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National surveillance on soil-transmitted helminthiasis in the People's Republic of China

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ABSTRACT

Soil-transmitted helminths (STHs) are widely distributed and remain a public health problem in the People's Republic of China. Altogether, 301 counties across 30 regions were investigated during the national surveillance on STHs carried out in 2016 based on the modified Kato-Katz thick smear method to examine faecal samples. A total of 305 081 people were investigated with 7 366 (2.4%) found to be infected. The infection rates were the following: hookworm 1.4%, *Ascaris lumbricoides* 0.8% and *Trichuris trichiura* 0.5%. Having established that the STHs infection rate is relatively low, it is time to move towards elimination. The national surveillance system is essential for providing basic data and formulation of useful control strategies towards achieving this goal.

1. Introduction

Soil-transmitted helminthiasis (STH) is caused by the parasites hookworm (*Necator americanus* and *Ancylostoma duodenale*), roundworm (*Ascaris lumbricoides*) and whipworm (*Trichuris trichiura*) (Bethony et al., 2006; Utzinger et al., 2012). This group of diseases constitute the most prevalent neglected tropical diseases (NTDs) worldwide (Pullan et al., 2014; Schulz et al., 2018; WHO, 2016). An estimated 1.5 billion people in more than half of all countries are affected by STH, with children more at risk than adults of an infection that can cause stunted growth (Stephenson et al., 2000), anaemia (Stoltzfus et al., 2004), and retarded cognitive development (Nokes et al., 1992), together amounting to an estimated 5 million disability adjusted life years (DALYs) lost (de Vlas et al., 2016; WHO, 2016). STH disease burdens are felt to be underestimated (Fenwick, 2012; Hotez et al., 2014; King, 2015) and it is well-known these infections commonly result in a vicious cycle by both resulting from and contributing to poverty in endemic communities (Hotez, 2008).

The London Declaration on NTDs (WHO, 2012) issued preventive chemotherapy plans for all of the STHs infections and the overall effect of anthelmintic drugs has received serious attention (Molyneux, 2017; WHO, 2012). Five drugs (albendazole, levamisole, mebendazole, pyrantel, and ivermectin) are currently on the World Health Organization (WHO) list of essential drugs for STH control (Keiser and Utzinger, 2010). The benzimidazoles (albendazole and mebendazole) have been used worldwide, usually as a single oral dose applied for MDA of national helminth control programmes (WHO, 2015) yet their efficacy varies due to many factors including helminth species (Vercruysse et al., 2011). Albendazole and mebendazole are effective against *A. lumbricoides*, however, mebendazol has reportedly low efficacy against hookworm (Schulz et al., 2018). In addition, neither albendazole nor mebendazole has high efficacy against *T. trichiura* (Schulz et al., 2018).

The first national STH survey conducted between 1988 and 1992 in the People's Republic of China (PR China). Over half the population (538 million people) was infected showing prevalence rates of ascariasis, trichuriasis and hookworm infection of 47.0%, 18.8% and 17.2%, respectively (Xu et al., 1999), and the infection intensity for each STH was shown in Table 1 Based on this outcome, the Chinese government initiated the “National Plan for Control of Parasitic Diseases during the Eighth Five-Year”, followed by “the Control Plan for Common Helminthiasis” and “The Comprehensive Control Plan for Common Helminthiasis among Students in China”. Under the direction of these plans, many provinces/autonomous regions/municipalities (hereinafter referred to as “regions”) implemented mass drug administration (MDA) against STHs infections from 1992 to 2006, mostly targeting school children. A total of 120 million people were treated against hookworm

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Table 1
The infection intensity (EPG*) for STHs in the first national survey.

Helminth	Light infection	Mild infection	Moderate infection	Heavy infection
Hookworm	75.4% (<400)	21.9% (400–3 000)	2.2% (3000–10 000)	0.6% (≥10 000)
Ascaris	77.0% (<5 000)	/	21.2% (5000–50 000)	1.8% (≥50 000)
Trichuris	94.6%(<1 000)	/	5.2% (1000–10 000)	0.2% (≥ 10 000)

* Eggs per gram of faeces (EPG) given for each infection as it varies between the parasites.

between 1992 and 1994 resulting in an 80% reduction in infection intensity with more than 14 million people cured. In Jiangsu Province, children older than 2 years were given benzimidazole for 7 successive years in rural areas, and the infection rate dropped from 25.3% in 1989 to 7.0%. By 2008, about 100 million people had received treatment. To control ascariasis, MDA (mainly albendazole, mebendazole and compound mebendazole) in combination with health education was implemented among primary and middle school students in endemic areas for 10 successive years, resulting in a strong fall in prevalence. In 1992, the infection rates in primary and middle school students in rural and urban areas were 26.6% and 14.9%, respectively. In 2000, the infection rate among students in rural and urban areas had dropped to 6.6% and 1.1%, respectively. With respect to trichuriasis, annual MDA using mebendazole and benzimidazole was adopted for control in primary and middle school populations for several years. Each area of the country implemented the MDA programme on their own, e.g., 83.9 million and 20.0 million people received treatment with these drugs from 1994 to 2005 in the provinces Jiangsu and Shandong, respectively (Tang et al., 2012).

When the second national survey on parasitic diseases was carried out in 2004, the prevalence of ascariasis, trichuriasis and hookworm infection had declined significantly to reach 12.5%, 4.2% and 5.7%, respectively. The estimated population infected with STHs has fallen to about 129 million (18.8%) (Wang, 2008), and the infection intensity for each STH was shown in Table 2. Compared to the first national survey, overall STHs infections had dropped by 65% in 2004.

The STHs infection rate used to be high, while the prevalence decreased significantly following MDA implementation that targeted primary and middle school children in each region with counties adapting the strategy to their situation as indicated by the second national survey carried out in 2004. Thereafter, demonstration plots of integrated STH control were established, and the control slogan “Health education as leading, infection source control as key intervention” was advocated as well as other control measures including improved access to potable water sources, latrine, personal habits (health education) and environmental modification were combined with MDA for implementation in eight counties across PR China between 2006 and 2009. The STH prevalence decreased by 78.4% (from 35.9% to 7.8%) in these demonstration spots, which proved the effectiveness of control strategy (Zhang et al., 2011; Zhu et al., 2011; Zhou, 2011) and was therefore adopted.

According to the third national survey carried out from 2014 to 2015, the STHs infection rate had fallen to 4.5% and the estimated infected population was 29.12 million (Zhou, 2018). The STHs infection rate decreased significantly compared to the 18.8% prevalence achieved in 2004 (Xu et al., 2005). Currently in PR China, lightly infected cases occur sporadically in most parts of the country but there are high-endemic areas in a few provinces or local regions. Between 2006 and 2015, 22 national surveillance spots were conducted in PR China (Chen and Zang, 2013; Zang et al., 2013) and this scheme expanded to 30 in 2016. Currently, more than 300 surveillance spots have been established nationwide (Fig. 1). Though, no further control measures other than detection and treatment were implemented, the infection rate decreased gradually from 20.9% in 2006 to 4.5% in 2015 across the national surveillance spots (Chen and Zang, 2013; Chen et al., 2019).

Table 2
The infection intensity (EPG*) for STHs in the second national survey.

Helminths	Light infection	Moderate infection	Heavy infection
Hookworm	96.3% (<2 000)	2.4% (2 000–4 000)	1.4% (≥4 000)
Ascaris	81.9%(<5 000)	16.6% (5000–50 000)	1.5% (≥50 000)
Trichuris	93.4%(<1 000)	6.1% (1000–10 000)	0.5% (≥10 000)

Eggs per gram of faeces (EPG) given for each infection as it varies between the parasites.

2. Materials and methods

2.1. Surveillance spots

The number of surveillance spots to implement in each area was determined by the local government agencies. Considering the feasibility, the counties implemented a unified sampling method during the survey. Each county was divided into 5 parts designated as East, West, North, South and Middle. From each part, one village belonging to one town were selected randomly. Using this method, 200 people from each part were selected by cluster random sampling, so that a total of 1000 people from each county were chosen for investigation.

2.2. Sample collection and examination

Stool samples (>30 g) were collected from each person and examined microscopically for parasite eggs by the modified Kato-Katz thick smear method (two slides for each sample) (Katz et al., 1972). With respect to hookworm diagnosis, a culture step was added to differentiate between *A. duodenale* and *N. americanus.* Fifty positive stool samples of hookworm in each county were cultured (all were cultured if less than fifty samples were positive) using the culture method as follows.

From each sample 0.5 g was smeared on a filter paper, which was put into a tube with water so that the water level reached the filter paper but not the stool sample. The tube was then kept in a moist atmosphere at 31 ℃ for 4 days or 26~30 °C for 6~8 days. After this time of culture each sample was dipped into water in a beaker at 45 °C for one hour to allow potential hookworm larva to emerge. The supernatant was carefully poured out after one hour keeping 0.5 ml water with the larva at the bottom of the beaker. Finally the sample was put under the microscope and species identified according to morphology (Xu, 2016).

2.3. Data analysis

SAS 9.3 (version 70068130) was employed for data analysis and the infection rates of STHs in the different regions were analysed by age and gender. Chi-square test was used for comparison of infection rates by different groups, and significant difference was defined (if $\alpha < 0.05$).

2.4. Quality control

To ensure data quality, the staff at the provincial disease control

Fig. 1. Distribution of national surveillance spots in 2016 (Each dot representing one surveillance spot (county). A total of 301 national surveillance spots from 30 regions in 2016 presented in the map).

agency was trained with regard to the use of surveillance manual and method of examination. Also, staff at the county level was trained by those at the provincial level. Thereafter, inspection was carried at the national and provincial level. To control accuracy, 10% of the positive stool samples and 5% of the negative samples were re-examined at each provincial agency, and selective examination was also done by the National Institute of Parasitic Diseases (NIPD), Chinese Center for Disease Control and Prevention (China CDC).

3. Results

A total of 305 081 people from 301 counties (surveillance spots) was investigated in 30 regions of PR China. The STHs infection rate was 2.4% (7 366/305 081) and the infection rate of hookworm, *A. lumbricoides* and *T. trichiura* were 1.4% (4 122/305 081), 0.8% (2 338/305 081) and 0.5% (1 398/305 081), respectively. We observed variation in species distribution across the different regions investigated. For instance, hookworm accounts for the most prevalent STHs in Zhejiang, Chongqing, Fujian and Sichuan but *A. lumbricoides* was the only STHs parasite detected in Jilin, Liaoning and Gansu, while *T. trichiura* occurred highest in Shandong. Infection rates of the three STHs species were about the same at Yunnan and there was no significant difference among them ($\chi^2 = 0.49$, $P = 0.78$) (Fig. 2).

3.1. Regional distribution

The regions with the highest prevalence STH rates were Yunnan, Hainan, Sichuan, Guizhou and Chongqing (Table 3, Fig. 2). Seventeen regions had an infection rate below 1% and 12 of these shows levels below 0.5%. No hookworm infection was found in 10 regions, and no *A. lumbricoides* infection was found in 3 provinces, no *T. trichiura* in 7 regions (Fig. 2).

3.2. Gender distribution

The STHs infection rates in males and females were 2.2% and 2.7%, respectively (Table 4) and it was higher in the females than that in the males ($\chi^2 = 70.94$, $P < 0.0001$). This higher rate was particularly dominating in infections due to hookworm and *A. lumbricoides* ($P < 0.001$) but not so with respect to *T. trichiura* ($\chi^2 = 0.88$, $P = 0.35$).

3.3. Age distribution

The STHs infection rate was highest in middle-age and elderly people; indeed the highest rates were seen in the 70–80 years old (4.6%), followed by 80–90 (3.9%) and the 60–70 age group (3.4%) with the youngest (0–5 years old) presenting the lowest prevalence (1.2%). This was particularly often seen in hookworm infections where the lowest infection rates were found in infants and pre-school aged children and then increasing with age to reach the highest in the >80 years old. However, the age distribution with respect to *A. lumbricoides* and *T. trichiuris* differed from the trend in STHs and hookworm. The highest prevalence was obtained for children below 10 years old, and the infection was relatively low in adults (Fig. 3).

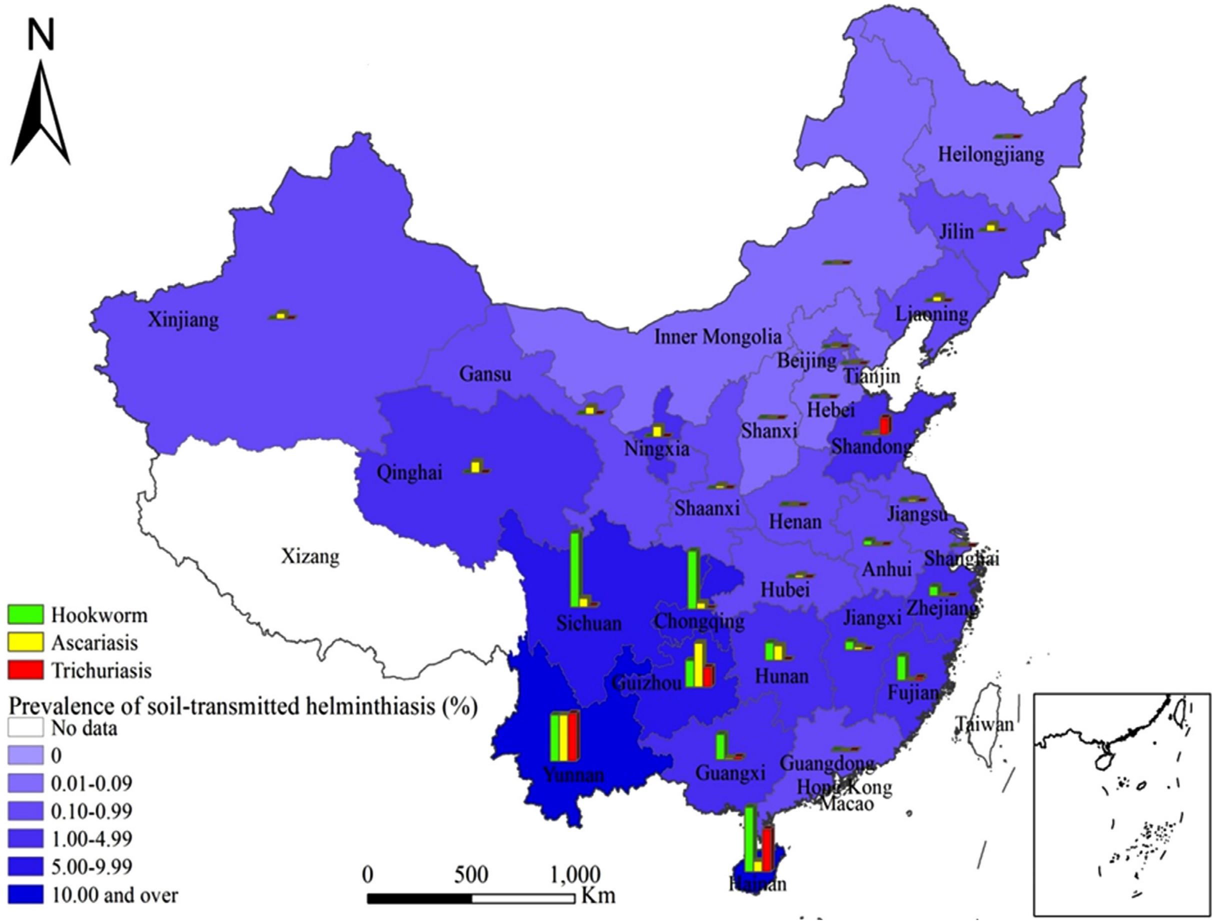

Fig. 2. STH prevalence according to results from the 2016 national surveillance.

Table 3
The regions with the highest prevalence according to the national surveillance in 2016.

Parasite	Highest	Second highest	Third highest
STHs in general	Yunnan (13.0%)	Hainan (11.8%)	Sichuan (9.2%)
Hookworm	Sichuan (8.2%)	Hainan (7.2%)	Chongiqng (6.4%)
Ascaris	Yunnan (5.1%)	Guizhou (4.9%)	Hunan (1.7%)
Trichuris	Yunnan (5.3%)	Hannan (4.7%)	Guizhou (2.2%)

3.4. Educational level distribution

The infection rate was highest among the illiteracy and semi-illiteracy group of all the groups assessed in the educational level (4.2%). Generally, STHs infection rate decreased with increasing educational level. There was a sharp decrease from primary school to middle school, and dropped to <1% from high school and above educational level (Fig. 4). High infection remains a problem in few provinces. For instance, 17.4% of hookworm cases in Hunan province were heavy infections, whereas light and moderate infections were 78.0% and 4.6% respectively. A particularly high infection was reported for *A. lumbricoides* at Hainan Province (20.8%), while 62.5% and 16.7% of the cases were of the light and moderate type, respectively. Out of all the 1 316 positive cases of *T. trichiura* obtained in Shandong and Hainan, only 2 heavy infections were detected. The constituent ratio was 0.1%, while moderate infections accounted for 5.7% (80/1316) of all positive cases.

Light infections accounted for most of the STHs infection cases, especially for hookworm and *T. trichiura*, in which more than 90% cases had light infections. The situation was the same for *A. lumbricoides* with >80% cases of light infection (Fig. 5).

3.5. Discrimination of *N. americanus* and *A. duodenale*

The positive hookworm stool sample cultures showed that *N. americanus* was the most prevalent hookworm of the two. Due to the limitation of the technical expertise, only 10 out of 20 regions with hookworm infection successfully cultured the positive stool sample, and *N. americanus* was the predominant species in these. The constituent

Table 4
The gender distribution of STHs according to national surveillance in 2016.

Gender	No. of examinations	STHs No. of infections	Infection rate (%)	Hookworm No. of infections	Infection rate (%)	*Ascaris* No. of infections	Infection rate (%)	*Trichuris* No. of infections	Infection rate (%)
Male	150 674	3 281	2.2	1 754	1.2	1 075	0.7	673	0.5
Female	154 399	4 085	2.7	2 368	1.5	1 263	0.8	725	0.5
Total	305 073*	7 366	2.4	4 122	1.4	2 338	0.8	1 398	0.5

* Eight cases of gender information were missing.

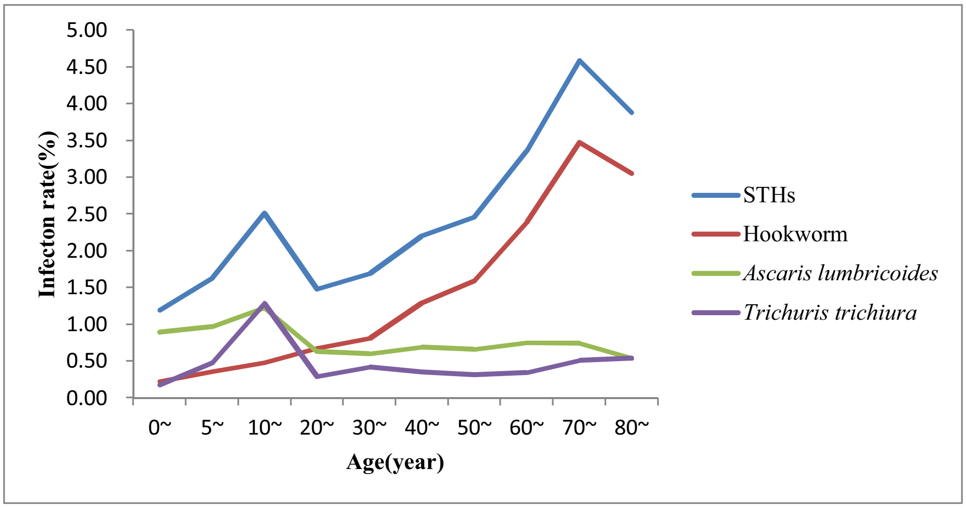

Fig. 3. Age distribution of STHs according to results from the national surveillance in 2016.

ratio of *N. americanus, A. duodenale* and co-infection were 94.7%, 4.80% and 0.5%, respectively. *N. americanus* was also detected in Chongqing, Guangxi, Jiangxi, Shandong and Guangdong, while both species were detected in the provinces of Sichuan, Yunnan, Guizhou, Fujian and Zhejiang. Co-infection was only found in Jiangxi Province (Fig. 6).

4. Discussion

According to the 2016 national surveillance results, STH epidemic is characterized by regional and population distribution. The high endemic areas with prevalence >5% are distributed in the south and southwest parts of China. The climate in these areas is warm and humid, and most of them are economically underdeveloped. Environment in these areas are suitable for parasite growth and reproduction, also, coupled with bad hygiene habits and unclean living conditions resulting from poverty promote disease transmission.

Findings from the national surveillance provide us information on STH endemic status in PR China. The overall STH prevalence was quite low and close to zero in some provinces. However, there exist areas with high STH prevalence or infection intensity. Hookworm infection account for the highest prevalence of the three STHs, while *N. americanus* was the main prevalent hookworm. The findings in this study indicated that the STH prevalence was higher in female than male, and the infection rate of hookworm was highest in people older than 60 years old, while the infection rates of *A. lumbricoides* and *T. trichiura* were highest in children. There is a need to pay more attention to women, children and the elderly in rural areas. It is, also, imperative that we explore ways to implement and communicate health education effectively.

A. lumbricoides has been implicated as the dominant STHs species in PR China as indicated in the results obtained from the first and second national surveys (Wang, 2008; Xu et al., 1999). The result is, however, different from that in this current study, with hookworm having the highest infection rate of all the STHs. This could be due to the fact that the drug administrated in PR China is less effective for hookworm, in particular in *N. americanus,* when compared to other STHs. This phenomenon of less efficacy in treatment of *N. americanus* infection is warrant to be investigated further. Also, the cultivation of vegetable is still dominant in the rural areas, more often, the farmers work on their farms barefooted and without hand gloves which expose them to the risk of hookworm infection.

Although the three STHs are targeted for control using same strategies but individual specie has peculiar transmission characteristics. For instance, hookworm is transmitted through human contact (walking barefooted) with soil contaminated with hookworm larvae

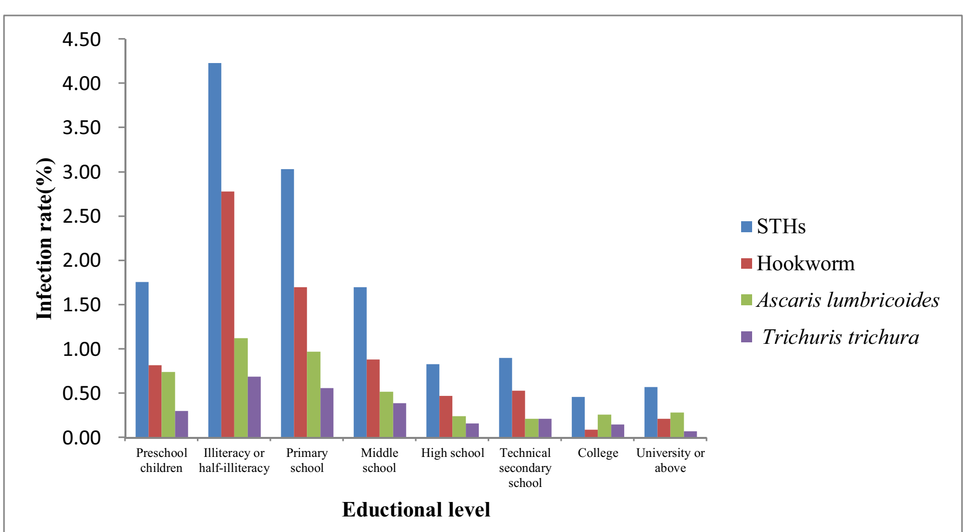

Fig. 4. Educational level distribution of STHs according to results from the national surveillance in 2016.

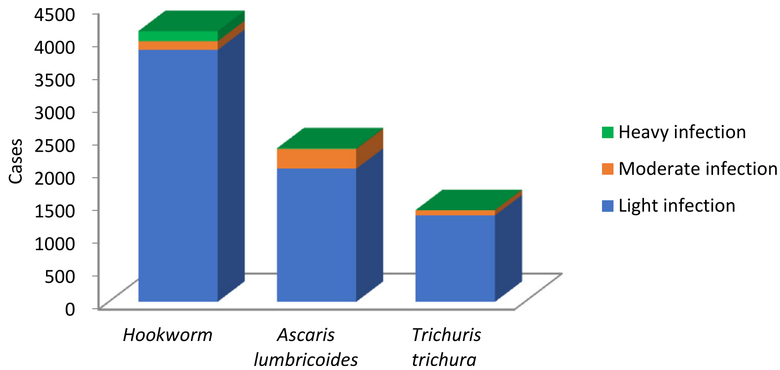

Fig. 5. Infection intensity of STHs according to results from the national surveillance in 2016.

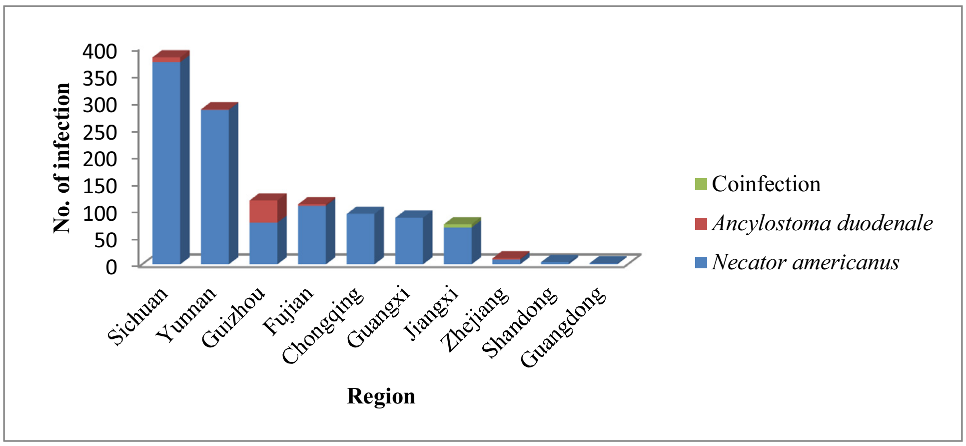

Fig. 6. Constituent ratio of two hookworm species in some regions.

while *A. lumbricoides* and *T. trichiuria* transmission is faeco-oral passway i.e. ingestion of food contaminated with the parasite's eggs. It is, also, important to note that these STHs species react differently (sensitivity) to drug treatment, therefore, it is imperative that we consider drug efficacy when preventive chemotherapy is administered.

It has been proved that STH endemicity has negative correlation with the economic level (Zhou, 2018). It is therefore, necessary that PR China incorporate a “help-the-poor” programme to enhance control strategy. The "National Control Programme for Echinococcosis and other Key Parasitic Diseases 2016–2020″ was initiated in 2016, to guide nationwide control activities of parasitic diseases, and target improved health for all by 2020 while working in synergy with the national surveillance system for key parasitic diseases established by the government to ensure decline in parasites infection rates. There is, therefore, need to ensure that the STH prevalence in low endemic areas be maintained targeting elimination while prevalence in high endemic areas be reduced by >20% when compared to 2015.

To further consolidate and build on the achievements made by STH control programme in PR China, some recommendations are to be considered as follows: (i) The “National Control Programme for Echinococcosis and other Key Parasitic Diseases (2016–2020)” should strengthen cooperation mechanism with all stakeholders including the leadership in government, various health and agricultural departments and the public. It is, also, important to commit more investment into the control programme to improve and strengthen control strategy, thereby, implementing comprehensive control strategies and also ensure quality surveillance. (ii) Comprehensive control strategies applied in the demonstration plots should be adopted in high endemic areas, thereby, improving people's awareness on STH to help them imbibe good hygiene culture and also, improve MDA administration. (iii) Health education should be enhanced as well as, ensure improved compliance to MDA. Residents in rural areas should cooperate with the government to promote construction of toilets in their localities to improve environmental sanitation. (iv)Operational research on STHs infectious should be encouraged, as well as, training of grass-roots personnel to achieve better coordination of control programme at the local level.

PR China's current progress in this area has made it the “most feasible” group to achieve STH transmission interruption (Brooker et al., 2015). It is imperative that great effort be made to achieve this task. However, most infections occur as light infection especially hookworm and *T. trichiura*, which makes diagnosis using the Kato-Katz method unreliable. Hence, we need to consider the use of new diagnostic methods such as FLOTAC technique or PCR in the future (Clarke et al., 2018; Coulibaly et al., 2016; Habtamu et al., 2011; Khurana and Sethi, 2017; Knopp et al., 2009; Qian et al., 2013). Having arrived at this stage of STHs control implementation and progressing towards the elimination goal, it is essential that we call for another national STH survey. Indeed, national surveillance could be carried out continuously to provide basic data for informed decision leading to STHs elimination.

5. Conclusion

Our findings indicate that PR China is fast approaching the STH elimination stage. Therefore, there are important points to consider in order to achieve our objectives. Firstly, there is strong need to incorporate the “help-the-poor” approach into the STH control programme to achieve desirable control outcome especially in the rural areas. Secondly, surveillance component of the control strategy should be strengthened to enhance control activities. Thirdly, prevention and control programme should always target precise or accurate implementation of control strategies.

It is, also, important to prioritize continuation of the expanded national surveillance system especially in areas with high STH endemicity, this would help provide insight on STH endemic status both horizontally and vertically in the country, as well as, equip control programme with relevant information for effective control implementation.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

Not applicable.

Funding

Not applicable.

CRediT authorship contribution statement

Hui-Hui Zhu: Conceptualization, Methodology, Software, Writing - original draft, Writing - review & editing. **Ji-Lei Huang:** Data curation, Writing - original draft, Visualization, Investigation. **Ting-Jun Zhu:** Data curation, Visualization, Investigation. **Chang-Hai Zhou:** Data curation, Visualization, Investigation. **Men-Bao Qian:** Software, Writing - review & editing, Validation. **Ying-Dan Chen:** Conceptualization, Supervision, Writing - review & editing. **Xiao-Nong Zhou:** Conceptualization, Supervision, Writing - review & editing.

Declaration of Competing Interest

The author declare that they have neither competing interests nor conflict of interests.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.actatropica.2020.105351.

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