

A successful experience of soil-transmitted helminth control in the Republic of Korea

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Abstract: Soil-transmitted helminths (STH), namely *Ascaris*, *Trichuris* and hookworms (*Ancylostoma* and *Necator*), present a global health problem to about a half of the earth's population. In the Republic of Korea, STH were highly prevalent and were considered a high priority target for national control. To promote the control, a non-governmental organization named Korea Association for Parasite Eradication (currently Korea Association of Health Promotion) was founded in 1964, and mass fecal examination followed by selective mass chemotherapy with anthelmintics was performed twice a year from 1969 to 1995 targeting whole nationwide schoolchildren. Meanwhile, decreasing patterns of national STH infections have been monitored by 7 times' quinquennial national surveys targeting general population. In 1971, the overall intestinal helminth egg positive rate was 84.3% (*Ascaris* 58.2%, *Trichuris* 65.4%, and hookworms 10.7%), which became 63.2% in 1976, 41.1% in 1981, 12.9% in 1986, 3.8% in 1992, 2.4% in 1997, and 4.3% (*Ascaris* 0.03%, *Trichuris* 0.02%, and hookworms 0%) in 2004. During the control period, national economy rapidly developed, and living standards including environment, sanitation, and agricultural technology greatly improved, which undoubtedly boosted the STH control effects. Our experience indicates that social driving force to establish an eligible national control system to conduct repeated mass chemotherapy, together with improvement of environment and sanitation, is important for initiating and achieving STH control in a developing community.

Key words: *Ascaris lumbricoides*, *Trichuris trichiura*, hookworm, soil-transmitted helminth, control, fecal examination, anthelmintics

INTRODUCTION

Soil-transmitted helminths (STH) are one of the most important groups of infectious agents and are causing world's major human health problems until now. Four species of helminths, namely, hookworms (*Ancylostoma duodenale* and *Necator americanus*), *Ascaris*

lumbricoides, and *Trichuris trichiura* are primary agents of STH, and estimated infected populations are 1.3 billion, 1.5 billion, and 1.0 billion, respectively (Crompton, 1999). STH are more important among children and in poor or malnourished populations in morbidity and mortality. It was speculated that 15% of host population harbored 70% of STH worm burdens (Bundy and de Silva, 1998). Inadequate hygiene, poor health care systems and facilities, social indifference, social instability, civil war, and natural disasters

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make situations worse. STH and poverty are intimately linked in a vicious cycle in most developing countries. The DALY (disability-adjusted life year) score of STH is around 4.65 million over the world (Horton, 2003). However, priority of STH control is often neglected even in wormy countries.

A high prevalence of STH, combined with poor hygiene and malnutrition, foretells future problems in the country, and suggests that priority be given to eradicate STH worldwide. In this context, the World Health Assembly agreed a strong recommendation for developing countries to conduct STH control programs in 2001 (Horton, 2003). The present paper reviews systematic activities of STH control and national helminth surveys in the Republic of Korea and suggests possible strategies of STH control.

OVERVIEW OF PARASITE CONTROL ACTIVITIES

STH were highly prevalent in the Republic of Korea until the 1970s, and the proportion of infected people far outweighed those uninfected. In addition to its high prevalence, the intensity of *Ascaris* infection also tended to be heavy (Korea Association of Health Promotion, 2004). In the 1960s, the Korean Government began 3 health promotion campaigns; family planning, tuberculosis control, and parasite control. Parasite control activities were approached systematically as a result of legislative support initiated by the 'Parasitic Diseases Prevention' Act. This law stipulated that all students of primary or middle schools should be screened by fecal examination periodically and that all egg positive individuals be treated with anthelmintic medications. The activity of examination and medication was conducted from 1969 to 1995. The Korea Association of Parasite Eradication (KAPE), which was later changed into the Korea Association of Health Promotion (KAHP), was organized as a non-governmental organization (NGO) to enforce this legislation, and became the principal organization to implement the national program of helminthiasis control. The KAPE's activity received significant budgetary support from Japan, for exam-

ple, through Overseas Technical Cooperation Agency, particularly during the launching period.

Having instituted these control activities targeting nationwide schoolchildren by means of mass examination and mass chemotherapy, the prevalence of ascariasis began to decrease rapidly (Table 1). The egg positive rate was 55.4-55.6% in 1969-1970, but the rate decreased to below 10% levels after 1982. Thereafter, the prevalence quickly decreased below 1% in 1987, and further to 0.02% in 1995, when the national mass examination and mass chemotherapy on schoolchildren were stopped. The incidences of hookworm infections and trichuriasis among schoolchildren also decreased in similar manners, and the decreases were remarkably rapid in the 1980s.

In the meantime, it was fortunate that remarkable economic development was achieved in the Republic of Korea during the period of chemotherapeutic control of STH. Reviewing the decreasing patterns of prevalence, it seems that the successful STH control was due not only to repeated mass chemotherapies but also to remarkably improved, social infrastructures and sanitation. In particular, thanks to government-driven economic development plans from the 1960s through 1980s, social infrastructures were rapidly and widely established. These included plumbing and sewage systems, housing, electricity supply, road construction and pavement, and significant cost-effective supplies of agricultural fertilizers, which greatly helped the STH control activities. Improvements in such social infrastructures themselves could contribute to reduction of STH, as evidenced by experiences in developed countries, but the process takes a considerably longer time than anthelmintic medications (Horton, 2003).

The Republic of Korea is one of the Asian countries which has successfully controlled STH, as shown by the results of 7 national surveys that have been conducted on the STH infection status, every 5 years since 1971 (Table 2) (Korea Association of Health Promotion, 2004). These surveys were executed by stratified probability-based random sampling of 1 per 1,000 Korean population, with the exception of 2004 when 1 per 2,239 population was sampled. National

Table 1. Changing patterns of *Ascaris lumbricoides* prevalence, worm burden, and other epidemiological indices among the student group, Korea

Year ^{a)}	No. students examined	Helminth egg posit. (%)	<i>Ascaris</i> egg posit. rate (%)	Mean E.P.G.	Estimated mean worm burden	k ^{b)}	R ^{c)}
1969	6,551,926	77.0	55.4	-	-	-	-
1970	10,871,280	74.5	55.6	-	-	-	-
1971	11,813,868	71.3	51.6	-	-	-	-
1972	11,243,033	63.9	45.8	-	-	-	-
1973	12,116,892	65.2	48.1	-	-	-	-
1974	11,901,236	53.4	38.2	3,004	1.765	0.35	1.282
1975	12,480,942	51.8	38.7	3,264	1.942	0.35	1.311
1976	13,423,636	45.5	33.7	1,671	0.866	0.34	1.139
1977	14,160,212	39.6	29.7	2,894	1.322	0.34	1.214
1978	15,030,061	27.9	19.4	1,823	0.543	0.34	1.087
1979	15,592,977	23.2	15.1	2,509	0.583	0.33	1.093
1980	15,495,361	19.7	12.2	1,967	0.370	0.33	1.060
1981	16,229,764	16.0	10.2	1,850	0.291	0.33	1.047
1982	16,216,136	12.0	6.9	1,340	0.142	0.32	1.023
1983	16,220,369	8.4	4.7	1,336	0.097	0.32	1.016
1984	16,091,005	5.5	3.1	925	0.044	0.32	1.007
1985	15,812,300	4.0	2.1	848	0.026	0.32	1.004
1986	14,861,006	2.7	1.4	1,342	0.029	0.31	1.005
1987	13,206,807	1.9	0.9	1,170	0.016	0.31	1.005
1988	12,703,799	1.2	0.6	915	0.008	0.31	1.0014
1989	9,594,316	0.8	0.3	837	0.004	0.31	1.0007
1990	9,146,913	0.6	0.2	-	-	-	-
1991	8,212,776	0.3	0.1	-	-	-	-
1992	4,294,499	0.2	0.07	-	-	-	-
1993	1,699,141	0.2	0.04	-	-	-	-
1994	1,531,706	0.2	0.04	-	-	-	-
1995	1,334,517	0.2	0.02	-	-	-	-

^{a)}Figures of 1969 to 1998 represent summed results of spring and autumn examinations, and figures of 1989 to 1995 are results from only one examination in autumn.

^{b)}'k' is an inverse measurement of the degree of worm aggregation in host individuals (Anderson and May, 1982).

^{c)}'R' = $[M(1 - z)/k + 1]^{k+1}$, where 'M' is the mean worm burden and 'z' is the density-dependent constraint on worm fecundity (0.96 by Anderson and May, 1982).

surveys of a disease status naturally precede control activities in specific areas, and 7 surveys on parasitic infections gave proper information on the effects of national control programs. National surveys and control programs were direct products of public consent for STH control in the Republic of Korea.

PRESENT STATUS OF HELMINTHIASES

Although most Korean people are not at a high risk, a low level of helminthiasis prevalence still remains.

The prevalence of STH is currently very low even in remote, previously endemic areas. However, the Chinese liver fluke, *Clonorchis sinensis*, is prevalent and has endemic areas along large and small rivers. The recent national survey in 2004 has shown that an estimate of 1.98 million Korean people are infected with intestinal helminths, such as, *C. sinensis*, *Metagonimus yokogawai*, *A. lumbricoides*, or *T. trichiura* (Korea Association of Health Promotion, 2004). Of them, infected population with *C. sinensis* was 1.35 million, which is an increased number compared with

Table 2. Changing patterns of national STH egg positive rates in the Republic of Korea

Year	No. of exam.	Helminth egg posit. rate (%)	Cumulative egg rate (%)	Egg positive rate (%)			GNP/capita (US\$)
				Al ^{a)}	Tt ^{a)}	Hw ^{a)}	
1969 ^{b)}	40,581	90.5	149.6	58.2	74.2	9.1	210
1971	24,887	84.3	147.1	54.9	65.4	10.7	286
1976	27,178	63.2	89.6	41.0	42.0	2.2	799
1981	35,018	41.1	54.5	13.0	23.4	0.5	1,749
1986	47,671	12.9	14.9	2.1	4.8	0.1	2,550
1992	46,912	3.8	3.9	0.3	0.2	0.01	7,183
1997	45,832	2.4	2.4	0.06	0.04	0.007	10,315
2004	20,546	4.3	4.4	0.03	0.02	0.0	14,162

^{a)}Al, *Ascaris lumbricoides*; Tt, *Trichuris trichiura*; Hw, hookworms including *Ancylostoma duodenale* and *Necator americanus*.

^{b)}This survey was carried out by Seo et al. (1969).

that in 1997. This increase was the main factor for a higher overall helminth egg positive rate in 2004 than in 1997. At least it can be said that clonorchiasis has been endemic without big changes during the past 7 years in the Republic of Korea. Though praziquantel has been proved to be highly effective against clonorchiasis, control of clonorchiasis is difficult to achieve only by repeated praziquantel medications, (Hong et al., 1998, 2001). In contrast to clonorchiasis, the prevalence of STH further decreased during the period from 1997 to 2004. In addition, new parasite fauna including new intestinal trematode species infecting humans have been discovered (Chai and Lee, 2002; Chai et al., 2005). With regard to protozoan diseases, vivax malaria reemerged since 1993 (Chai, 1999).

Thus, the present status of parasitic diseases in the Republic of Korea can be summarized as, almost complete disappearance of STH and intestinal protozoa, active transmission of foodborne trematodes, and reemergence of malaria. At present, instead of STH, *C. sinensis* and *M. yokogawai* became 2 major helminths in the Republic of Korea. These helminths are transmitted by freshwater fish, and local people prefer to eat raw fish as recreation or epicurism. These findings together suggest that the pattern of parasitic diseases in the Republic of Korea has been changed in a manner commensurate with environmental and society-based changes as well as with economic development.

FACTORS INFLUENCING PREVALENCE AND CONTROL

The distribution of parasitic infections is determined by several factors, i.e., environment, food habit, cultural tradition, social status, economic situation, and others. Each parasite has its own natural and social habitat, and favorable environment is a prerequisite for its transmission. For example, STH are highly prevalent in poor agricultural societies, where human feces are used as a fertilizer (Bundy and de Silva, 1998; Crompton, 1999; Horton, 2003). Fish-transmitted flukes are prevalent among raw-fish eating communities along river basins and seaside areas (Chai et al., 2005), and schistosomiasis is transmitted to people residing along endemic rivers or water reservoirs. In a word, the prevalence of a parasitic infection is a consequence of both natural and cultural factors, but its control is a product of social consent and change of behavior. The implementation of helminthiasis control in a country demands social agreement for allocation of appropriate resources. However, it seems true that in most developing countries it is difficult to give STH control a high priority due to limited resources and to other high priority health problems. This is the right reason for sustained prevalence and worm burdens of STH in developing countries.

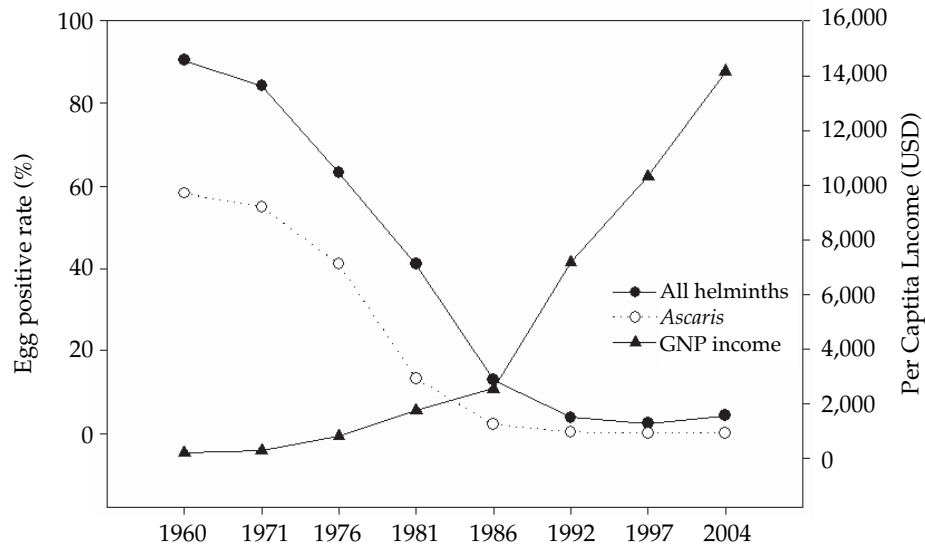


Fig. 1. Changing patterns of national egg positive rates of overall intestinal helminths and *Ascaris lumbricoides*, respectively, in comparison with GNP per capita income of South Korean population.

BACKGROUND OF STH CONTROL ACTIVITIES

Ascariasis is a representative disease among those caused by STH. Of the world's 218 countries, *Ascaris* is known to be distributed in 153 countries; no data are available on its distribution in the remainder. In 1947, globally 650 million people were estimated to be infected with *Ascaris*, but this scored to 1,472 million in 1999 (Crompton, 1999). Moreover, these estimates suggest that the overall prevalence of ascariasis has remained almost unchanged over the last 50 years. Most of the infected are believed to live in Asia, Africa, and Central or South America. However, in Asia, *Ascaris* has been almost completely eradicated from Japan, the Republic of Korea, and Taiwan. China is currently showing a rapid decrease of its prevalence in urban and developed areas (Tang, 2002). Therefore, the estimates in Asia need to be revised.

The high prevalence of STH in particular areas implies that such areas would be poor and agricultural. *Ascaris* continuously reinfect humans if human feces are used as a fertilizer, because this agricultural process literally seeds the *Ascaris* eggs into the environment. Not surprisingly, the cessation of this prac-

tice provides definitive means of controlling *Ascaris*, because it can block the reinfection cycle. In the Republic of Korea, production of cheap chemical fertilizers has reduced the need to use human feces as a fertilizer, and is considered to have certainly contributed to successful control, and as a spin-off, facilitated agricultural investment. Thus, the social changes, required for STH control, occurred simultaneously with mass control activities according to industrialization and urbanization of the society, and were rapidly accompanied by a reduction in the incidence of diseases transmitted by fecal contamination.

PREVALENCE AND REINFECTION OF STH

The overall helminth egg positive rate among general population in the Republic of Korea was about 90% until the 1960s (Seo et al., 1969), then reduced to 60-80% in the 1970s, 10-40% in the 1980s, and 2-4% in the 1990s and 2000s (Korea Association of Health Promotion, 2004) (Table 2 and Fig. 1). According to the remarkable decrease of the total egg positive rate, the cumulative egg positive rate also decreased in a similar manner, which means that in the past a great majority of egg positive cases were infected with 2 or

3 kinds of parasites whereas recently most infections are with only 1 kind. The decrease of the overall helminth egg positive rate, as revealed by quinquennial national surveys, was contributed mainly by the rapid decrease of STH infections (Korea Association of Health Promotion, 2004). The national survey data show that the period between 1981 and 1986 was critical for breaking the transmission cycle of STH in the Republic of Korea; the overall egg positive rate in 1981 was 41.1%, but in 1986 this fell to 12.9%.

With regard to the prevalence of *Ascaris*, the egg positive rate in national surveys was reduced remarkably from 41.0% in 1976 to 13.0% in 1981, and then to 2.1% in 1986 (Table 2). The remarkable reduction of the egg positive rate during 1976 and 1986 indicates that this period was critical for reducing the reinfection force of *Ascaris*. The egg positive rate of 1981 was still at a level of possible resurgence, but not the figure of 1986.

In order to estimate the reinfection force of *Ascaris* in a community, the concept of the basic reproductive rate (R) was introduced (Anderson and May, 1982). This 'R' rate, calculated from the prevalence, worm burden, and frequency distribution pattern of worms (Table 1), represents the number of female worms that successfully mature in man among those reproduced from an adult female *Ascaris* during its lifetime. Thus, if the 'R' in an endemic area approaches to 1.0, it is called transmission threshold, i.e., breakpoint of reinfection, below which *Ascaris* lose its ability to reinfect and is unable to maintain in the human population. In the Republic of Korea, the 'R' rate was calculated to be 1.09-1.28 in the 1970s and 1.001-1.06 in the 1980s among the schoolchildren (Table 1), and 1.16-2.11 in the 1970s and 1.03 in 1984-1985 among the general people (Chai et al., 1985). It is suggested that in the 1970s *Ascaris* was highly infective, but in the mid-1980s, the situation was approaching to the breakpoint of reinfection. The high 'R' rates in the 1970s were calculated based on findings from remote agricultural areas where ascariasis was highly prevalent. The average 'R' rate in the Republic of Korea must have been lower than these figures. Anyhow, the observations made in the Republic of Korea clearly

showed that *Ascaris* lost its force of reinfection after the mid-1980s.

STH CONTROL AND GNP INCOME

The average gross national product (GNP) per capita in the Republic of Korea was US\$210 in 1969 and US\$286 in 1971 (Table 2 and Fig. 1). The national school deworming program was started in 1970, and the first population-based national survey was conducted in 1971. It is now surprising to review that these national STH control activities began to set forth when the average GNP per capita was only at these low levels. Even though financial resources were very limited at that time, a vision for the future must have provoked strong requirement for social development and welfare, which included STH control. Such a social drive seems to be a pre-requisite for STH control in developing communities with limited available resources.

Fortunately, in the Republic of Korea, investment for STH control, including mass chemotherapy and environmental sanitation, increased continuously during the active control period, and as mentioned above, the 'R' rate of *Ascaris* declined to 1.03 in 1984-1985. After then, *Ascaris* seem to have lost its force of reinfection, and then the worm population rapidly declined, seemingly to an irreversible level. The average GNP income in the Republic of Korea continued to increase and reached US\$1,749 in 1981 and US\$2,550 in 1986; around these years the reinfection force of *Ascaris* was nearly under control. These data show that the national STH control activity was started when the average GNP was as low as US\$200 and that a successful control was achieved when the GNP became US\$2,000. Interestingly, the national STH prevalence and the GNP growth in the Republic of Korea are shown to be inversely correlated (Fig. 1). The correlation coefficient between the national egg positive rate of overall intestinal helminths and the gross domestic products per capita (GDP) was -0.7976 ($P = 0.0177$) and that between the egg positive rate of *Ascaris* and GDP was -0.7310 ($P = 0.0394$).

Another important factor is that selective mass

chemotherapy continued twice a year over the country without interruption even after the 'R' rate approached to almost 1.0 in the mid-1980s. Officially the schoolchildren-based deworming program discontinued from 1996 after observing that *Ascaris* egg positive rate among them became 0.02% in 1995. However, STH infection never resurged after then although there was no systematic control activity.

NEW VILLAGE (= SAEMAUL) MOVEMENT AND STH CONTROL

In terms of social consent for STH control, the Republic of Korea was very fortunate. Public awareness of the need for STH control was high and the high priority was unanimously accepted in the late 1960s. In addition, the Korean government authorities led an excellent national campaign to promote living standards of the Korean people in the early 1970s. The campaign included an economic development program with particular emphasis on manufacturing industries and a mental reform movement to promote the quality of life. Consequently, the government started a new village (= Saemaul) movement in the early 1970s, which focused on cleaning the environment, new housing, improvement of toilets, road construction, and increase of GNP per capita income. This strong social campaign is now considered to have greatly boosted the STH control effects and also contributed to improvement of health and living standards of the Korean people. In other words, the new village movement and the national STH control program are now suggested to have been highly synergistic.

MILESTONES IN STH CONTROL

Organization of an NGO for STH control

An NGO, named KAPE (currently KAHP) was organized as a result of agreement on the 'Parasitic Diseases Prevention' Act in 1964. Schoolchildren throughout the country were subjected to mass screening on intestinal helminths by KAPE and were administered anthelmintic medications from 1969 to

1995.

Use of anthelmintics

Anthelmintic drugs used for mass chemotherapy in the Republic of Korea have evolved continuously. Santonin-kainic acid was administered in 1969 and early 1970s, piperazine was used from 1971 to 1981, pyrantel pamoate from 1973 to 1988, mebendazole from 1983 to 1993, and albendazole since 1988. Mebendazole and albendazole have been produced as Korean products in the Republic of Korea at cheap prices and supplied at no cost to schoolchildren by the government.

National quinquennial surveys on the prevalence of intestinal helminths

A total of 7 quinquennial surveys have been conducted to monitor the infection status of intestinal helminths with financial supports from the government since 1971. These survey data are regarded as official national statistics and have provided basic information to develop proper control strategies.

Parasitology as a science

Departments of Parasitology have been founded in majority of medical and veterinary schools in the Republic of Korea. In 1954, Seoul National University founded Department of Parasitology in College of Medicine, for the first time in the Republic of Korea. The Korean Society for Parasitology was founded in 1959, and subsequently issued the first volume of the Korean Journal of Parasitology in 1963. Parasitologists in the Republic of Korea have participated in drafting guidelines and data analyses, and acted as consultants to the national STH control program, and made researches on biology and epidemiology of STH. They actively persuaded the society people, promoted and supported efforts to achieve STH control, and made significant contributions to the field of parasitology and parasite control.

CONCLUSION AND PERSPECTIVES

Strong public support is essential for eradicating

STH. The public must realize that STH control is an essential cornerstone for development from a wormy country. Secondly, experiences have identified that mass chemotherapy with proper anthelmintics is essential. Anthelmintics should be inexpensive and convenient to use (dose, regimen and frequency) for repeated treatments, and should effectively reduce not only morbidity but also the ability of helminths to reinfect. In a society with a prevalence of higher than 30%, a blanket mass treatment is recommended rather than a targeted treatment (Bundy and de Silva, 1998; Crompton, 1999; Horton, 2003). In blanket mass treatments, medication without examination is recommended. A school-based control program or a program based on some similar organization is both straight-forward and cost-effective (Bundy and de Silva, 1998; Horton, 2003). Thirdly, control programs of STH combined with control of schistosomiasis, filariasis, malaria, and other health promotion activities can be more effective (Savioli et al., 2002; de Silva et al., 2003). Fourthly, overseas financial supports greatly help deworming activities of a developing country at its launching stage. In this respect, developed countries or world organizations have to play pivotal roles to help and encourage developing countries.

In conclusion, STH control must be synergistic with a country's development. In order to achieve the goal, public consent on high priority of STH control is definite and essential. The public consent could effectively organize systematic and continuous eradication programs and the body to conduct the programs.

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