou, Shi-Zhu Li, Jing Xu, Shan Lv and Chun-li Cao designed and guided this study, Jing-yi Guo and Li-juan Zhang wrote the main manuscript text. All authors reviewed the manuscript and approved the final manuscript for publication.

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Availability of data and materials

All data generated or analyzed during this study are kept confidential by NIPD, China CDC. The datasets are available from the corresponding author on a reasonable request.

Ethics approval and consent to participate

This article was based on analysis of routine surveillance data from NIPD, China CDC. The project leaders and staff led the review, analysis and interpretation of the data. No personal information was disclosed.

Consent for publication

Written informed consent for publication was obtained from all participants.

Competing interests

The authors declare that they have no competing interests.

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Figures

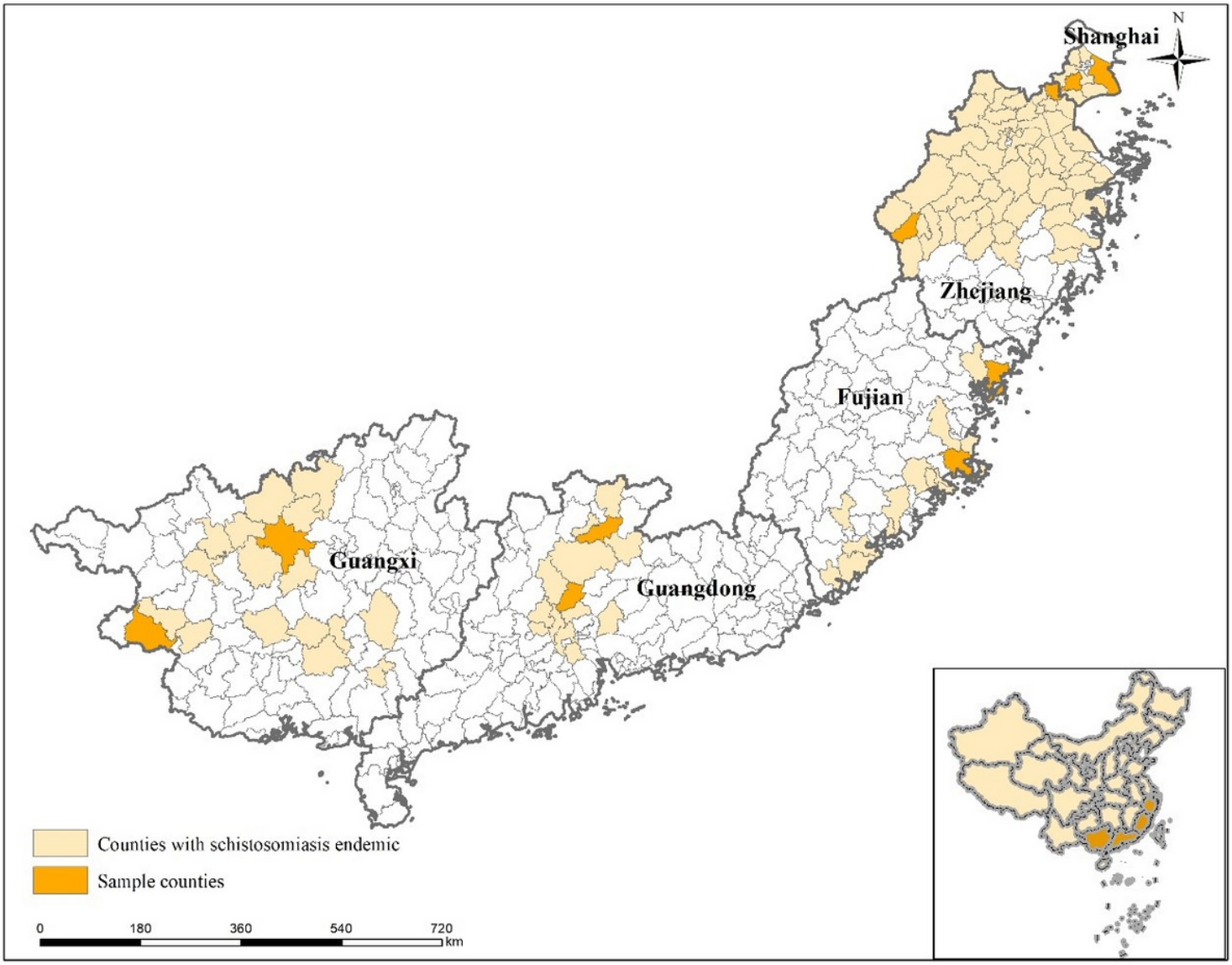

Figure 1

The location of research settings. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

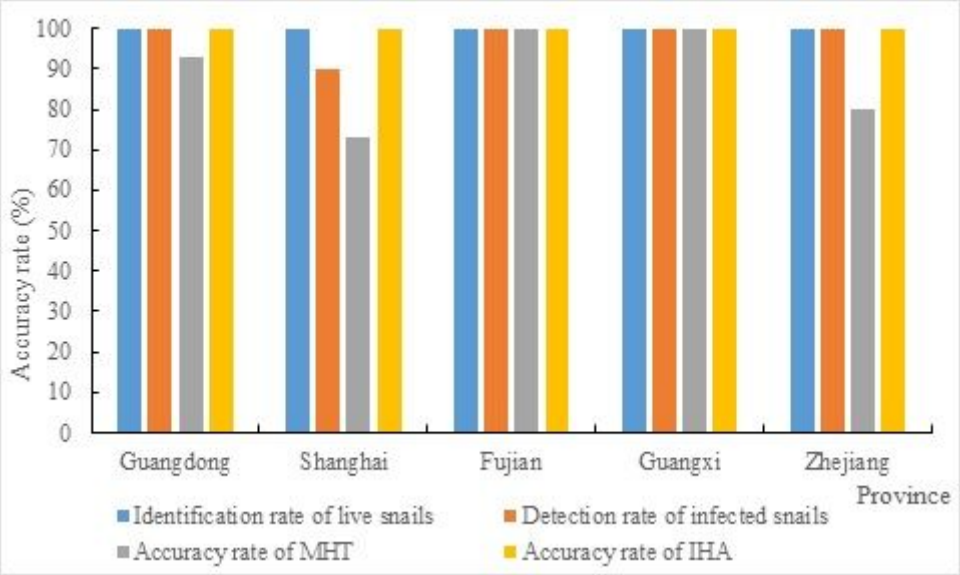

Figure 2

Evaluation results of schistosomiasis diagnosis and snail detection among fifteen institutions in the five provinces

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