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Original Article

The Half-life of *Ascaris lumbricoides* Prevalence in Japanese School Children

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In the present study, we examined the dynamic of school-health-based parasite control and the related socio-economic influences. This is an ecological study based on data from 46 prefectures in Japan. The exponential decay of *Ascaris lumbricoides* prevalence was calculated by iterative least-squares method. Pearson's correlation and multiple linear regression model analysis were performed to assess the associations between the prevalence of *Ascaris lumbricoides* in Japanese school children and socio-economic variables such as the prefecture income per capita, the percentage of primary industry, the population density per 1 km^2, the diffusion rate of population under water supply, and the percentage of upper secondary school enrollment. The results indicated that the parasite carrier rate was higher in younger students. The half-life of *Ascaris lumbricoides* prevalence was approximately 3 years with significant variation among prefectures. Multiple regression analyses showed that the decrease of infection in elementary and lower secondary school children had a significant positive association with primary industry and a significant negative association with prefecture income per capita. The school-health-based parasite intervention differs by prefecture and has changed over time according to the respective prefectural stage of economic development.

Key words: *Ascaris lumbricoides*, parasite control, school-health-based approach, economic growth

Intestinal parasitic infections negatively affect the health and development of a high proportion of school-age children, especially in countries and regions with lower socio-economic conditions [1, 2]. Many societies look to the schools to reduce skill gaps across socioeconomic groups [3], and the schools in Japan have had hygiene and disease-control programs since 1870 as part of a practical mission to improve health standards at the national level [4].

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Ascaris lumbricoides (roundworm) was the most common soil-transmitted helminthiasis in Japan in the first half of the 20th century [5]. Clinical disease arises from larval migration into the lungs or the effects of the adult worm in the intestines [6]. During the lung phase, patients may develop bronchospasm, often of the asthmatic type with pulmonary infiltrates (Löffler's syndrome) [7]. Adult worms accumulate in the small intestine, reach up to 40 cm and usually cause no symptoms. However, in heavy infections, particularly in children, a large bolus of entangled worms can cause pain, oral expulsion of worms, and surgical acute abdomen [6]. Transmission typically occurs through fecally contaminated soil and is due either to a lack of sanitary facilities or to the use of human excreta as fertilizer. With their propensity for hand-to-mouth fecal carriage, younger children in impoverished rural areas are most affected [6].

Japan is one of the few countries that has achieved successful and sustained nationwide school-health-based parasite control [8-11]. This achievement has attracted considerable attention from the outside world. The Japanese model has been emulated by South Korea (1966), Taiwan (1969) and several others countries and regions in Asia and Africa [5, 12].

The successful control of *A. lumbricoides* began after the termination of World War II. Beginning in 1945 and continuing for a decade, Japan was engaged in recovering from the devastations of the war and the resulting economic collapse. There were no resources available to prevent the widespread infection of the population by *A. lumbricoides*-contaminated vegetables, which resulted from the widespread use of human excreta as a fertilizer for food cultivation. As Japan rebuilt, it developed a wide-ranging public health center system, promoted measures for maternal and child health care and enhanced both health care services in school and environmental management [13].

The problem of parasite infections was addressed in the post-war period by using a school-health-based approach through triangular cooperation among government, private sector organizations and scientific experts [14-16]. The program targeted all school children at first, and then was extended to the wider community. The program included mass stool examination, mass treatment, health education, and measures to prevent the use of human excreta in agriculture [16]. The Tokyo Public Hygiene Association, set up in 1949, took numerous steps to expand this campaign, including the formation of the Japan Association of Parasite Control in 1955, which in turn continued to orchestrate the program through its 37 branch associations [4]. Independent financing by the private sector and laboratories covered stool examination. The Japanese government supported the parasite control program through the Parasitosis Prevention Law of 1931, and then through the School Health Law in 1958, which further strengthened parasite control measures [4, 5, 14]. After 1965, because the prevalence rate was less than 5% and most of these infections involved non-fertilized eggs [17], *A. lumbricoides* was considered to be eradicated. Other countries have since followed Japan's school-health-based program.

However, a question arises as to whether Japan's success at controlling and eradicating *A. lumbricoides* was due solely to its administrative measures or whether other factors also contributed, and if so, to what degree. Previous studies have suggested that the rapid economic development in Japan at the time did not necessarily have an important role in parasite control [5]. Also, several authors have posited that improvements in the quality of life and environmental conditions, such as the modernization of agriculture and the use of chemical fertilizer, could have contributed to the decrease of intestinal parasites in Japan [8, 13, 18, 19]. However, there has been no systematic investigation to confirm these findings. Nor have there been any studies using school health data to identify the relative contributions to successful parasite control. Lastly, there has been no assessment of long-term school-health-based parasite control at the prefectural level.

The following argues that the successful *A. lumbricoides* control was due not only to the active pursuit of school health initiatives as one of the earliest public health interventions targeted specifically at children [19], but also to other public-health-related activities in addition to economic development. The present research suggests that a systematic and evaluative school-heath-based parasite control program must take into account the local socio-economic circumstances.

Therefore, the present study was performed to examine (1) the characteristics of the evolution of *A. lumbricoides* prevalence and the consequence of parasite control in school children from 1950 to 1973; (2) the half-life of *A. lumbricoides* prevalence by prefecture, using an exponential function model; and (3) the influence of socio-economic conditions during this period.

Materials and Methods

Study units and observation period. The study units in the present examination were all the prefectures of Japan, except for Okinawa prefecture, which reverted to Japan in 1972.

Prevalence of A. lumbricoides infection. We used the ratio of children positive for *A. lumbricoides* eggs to the total number of school children (5-18 years old) participating in the annual school health parasite examination by prefecture (expressed as a percentage). The prevalence data from 1949 to 1973 were retrieved from the School Health Examination Survey (SHES) [21]. The SHES provided the fundamental data with respect to school hygienic administration, and involved 3.4% of the subjects attending 14% of all educational institutes, since 1948. The annual parasite examination was compulsory according to the Parasitosis Prevention Law (1931) and School Health Law (1958) for all children in both public and private schools.

To take an overview of Japanese parasite control, we used the data on *A. lumbricoides* prevalence in elementary school children from SHES (1949–1973), except for the prevalence before 1949 and the "intestinal parasite" prevalence (1926–1973) [16]. The *A. lumbricoides* control program that began after World War II can be divided into the following three periods [22]. I) The inactive period (1945–1949): due to the consequences of war, *A. lumbricoides* control was not a priority and there were no proper control measures. II) The parasite control period (1950–1965): the period of intervention to prevent parasite infection. Control measures were limited until 1952–1953, and thereafter extended to all schools in all regions. III) The eradication period (after 1965): the prevalence rate of <5% is considered a very low infection rate because it mostly involved non-fertilized eggs [17].

Socio-economic variables selected. Other socio-economic variables used in the present study were obtained from the Japan Annual Statistical Reports [23], which provide socio-economic information on an annual basic for all prefectures of Japan.

Prefecture income per capita was calculated by dividing the prefectural income, including compensation for employment, property income and business income, by prefectural population.

Percentage of primary industry by prefecture was used as the indicator of the type of industry that might contribute to the increase of the prevalence of parasitosis. Most farmers used human excreta as a plant fertilizer before the parasite prevention law.

Population density per 1 km^2 was used as the indicator of the population density by prefecture.

Diffusion rate of population under water supply was defined as the percentage of the population living in the service area where the drinking water supply system was available among the total prefectural population. We used the data for 1952 instead of 1950, which was unavailable.

Percentage of upper secondary school enrollment was used as the indicator of education levels by prefecture, because such education was elective.

Statistical analyses. We calculated the half-life using the data of *A. lumbricoides* prevalence in elementary and secondary school children from 1955 to 1973, during the parasite control period [24]. The exponential function model for the half-life of *A. lumbricoides* prevalence indicator (y) by prefecture was expressed as: $y = a\, e^{kx}$.

In this equation, a is a constant and k is a slope constant for each prefecture of *A. lumbricoides* infection for which the half-life was calculated.

Pearson's correlation coefficient was used to measure the strength of the association between *A. lumbricoides* prevalence and socio-economic variables among the prefectures every 5 years from 1950 to 1970. Variables that were correlated with a significant change in the prevalence of *A. lumbricoides* from 1955 to 1965 ($p < 0.05$) were entered into the multiple linear regression model in a stepwise method. The entry and exit criteria were set at 0.05 and 0.10, respectively. All statistical analyses were performed with SPSS 12.0 (SPSS Inc., Chicago, IL, USA).

Results

The period of parasite control after the war. The dynamic consequences of repeated mass chemotherapy, temporary suspension of parasite control, and environmental changes are shown in Fig. 1. After the war, the parasite control measures were temporarily suspended and intestinal parasitic infection increased dramatically. The parasite control program was begun in 1949, and *A. lumbricoides* infection decreased from about 64% in that year to less than 5% nationally by 1965.

Prevalence of A. lumbricoides infection in school children. The prevalences of *A. lumbricoides* infection were 63.4%, 59.3% and 49.9% for elementary school children and lower and upper secondary school children, respectively, at the start of 1950. In 1973, the prevalence was approximately zero in all schools in all prefectures (Fig. 2). The *A. lumbricoides* prevalence in elementary school children decreased by 73% in only 10 years, by 92% in 15 years and by 97% in 20 years. Younger children had a higher infection rate of *A. lumbricoides*. There was no significant difference between males and females in the prevalence of *A. lumbricoides* in any of the 3 groups.

Half-life of A. lumbricoides prevalence during the period of parasite control. The prevalence of *A. lumbricoides* infection in school children by prefecture was analyzed and the 95% confidence interval was calculated (Table 1 and Table 2). The results indicated that the national half-life of parasite control was 3.04 years (2.93–3.15) for males and 3.01 years (2.90–3.13) for females in elementary school. The half-life for males in lower secondary school was 3.12 years (2.97–3.29) and that for females was 3.07 years (2.96–3.20) with a wide fluctuation among prefectures for both sexes. In the case of elementary school children (male), some prefectures, especially the most economically developed ones [23], showed markedly shorter half-lives, such as 1.71 years (1.51–1.96) for Kanagawa and 2.12 years (1.95–2.31) for Tokyo. On the other hand, the prefectures of Iwate and Shiga showed much slower decay in prevalence, with half-lives of 4.27 years (3.71–5.02) and 4.22 years (4.02–4.44), respectively (Fig. 3). These prefectures had a lower rate of economic growth than the national average. Similar results were observed for lower secondary school children in both males and females (Table 1 and Table 2).

Association between A. lumbricoides prevalence and socio-economic variables. As shown in Table 3, after 1950 significantly negative correlations were found between *A. lumbricoides* prevalence in elementary and secondary school children and socio-economic variables such as the increase of prefecture income per capita, the diffusion rate of population under water supply, the population density per 1 km^2, and the level of upper secondary school enrollment by prefecture. We also found significant positive correla-

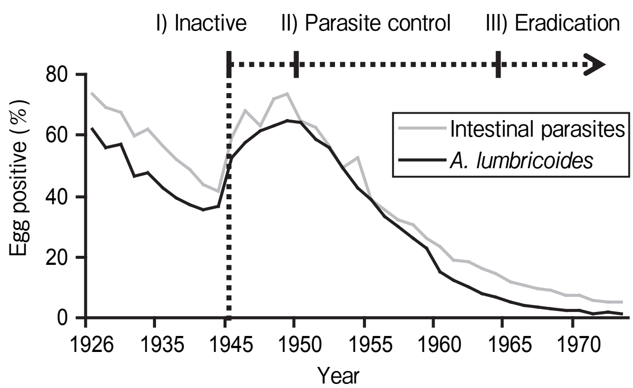

Fig. 1 Annual moving average of intestinal parasite and *A. lumbricoides* prevalences from 1926 to 1973. After the enactment of the Parasite Control Law in 1931, the *A. lumbricoides* prevalence decreased partially before World War II. A further drastic decrease in intestinal parasite infection occurred several years after the World War II. The decay of parasite control was divided into 3 periods: I) the inactive period (1945–1949), II) the parasite control period (1950–1965), and the eradication period (after 1965).

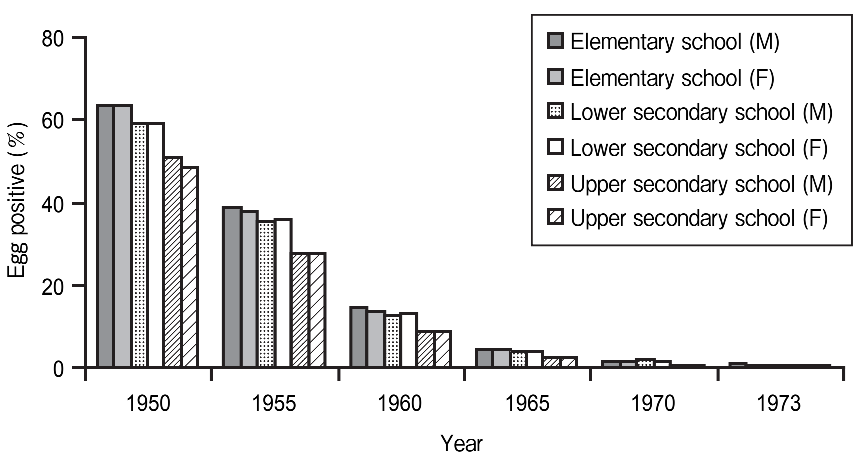

Fig. 2 Change of *A. lumbricoides* prevalence every 5 years in children attending elementary school and lower and upper secondary schools by sex, from 1950 to 1973 based on prefectural data.

Table 1 Half-lives of *A. lumbricoides* prevalence by the exponential function model for Japanese elementary school children, 1955–1973

	Elementary school (male)			Elementary school (female)		
	Half-life (years)	95% CI	*p*	Half-life (years)	95% CI	*p*
Japan	3.04	2.93–3.15		3.01	2.90–3.13	
Hokkaido	2.82	2.40–3.44		3.04	2.71–3.47	
Aomori	3.51	3.28–3.78	*	3.19	2.85–3.61	
Iwate	4.27	3.71–5.02	*	4.00	3.55–4.58	*
Miyagi	3.70	3.29–4.22	*	3.28	3.11–3.46	
Akita	2.99	2.62–3.49		2.97	2.65–3.37	
Yamagata	2.50	2.27–2.78	*	2.40	2.14–2.75	*
Fukushima	2.94	2.68–3.25		3.00	2.72–3.36	
Ibaraki	2.90	2.64–3.22		2.82	2.56–3.13	
Tochigi	2.72	2.52–2.94		2.63	2.46–2.84	*
Gunma	2.57	2.36–2.83	*	2.41	2.12–2.79	*
Saitama	2.53	2.30–2.81	*	2.55	2.31–2.83	*
Chiba	2.21	2.03–2.42	*	2.15	1.93–2.43	*
Tokyo	2.12	1.95–2.31	*	2.17	1.96–2.45	*
Kanagawa	1.71	1.51–1.96	*	1.77	1.61–1.97	*
Niigata	2.53	2.33–2.78	*	2.42	2.12–2.82	*
Toyama	2.75	2.43–3.16		2.72	2.42–3.12	
Ishikawa	3.18	2.74–3.77		3.19	2.72–3.86	
Fukui	3.17	2.93–3.47		3.26	2.99–3.59	
Yamanashi	2.61	2.41–2.85	*	2.55	2.38–2.75	*
Nagano	2.73	2.47–3.05		2.78	2.54–3.06	
Gifu	3.07	2.79–3.41		2.91	2.63–3.26	
Shizuoka	2.60	2.39–2.85	*	2.49	2.29–2.73	*
Aichi	2.46	2.23–2.75	*	2.49	2.23–2.81	*
Mie	2.80	2.65–2.97		2.73	2.55–2.95	
Shiga	4.22	4.02–4.44	*	4.29	4.07–4.54	*
Kyoto	3.96	3.74–4.21	*	3.91	3.64–4.23	*
Osaka	2.47	2.23–2.75	*	2.37	2.17–2.61	*
Hyogo	2.73	2.53–2.96		2.66	2.44–2.92	
Nara	3.64	3.34–4.01	*	3.53	3.21–3.91	*
Wakayama	2.70	2.48–2.96		2.56	2.34–2.82	*
Tottori	2.99	2.74–3.28		3.09	2.83–3.40	
Shimane	2.83	2.64–3.05		2.99	2.78–3.24	
Okayama	2.56	2.33–2.84	*	2.69	2.51–2.91	
Hiroshima	2.45	2.25–2.70	*	2.57	2.27–2.96	
Yamaguchi	2.58	2.38–2.81	*	2.21	1.94–2.56	*
Tokushima	3.52	3.29–3.78	*	3.38	3.14–3.66	*
Kagawa	2.49	2.34–2.66	*	2.50	2.34–2.68	*
Ehime	2.71	2.42–3.09		2.71	2.52–2.92	
Kochi	2.66	2.36–3.05		2.49	2.19–2.89	*
Fukuoka	3.00	2.55–3.64		2.77	2.43–3.21	
Saga	2.80	2.51–3.18		2.81	2.55–3.12	
Nagasaki	3.32	3.10–3.58		3.40	3.17–3.67	*
Kumamoto	2.76	2.53–3.04		2.97	2.68–3.32	
Oita	3.38	3.11–3.70		3.35	3.12–3.62	
Miyazaki	2.88	2.68–3.12		2.87	2.66–3.11	
Kagoshima	3.06	2.69–3.56		2.90	2.50–3.45	

95% CI, 95% confidence interval. *$p < 0.05$ compared with the national prevalence of *A. lumbricoides*.

Table 2 Half-lives of *A. lumbricoides* prevalence by the exponential function model for Japanese lower secondary school children, 1955–1973

	Lower secondary school (male)			Lower secondary school (female)		
	Half-life (years)	95% CI	*p*	Half-life (years)	95% CI	*p*
Japan	3.12	2.97–3.29		3.07	2.95–3.20	
Hokkaido	2.77	2.36–3.35		3.25	2.67–4.15	
Aomori	3.51	3.24–3.84		3.07	2.67–3.63	
Iwate	4.14	3.71–4.68	*	4.16	3.68–4.78	*
Miyagi	3.28	2.85–3.87		3.21	2.96–3.51	
Akita	3.19	2.84–3.63		3.04	2.69–3.49	
Yamagata	2.77	2.58–3.01		2.57	2.34–2.84	*
Fukushima	3.25	3.05–3.48		2.97	2.74–3.24	
Ibaraki	2.66	2.34–3.08		2.51	2.26–2.81	*
Tochigi	2.74	2.60–2.90	*	2.83	2.66–3.03	
Gunma	2.33	2.11–2.61	*	2.49	2.25–2.78	*
Saitama	2.25	2.06–2.48	*	2.30	2.14–2.48	*
Chiba	2.38	2.14–2.69	*	2.20	2.07–2.36	*
Tokyo	2.11	1.96–2.29	*	2.16	1.92–2.47	*
Kanagawa	1.88	1.72–2.09	*	1.86	1.69–2.07	*
Niigata	2.59	2.39–2.83	*	2.41	2.10–2.82	*
Toyama	2.89	2.45–3.53		2.41	2.04–2.95	*
Ishikawa	3.23	2.82–3.77		3.44	2.99–4.06	
Fukui	3.29	3.00–3.65		3.23	2.95–3.56	
Yamanashi	2.75	2.49–3.07		2.61	2.39–2.88	*
Nagano	3.05	2.82–3.33		3.10	2.90–3.33	
Gifu	3.13	2.73–3.67		3.09	2.76–3.51	
Shizuoka	2.64	2.42–2.91	*	2.54	2.31–2.81	*
Aichi	2.60	2.42–2.82	*	2.54	2.32–2.81	*
Mie	2.87	2.65–3.12		2.90	2.71–3.10	
Shiga	4.06	3.66–4.55	*	4.03	3.67–4.48	*
Kyoto	3.11	2.67–3.71		3.96	3.52–4.52	*
Osaka	2.67	2.09–3.70		2.22	2.00–2.51	*
Hyogo	2.76	2.43–3.18		2.66	2.49–2.85	*
Nara	3.35	3.08–3.66		3.28	2.89–3.78	
Wakayama	2.50	2.22–2.85	*	2.43	2.19–2.74	*
Tottori	3.39	2.77–4.36		3.27	2.81–3.90	
Shimane	3.09	2.85–3.39		3.02	2.74–3.35	
Okayama	2.86	2.68–3.06		2.94	2.62–3.35	
Hiroshima	2.42	2.14–2.78	*	2.63	2.40–2.90	*
Yamaguchi	2.65	2.44–2.90	*	2.68	2.50–2.88	*
Tokushima	3.67	3.27–4.20		3.65	3.31–4.06	*
Kagawa	2.81	2.55–3.13		2.76	2.56–3.00	
Ehime	3.02	2.73–3.39		3.10	2.87–3.37	
Kochi	2.41	2.26–2.59	*	2.61	2.36–2.90	*
Fukuoka	2.69	2.49–2.93	*	2.92	2.69–3.20	
Saga	2.65	2.48–2.85	*	2.67	2.52–2.85	*
Nagasaki	3.02	2.72–3.40		3.17	2.88–3.52	
Kumamoto	2.84	2.66–3.06		2.54	2.38–2.72	*
Oita	3.97	3.53–4.54	*	3.59	3.28–3.97	*
Miyazaki	2.96	2.67–3.33		3.04	2.81–3.30	
Kagoshima	2.85	2.65–3.08		2.69	2.51–2.91	

95% CI, 95% confidence interval. *$p < 0.05$ compared with the national prevalence of *A. lumbricoides*.

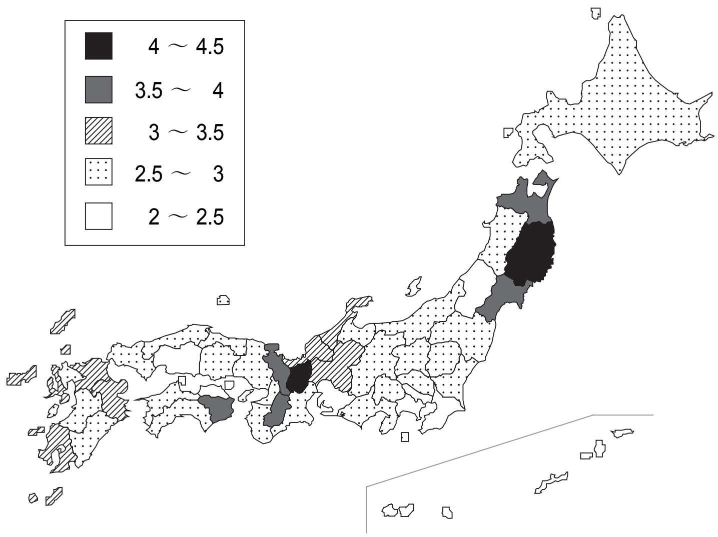

Fig. 3 The half-life by prefecture of *A. lumbricoides* prevalence in elementary school children (male), from 1955 to 1973 is presented on the map. No data available for Okinawa. Data are duplicated from Table 1.

Table 3 Pearson's correlation between the prevalence of *A. lumbricoides* in school children and socio-economic variables from 1950 to 1970

Variables	1950 Elementary	1950 Lower sec.	1950 Upper sec.	1955 Elementary	1955 Lower sec.	1955 Upper sec.	1960 Elementary	1960 Lower sec.	1960 Upper sec.
Prefecture income per capita (×¥1000)	0.05	−0.03	0.17	−0.59**	−0.59**	−0.35*	−0.61**	−0.47**	−0.31*
Primary industry (%)	−0.09	−0.03	−0.18	0.59**	0.59**	0.29	0.67**	0.50**	0.37*
Population density per 1 km^2	0.12	0.02	0.13	−0.37*	−0.37*	−0.21	−0.43**	−0.36*	−0.24
Diffusion of population under Water supply (%)[a]	0.18	0.11	0.26	−0.29*	−0.29*	−0.18	−0.55**	−0.39**	−0.36*
Upper secondary school Enrollment (%)	0.22	0.09	0.22	−0.44**	−0.44**	−0.11	−0.56**	−0.43**	−0.30*

Variables	1965 Elementary	1965 Lower sec.	1965 Upper sec.	1970 Elementary	1970 Lower sec.	1970 Upper sec.
Prefecture income per capita (×¥1000)	−0.57**	−0.52**	−0.31*	−0.40**	−0.42**	−0.05
Primary industry (%)	0.64**	0.60**	0.37*	0.43**	0.52**	0.16
Population density per 1 km^2	−0.40**	−0.41**	−0.25	−0.36*	−0.34*	−0.20
Diffusion of population under Water supply (%)	−0.40**	−0.41**	−0.19	−0.27	−0.33*	−0.09
Upper secondary school Enrollment (%)	−0.65**	−0.58**	−0.33*	−0.45**	−0.36*	−0.01

Lower sec., lower secondary; Upper sec., Upper secondary[a]. The 1952 data was a substitute for 1950. *$p < 0.05$, **$p < 0.01$.

tions between *A. lumbricoides* prevalence and the decrease in the percentage of primary industry over the same period. These correlations were stronger for elementary and lower secondary school children, especially during 1955–1965. In the multiple linear regression model, the increase of prefecture income per capita and decrease of primary industry per prefecture were associated with a statistically significant decrease of *A. lumbricoides* prevalence in elementary and lower secondary schools (Table 4).

Discussion

This study was the first to calculate the half-life of

Table 4 Results of multiple linear regression analyses with the change in prevalence of *A. lumbricoides* in school children from 1955 to 1965 as a dependent variable and changes of socio-economic variables over the same period as independent variables

Independent variables	Change of *A. lumbricoides* prevalence (%) ß	p	R^2
Elementary school			
Change of Prefecture income per capita	−0.34	0.015	
Change of Primary industry	0.31	0.027	0.263
Lower secondary school			
Change of Primary industry	0.33	0.021	
Change of Prefecture income per capita	−0.30	0.032	0.246

ß, standardized regression coefficient.

A. lumbricoides infection using an exponential function model in order to examine the effectiveness of school-health-based parasite control by prefecture in Japan. Our model was applied to all prefecture data that suggested common factors or mechanisms which may have contributed to parasite control. Although the school-health-based parasite control initiatives were scheduled equally for all schools, the half-life of *A. lumbricoides* prevalence differed by prefecture. These results indicate that the decrease in *A. lumbricoides* infection during the period studied was due not only to the control of parasites through the school-health initiatives, but also possibly due to regional socio-economic development, which could have influenced the speed of parasite control.

The exponential function model for the half-life of *A. lumbricoides* prevalence was applicable for every prefecture during the parasite control period. It is noteworthy that this period coincided with economic growth in Japan. It has been noted that the dynamics of the parasite cycle can be perturbed not only by control interventions but also by environmental changes [24]. Therefore, in seeking an explanation for the dramatic efficacy of Japan's parasite control program, the school-health-based intervention should not be the only factor considered, and factors such as health or sanitary improvement measures can not be neglected.

The present results demonstrated that the parasitic infections were high when parasite control was temporarily suspended due to the catastrophic consequences of wars (Fig. 1) and before enactment of the Parasite Prevention Law (1931) in Japan. Komiya [22] reported that after 1949–1950 periodical control was first incorporated only for selected schools, before being expanded to a nationwide program over 1952–1953. This might explain why this model did not fit well before 1955.

In this study, the model was equally applicable to both male and female students in elementary and lower secondary schools, because the parasite control was applied to all children that attended such schools. We considered the lack of difference between male and female students meaningful, because both sexes had equal access to education and school health programs, which in the future would lead to improvements in maternal-child health and socio-economic development (Table 1 and Table 2). Such equal opportunity may not be available in some countries or regions due to socio-economic or cultural factors [25, 26]. Anderson *et al.* [24] reported the effectiveness of *A. lumbricoides* control intervention in high-risk groups. We also observed a similar pattern of decay from the group selected during the period of the parasite control. However, other studies have shown that, in the absence of a control program, no such patterns of decay are observed [25, 27]. Thus, a successful and cost-effective control strategy can be achieved by targeted chemotherapy of the most heavily infected age groups through a school health program [28, 29].

The half-life of school-health-based parasite control differed among the prefectures, and the change of *A. lumbricoides* prevalence was associated with a decrease in primary industry and an increase in economic development. Over the period studied, the economic development of Japan was characterized by a reduction of primary industry and increases in secondary and tertiary industry [23]. In our study, the higher prefecture income per capita in the economically developed prefectures correlated with a lower half-life of *A. lumbricoides* prevalence. An association between a higher prevalence of parasite infections and poor socio-economic and sanitary conditions has been observed in other studies [1, 28]. The principle that the socio-economic position of individuals, groups, and places defines their levels of health and disease [30] could be said to apply to the case of parasitosis.

Previous publications on school health activities have reported a higher prevalence of parasitic infections in agricultural and rural communities and a low risk of infection for economically developed prefectures [21, 22]. Thus, the parasite control program was divided according to areas of risk and was implemented with active community participation [31, 32] during the period of parasite control. Therefore, for many years now, the school health programs in Japan have been good examples of "health-promoting" initiatives [33]. Also, the present results are in agreement with previous studies at the individual and population levels [22, 24] that show an exponential decay of parasite infection after periodical treatment or a parasite control program with different rates of success depending on the social group treated.

Japanese schools provided a strategic physical network for the initiation of parasite control involving all school children. The universal access to schools with school health facilities was key in allowing a parasite control program at the national level. Also, in order to ensure universal education, communities in Japan were organized into different school districts. Thus a student, depending on where he or she lives, belonged to a given school district and attended the corresponding school [34]. Therefore, the type of community, its organization and its economic development were closely correlated with school health activities.

Because the prevalence of *A. lumbricoides* and prefectural variables were at the population-level in this study, ecological fallacies may occur in applying our results at the individual level. In this study, we used the data from elementary and lower secondary schools to measure the half-life of *A. lumbricoides* prevalence because all these students were involved in compulsory education. Also, these groups had higher infection rates and were strongly influenced by socio-economic factors.

Our analysis included the critical factors associated with parasite control and the results were carefully interpreted. The present study, however, lacks data for the diffusion of human excreta as fertilizer and its replacement by the chemical products used by prefectures for the period selected.

We concluded that the school-health-based parasite control was effective, but was significantly influenced by surrounding environmental conditions. This study was done to obtain basic data so that an effective school-health-based parasite control program for a developing country may be better planned. According to our results, we suggest the widespread parasite control in school children through school health programs is necessary as a short-term goal. Parallel to and following the parasite control program, improvements in personal hygiene will be necessary, and must be expanded to the whole population level, involving active community participation for definitive parasite control. Therefore, for long-term control, the influences of socio-economic development must be considered. What we learned from Japan's success at parasite control may be helpful for solving similar problems in developing countries, and will be useful for taking appropriate measures against re-emerging parasite infections.

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