Reduction patterns of prevalence and intensity of Schistosoma haematobium infection after MDA with praziquantel between regions with and without previous intervention in Sudan

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Abstract

Background: Mass drug administration (MDA) with praziquantel has been the mainstay for schistosomiasis control in endemic countries. To evaluate the effects of repeated MDA, we compared urogenital schistosomiasis prevalence at two localities in White Nile State, Sudan: Al Jabalain with previous MDA and El Salam without previous MDA.

Methods: A cross-sectional survey was carried out to examined the prevalence and intensity of Schistosoma haematobium infection using urine samples from 10,644 primary school-aged children (SAC) of two localities at the baseline survey, and then a single dose of 40 mg/kg praziquantel was mass administered to whole SAC of both localities. Of the total, 3,197 SAC of sentinel schools were examined urine samples at 8 months after the MDA.

Results: The overall prevalence of S. haematobium infection was 5.5% in Al Jabalain and 27.5% in El Salam at the baseline survey. In sentinel schools, the prevalences in Al Jabalain and El Salam were significantly reduced after MDA, 80.3% and 84.4% respectively, not significant between two localities. The geometric mean intensity (GMI) of egg counts from the infected children at the baseline survey was 14.5 eggs per 10 mL of urine (EP10) in Al Jabalain and 18.5 EP10 in El Salam. At the follow-up survey, the GMI reduction rate was significantly reduced, 51.0% in Al Jabalain and 39.5% in El Salam, however the infection intensity after MDA was reduced significantly less in SAC who had higher baseline prevalence and infection intensity. The overall intensity of infection was significantly reduced after MDA in girls, but not in boys.

Conclusions: Single MDA produces a similar prevalence reduction regardless of endemicity but less reduction of infection intensity in highly endemic populations. It is necessary to implement repeated MDAs to eliminate urogenital schistosomiasis in endemic regions..

Background

Schistosomiasis is a parasitic disease caused by a blood-fluke of the *Schistosoma* species. Humans are usually infected when they come into contact with contaminated freshwater and suffer from hematuria, anemia, enlargement of the liver and spleen, and growth retardation [1]. Schistosomiasis is endemic in 78 countries and is a major public health problem in many tropical countries–particularly in Africa, where more than 90% of the global burden of schistosomiasis occurs [2]. The global burden of schistosomiasis was conservatively estimated at 1.43 million disability-adjusted life years in 2017 [3]. More than 220.8 million people required preventive chemotherapy for schistosomiasis in 2017, and 102.3 million of them were treated [4–6].

Mass drug administration (MDA) refers to the preventive chemotherapy of targeted populations irrespective of individual infection status. Currently, five major ‘tool-ready’ neglected tropical diseases with MDA are lymphatic filariasis, onchocerciasis, schistosomiasis, soil-transmitted helminthiasis, and trachoma [5]. MDA of praziquantel to at-risk populations has become the cornerstone of schistosomiasis

control, especially for school-aged children (SAC) of 6–15 years, who have the highest risk of infection [6–8]. Until now, MDA in Sudan was implemented only a few times, including the Schistosomiasis Control Project by the Korean government [9] and the Blue Nile Health Project [10].

Sudan has one of the highest schistosomiasis prevalence rates in the world. About 15% of the total population (~ 5.8 million people) requires treatment, with the majority being children [11,12]. According to the published reports about the prevalence of schistosomiasis in Sudan, urogenital and intestinal schistosomiasis occurs in Sudan, and urogenital schistosomiasis by *S. haematobium* is dominant in the East Darfur, South Darfur, White Nile, Southern Kordofan and Khartoum States [11,13–16].

The White Nile State of Sudan has wide river basin areas along the White Nile River and large irrigated agricultural sectors along the banks. From 2009 until 2011, the Korea International Cooperation Agency (KOICA) implemented an integrated schistosomiasis control project at Al Jabalain in the White Nile State of Sudan (The 1st Phase of the KOICA Project) as an ODA Program of the Korean government [9]. The 2nd Phase of the KOICA Project started in 2012 again at Al Jabalain and included El Salam as a new area. In the present study, parasitological data of the 2nd Phase control activity were analyzed to compare the effects of praziquantel MDA between the 2 localities owing to their different MDA background: Al Jabalain had previous MDA while El Salam did not.

Materials And Methods

Study area and design

The White Nile State is located along the White Nile River in the southeastern part of Sudan, and water canals are well-developed in connection with the river in this region. This study was conducted in Al Jabalain and El Salam localites of the White Nile State, Sudan, composed of six and five units, respectively, from 2013 to 2014 (Fig. 1). In Sudan, the unit is the last step of local administrative organization, which we used as a basic structure for implementation activities. In this study, the target population for schistosomiasis control consisted of 94,549 SAC from 245 primary schools in Al Jabalain and El Salam (Table 1). Before the 2nd Phase activity, Al Jabalain received 2 rounds of MDA in 2009 and 2011 during the 1st Phase of the KOICA project [9] while El Salam did not (Fig. 2).

We first randomly selected primary schools from each unit in Al Jabalain and El Salam to evaluate the baseline prevalence and intensity of *S. haematobium* infection before MDA. Afterward, a single dose of 40 mg/kg praziquantel was delivered to all SAC of both localities. For the follow-up survey at 8-month after MDA, 1 or 2 sentinel schools were randomly selected at each unit among the baseline survey-conducted schools. Urine specimens were collected from 10,644 and 3,197 SAC for the baseline and follow-up surveys, respectively, and examined for *S. haematobium* eggs by urine sedimentation technique using a microscope. The baseline surveys and MDA were done in 2013; the follow-up survey was conducted in 2014 (Fig. 2 and 3).

[Insert Table 1 here.]

Ethics statement

This study protocol was reviewed and approved by the Institutional Review Board (IRB) of the Korea Association of Health Promotion (KAHP) (IRB approval No. 12-C–01). KAHP implemented the 1st and 2nd Phase KOICA projects granted by the Korean government. This study protocol received further ethical clearance from the Federal Ministry of Health of Sudan. Written informed consent from each student was waived by the IRB.

Data were collected from the primary-school students according to the IRB-approved framework. Before the commencement of the study at each school, health workers explained the objectives of the study and verbal informed consent was first obtained from the schoolmaster and teachers prior to the recruitment of children. After the health workers explained the study protocol, verbal informed consent was also obtained from each student with the presence of schoolteachers.

Sample size for the baseline survey

The target numbers for praziquantel MDA were 94,549 SAC; about 10,000 children were selected for the baseline survey following the recommendations of Korean and Sudanese Parasitology Experts Committee. Assigned numbers of students for each unit were calculated by dividing of total student numbers of each unit by 9.4. The numbers of surveyed schools were calculated by dividing half of the mean number of students in each school, in each unit, because samples from the 1st, 3rd and 5th grade classes of each school were collected. Since there were some differences in student numbers for each school, we determined the number of schools to collect samples at each unit by a number of averages ± 20%.

A total of 50 primary schools were randomly selected for the baseline survey; 37 schools in Al Jabalain and 13 schools in EL Salam. In one school, we collected 80-250 samples, but not more than 300. If the number of students from one school was less than 100, all students were subjected.

Urine sample collection and examination

The prevalence and intensity of *S. haematobium* infection in Al Jabalain and El Salam were evaluated using urine samples collected from 1st, 3rd, and 5th graders of each school. Containers were delivered early morning to the schools and collected on the same day (usually around 2–4 pm before leaving school). The collected samples were immediately transferred to the SUKO Center (Sudan-Korea Schistosomiasis Control Center established by the KOICA project) in Kosti, White Nile State.

After collection, parasitological examinations were carried out on the same day by laboratory technicians with more than 5 years of experience in urine and stool microscopy. *S. haematobium* eggs were detected in the urine samples via the urine sedimentation method, as described elsewhere [17,18]. Briefly, 10 mL of urine in each tube was centrifuged at 1,500 rpm for 5 minutes at room temperature, and the sediments

were transferred onto 2–4 glass slides to examine the whole pellet. The slides were examined via microscopy to detect and count *S. haematobium* eggs. Infection intensities of *S. haematobium* were expressed as geometric mean intensity (GMI) of eggs per 10 mL of urine (EP10) and classified into 2 categories: light intensity (EP10 < 50) and heavy intensity (EP10 ≥ 50) of infections [17].

For quality control, 10% of slides were randomly selected and re-examined at the end of each day by parasitology experts that were blinded to the results of the first examination. In case of disagreement, the results were discussed with the concerned technician, and the discordant slides were re-examined until an agreement was reached.

MDA of praziquantel

The chemotherapy strategy followed the schistosomiasis control protocol of the Sudanese government, which was a modified treatment strategy of the WHO recommendation [19]. The parasitology experts controlled all drug treatments. The drugs were delivered through the school-based system by health workers. All health workers were White Nile State Ministry of Health officers and were educated on drug treatment and schistosomiasis control projects by parasitology experts before the study.

For MDA of praziquantel (Distocide®, GMC Co. Ltd., Khartoum), health workers went to schools in the morning and administered praziquantel to the school children directly. In this study, we administered praziquantel to all primary school students regardless of the baseline prevalence of schistosomiasis at 2013 according to the schistosomiasis control protocol of the Sudanese government. The WHO dose pole was used to determine the dosage of praziquantel (40 mg/kg) for school children [19].

Selection of sentinel schools and follow-up evaluation

To evaluate the prevalence and intensity of *S. haematobium* infection after MDA, we selected 1–2 sentinel schools from each unit for a follow-up survey among the baseline survey-conducted schools and repeated the survey at 8 months after MDA. Simple random sampling was used to select the sentinel primary schools from each unit [20]. Among the listed SAC of all baseline-surveyed primary schools, 150–300 SAC 20% from 1–2 schools were selected in each unit. The follow-up survey was carried out at 12 primary schools in 2014: 6 in Al Jabalain and 6 in El Salam. The names of sentinel schools at each unit are Dar Al Salam mixed (Al Jabalain unit), Al Hajaleej mixed (Assalaya unit), Tayba boys (Jazeera Aba unit), Al Ganaa mixed (Joda unit), Al Farook Basis boys (Kenana unit), Al Khalifa Allah boys (Rabak unit), Al Rawat boys (Al Rawat unit), Wad Al Koot mixed (Al Rawat unit), Al Siferia mixed (Al Zelit unit), Al Naeem boys (Al Naeem unit), Dabkt Al toor mixed (AL Kewaik unit) and Al migainis (Al Migainis unit).

Statistical analysis

Cross-sectional analysis was conducted on the baseline data collected in 2013 before MDA and the follow-up data collected in 2014 after MDA. SPSS version 16.0 software (SPSS Inc., San Diego, California, USA) was used to analyze the experimental data. Due to the deviation from a normal distribution, *S. haematobium* infection intensities were calculated as GMI of EP10. The differences in continuous variables among groups were tested using the Mann-Whitney test and Student's *t*-test. The rate of prevalence and infection intensity reduction was calculated by the formula: Reduction rate = (prevalence or infection intensity at baseline survey - prevalence or infection intensity at follow-up survey)/prevalence or infection intensity at baseline survey 100. Adjusted odds ratios at 95% confidence interval were used. *P*-values <0.05 were considered statistically significant.

Results

Baseline prevalence before MDA

As shown in Table 2, a total of 10,644 urine samples were collected from SAC; parasitological examination identified 1,020 SAC infected with *S. haematobium;* thus, the overall baseline prevalence of *S. haematobium* infection was 9.6%. The baseline prevalence rates at Al Jabalain and El Salam were 5.5% and 27.5%, respectively, showing a significant difference ($P<0.001$). The prevalence rate varied within each unit from 1.0% to 11.3% in Al Jabalain and 4.9–43.3% in El Salam. High baseline prevalence rates were found at the Al Zelit (43.3%), Al Migainis (31.8%), and Al Rawat (29.0%) units, whereas those at the Jazeera Aba (1.0%), Joda (1.1%), and Rabak (3.6%) units were low.

[Insert Table 2 here.]

MDA with praziquantel

We administered a single dose of 40 mg/kg praziquantel to all primary school children in 2013, except absentees, the ill or those allergic to praziquantel. The targeted and treated numbers and coverage rates of each unit are shown in Table 1. In 2013, 85,554 of the 94,549 SAC were treated with praziquantel; thus, the drug coverage rates were 92.1% in Al Jabalain, 82.3% in El Salam, and 90.5% for the combined total. The coverage rates of each unit varied from 77.9% (Jazeera Aba unit) to 97.7% (Al Jabalain unit).

Comparison of prevalence change after MDA

The overall prevalence rate at the 12 sentinel schools from both localities was 19.9% at the baseline survey in 2013 and 3.6% at the follow-up survey in 2014, indicating an 82.1% prevalence rate reduction after MDA ($P < 0.001$; 95% CI = 0.12–0.18). The prevalence at the 6 sentinel schools in Al Jabalain was reduced from 9.1% at the baseline survey to 1.8% at the follow-up survey with an 80.3% reduction rate ($P < 0.001$; 95% CI = 0.12–0.27). The prevalence at the 6 sentinel schools in El Salam was 35.2% at the baseline survey and 5.5% at the follow-up survey, with an 84.4% reduction rate ($P < 0.001$; 95% CI = 0.08–

0.14). When sorting by unit level in both localities, the reduction rates of prevalence were high in the Jazeera Aba (100%), Al Zelit (96.5%) and Al Kewaik (97.0%) units, and low in the Joda (67.2%) and Al Naeem (69.3%) units. The baseline prevalence after MDA was profoundly reduced in all units except the Jazeera Aba and Joda units; however, the reduction rates of each unit were not significantly different from other units (Table 3).

By gender, the overall prevalence rates in boys and girls were both 19.9% at the baseline survey for both localities. After MDA, the prevalence reduction rate for boys was 81.0% ($P<0.001$; 95% CI = 0.12–0.20), with the same pattern seen in girls ($P<0.001$; 95% CI = 0.08–0.19). According to the stratified age groups, the overall baseline prevalence rates of 9, 10–12, and 13≤ year-old children for both localities were 18.2%, 20.8%, and 21.2%, respectively. After MDA, the prevalence reduction rates in the 9, 10–12, and 13≤ year-old groups were 86.7%, 79.2%, and 81.2%, respectively, which were significant differences between baseline and follow-up prevalence rates for all three age groups ($P<0.001$; 95% CI = 0.07–0.17 ~ 0.13–0.23); in contrast, there were no significant differences of prevalence reduction rates between localities and genders as well as among units of each locality and age groups (Table 3).

[Insert Table 3 here.]

Comparison of infection intensity change after MDA

Table 4 shows the infection intensity of *S. haematobium*-infected children at the baseline and follow-up surveys in Al Jabalain and El Salam in 2013 and 2014. The overall GMI of the 12 sentinel schools for both localities was 17.3 EP10 at the baseline survey and 9.5 EP10 at the follow-up survey; thus, the overall reduction rate of GMI was 45.1%, showing a significant difference between baseline and follow-up surveys ($P<0.001$; 95% CI = 0.26–0.33). In detail, the GMI of the infected children at the 6 sentinel schools in Al Jabalain was reduced from 14.5 EP10 in the baseline survey to 7.1 EP10 in the follow-up survey–a significant reduction rate of 51.0%, ($P<0.001$; 95% CI = 0.25–0.41). The GMI of the infected children in the baseline and follow-up surveys in El Salam were 18.5 and 11.2 EP10, respectively, which constituted a significant reduction rate of 39.5% ($P<0.001$; 95% CI = 0.23–0.30). At the unit level of both localities, the high reduction rate of GMI was observed in the Jazeera Aba (100%), Joda (84.1%) and Rabak (81.5%) units, whereas the reduction rates of GMI were low in the Assalaya (27.8%), Kenana (38.8%) and AL Kewaik (45.6%) units. In contrast, the follow-up GMI in the Al Naeem unit increased after treatment in comparison to the baseline GMI (reduction rate, −4.8%).

There were no significant differences in the baseline GMI of infected children according to gender (15.8–17.8 EP10) or age group (16.0–18.3 EP10). At the follow-up survey, the GMI was significantly reduced in infected girls (69.6%) after MDA, but not in boys (30.9%). According to age group, the GMI reductions for the 9, 10–12, and 13≤ year-old infected children of both localities after MDA were significant ($P<0.001$).

We also classified the intensity of *S. haematobium* infection into 2 categories: light intensity (50 EP10) and heavy intensity (50 EP10) of infections. As shown in Table 5, a total of 7.7% had heavy intensity of infection at the baseline survey; 2.9% in Al Jabalain and 14.4% in El Salam. After MDA, the percentage of heavy infection intensity was significantly reduced in Al Jabalain (93.9%, $P<0.001$) and El Salam (93.2%, $P<0.001$). By locality and unit level, the percentages of heavy intensity of infection were significantly reduced at both localities. By gender and age group, the percentages of heavy intensity of infected children of each group were significantly reduced, and there were significant differences of the percentages of heavy intensity of infected children between boys and girls (Table 4).

[Insert Table 4 here.]

[Insert Table 5 here.]

Discussion

The present study compared qualitative and quantitative urine microscopy findings after a single MDA of praziquantel for urogenital schistosomiasis between Al Jabalain and El Salam in the White Nile State, Sudan. The baseline prevalence of *S. haematobium* infection was 5.5% in Al Jabalain and 27.5% in El Salam. All SAC in Al Jabalain received 2 MDAs within the recent 4 years, while those in El Salam had not. At 8 months after the MDA, the prevalence rates in both Al Jabalain and El Salam were significantly reduced compared to baseline rates (80.3% and 84.4%, respectively). The two reduction rates of prevalence were similar regardless of the baseline prevalence rate. Also, the reduction rates of prevalence were almost similar between boys and girls, or among age groups. The 2013 baseline prevalence rate of 27.5% in El Salam locality was at the level of the past prevalence of *S. haematobium* infection in the White Nile State (21.4%) in 1996 [11] and the baseline prevalence in Al Jabalain before MDA in 2009 (28.5%) [9]. Although the two localities had different MDA histories, the chemotherapeutic effect of a single praziquantel MDA was good and stable based on the observed reduction rate of prevalence. Reduction of prevalence rate after MDA represents the proportion of cure among the infected population, and the present similar findings were observed between gender and age groups as well as between the two localities. Our reduction rate of prevalence after a single dose of praziquantel was similar to previous reports in SAC of Sudan and Burkina Faso [21–22].

The infection intensity–which is quantified using egg counts (GMI of EP10 in the present study)–is an important index of schistosomiasis epidemiology. The egg counts can estimate the burden of infecting worms and represent the degree of morbidity by eggs in the bladder [23]. In the present study, the baseline GMI of Al Jabalain was 14.5 EP10, which was significantly lower than 18.5 EP10 in El Salam. The GMI of EP10 was significantly reduced by MDA in both localities, and the reduction rate was lower in El Salam (39.5%) than in Al Jabalain (51.0%). By gender, the GMI reduction was significantly higher in girls than in boys. While the prevalence reduction was similar, the findings suggest less reduction of infection intensity in populations with heavier infection burdens.

El Salam demonstrated a higher prevalence rate of urogenital schistosomiasis and higher EP10 counts than Al Jabalain. A single MDA produced a similar reduction efficacy of prevalence rate (i.e. cure rate) in El Salam, but a lower efficacy of worm reduction in the human body; this suggested that most of the light burden children were cured by MDA and the proportion was similar in both localities, but heavy burden cases remained uncured with lowered EP10 counts after MDA. A complete cure is important for individual care; therefore, it is recommended to use 20 mg/kg praziquantel × 2 for diagnosis-based medication of individuals [24] while MDA reduces the general prevalence and morbidity in a community. The present findings support the idea that a single MDA with a 40 mg/kg dose is less effective to cure heavy burden schistosomiasis, and recommends repeated MDAs for community control programs.

The above-mentioned results were analyzed on the basis of each locality. When we breakdown the prevalence rates and egg counts by subdistricts in the localities, there were wide variations in both localities. Even in Al Jabalain, there were subdistricts with a low reduction rate of prevalence, such as Joda and Al Naeem units. In Al Naeem unit, the GMI increased after MDA, because many absent children with high GMI of *S. haematobium* infection were involved at follow-up survey however they did not participate the baseline survey and praziquantel treatment. Ongoing refugee immigration from South Sudan also influences the villages of both localities and necessitates extra care of this population during refugee migration and settlement.

When interpreting the MDA effects between the 2 localities, we have to consider reinfection. We examined the urine microscopy at 8 months after MDA, which was a long enough period to be influenced by reinfection after MDA. A single 40 mg/kg dose of praziquantel is known to produce a 73.6% cure rate and a 94.7% egg reduction rate for *S. haematobium* infections [25]. The present prevalence reduction rate was over 80%, which was similar to the known cure rate. However, the intensity reduction rate (39.5% in El Salam and 51.0% in Al Jabalain) was much lower than the known 90% egg reduction rate, although the estimation method was different. The egg passers after MDA included failed treatments and reinfected cases together without clear identification. In heavy endemic areas, children are more rapidly and heavily reinfected after chemotherapy because they are more exposed. The reinfection force is determined by the egg seeding amount within the local area. Other risk factors, such as drug coverage rates and seasonality of the follow-up survey, may have affected the reduction rates of infection intensity in this study. The praziquantel coverage rate in El Salam was lower than in Al Jabalain, thus it may be possible that the proportion of infected SAC at the follow-up survey was higher in El Salam. The follow-up survey was done 8 months after MDA, after passing the hot and humid rainy season and long summer vacation; thus, SAC may contact water (such as during swimming) more frequently. The present study confirmed that the intensity reduction was much less in Sudan than expected. Therefore, repeated MDA may diminish the reinfection force by reducing the egg seeding population and the total amount of egg production in a community. Once repeated MDA starts to effectively keep the egg seeding amount under the reinfection threshold, schistosomiasis may finally be eliminated.

The present study had some limitations. The follow-up data at 8 months after the MDA included both treatment failure and reinfection after medication, but it was impossible to differentiate their impacts.

The other limitation was the influence of immigrants from South Sudan who were included in the study population.

Conclusion

The aim of paper is to compare the effects of MDA with praziquantel in contrasting regions that are geographically adjacent but profoundly different from the baseline infection status of urogenital schistosomiasis. Through this study, our data shown that praziquantel administration was effective to reduce the prevalence of *S. haematobium* infection regardless of baseline prevalence levels in endemic areas, however single dose of praziquantel is not enough to reduce the infection intensity sufficiently at high infection status. Thus, this study provides a real site information about the reduction patterns of prevalence and infection intensity after praziquantel treatment in endemic regions with different levels of basal infection status. In conclusion, single MDA produces a similar prevalence reduction regardless of endemicity but less reduction of infection intensity in highly endemic communities. It is necessary to implement repeated MDAs to eliminate urogenital schistosomiasis.

Declarations

List of abbreviations

MDA: mass drug administration; SAC: school-aged children; EP10: number of *Schistosoma haematobium* eggs per 10 mL of urine; GMI: geometric mean intensity; SUKO Center: Sudan-Korea Schistosomiasis Control Center in Kosti, White Nile State of Sudan; IRB:Institutional Review Board; KAHP: The Korea Association of Health Promotion.

Ethics approval and consent to participate

This study was one of the 2nd Phase of KOICA project as an ODA Program of Korean government, which was carried out under an official agreement between the Korean government and the Sudanese government (Project No. P2011–00240–1). Prior to the implementation of the study, this study protocol was reviewed and approved by the Institutional Review Board (IRB) of the Korea Association of Health Promotion (KAHP) (IRB approval No. 12-C–01). This study protocol also received further ethical clearance from the Federal Ministry of Health of Sudan. Written informed consent from each student was waived by the IRB.

Consent for publication

Not applicable.

Availability of data and materials

Data supporting the conclusions of this article are included in this article. Further information on datasets used and/or analysed during the current study are available from the corresponding author upon reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

YHL, SC and STH contributed to conceptualization of the study, conducted field and sampling work, interpreted the findings and drafted the manuscript. JSL, HGJ, AAWS and MSE coordinated the implementation of the study. ISK conducted the statistical analyses. All authors have read and approved the final version of the manuscript.

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References

1. Gryseels B. Schistosomiasis. Infect Dis Clin North Am. 2012;26(2):383–97.
2. Hotez PJ, Kamath A. Neglected tropical diseases in sub-Saharan Africa: review of their prevalence, distribution, and disease burden. PLoS Negl Trop Dis. 2009;3:e412
3. GBD and HALE Collaborators. Global, regional, and national disability-adjusted life-years (DALYs) for 359 diseases and injuries and healthy life expectancy (HALE) for 195 countries and territories, 1990–

2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet. 2018;392:1859–1922.

4. WHO. Fact Sheet on Schistosomiasis. Geneva: World Health Organization; 2017. Available at http://www.who.int/mediacentre/factsheets/fs115/en/. Accessed 24 July 2019.
5. Zhang Y, MacArthur C, Mubila L, Baker S. Control of neglected tropical diseases needs a long-term commitment. BMC Med. 2010;8:67.
6. WHO. Schistosomiasis progress report 2001–2011, strategic plan 2012–2020. Geneva: World Health Organization; 2013. Accessed 4 July 2019.
7. WHO. Helminth Control in School Age Children: A Guide for Managers of Control Programmes-–2nd Edn. World Health Organization (2011). Accessed 24 July 2019.
8. Atalabi TE, Adubi TO. The epidemiology and chemotherapeutic approaches to the control of urinary schistosomiasis in school-age children (SAC): a systematic review. BMC Infect Dis. 2019;19:73.
9. Lee YH, Jeong HG, Kong WH, Lee SH, Cho HI, Nam HS, et al. Reduction of urogenital schistosomiasis with an integrated control project in Sudan. PLoS Negl Trop Dis. 2015; 9: e3423.
10. El Gaddal AA. The Blue Nile Health Project: a comprehensive approach to the prevention and control of water associated diseases in irrigated schemes of the Sudan. J Trop Med Hyg. 1985;88:47–56.
11. Cha S, Elhag MS, Lee YH, Cho DS, Ismail HA, Hong ST. Epidemiological findings and policy implications from the nationwide schistosomiasis and intestinal helminthiasis survey in Sudan. Parasites Vectors 2019; accepted and in press.
12. http://www.emro.who.int/sdn/sudan-events/launch2013-schistosomiasis.html. Accessed 26 July 2019.
13. Ahmed ES, Daffalla A, Christensen NO, Madsen H. Patterns of infection and transmission of human schistosomiasis mansoni and schistosomiasis haematobium in White Nile Province, Sudan. Ann Trop Med Parasitol. 1996: 90:173–80.
14. Ismail HA, Hong ST, Babiker AT, Hassan RM, Sulaiman MA, Jeong HG, et al. Prevalence, risk factors, and clinical manifestations of schistosomiasis among school children in the White Nile River basin, Sudan. Parasit Vectors. 2014;7:478.
15. Abou-Zeid AH, Abkar TA, Mohamed RO. Schistosomiasis infection among primary school students in a war zone, Southern Kordofan State, Sudan: a cross-sectional study. BMC Public Health. 2013;13:643.
16. Hajissa K, Muhajir AEMA, Eshag HA, Alfadel A, Nahied E, Dahab R, et al. Prevalence of schistosomiasis and associated risk factors among school children in Um-Asher Area, Khartoum, Sudan. BMC Res Notes. 2018;11:779.
17. WHO. Sedimentation method. In Basic laboratory methods in Medical Parasitology. WHO Geneva; 1991,p. 33–35.
18. Atalabi TE, Adoh SD, Eze KM. The current epidemiological status of urogenital schistosomiasis among primary school pupils in Katsina State, Nigeria: An imperative for a scale up of water and

sanitation initiative and mass administration of medicines with Praziquantel. PLoS Negl Trop Dis. 2018;12:e0006636.

19. WHO. Prevention and control of schistosomiasis and soil-transmitted helminthiaisis. WHO Tech Report Series No.912. 2002; Geneva: WHO.
20. Nagelkerke NJ, Borgdorff MW, Kalisvaart NA, Broekmans JF. The design of multi-stage tuberculin surveys: some suggestions for sampling. Int J Tuberc Lung Dis. 2000;4:314–20.
21. Ahmed AM, Abbas H, Mansour FA, Gasim GI, Adam I. Schistosoma haematobium infections among school children in central Sudan one year after treatment with praziquantel. Parasites Vectors. 2012;5:108.
22. Touré S, Zhang Y, Bosqué-Oliva E, Ky C, Ouedraogo A, Koukounari A, et al. Two-year impact of single praziquantel treatment on infection in the national control programme on schistosomiasis in Burkina Faso. Bull World Health Organ. 2008;86:780–7.
23. Andrade G, Bertsch DJ, Gazzinelli A, King CH. Decline in infection-related morbidities following drug-mediated reductions in the intensity of Schistosoma infection: A systematic review and meta-analysis. PLoS Negl Trop Dis. 2017;11:e0005372.
24. Zhou XN, Xu J, Chen HG, Wang TP, Huang XB, Lin DD, et al. Tools to support policy decisions related to treatment strategies and surveillance of Schistosomiasis japonica towards elimination. PLoS Negl Trop Dis. 2011;5:e1408.
25. Zwang J, Olliaro P. Efficacy and safety of praziquantel 40 mg/kg in preschool-aged and school-aged children: a meta-analysis. Parasit Vectors. 2017;10:47.

Tables

Due to technical limitations, Tables 1 - 5 are only available for download from the Supplementary Files section.

Figures

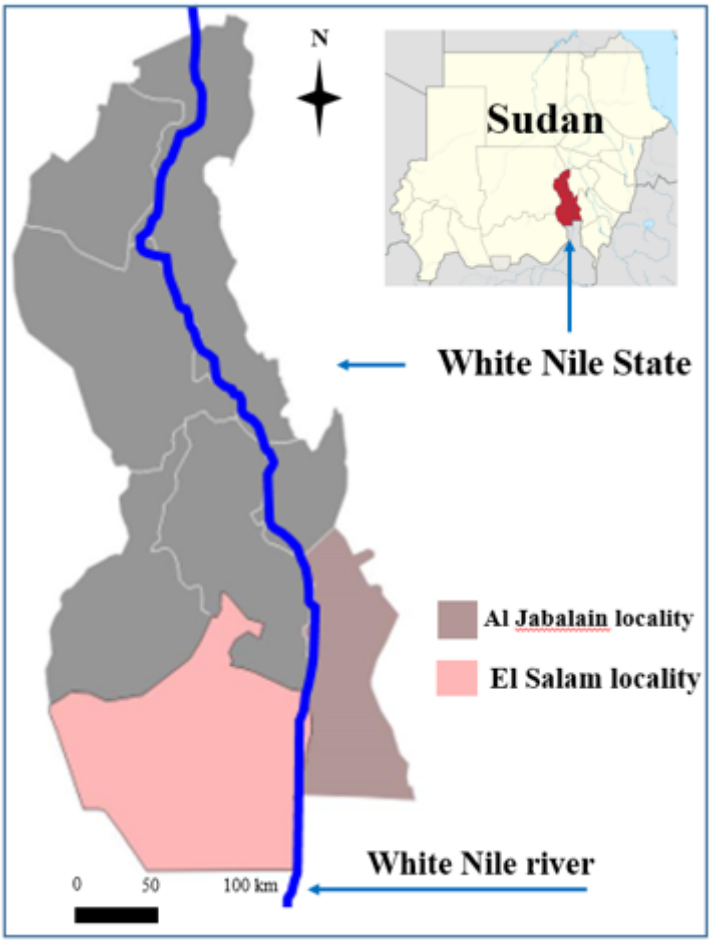

Figure 1

Location of Al Jabalain and El Salam in the White Nile State of Sudan.

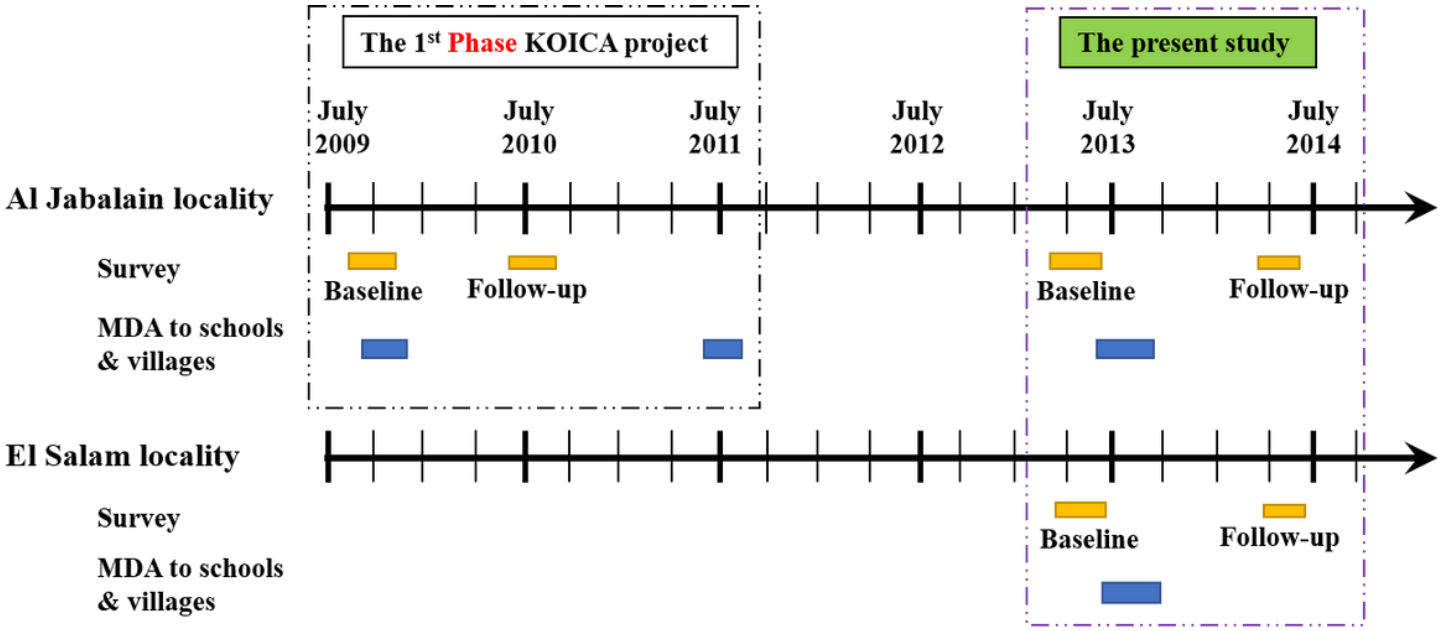

Figure 2

Schematic illustration of study design and regional background of mass drug administration (MDA) with praziquantel to school-aged children in Al Jabalain and El Salam localities in the White Nile State of Sudan.

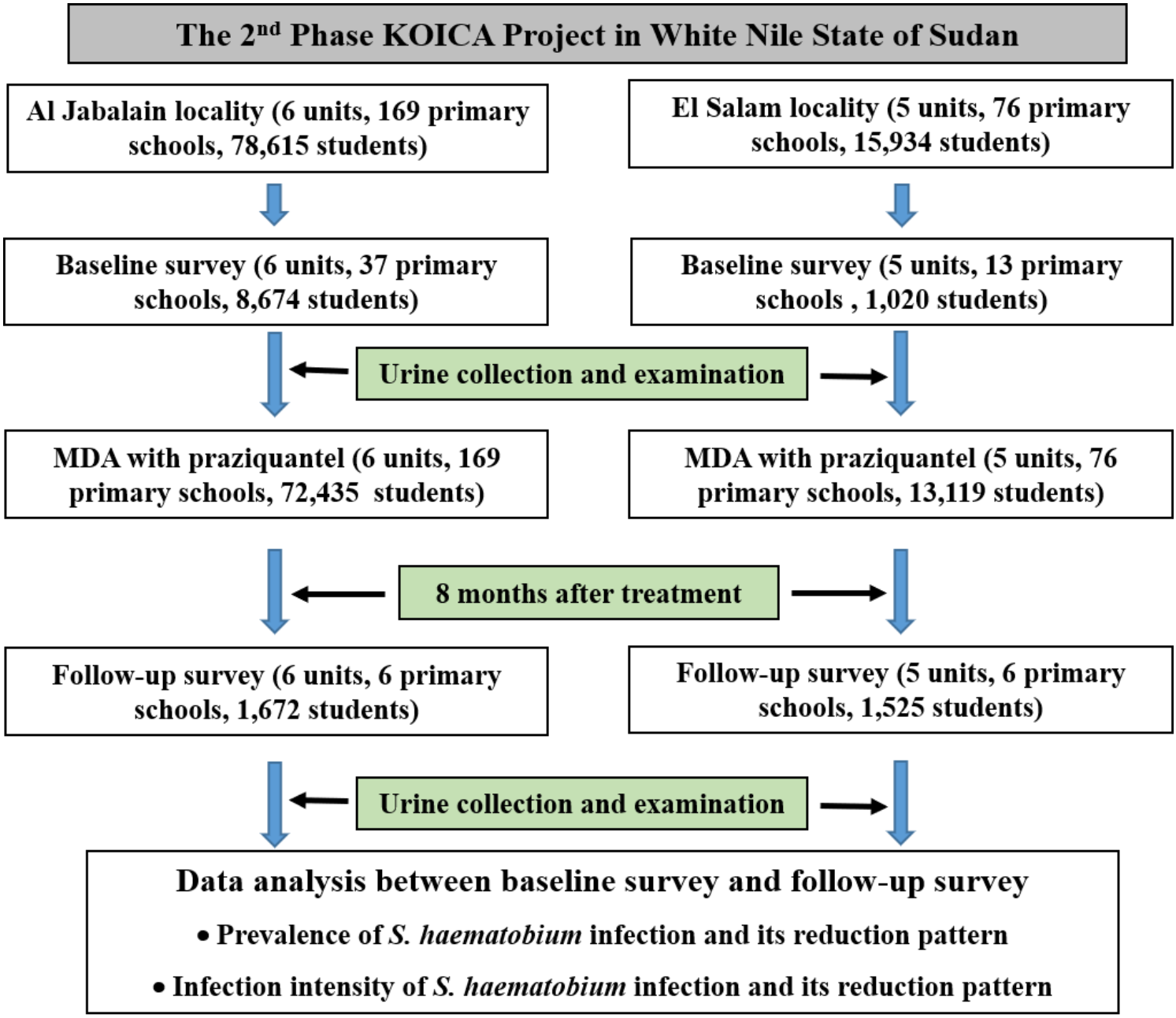

Figure 3

Flow chart of participation and study methods. This project was carried out at Al Jabalain and El Salam localities in the White Nile State of Sudan from 2013 to 2014.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Table4.pdf
- Table5.pdf
- Table3.pdf
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