Cost implications of a nationwide survey of schistosomiasis and other intestinal helminthiases in Sudan

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Abstract

Background: It is vital to share details of concrete experiences of conducting a nationwide survey, so that the global health community could adapt it to expand geographic mapping programs, eventually contributing to the development of control and elimination strategies with limited resources. A nationwide survey of schistosomiasis and nine other intestinal helminthiasis was conducted from December 2016 to March 2017 in Sudan.

Objectives: We aimed to describe details of the key activities and components required for the nationwide survey of schistosomiasis and other intestinal helminthiasis and to analyze its costs.

Methods: We estimated financial and economic costs from the provider's perspective. Cash expenditures incurred to implement the survey were defined as financial costs. We took into account all of the resources invested in the survey for economic costs, including the components that were not paid for, such as vehicles and survey equipment provided by the Ministry of Health, Sudan and the opportunity costs of primary school teachers' time spent on the survey. We ran one-way sensitivity and probabilistic analyses using Monte-Carlo methods with 10,000 draws to examine the robustness of the primary analysis results.

Results: A total of USD 1,465,902 and USD 1,516,238 was incurred for the financial and economic costs, respectively. The key cost drivers of the nationwide survey were personnel and transportation, for both financial and economic costs. Personnel and transportation accounted for around 64% and 18% of financial costs, respectively.

Conclusions: The cost is expected to vary depending on the quantity and quality of existing laboratory facilities, equipment, and consumables, and the capability of laboratory technicians and sample collectors. Establishing central-level and independent supervision mechanisms to

ensure the quality of the survey is equally important. We expect the global health community to draw on this study when developing nationwide surveys of schistosomiasis and other intestinal helminthiases.

Key Words: cost, a nationwide survey, Sudan, schistosomiasis, intestinal helminthiases

Author Summary

Although large-scale mapping of schistosomiasis and other intestinal helminthiasis has been conducted in some countries, little is known about the details of nationwide surveys, such as the necessary scale of the workforce, logistics, and the cost of conducting a nationwide survey. A nationwide survey of schistosomiasis and nine other intestinal helminthiasis was conducted from December 2016 to March 2017 in Sudan. A total of 105,167 students participated in the survey from 1,772 primary schools in 183 districts of all 18 states of Sudan. Herein, we present the activities that were necessary to prepare and conduct a nationwide neglected tropical disease survey, along with details on the types and amounts of personnel, survey equipment, and consumables that are required. In addition, through an analysis of the costs of the nationwide survey, we generated average costs at the district and sub-district level. The key cost drivers were personnel and transportation, both of which were recurrent costs. Establishing a steering committee to develop and reach consensus on a survey protocol, assessing the capacities of potential staff (particularly laboratory technicians), and training laboratory technicians and data collectors were key components required to prepare a nationwide survey. If a government finds a way to mobilize existing government officials with no additional payment using the health system already in place, the cost of a nationwide survey would be remarkably lower. We expect the global health community to draw on this study to develop nationwide surveys for schistosomiasis and other intestinal helminthiasis.

Background

Neglected tropical diseases (NTDs) have been chronically underfunded, making it necessary to allocate limited resources efficiently [1, 2]. Although investments in disease mapping have increased in the past decade, in many parts of the world, the prevalence of NTDs remains unknown or patchy, or the data are outdated [3, 4]. The gaps in the known prevalence of schistosomiasis and intestinal helminthiases, including soil-transmitted helminthiases (STHs), are considerable, and prevalence data are only available for fewer than half of all districts in sub-Saharan Africa [5].

Implementation of NTD control has been hampered by a lack of data on their geographical distribution and limited funds. Operational experience with nationwide NTD surveys is limited, and this is particularly true for integrated surveys [6]. Therefore, it is vital to share the details of concrete experiences of conducting a nationwide survey, so that the global health community could adapt it to expand geographic mapping programs, eventually contributing to the development of control and elimination strategies with limited resources.

In recent years, several studies [6-10] have begun exploring the main drivers of NTD survey costs and the potential effects of modifying standard operating procedures. The first study [6] analyzed the cost of the integrated surveys for lymphatic filariasis, schistosomiasis, and STH infection conducted in South Sudan by Kolaczinski and colleagues [6]. They called on the global community to undertake similar studies to compare results across different settings. However, the survey in South Sudan was not conducted throughout the nation (instead, it was carried out only in one state), and previous studies [6-10] were limited to analyzing cost only. We need to understand what activities are necessary to prepare and conduct a nationwide NTD survey, and the types and amounts of personnel, survey equipment, and consumables that are

required.

Sudan was one of the African countries with the largest unmapped areas of schistosomiasis and STHs, and it was necessary to update the prevalence data [11]. A nationwide survey of schistosomiasis and other intestinal helminthiases, including STHs, was conducted from December 2016 through March 2017, in which 105,167 students participated from 1772 schools in 183 districts of all 18 states of Sudan. Herein, we aim to describe the details of the key activities and components required to prepare and undertake a nationwide survey of schistosomiasis and other intestinal helminthiases, and to analyze the costs of the nationwide survey. We compare the results with those of previously conducted surveys to obtain insights into the key cost drivers of a nationwide survey of schistosomiasis and other intestinal helminthiases and to contribute to the development of survey designs elsewhere. Sharing experiences of nationwide surveys is important for the global health community to expand global mapping activities [12]. To the best of our knowledge, this is the first study of its kind to examine the details of the activities, logistics, and costs of a nationwide survey of schistosomiasis and other intestinal helminthiases.

Methods

This nationwide survey was carried out under the umbrella of the SUKO project, which was the Sudan-Korea collaboration project of schistosomiasis and other intestinal helminthiasis control supported by the Korea International Cooperation Agency (KOICA). The survey protocol has been described in detail elsewhere [13].

Ethical statement

For this study, ethical approval was obtained from the Federal Ministry of Health, Sudan (FMOH/DGP/RD/TC/2016) and the Korea Association of Health Promotion (130750-20,164-HR-020). Prior to the survey, we provided the survey protocol to the Ministries of Health of all 18 states, including a description of the proposed activities. We explained the survey protocol to the head teachers, teachers, and schoolchildren. We obtained informed consent from the head teachers and schoolchildren in written form. We could not obtain informed consent from the parents due to the large sample size. Instead, schoolteachers informed the parents about the survey details through students and checked for parental consent before launching the survey. Data collection was undertaken using tablet PCs and the data were anonymized.

Study area

Sudan is the third largest country in Africa, comprising 189 districts in 18 states. The estimated Sudanese population is 37.4 million in 2016, of whom 45.6% are children younger than 15 years and 3.9% are people aged above 59 years. The White Nile, the Blue Nile, and the River Nile flow through the country. Sixty-one percent of people have access to improved drinking water and 27% to improved sanitation. The study population was students aged 8-13 at 15,761 primary schools across the country.

Sampling

We used two-stage random sampling for the nationwide survey. We applied probability-proportional-to-size sampling to select the schools. Twenty students from the second, fourth, and sixth grades were selected at each school. Based on compelling evidence of the focalized nature of schistosomiasis infections, we divided each district into one to three different ecological zones depending on its distance to water bodies (near, less than 1 km; medium, 1-5 km; far, 5 km or above). We defined an ecological zone as an area located within a similar distance from bodies of water in a district. There were only one or two ecological zones in some districts. We used random sampling for schools and students to derive precise estimates of prevalence with a sufficient sample size. Finally, we surveyed 105,167 students from 1772 primary schools from 390 ecological zones in 183 districts of 18 states across Sudan. The nationwide survey was conducted from December 2016 to March 2017.

Detection of schistosomiasis and other helminthiases

Stool and urine samples were processed within 24 hours. A training module was given to each state level team, which included color images of the various parasites expected. We used the Kato-Katz technique for the eggs of *Schistosoma mansoni* and other intestinal helminthiases using two smears [14]. We used centrifugation to examine *S. haematobium* eggs. Two slides were observed for each sample and a federal supervisor cross-checked the results of the examinations by state laboratory technicians to validate them. Federal-level supervisors randomly selected 10% of slides examined by laboratory technicians and re-examined them on a daily basis. An independent team of biologists and parasitologists re-examined 5% of the slides for quality control purposes. A total of 655 people were deployed for the survey.

Collection of data

For cost analysis, we applied the same methods suggested by Kolaczinski and colleagues [6]. We estimated financial and economic costs from the provider's perspective. Cash expenditures incurred to implement the survey were defined as financial costs. We organized costs into capital and recurrent items. We calculated the average financial daily cost using straight-line depreciation for capital items. The total number of survey days was considered for the capital costs. We took into account all the resources invested in the survey, including the components that were not paid for, such as vehicles and survey equipment provided by the Ministry of Health, Sudan and the opportunity costs of primary school teachers' time spent on the survey. Capital items were discounted with a 3% discount rate over their lifespan. Daily economic costs for all capital items were calculated and multiplied by the number of days they were used for the survey. We used the same estimated lifespan for vehicles and survey equipment (4 and 2 years, respectively) that were used in South Sudan [6], since similar harsh climactic conditions are present in both Sudan and South Sudan. Data for costs were collected from the financial records of the project. We used an average exchange rate of 1 USD = 0.15264 SDG for the costs of survey activities between September 2016 and March 2017. We did not use shadow prices. To estimate the total value of goods or services, we multiplied their unit price by the total number of each item. For office overhead costs, we directly requested the implementing organization to share the actual amount with the study team [15]. We presented the costs by district, sub-district, schools, and individual levels to allow for comparison with other studies. For key activities, real-time weekly and monthly reports were documented with budget components.

Sensitivity analysis

We ran one-way sensitivity and probabilistic analyses using Monte-Carlo methods with 10,000

draws to examine the robustness of the primary analysis results [15]. Discount rates and the lifespan of vehicles and survey equipment were adjusted. A cumulative probabilistic curve was examined for the cost of survey per ecological zone and district.

Results

Table 1 shows the main activities conducted in the nationwide survey from its preparation to results-sharing. A steering committee was established to supervise the overall program, consisting of high-profile Sudanese government officials, the World Health Organization country office staff, and parasitologists or epidemiologists from both Sudan and Korea. The first committee meeting was held in October 2016 to reach a consensus on the study protocol. After the committee agreed on the protocol, a workshop was organized to train state-level laboratory technicians and potential state-level supervisors. Thirty-six laboratory technicians and 18 state government officials were invited from 18 states. An additional objective of this workshop was to examine the capability of state-level laboratory technicians in order to help the management team understand the required intensity and duration of training to be conducted prior to the survey. During the three-day workshop, they were trained and their capability was assessed through classroom-based lectures and field-based mock surveys. Overall, the state-level laboratory technicians' capability was found to be satisfactory. Most of them were laboratory technicians working for the state-run central laboratory, and they had experience examining various parasites for their routine work. Therefore, they were appropriately equipped with the required skills to detect schistosomiasis and other intestinal helminthiasis through microscopy and centrifugation. All personnel for the survey were recruited in December 2016, including 18 federal-level supervisors for laboratory examinations, 18 federal-level supervisors for field visit activities for specimen collection and questionnaire administration, 18 state-level supervisors, 218 state-level laboratory technicians, 244 state level field-based data collectors, 3 independent quality control supervisors, 3 federal-level operation team members, and 2 independent data management support team members.

Table 1. Main activities and financial costs

Time	Day	Main activities	Purpose	Trainers/Facilitators	Participants	Cost (US\$)	%
October 23~25, 2016	3	Workshop	Examine the capacity of laboratory technicians and state coordinators	Senior laboratory technicians of Blue Nile Institute (1 Professor, 1 PhD) Federal Ministry of Health (1 PhD, 1 MD) External specialists (2 Professors, 1 PhD) Project management staff (5)	State level laboratory technicians (36) State coordinators (18)	17,750	1.1%
October 23, 2016	1	Steering board meeting	Reach a consensus on the study protocol of a nationwide survey	Project management staff (5)	Board members (8)	1,448	0.1%
December 18~22, 2016	5	Workshop & Training	Orientation Introduce overall project Help to understand study methods Train data collection methods Train laboratory examination	Federal Ministry of Health (1 PhD, 1 MD) External specialists (2 Professors, 1 PhD, 1 MSc) Project management staff (5)	State supervisors (18) Federal Supervisors - Senior laboratory technicians (18) - Supervisors for specimen collection and household survey (18)	64,791	3.9%
December 31, 2016- January 10, 2017	1	Workshop	Introduce project; Obtain consent	State Coordinators	Head teacher from target schools (1811)	92,612	5.6%
December 31, 2016 ~ March 15, 2017	12-30	Nationwide survey	Carry out a nationwide survey on schistosomiasis and other helminthiases	State level laboratory technicians (218) State level data collectors (244) Federal level supervisors (36) Independent quality control supervisors (3) External specialists (1) Central level operation team (5) Independent data management support team (2)	105,167 students, 1772 schools in 390 ecological zones, 183 districts	1,465,902	88.4%

March 19 2017	1	Post-survey workshop	Share lessons learnt Collect suggestions and recommendations for a next round of nationwide survey Discuss details of a community-based survey	Federal Ministry of Health (1 PhD, 1 MD) External specialists (2 Professors, 1 PhD) Project management staff (5)	State coordinators (18) Federal Supervisors - Senior laboratory technicians (18) - Supervisors for specimen collection and household survey (18)	10,745	0.6%
March 20 2017	1	Steering board meeting	Share key findings Understand policy implications Discuss future plans	Project management staff (5)	Board members (8)	5104	0.3%
Grand Total						1,658,352	100%

In December 2016, 36 federal-level supervisors and 18 state-level supervisors were trained for five days in Khartoum, the capital city. It was ensured that they understood the survey objectives, student sampling methods, and details of questionnaires. They practiced laboratory techniques at National Laboratory of Federal Ministry of Health, Sudan to examine samples for *S. haematobium*, *S. mansoni*, and nine other intestinal helminthiases, including STHs, using real parasite egg samples. A private consultant company was contracted to develop and install a program to facilitate the real-time management of data. The consultant trained the supervisors on how to enter and manage data with tablet PCs purchased by the project team. Prior to the survey, the head teachers of 1811 target primary school were invited by the Ministry of Health at the state level. State-level supervisors helped them to understand the overall objectives and methods of the study, and obtained their consent with, and support for, the survey between late December 2016 and early January 2017. The state-level laboratory technicians and data collectors were trained by federal- and state-level supervisors. Thirty-six federal-level supervisors were deployed to each state for the entire period of the nationwide survey, during which they undertook daily monitoring and supervision, and reported real-time results to the central operation team.

The nationwide survey was conducted between December 31, 2016 and March 15, 2017. The starting and ending date varied depending on the state, and the duration of the survey in each location ranged from 12 days to 30 days. Immediately after the survey, in March 2017, federal- and state-level supervisors participated in a post-survey workshop conducted to collect and share lessons learned and experiences, and to make recommendations for future surveys. Finally, a steering committee meeting was held to share key findings, discuss future plans, and derive policy recommendations. A total of USD 1,658,352 (financial cost) was spent for the

overall activities of the nationwide survey, including preparation, the post-survey workshop, and steering committee meeting, of which USD 1,465,902 (88%) was incurred by the actual survey.

A reference case scenario is outlined in S1 Appendix, in which we applied the same scenario that was used for costing in South Sudan [6]. Table 2 shows the total financial and economic costs for the nationwide survey. A total of USD 1,465,902 and USD 1,516,238 was incurred for the financial and economic costs, respectively. The key cost drivers of the nationwide survey were personnel and transportation, for both financial and economic costs. Personnel and transportation accounted for around 64% and 18% of financial costs, respectively. Capital costs amounted to only 0.5% of the total financial costs and 1.4% of the total economic costs. There was a slight increase in capital economic costs, which mainly resulted from the opportunity cost of vehicles and survey equipment supported by the Ministry of Health, not paid for by the SUKO project. The fuel for those government vehicles was covered by the SUKO project and was already included in the financial costs. Seventeen government vehicles and 144 microscopes were provided by the Ministry of Health, Sudan with no charge for the SUKO project. Tables 3 and 4 present the details of financial and economic costs, respectively. For the survey, 422 vehicles $\times$ days and 3,464 microscopes $\times$ days were supported, which resulted in USD 10,886 and USD 2,877, respectively. In total, 5,316 school teachers were mobilized to facilitate specimen collections and questionnaire-based surveys; at one day per teacher, this was translated into USD 94,811 of economic costs. By implementation unit, the economic cost was USD 8,285 per district or USD 3,888 per ecological zone. Based on the results of sensitivity analyses adjusting for the discount rate or lifespan of vehicles, the estimates did not change to a meaningful extent (Table 5, Figure 1). The results of the Monte

Carlo analysis with 10,000 trials show a range of all the cost metrics. Figure 1 presents the cumulative density functions of the costs at the district and sub-district levels. The fifth percentile of the costs was US\$ 8,215 and USD 3,855 at the district and sub-district level, respectively, while the 95th percentile reached USD 8,357 and USD 3,921.

Table 2. Financial and economic costs

	Total financial cost		Total economic cost	
	US\$	%	US\$	%
Capital cost				
survey equipment	7,256	0.5%	10,461	0.7%
Vehicles			10,886	0.7%
Sum	7,256	0.5%	21,347	1.4%
Recurrent cost				
Transportation (vehicle hiring)	260,479	17.8%	260,479	17.0%
Personnel	942,272	64.3%	978,517	64.0%
Survey consumable	54,687	3.7%	54,687	3.6%
Others	170,104	11.6%	170,104	11.1%
Sum (recurrent cost)	1,427,542	97.4%	1,463,787	95.7%
Total (capital and recurrent cost)	1,434,798	97.9%	1,485,134	97.1%
Overhead	31,104	2.1%	31,104	2.0%
Grand	1,465,902	100.0%	1,516,238	99.1%
District	8,010		8,285	
Ecological zone	3,759		3,888	
School	827		856	
Person	14		14	

Table 3. Details of financial costs

	Items	Unit	Quantity	Unit cost (US\$)	Total cost (US\$)
Capital cost					
Survey equipment	Microscope		40	72	2,860
	Centrifuge		57	35	1,968
	Refrigerator		17	80	1,362
	Tablet Pcs		50	19	930
	Generator		1	117	117
	Wifi Eggs		2	9	18
	Sub-total			331	7,256
Recurrent cost					
Vehicle (Darfur)	Vehicle (rent, fuel & maintenance)	days	773	160	123,848
Vehicle (others)	Vehicle (rent, fuel & maintenance)	days	1,616	70	113,120
	MOH vehicle (fuel, per-diem)	days	422	56	23,511
	sub-total				260,479
Personnel	Operational team	days	420	56	23,526
	Interviewers & sample collectors	days	7,332	33	245,421
	Lab technicians	days	7,585	45	343,196
	Lab assistants	days	2,523	34	85,008
	Cleaners	days	514	12	6,045
	State coordinators	days	514	50	25,521
	Federal supervisors	days	1,028	80	82,380
	Independent supervisors	days	21	120	2,516
	Foreign experts	days	222	152	33,849
	School teachers	days	5,316	18	94,811
	Sub-total	days			942,272
Survey consumable	Urine container		200,000	0.027	5,400
	Stool container		200,000	0.027	5,400
	Microscope slide tray		400	7.000	2,800
	Slide		600,000	0.024	14,460
	Cover		200,000	0.003	680
	Pincette		54	2.000	108
	Trans pipette (3 mL)		300,000	0.029	8,700
	Trans pipette (1 mL)		200,000	0.075	15,000
	Mess cylinder		18	3.000	54

	Items	Unit	Quantity	Unit cost (US\$)	Total cost (US\$)
	Wood stick		50,000	0.008	400
	Conical tube		2,000	0.045	90
	Tube rack		2,000	0.015	30
	Phenol		18	18.750	338
	Glycerol		9	25.000	225
	Malachite green oxalate		4	10.000	40
	Plastic box		36	1.870	67
	Mesh membrane		100	6.250	625
	Mask		54	5.000	270
	Sub-total				54,687
	T-shirts		400	15.000	6,000
	Hat		400	8.000	3,200
	Gloves		90	3.130	282
	Sub-total				9,482
	Manual		36	20.000	720
	Poster		20		200
	Questionnaire				629
	Stationary				595
	Delivery				3,774
Others	Project management	days	90		5,086
	Accommodation	days	1,028	44	44,876
	Accommodation	days	222	80	17,760
	Food	days	222	60	13,320
	Communication	days	90	15	1,349
	Visa	frequency	6	79	472
	Insurance	frequency	6	32	189
	Air ticket	frequency	6	2028	12,170
	Software program				50,000
	Sub-total				170,104
	Sub-total (recurrent cost)				1,427,542
	Sub-total (capital + recurrent cost)				1,434,798
	Overhead				31,104
	Grand				1,465,902

Table 4. Details of economic costs

Items	Unit	Quantity	Unit cost (USD)	Total cost (USD)
Capital cost (SUKO project)				
Survey equipment	Microscope	40	72	2,990
	Centrifuge	57	35	2,057
	Refrigerator	17	80	1,424
	Tablet pcs	50	19	973
	Generator	1	117	122
	Wifi-eggs	2	9	19
	Sub-total		331	7,584
Capital cost (Ministry of Health, Sudan)				
Vehicles		17 vehicles, 422 days 144		10,886
Microscope		microscopes, 3,464 days		2,877
Sub-total				13,763
Total capital cost				21,347
Recurrent cost (SUKO project)*				
Personnel (Ministry of Education)		5,316 teachers, 5,316 days		36,245
Sub-total (recurrent cost)				1,463,787
Sub-total (capital + recurrent cost)				1,485,134
Overhead				31,104
Grand				1,516,238

*The values of all other components omitted in table 4 are same as the financial costs in table 3.

Table 5. Sensitivity analysis to cost estimates

Assumptions tested			District level	% Deviation from base case	Ecological zone level	% Deviation from base case
One-way	Base case		8,285		3,888	
	Discount rate	1%	8,282	-0.04%	3,886	-0.05%
		10%	8,303	0.22%	3,896	0.21%
	Vehicle lifespan	8 years	8,258	-0.33%	3,875	-0.33%
	Equipment lifespan	4 years	8,259	-0.31%	3,875	-0.33%

Fig 1. Cumulative probability distribution (Monte-Carlo probabilistic sensitivity analysis, 10,000 draws)

Discussion

We provided details of the nationwide survey of schistosomiasis and other intestinal helminthiasis in terms of the key activities and costs in Sudan, therefore when planning to undertake future nationwide NTD surveys, the global health community could adapt and refine the activities and cost elements of the survey described herein.

The main cost drivers were recurrent costs: transportation (particularly hiring vehicles) and personnel. Prior to the survey, we assessed the capabilities of state-level laboratory technicians and data collectors. We invited 36 laboratory examiners and 18 state coordinators, who were purposively selected by the State Ministry of Health. Based on the assessment, we realized that there was a sufficient number of laboratory technicians qualified for the survey. If there had not been enough laboratory technicians with the required skills to detect schistosomiasis and other intestinal helminthiasis through microscopy and centrifugation, the project team would have organized a more intensive training for a longer duration with closer supervision, all of which would have increased costs.

Additionally, Sudan had state-level laboratory facilities, many of which had microscopes and centrifuges, although the quantities were not sufficient. In some exceptional cases, such as North Kordofan, we had to operate a mobile laboratory due to the remoteness of some schools, but in general, laboratory work was carried out at state-run central laboratories. If a nationwide survey is to be conducted in settings with no local laboratory, more costs will be incurred for the laboratory setting, including the cost for equipment.

When designing the study protocol, the project team planned to purchase seven vehicles (six for the state-level survey team and one for the central-level operation team). However, vehicle purchase was not possible during the survey period, and therefore vehicles had to be hired from

local rental-car companies, which led to a substantial rise in recurrent costs.

The reference case suggested by Kolaczinski and colleagues [6] was applied for this study. The nationwide survey of schistosomiasis and other intestinal helminthiasis in Sudan was much less expensive than the survey conducted in 2009 in South Sudan, its neighboring country. The average economic cost of the schistosomiasis, STH, and lymphatic filariasis survey in South Sudan was USD 40,206 or USD 9,573 per district (county) or sub-district (*payam*), respectively. In Sudan the average economic cost was USD 8,285 or USD 3,888 respectively. In Sudan, the average economic cost per school or per student was USD 856 or USD 14, respectively. The results of the Monte-Carlo analysis demonstrated that the costs varied little across a range of discount rates and lifespans of vehicles and survey equipment (5–95th percentile of cumulative distribution: US\$ 8,215-8,357 at the district level and US\$ 3,855-3,921 at the sub-district level).

Caution is needed when interpreting the results of this study because our findings cannot be generalized to every other context with a high prevalence of schistosomiasis and other intestinal helminthiasis, which is the major limitation of this study. In particular, Sudan has a number of highly skilled laboratory technicians, and NTDs are prioritized by both the Federal and State Ministry of Health [16, 17], making it feasible to mobilize a considerable number of capable workforce for conducting the survey. Another limitation of this study lies in the number of samples, which also relates to the generalizability of the study. Unlike the conventional methods recommended by the WHO making a decision of mass drug administration at the district level [18], we divided each district into smaller areas according to the proximity to water bodies to reflect the focalized nature of schistosomiasis prevalence [19-21]. In addition, we sampled a sufficient number of students to derive precise estimates of prevalence at the state level [22]. This led to sampling far more students at the district level than would have

been done using the conventional method (250 students from five schools per district using conventional methods vs. 900 students from 15 schools per district in this study). If this survey had applied the conventional methods, the average economic cost per district would have amounted to the current cost per ecological zone of this study (i.e., USD 3,888).

Personnel (64%) and transportation (18%) were the key cost drivers in Sudan, while personnel (38%) and survey consumables (27%) were the key drivers in South Sudan [6]. Whereas the survey in South Sudan was conducted only in a single state [23], the survey in Sudan was undertaken in all 18 states, which required an enormous workforce and a large amount of vehicles. Additionally, for the nationwide survey in Sudan, we incorporated federal-level supervision and an independent supervision mechanism for enhancing quality control, which led to a rise in costs. The participants of this study were 105,167 students from 1,772 schools in 390 ecological zones in 183 districts of all 18 states of Sudan. We suggest that the greatest share of costs for personnel and transportation should be reflected when budgeting future surveys for schistosomiasis and other intestinal helminthiasis.

Apart from the key activities and costs, we provided considerable detail about the nationwide survey including the duration of the survey, the number of personnel by position and role, and the total number of each capital or recurrent item. We estimated the costs from the provider's perspective. However, if we had applied the societal perspective for costing [24, 25], the result would not have changed considerably because few items were not paid for in this survey. No volunteers [26] were mobilized and parents or community members were not participated in this survey because it was conducted at the school level. We used the same lifespan for capital items as in the reference case in the South Sudan [6]. The relatively short lifespan of capital items (i.e., 4 years for vehicles and 2 years for survey equipment) made the cost estimates more

conservative.

Conclusion

Establishing a steering committee to develop and consensus a survey protocol, assessing the capabilities of potential staff (particularly laboratory technicians), and training laboratory technicians and data collectors are key components required to prepare a nationwide survey. Collecting lessons learned from frontline staff, sharing the results, and developing future plans with stakeholders are crucial activities after carrying out a nationwide survey. Key cost drivers are personnel and transportation. In particular, the personnel component accounts for a substantial share of the cost. The cost is expected to vary depending on the quantity and quality of existing laboratory facilities, equipment, and consumables, and the capability of laboratory technicians and sample collectors. Establishing central-level and independent supervision mechanisms to ensure the quality of the survey is equally important. It is worth noting that if a government finds a way to mobilize existing government officials with no additional payment using the health system already in place, the cost of a nationwide survey would be remarkably lower. To the best of our knowledge, this is the first empirical study to investigate the key activities and cost drivers of a nationwide survey of schistosomiasis and other intestinal helminthiasis. We expect the global health community to draw on this study when developing nationwide surveys of schistosomiasis and other intestinal helminthiasis.

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Supporting information

S1. Appendix. Reference case scenario

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cumulative probability distribution (Monte-Carlo analysis)

Figure