STH ELIMINATION STRATEGY SUPPORT - OBJECTIVE 1: PAST STH ELIMINATION PROGRAMS

UNIVERSITY OF WASHINGTON GLOBAL HEALTH START PROGRAM
REPORT TO THE BILL & MELINDA GATES FOUNDATION

FEBRUARY 17, 2015

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EXECUTIVE SUMMARY

This report summarizes work conducted by the University of Washington's Global Health Strategic Analysis and Research Training Program (START) team in response to first objective of the Bill & Melinda Gates Foundation's (the foundation) work order *NID STH Elimination Strategy Support.* It summarizes efforts to control and eliminate soil-transmitted helminths (STHs) over the past century in the United States, Japan, and South Korea, describing the policies, tools, and interventions used and the progress achieved.

The Rockefeller Sanitary Commission began a massive control campaign against hookworm throughout the southern US in 1910, but closed after only five years. The impact of hookworm disease was greatly lessened, but the sparse data available suggests some degree of infection persisted for many decades, at least into the 1970s.

In Japan, several volunteer organizations were formed in the aftermath of WWII to combat STHs, especially *Ascaris lumbricoides* infection, which had spiked in the economic turmoil following the war. The independent organizations were eventually consolidated into the Japan Association of Parasite Control, which led a biannual school-based mass screening and treatment program. Deworming continued for more than 30 years, eventually leading to very minimal levels of *Ascaris* by the mid-1980s.

The Korea Association for Parasite Eradication modeled their program after the successful Japanese experience, also using a biannual school-based mass screening and treatment program that ran from 1969 to 1995. Prevalence levels of *Ascaris* and hookworm have continued to decline since the program ended in 1995 suggesting the elimination breakpoint was reached. Levels of *Trichuris Trichiura* have slowly risen however, reaching pre-1992 levels in 2012 (though only to a prevalence of 0.41%) (5).

Comprehensive school-based screening and treatment proved to be a successful strategy in both Korea and Japan, though elimination took at least 25-30 years in each case. It is important to note that both Japan and Korea underwent massive rural development in the same years that STH elimination was achieved, lowering transmission pressure. Models suggest that to be successful in countries with moderate or high transmission, elimination programs would either need to target segments of the population beyond school-aged children or institute effective sanitation or hygiene behavior change interventions in addition to chemotherapy.

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INTRODUCTION

This report explores the methods, tools, and policies used in soil-transmitted helminth programs in countries that have successfully eliminated STHs. While control programs have been implemented in a broad swath of countries globally, two countries stand out as having engaged in deworming campaigns that eventually eliminated STH infection on a national scale: the Japan Association of Parasite Control (JAPC) in Japan and the Korea Association for Parasite Eradication (KAPE) in South Korea. This report also explores the early efforts of the Rockefeller Sanitary Commission (RSC) in the southern United States.

COUNTRY 1: UNITED STATES

DATA SOURCES

Our data from the Rockefeller Sanitary Commission hookworm program in the US comes from their five Annual Reports for 1910-1914. The RSC was thorough in their documentation, but their data is limited as they very rarely visited the same county multiple times and thus provide only baseline infection prevalences. We were directed to find digital copies of the RSC Annual Reports on Google Books by Dr. Hoyt Bleakly who in 2007 published an analysis of the economic effects of the RSC's work. We were able to supplement the RSC baseline data with resurvey data found in a small number of articles published in the years following the RSC's involvement.

Data obtained:

- Baseline hookworm prevalences and numbers treated at county-level for 11 states, 1910-1914 (1)
- Baseline counts and quality of privy at county-level for 11 states, 1910-1914 (1)
- Hookworm prevalences at state-level for five states, 1923 (6)
- Hookworm prevalences at county-level for Alabama, 1929 (4)
- Hookworm prevalences at county-level for eight states, 1930-1938 (3)
- STH prevalences for communities throughout the South, 1942-1982, see Table 1 in the Appendix (7).

TIMELINE

- Dr. Charles Stiles brought hookworm to the attention of John D. Rockefeller in 1909
- Rockefeller Sanitary Commission established in 1909
- RSC conducted activities in 11 southern states from 1910-1914
- RSC closed in 1915 and the International Health Board (IHB) was founded to explore public health philanthropy internationally
- The fight against hookworm was passed off to individual state health boards, though limited support was offered through the IHB until 1921
- Rockefeller Foundation claimed near elimination of "hookworm disease" in 1926, though there is evidence of sustained hookworm infection in the follow decades (8)
- Hookworm remained endemic throughout the southern US at least through the 1930s (3) and quite possibly through the 1970s and beyond (7)

INTERVENTIONS

The goals of the RSC at outset were threefold:

1. Determine the distribution and degree of hookworm infection
2. Treat those infected
3. Prevent soil pollution through education and sanitation

SURVEYS

To determine the distribution of hookworm in the southern US, the RSC performed hookworm infection and sanitary surveys in conjunction with their mobile treatment dispensaries as they moved county by county through the 11 states. The infection survey microscopically examined up to 25-50% of each county, including at least 200 rural children (aged 6-18) in each. They found that of the 548,992 children examined overall, 39% were infected with hookworm (1).

The sanitary survey inspected the "sanitary conditions surrounding homes, churches, schools, saw-mills and similar industrial plants" (1). They ultimately inspected 250,680 farm homes in 653 counties. The sanitary index ranked homes on a strict scale from A-F for the presence of a privy and its sanitary quality. The index was on a scale of 0% for no privies and 100% for all highly sanitary privies. The index for the 653 counties together was only a 6.3%. A county-level analysis of the relationship between the proportion of the population with any privy and their hookworm prevalence did not show any correlation (Appendix, Figure 1).

TREATMENT

The primary intervention of the RSC campaign was testing and treating the public. Their approach involved mobile laboratories and dispensaries that set up in counties and offered free examination and treatment to the public one day per week for six to eight weeks at five or more sites in each county. Treatment was offered at diagnosis and, if diagnosis was doubtful, a fecal sample was examined microscopically using the plain smear method. The deworming chemotherapy was an oral dose of thymol (a drug derived from the common thyme plant) given in a paper envelope marked with instructions. The chemotherapy was not directly observed. There were some serious side effects due to the treatment and acceptance, especially in the first years, was limited. It was common that one dose was not sufficient to clear the infection and up to five additional doses were administered. The RSC also conducted research into using oil of chenopodium with promising results, but after reports of a fatality, the research was stopped.

Over the five years of the RSCs involvement, their annual reports indicate the mobile dispensaries covered 596 of 968 counties in 11 southern states including: Alabama, Arkansas, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, East Texas and Virginia. From 1910 through 1914 a total of 1,273,345 people were tested and 694,494 were treated (1).

EDUCATION

The RSC viewed education of hookworm and the associated risks as central to its mission. They coordinated a comprehensive education campaign including public lectures, pamphlets, school visits, newspaper articles, and traveling exhibits at fairs and clubs. The campaign focused on teaching the basics of hookworm infection and the importance of sanitation and treatment. The education campaign also worked to educate local physicians and ensure that information on hookworm was included in medical schools' curriculum throughout the South.

INTENSIVE COMMUNITY PROGRAMS

Beyond the sanitary survey and sanitation education programs described above, the sanitation infrastructure component of the RSC's work was limited. The construction of privies was mostly limited to those built as examples at fairs and those built in twelve "intensive community work" demonstrations. In 1914, their final year of operation, the RSC chose a dozen specific communities where they strove to prove that hookworm could be eliminated given enough pressure (see Appendix, Table 1). In these 12 communities across four states, the RSC tried to examine every resident and treat every infected person. They also attempted to renovate or construct new privies for every household. These communities were held up in educational brochures as examples. The program was more successful in some communities than others and in the end, time ran out before even one community reached the elimination goal (8).

INTERVENTION EFFECTIVENESS

The Rockefeller Foundation in an Annual Report for 1926 claimed that "hookworm disease has almost disappeared from the United States" (8). Dr. Charles Stiles, whose initial appeal to John D. Rockefeller sparked the foundation's involvement, was skeptical of this claim. He subsequently toured the South, testing samples of the population, and found sustained prevalence levels between 26-49% (8). He publicly criticized the Rockefeller Foundation's "mission accomplished" message, which responded that while infection may remain, the associated morbidities were greatly reduced. Little data was gathered by the RSC or in subsequent studies on levels of anemia or other morbidities, but county-level resurveys in Alabama in 1929 (4) and throughout the South from 1920-1923 (6) and again in 1930-1938 (3) confirmed Dr. Stiles' assertions that hookworm infection continued to be widespread.

Figure 1 shows hookworm infection at the county-level in Alabama from 1910 through the 1930s; prevalences declined substantially, but the state was far from achieving elimination. Figure 2 depicts similar sustained prevalence throughout the southern United States. A 2011 systematic review of STH infection in the US (7) (see the Appendix, Table 2) found evidence of at least pockets of hookworm infection as late as 1972 in Georgia (13.6% prevalence). A study of native-born children in Clay County, Kentucky measured respective prevalences of 3.6% for hookworm, 48.6% for *Ascaris*, and 55.2% for *Trichuris* in 1965. A subsequent 1982 study in the same county measured prevalences of 14.4% for *Ascaris*, 12.6% for *Trichuris,* 0.2% for hookworm and 24% for any intestinal parasite, suggesting STHs remained "highly endemic in southeastern Kentucky" (9).

While the RSCs efforts undoubtedly had an impact on hookworm infection in the South, raising awareness of the infection and catalyzing public health efforts more broadly, their limited five-year campaign was far from what was required to bring the US near to elimination. It is unclear when elimination of hookworm was achieved, but it appears not to have occurred until the 1980s at the earliest.

Figure 1 - Hookworm prevalences by county in Alabama. Data come from the RSC (1); Havens and Castles resurveys (4); and Keller, Leathers, and Densen resurveys (3), respectively.

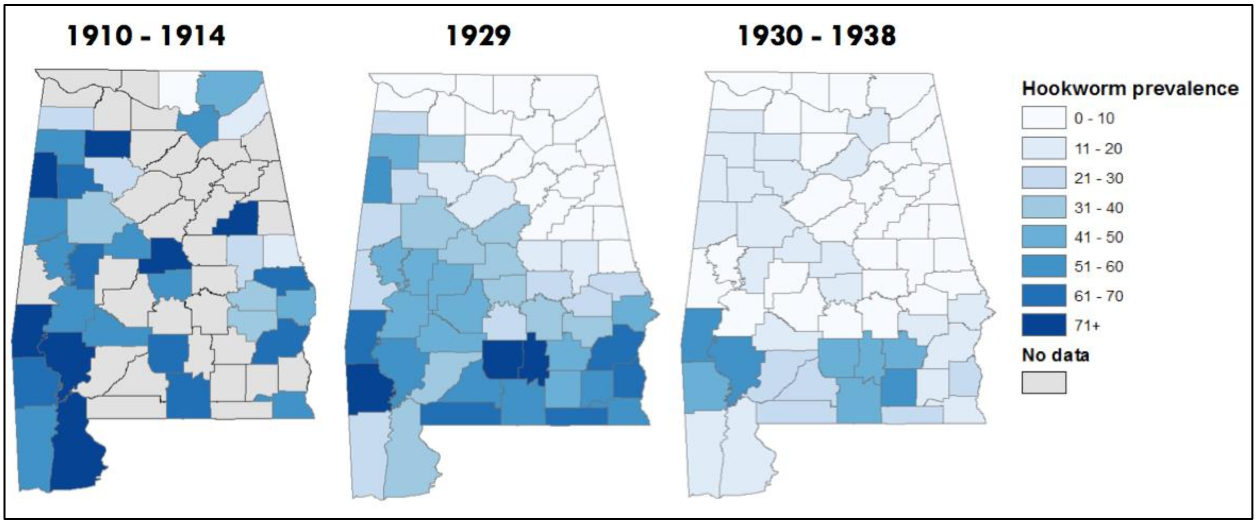
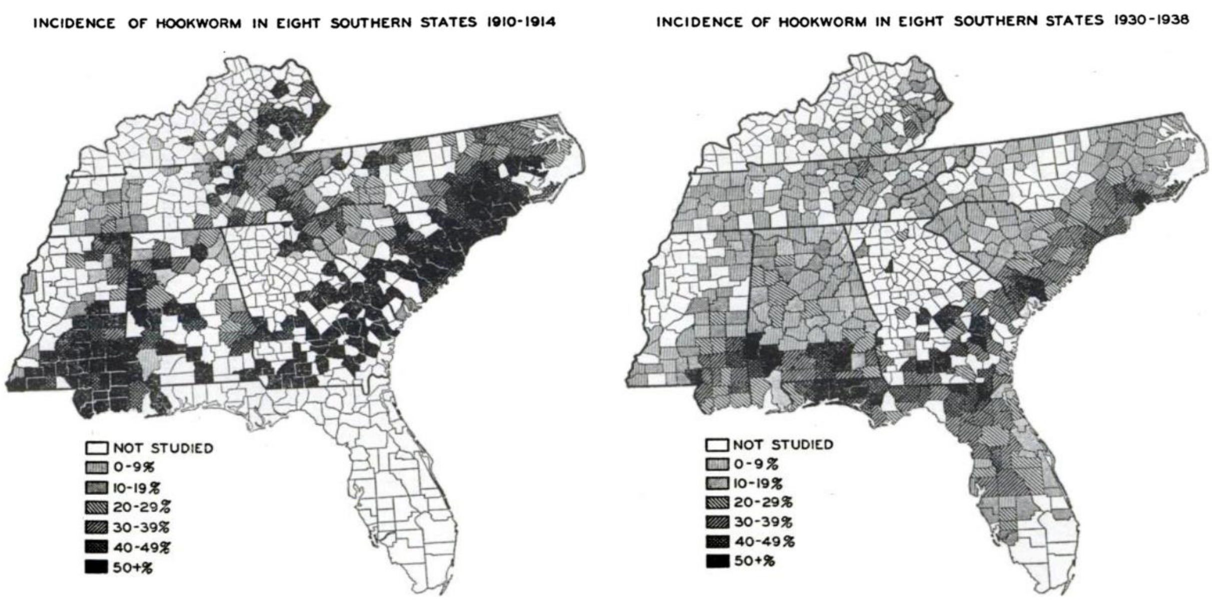


Figure 2 - Hookworm prevalences by county in the Southern US; 1910-1914 data on left from RSC, 1930-1938 data on right from Keller, Leathers, and Densen. (3)



COUNTRY 2: JAPAN

DATA SOURCES

Our data from deworming programs in Japan came from a lecture transcript in a publication following the 1984 Banff conference on ascariasis organized by WHO Parasitic Diseases Programme and Division of Nutritional Sciences.

Data obtained:

- *Ascaris* prevalence rates from 1927, 1933, and 1941-1982, every other year (2)
- Baseline data for each STH by district (1947-1951) (2)

TIMELINE

- Spike in *Ascaris* and *Trichuris* prevalences were identified in the wake of WWII due to economic collapse and resultant drop in sanitation, 1943-1949
- Volunteer organizations formed in Tokyo and Osaka in 1949, biannual school-based mass screening and treatment began
- The volunteer organizations consolidated into the Japan Association of Parasite Control (JAPC), with "encouragement and direction" from the government in 1955
- Substantial progress was made and the Overseas Technical Cooperation Agency encourages deworming outside Japan; Korea started their deworming campaign in 1969
- National elimination was achieved by the 1980s

SETTING

In the aftermath of World War II, and the near total collapse of the Japanese economy, food supply and environmental sanitation deteriorated substantially and remained poor for several years. Even in urban areas, all open space was used for vegetable gardens and night soil was commonly used as fertilizer. As a result of the decline in sanitation, the prevalence of *Trichuris* and especially *Ascaris* infection rose substantially (2, 10).

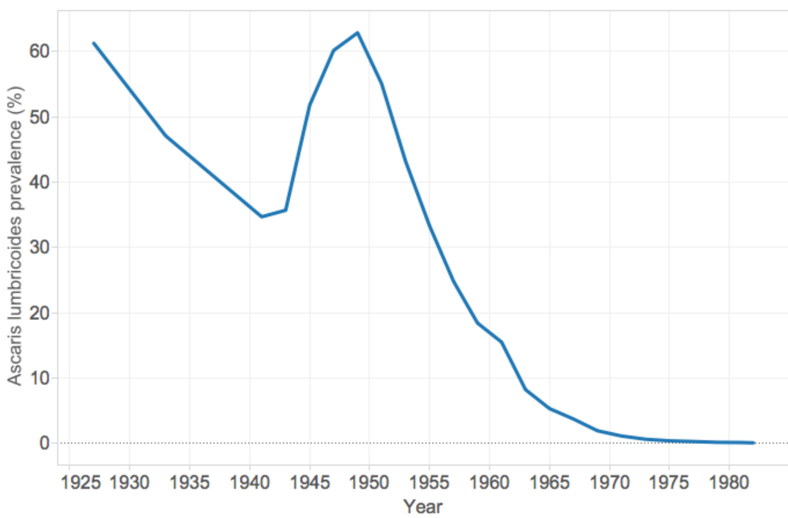
In 1949, to counteract the rising prevalences, voluntary organizations were founded in Osaka and Tokyo. Organizations and laboratories in other prefectures followed and were eventually consolidated into the Japan Association of Parasite Control (JAPC) with "encouragement and guidance" from the government (2).

INTERVENTIONS

Early on, there was a debate over whether to concentrate on sanitation or chemotherapy. Due to the expense of modern sanitation, JAPC decided to focus on chemotherapy and left environmental and infrastructure improvements to the government.

SCREENING

Figure 3 - *Ascaris* prevalence in Japan, 1927-1982 (2)



The JAPC intervention approach was to perform biannual school-based mass screening and treatment. Since the post-war health system in Japan was weak, schools presented a more reliable cost-effective infrastructure for offering deworming (10). Testing and treatment took place each June/July and November/December due to seasonal flux in prevalence. To efficiently test such a large number of students, researchers in the 1960s at the Public Health Institutes in Japan developed the now commonplace cellophane thick smear (Kato-Katz) technique for preparing and examining stool for helminth eggs and Harada-Mori's cultivation method for hookworm larvae (2).

TREATMENT

For chemotherapy, they used a combination of santonin (50 mg) and conic acid (5.0 mg) until pyrantel pamoate and other broad-spectrum anthelmintics became available (2). A timeline was not given for the changes in treatment drugs in Japan, but it is likely similar to the timeline of changes in Korea, which switched to pyrantel pamoate in 1973 and to benzimidazoles in the early 1980s (11).

INTERVENTION EFFECTIVENESS

The deworming campaign in Japan was very successful. Figure 3 shows prevalence began declining immediately after deworming began in 1949, dropping below 1% in 1973, and down to 0.05% in 1982.

It is interesting to see in Figure 3 how the prevalence of *Ascaris* ebbed and flowed with the development gains and losses before, during, and after WWII. The prevalence began dropping immediately in 1949 with the introduction of the school-based deworming intervention. Once below 0.05% in the mid-1980s, it became clear the screening and treatment program was a success. Some proportion of the decline is undoubtably due to the massive economic and sanitation infrastructure improvements in the decades following the war, but it is impossible to say how much longer it would have taken in their absence, if it would have been feasible at all. Even with fast economic development, elimination still took about 30 years.

COUNTRY 3: SOUTH KOREA

DATA SOURCES

Some national-level data from the deworming programs in South Korea are available in the published literature, but we received more detailed regional data for more years from Dr. Antonio Montresor at the WHO, who received access to program reports from the Korean Ministry of Health and Welfare. An intern at the WHO translated and extracted the data.

Data obtained:

- For the program target population (school children): annual *Ascaris* prevalence rates from the entire length of the deworming program, 1969-1995 (N = 16,000,000 at the height of the program in the 1980s) (12)
- For a sample of the national population: region-level prevalences of each STH, every five to seven years, 1971-2012 (N = 20,000 – 47,000) (5)

TIMELINE

- Korea Association for Parasite Eradication (KAPE) NGO formed in 1964
- Korean National Assembly passed the Parasitic Diseases Prevention Act, mandating screening and treatment of all school children in 1966
- KAPE began nationwide deworming with a three-year assistance program from the Overseas Technical Cooperation Agency in Japan, 1969
- Biannual school-based screening and treatment for STHs conducted, 1969-1987
- Annual school-based screening and treatment for STHs conducted, 1987-1995
- South Korea declared "essentially worm-free" by WHO, 1997

SETTING

In the decades before mass deworming began in Korea, very high proportions of residents harbored parasites in all regions. The baseline national survey in 1969 found an estimated 90.5% of the population infected with one or more STH (58.2% with *Ascaris*, 74.2% with *Trichuris*, and 9.1% with hookworm) (13). The KAPE had formed five years earlier to address the problem, but was unable to begin a nationwide deworming program until the Overseas Technical Cooperation Agency in Japan offered a three-year assistance program starting in 1969 (12).

INTERVENTIONS

SCREENING AND TREATMENT

The KAPE formed with a goal of STH elimination within 10 years, a goal that quickly proved overly ambitious. Their intervention approach was modeled after the JAPC strategy currently proving successful in Japan. They performed biannual comprehensive school-based mass screening and treatment covering all elementary, middle, and high schools in the country. For chemotherapy, the KAPE used a number of different drugs, changing as new anthelmintics were released (11):

- Santonin and conic acid (1969-early 70s)
- Piperazine (1971-81)
- Pyrantel pamoate (1973-88)
- Mebendazole (1983-93)
- Albendazole (1988-95)

By 1987, the prevalences of each STH had dropped below 5% and the KAPE decided that biannual mass screening and treatment was no longer necessary. That year they transitioned from a biannual schedule of every spring and autumn to an annual intervention in autumn only. They continued for eight more years before halting the program in 1995.

EDUCATION

Alongside the screening and treatment efforts, the KAPE mounted a public education campaign through the school system to raise awareness, encourage participation, and promote sanitary prevention habits. Educational messages included the health consequences, infection routes and risk factors, and practical habits for prevention such as hand washing and vegetable washing. These messages were disseminated via posters, pamphlets, lectures, videos and even feature films (12).

SANITATION

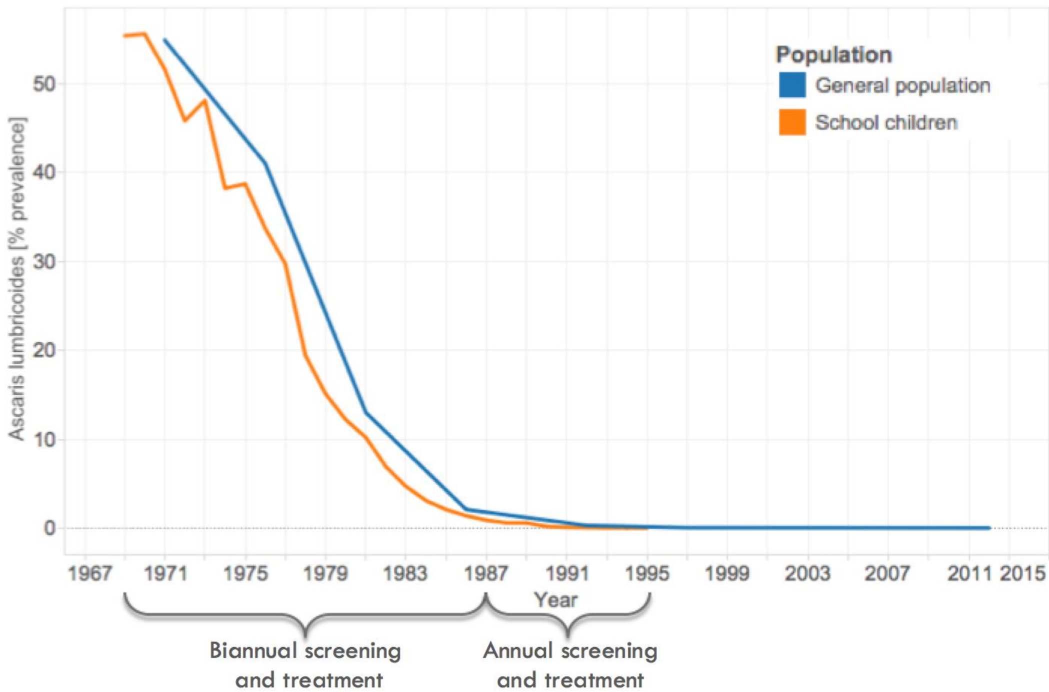
While South Korea underwent massive economic development, which undoubtedly improved sanitary conditions and influenced the rate of decline of STH infections, the sanitation part of the KAPE's program was limited to small pilots and demonstration projects of septic tanks and composting toilets (12).

INTERVENTION EFFECTIVENESS

The rate of decline of *Ascaris* infection in Korea during the KAPE school-based intervention was very similar to the JAPC program in Japan. Prevalence estimates for the general public fell alongside the prevalence in the treated school children, with only one to two years' delay (Figure 4). Rapid decline in prevalence was seen in all age groups (Figure 2, Appendix), in both the cities and rural areas (Figure 3, Appendix).

Figure 4 in the Appendix shows the decline of *Ascaris*, *Trichuris*, and hookworm in the general population over the years of the intervention. Figure 5 in the Appendix shows the same graph with the y-axis changed to below 1% to show progress toward elimination. The prevalence of all three STHs declined quickly through to the mid-1990s. After the end of the deworming program in 1995, the prevalence of *Ascaris* and hookworm continued to decline while we see a slight uptick in *Trichuris* infection in 2004 and again in 2012. This may be evidence that the elimination breakpoint (beyond which female worms cannot find a mate) was reached for *Ascaris* and hookworm, but not for *Trichuris*. If this were the case, if we look at the same data, disaggregated by province (Appendix, Figure 6) we might expect to see the breakpoint reached in some provinces, but not in others. Instead the data appears to continue to drop after 1997 for some higher prevalence provinces and rise for many provinces that measured 0% prevalence in 1997. It may simply be that the data coverage is insufficient to measure elimination at the province-level. Sample sizes for each region were generally in the range of 1,000-3,000 subjects and we do not know how representative the samples were (5). There may also be enough population mixing between the small provinces that reinfection occurs for provinces that passed the breakpoint.

Figure 4 - *Ascaris* prevalence in school children and the general population in South Korea, 1969-2012



DISCUSSION

The experience of the Rockefeller Sanitary Commission showed early on that STH infections are especially difficult to sustainably remove from a population. Elimination requires far more than the one-time intervention offered by the RSC in the 1910s. Data over the following decades in the US is sparse, but what little data we do have suggests that STH infection remained at least in pockets into the 1980s.

Comprehensive school-based screening and treatment proved to be a successful strategy in both Korea and Japan, though elimination took at least 25-30 years in each case. This timeline could likely have been shortened somewhat by employing mass drug administration during the years of high prevalence, which would treat the false negatives missed in screening.

It is important to note that both Japan and Korea underwent massive rural development in the same years that STH elimination was achieved. Undoubtedly, improved sanitation levels and the quality of health care played a role in elimination. Sir Roy Anderson has developed mathematical models that predict that STH elimination programs with an intervention scope limited to only school-aged children are unlikely to be successful in any but the lowest transmission settings (14). This is especially true in settings where hookworm is the dominant parasite, as adults tend to harbor a majority of hookworm infection. Anderson's models estimate the coverage levels for specific subpopulations that would be required to achieve elimination within 20 years in various transmission settings for each STH. To be successful in countries with moderate or high transmission, elimination programs would either need to target segments of the population beyond school-aged children or institute effective sanitation or hygiene behavior change interventions in addition to chemotherapy.

Sanitation and preventative education were recognized early on as vital components of a campaign to interrupt reinfection. The RSC campaign focused much of their program on them. Surprisingly, the Rockefeller baseline sanitary survey did not show a correlation with baseline hookworm infection rates. The lack of an association may simply be due to the fact that the quality of the privies was not sufficient to prevent contamination. Indeed nearly all the privies noted by the sanitary survey fell in the lowest two sanitation rankings.

Thus far, direct evidence of the effectiveness and relative importance of the various water, sanitation, and hygiene (WASH) components has been difficult to demonstrate. It is likely that these hygiene and sanitation improvements played major roles in the success of deworming campaigns in each of the three countries, though attributing success in limiting transmission to specific changes is difficult. Improvements in sanitation are difficult to measure and the effects on environmental infectivity are slow. Difficulty in quantifying the impact of WASH interventions continues. While the theory behind the impact of WASH interventions is strong, trials continue to struggle to demonstrate positive effects in the short term. Current evidence from randomized trials regarding the effectiveness of WASH interventions is summarized in the report for Objective 2.

APPENDIX

Table 1 – Table of the twelve “intensive community programs” where the Rockefeller Sanitary Commission attempted to show elimination was feasible using their methods (1)

State	County	Community	Field Director	Dates	Area (Sq. Mile)	Census	Examined	Infected	Treated	Cured	Number of Families in Community	Began: No. of Families With Privies	Began: No. of Families Without Privies	Ended: No. of Families With Privies.	Ended: No. of Families Without Privies
Lousiana......	Cameron.....	Cameron......	McKinney.....	Oct. 2 Dec. 31	12	1,300	1,185	350	350	318	224	134	90	212	12
Louisiana......	Livingston....	Maurepas.....	Adams.........	Oct. 3 Dec. 31	45	1,017	759	263	260	6	189	135	54	150	39
Louisiana......	Lincoln.......	Choudrant.....	Baucum........	Oct. 10 Dec. 31	60	1,180	608	250	266	...	185	74	111	132	53
North Carolina	Sampson.....	Salemburg.....	Collinson......	May 9 Sept. 30	25	875	754	251	251	145	168	71	97	149	19
North Carolina	Robeson......	Philadelphus...	Absher.........	May 23 Oct. 17	23	941	766	217	177	12	186	67	119	186	......
North Carolina	Nash.........	Red Oak......	Champion.....	June 20 Nov. 14	30	1,135	1,091	281	228	30	199	109	90	199	......
North Carolina	Columbus....	Hallsboro......	Covington.....	Aug. 1 Dec. 5	63	1,245	1,237	479	479	93	245	94	151	245	......
North Carolina	Nash.........	Mount Pleasant	Kibler.........	Sept. 19 Dec. 31	27	801	624	99	95	4	154	53	101	129	25
North Carolina	Sampson.....	Ingold........	Collinson......	Oct. 31 Dec. 31	25	551	365	102	91	10	115	38	77	115	......
South Carolina.	Spartanburg..	Reidville......	Routh.........	Aug. 8 Dec. 9	16	1,088	329	59	3	...	188	111	77	116	72
South Carolina.	Cherokee.....	Sunnyside.....	Rodgers.......	Aug. 29 Dec. 12	20	699	511	31	28	4	119	34	85	100	19

Table 2 - Studies reporting prevalences of STH infection in the United States, 1942-1982 (7)

Year	State	Sampling approach	Population description	N	STH Prevalence (%)			
					Hookworm	*T. trichiura*	*A. Lumbricoides*	*S. stercoralis*
1942	KY	College-based	70% Appalachia	2,393	14.6	7.9	5.1	3.8
1955	TN	School-based	Rural poor, 5-16 years old	2,908	19.6	1.4	6.1	0.1
1956	KY	Community-based random sample	January to March, 1955	1,800	0.5	14.6	21.3	2.6
1956	KY	Community-based random sample	April to July, 1955	843	0	24.2	26.8	1.2
1965	KY	School-based	Native-born 6-12 years old	366	3.6	55.2	48.6	3.8
1969	NC	School-based	Cherokee Native Americans, 6-16 years old	631	3	38	49.4	-
1970	KY	School-based	10-14 years old	439	14.8	4.8	7.7	0
1972	GA	School-based	Caucasian children 5-15 years old	3,729	4.6	0.5	1.3	-
1972	GA	Community-based random sample	550 Caucasians, 199 African-Americans	749	13.6	0.5	4.3	-
1972	LA	Community-based random sample	Lowest 25% socioeconomic strata	1,651	0.4	12.3	5.3	0.3
1972	SC	School-based	32% African-American, 5-15 years old	2,932	1.8	1.1	21.5	-
1974	LA	School-based	Mostly African-Americans, 5 years old	887	0.1	5.3	2.3	-
1975	LA	Community referral to health center	10 months to 7 years old	1,078	0.1	14.5	3.9	-
1982	KY	School-based survey	Native-born, 3-7 years old	561	0.2	12.6	14.4	3.0

Figure 1 – Scatterplot of the proportion of households that have a privy vs hookworm prevalence in Alabama counties, 1910-1914 (1)

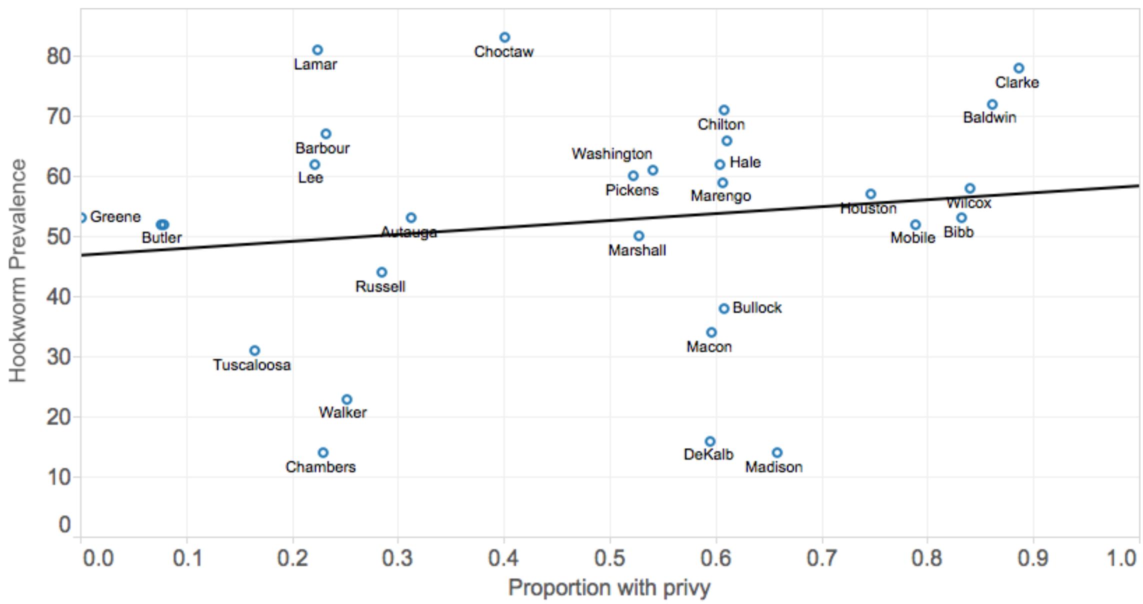


Figure 2 - STH prevalence in South Korea by 10-year age band, 1976-2004 (15)

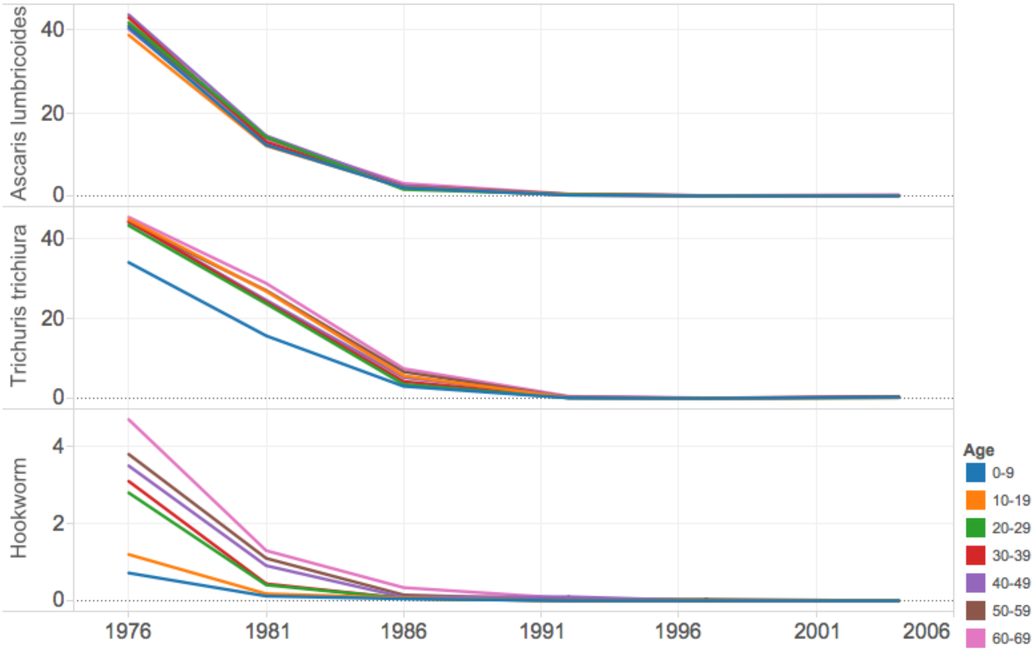


Figure 3 - STH prevalence in South Korea in urban and rural regions, 1971-2012 (15)

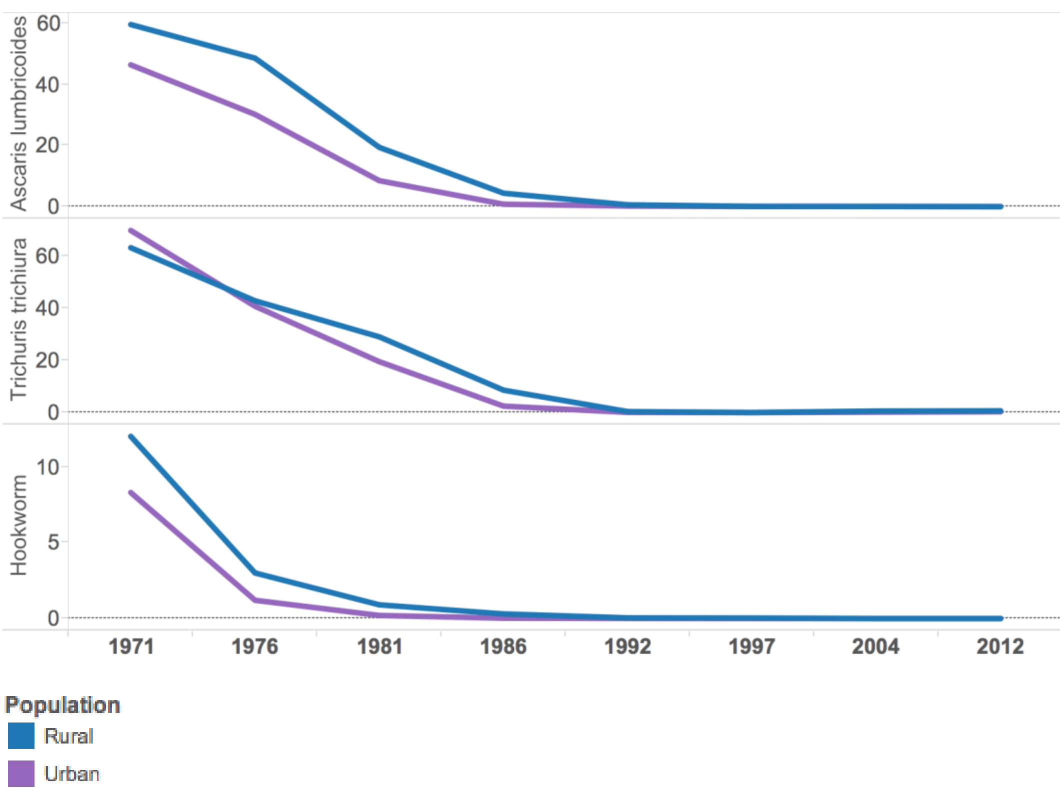


Figure 4 – Prevalences of *Ascaris, Trichuris*, and hookworm, 1969-2012

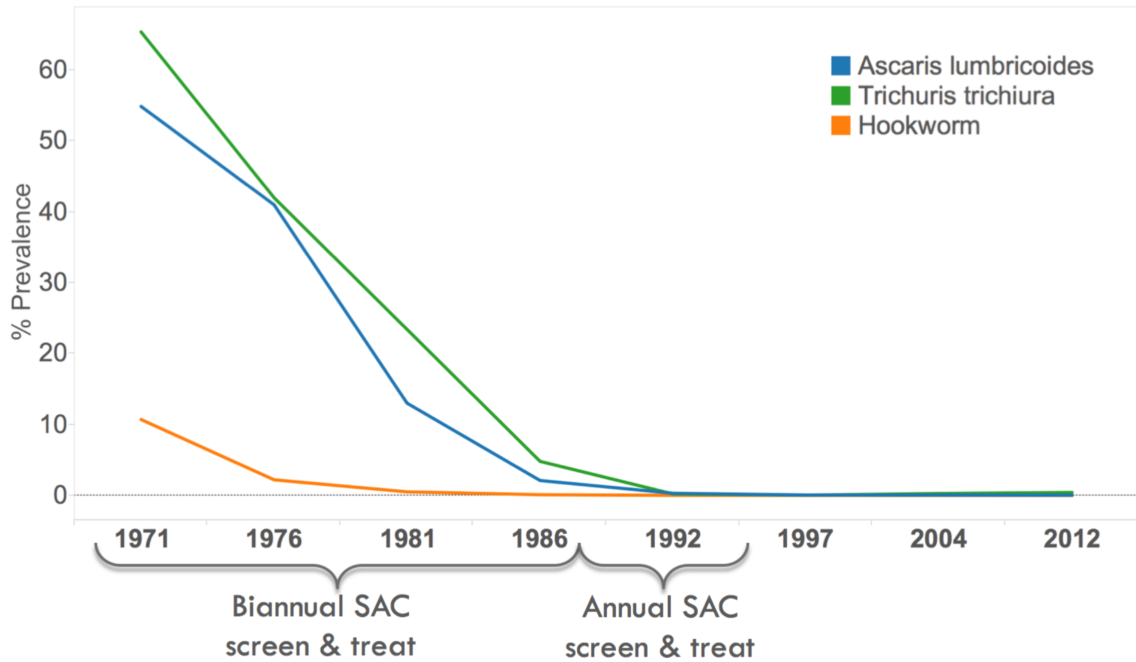


Figure 5 – Prevalences of *Ascaris, Trichuris*, and hookworm, 1969-2012

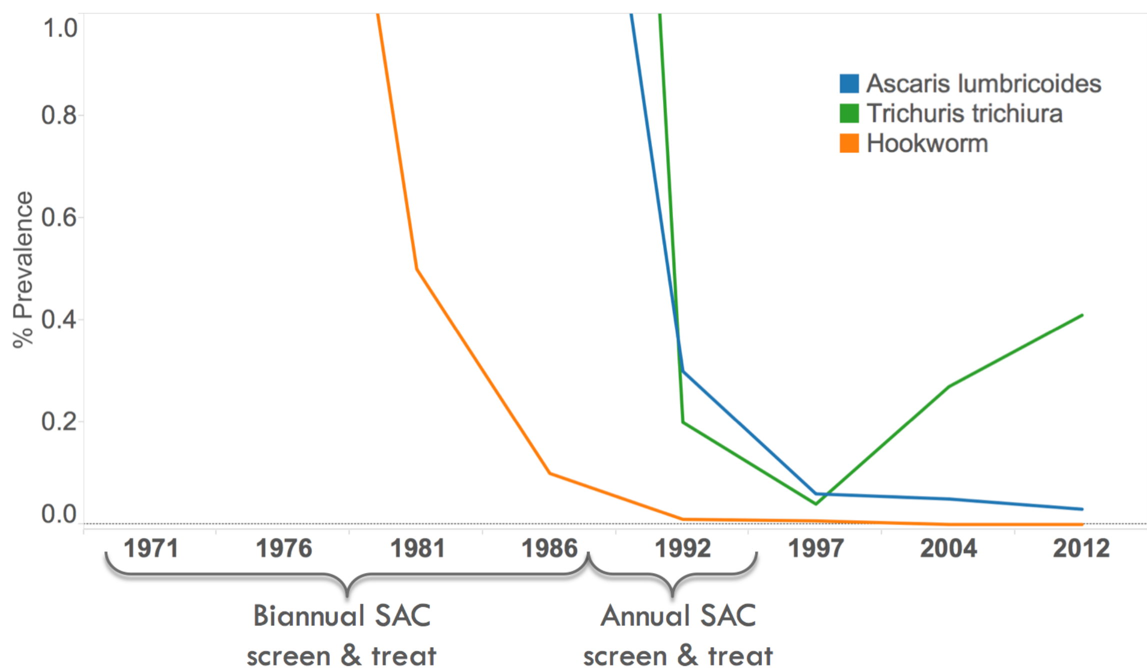
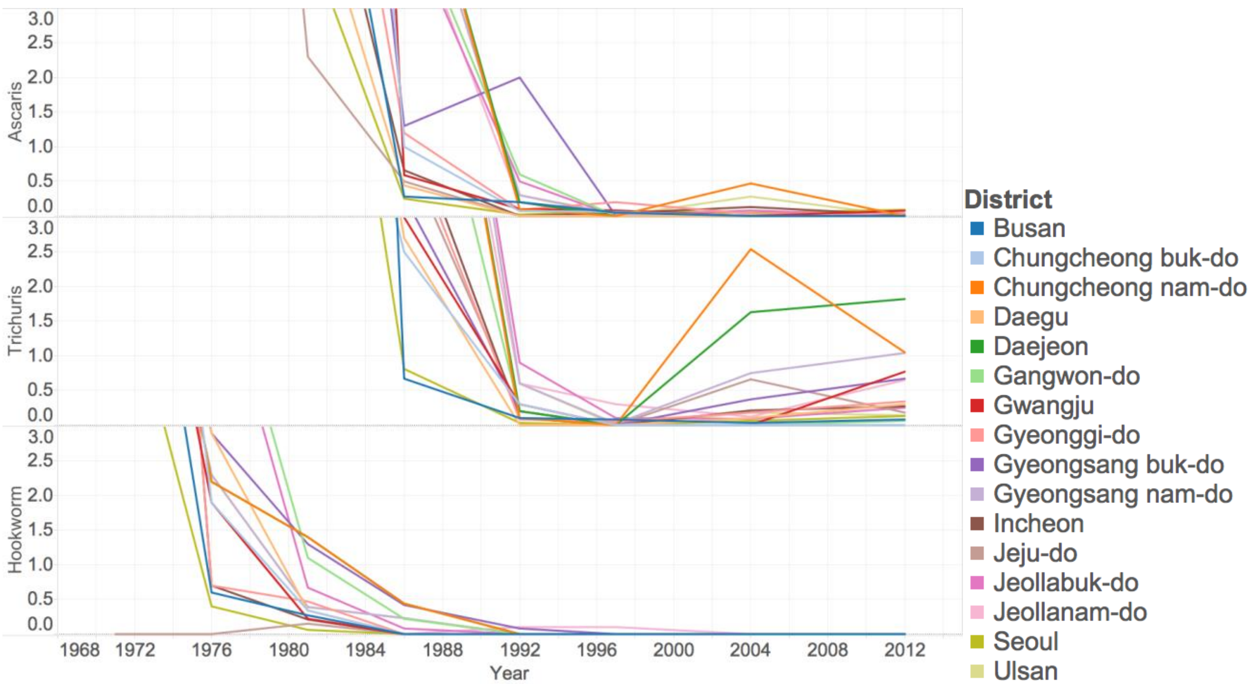


Figure 6 – Prevalences of *Ascaris, Trichuris*, and hookworm by Korean Province, below 3%, 1969-2012



REFERENCES

1. Rockefeller Sanitary Commission. Annual Reports. New York, N. Y.: Rockefeller Foundation, 1910-1915.
2. Yokogawa M, Crompton D, Nesheim M, Pawlowski Z. JOICFP's experience in the control of ascariasis within an integrated programme. Ascariasis and its public health significance. 1985:265-77.
3. Keller AE, Leathers W, Densen PM. The Results of Recent Studies of Hookworm in Eight Southern States. American Journal of Tropical Medicine. 1940;20(4):493-509.
4. Havens LC, Castles R. The Evaluation of the Hookworm Problem of Alabama by Counties. Journal of Preventive Medicine. 1930;4(2):109-14.
5. Republic of Korea - Ministry of Health and Welfare. Reports on the Prevalence of Intestinal Parasitic Infections in Korea. New York, N. Y.: Rockefeller Foundation, 1981-2013.
6. Jacocks W. Hookworm infection rates in eleven southern states: As revealed by resurveys in 1920-1923. Journal of the American Medical Association. 1924;82(20):1601-2.
7. Starr MC, Montgomery SP. Soil-transmitted Helminthiasis in the United States: a systematic review--1940-2010. The American journal of tropical medicine and hygiene. 2011;85(4):680-4.
8. Ettling J. The germ of laziness : Rockefeller philanthropy and public health in the New South. Cambridge, Mass.: Harvard University Press; 1981. x, 236 p. p.
9. Walzer PD, Milder JE, Banwell JG, Kilgore G, Klein M, Parker R. Epidemiologic features of Strongyloides stercoralis infection in an endemic area of the United States. The American journal of tropical medicine and hygiene. 1982;31(2):313-9.
10. Takeuchi T, Nozaki S, Crump A. Past Japanese successes show the way to accomplish future goals. Trends in parasitology. 2007;23(6):260-7.
11. Hong S-T, Chai J-Y, Choi M-H, Huh S, Rim H-J, Lee S-H. A successful experience of soil-transmitted helminth control in the Republic of Korea. The Korean journal of parasitology. 2006;44(3):177-85.
12. Kim T, Chai JY, Jang HG. Sustained national deworming campaign in South Korea 1969-1995. Knowledge Sharing Program: KSP Modularization 2013. 2014.
13. Seo HG, Hwang S, Chae JI. [Study on the transition of intestinal parasites in Korea from 1913 to 1989]. Ui sahak. 1991;1(1):45-63.
14. Anderson R, Truscott J, Hollingsworth TD. The coverage and frequency of mass drug administration required to eliminate persistent transmission of soil-transmitted helminths. Philosophical transactions of the Royal Society of London Series B, Biological sciences. 2014;369(1645):20130435.
15. Kim TS, Cho SH, Huh S, Kong Y, Sohn WM, Hwang SS, et al. A nationwide survey on the prevalence of intestinal parasitic infections in the Republic of Korea, 2004. The Korean journal of parasitology. 2009;47(1):37-47.