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Epidemiological Studies on *Ascaris lumbricoides* Reinfection in Rural Communities in Korea

1. The Relationship between Prevalence and Monthly Reinfection Rate

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INTRODUCTION

The current status of *Ascaris lumbricoides* infection in Korea has been remarkably improving since the inauguration of the national mass treatment programme in 1960s (Korean Society for Parasitology; KSP, 1982; Seo, 1983). However, recent nationwide surveys show that the prevalence is 13.0 and 6.9% in egg positive rate among randomly selected inhabitants and student group respectively (Ministry of Health and Social Affairs & Korea Association for Parasite Eradication: MHSA & KAPE, 1981; KAPE, 1982). These figures are still by no means satisfactory and continuous expansion of control activity is indispensable.

In epidemiological aspects of ascariasis control, it is undoubtedly true that the most important factor to be considered is the persistent occurrence of reinfection in endemic areas. It is well known that, due to reinfection, the prevalence returns to the pre-treatment level within one year even after intensive mass treatment using effective anthelmintic (Kozai, 1962; Lechat *et al.*, 1974; Cabrera *et al.*, 1975; Arfaa *et* Ghadirian, 1977; Seo *et al.*, 1980). Therefore, success or failure in control greatly depends on the rate and frequency of reinfection.

It was described that the reinfection rate of *A. lumbricoides* seems highly dependent upon the current prevalence (or endemicity) in a community (Morishita, 1972). However, there has been no detailed observation on the relationship between prevalence and reinfection rate, because there were no precise tools to measure the rate or frequency of reinfection during a defined period. In the meantime, Cho (1977) proposed a method measuring the amount of reinfected worms during the past 2 months by repeated blanket mass chemotherapy every 2 months by pyrantel pamoate and collection of the expelled worms. According to him, nearly all of the worms collected were young (=immature) worms shorter than 13 cm and lighter than 500 mg and it was indicated that the total number of young worms clearly represent the frequency (amount) of reinfection during the past 2 months.

Therefore, if the worm collection method is applied with blanket mass chemotherapy with pyrantel pamoate, the reinfection rate for 2 months can be estimated simply by discriminating the cases harbouring young worm(s). The relationship between prevalence and reinfection rate in terms of all worm and young worm positive rates respectively is also expected to be established in each area.

The objective of the present study is to observe the epidemiological relationship between the current prevalence and the monthly reinfection rate of *A. lumbricoides* in rural communities in Korea, applying the basic formula of the time-prevalence curve proposed by Hayashi (1977).

MATERIALS AND METHODS

A total of 10 rural (or suburban) villages in various localities were subjected for this study (Table 1). When surveyed, these areas were considered to have attained equilibrium of *A. lumbricoides* infection, since there had been no parasite control measure undertaken during the past one year.

During the period from 1975 to 1980, a total of 4,466 inhabitants in the subjected areas were treated with 10 mg/kg of pyrantel pamoate regardless of egg detection results. And 2,547 among them were cooperative for collection of their whole-day stools passed for 2 consecutive days directly after the treatments, and examined for the presence of the expelled worms of *A. lumbricoides*. The expelled worms were collected by filtration of the fecal material through fine mesh in order to collect all of the worms even as small as 1∼2 cm in length. The collected worms were counted in each case to check the worm burden and measured the length and weight to discriminate young worms. The length measurement was done by tracing a flexible wire through the anterior to posterior ends and the weight was measured on a torsion balance.

After the prevalence (positive rate for all worms) and the reinfection rate for 2 months (positive rate for young worms) were obtained, the relationship between the two values were established (Table 2), applying the theoretical equation for the time-prevalence curve by Hayashi (1977): $Y=G\{1-(1-X)^{N-r}\}$, where 'X' is monthly reinfection rate, 'Y' is prevalence, 'N' is time elapsed in months, 'r' is incubation period for worm maturation, and 'G' is maximum prevalence to be reached in the area. The above equation was modified under the consideration that 'G' should be 1 (100%) and 'r' be 0 when 'X' and 'Y' values were expressed by worm positive rates, as follows: $Y=1-(1-X)^N$. The monthly reinfection rate was obtained using the known values of 'Y_y' (young worm positive rate) and 'N' (2 months) according to the equation, $Y_y=1-(1-X)^2$.

When the monthly reinfection rates in 10 areas were thus obtained, their relationship with prevalence was analyzed. As the equation was $Y=1-(1-X)^N$, the values of 'N' were calculated again with the known 'X' and 'Y' values. Ten kinds of 'N' values were obtained by this procedure and the mathematical and geometric means as well as the median value were calculated and compared one another with statistical test for the best fitness.

RESULTS

The prevalence (worm positive rate) of *A. lumbricoides* in 10 areas surveyed was in the range, 13.6∼72.3% (Table 1). And a total of 2,570 worms (2,202 adults and 368 young worms) were collected from 796 overall worm positive cases. The average worm burden per infected individual ranged 1.4∼10.2 according to areas and there was a close positive correlation between the prevalence and the average worm burden.

A total of 273 cases harboured young worms with/without adult worms (Table 2). The young worm positive rates in various localities were in the range, 5.1∼29.8%, which were also positively correlated with the prevalence. The calculated values of the monthly reinfection rate using the equation already described were, 2.6% when the prevalence was 13.6%, 3.7% when it was 23.1%, and so on, up to 16.2% when the prevalence was 72.3%.

In order to obtain the correlation equation between prevalence and monthly reinfection rate, the value 'N' in the equation, $Y=1-(1-X)^N$, was calculated in 10 occasions of prevalence (Y) and monthly reinfection rate (X) (Table 2). The simplified equation to

Table 1. The results of worm collection study of *A. lumbricoides* in various areas, Korea (1975~'80)

Area* code	Areas	No. treated	No. exam. for worms	No. worm posit. (%)	No. total worms		
					Adult	Young	Total (Aver.)
A	Jinyang-gun	59	47	34 (72.3)	322	24	346 (10.2)
B	Kangjin-gun	120	59	42 (71.2)	295	26	321 (7.6)
C	Machŏn-dong	194	154	97 (63.0)	395	63	458 (4.7)
D	Janghŭng-gun	92	61	36 (59.0)	121	22	143 (4.0)
E	Hoengsŏng-gun	54	39	21 (53.8)	62	10	72 (3.4)
F	Hwasŏng-gun[A]	925	540	211 (39.1)	495	77	572 (2.7)
G	Hwasŏng-gun[B]	409	165	60 (36.4)	152	36	188 (3.1)
H	Eujŏngbu city	285	193	55 (28.5)	87	22	109 (2.0)
I	Hwasŏng-gun[C]	1,170	684	158 (23.1)	193	54	247 (1.6)
J	Hwasŏng-gun[D]	1,158	605	82 (13.6)	80	34	114 (1.4)
	Total	4,466	2,547	796	2,202	368	2,570

* A: Kyŏngsangnam-do, B & D: Chollanam-do, C: Suburban Seoul, E: Kangwŏn-do, F, G, H, I & J: Kyŏnggi Do

Table 2. Young worm positive rate and monthly reinfection rate of *A. lumbricoides*

Area code	Worm posit. cases* (%)	Young worm posit. cases (%)	Monthly reinf. rate** (%)	N***
A	34 (72.3)	14 (29.8)	16.2	7.26
B	42 (71.2)	17 (28.8)	15.6	7.34
C	97 (63.0)	43 (27.9)	15.1	6.07
D	36 (59.0)	14 (23.0)	12.3	6.79
E	21 (53.8)	6 (15.4)	8.0	9.26
F	211 (39.1)	63 (11.7)	6.0	8.02
G	60 (36.4)	16 (9.7)	5.0	8.82
H	55 (28.5)	20 (10.4)	5.3	6.16
I	158 (23.1)	49 (7.2)	3.7	6.97
J	82 (13.6)	31 (5.1)	2.6	5.55
Total	796	273		

* Prevalence

** Calculated from the equation, $Yr=1-(1-X)^2$, where 'X' is monthly reinfection rate and 'Yr' is young worm positive rate

*** Calculated from the equation, $Y=1-(1-X)^N$, where 'X' is monthly reinfection rate and 'Y' is the current prevalence, and 'N' is time in month

obtain 'N' values was, $N=ln(1-Y)/ln(1-X)$ and the values obtained were in the range, 5.55~9.26 according to the localities surveyed (Table 2 & Fig. 1).

The mathematical mean of 'N' values was 7.2 and the geometric mean as well as the median value was 7.1. When the theoretical 'X' values were reversely calculated with two 'N' values, the fitness between theoretical and observed ones was exactly the same ($X^2=1.44$ and $p>0.975$ by 7.2 or 7.1 'N' values).

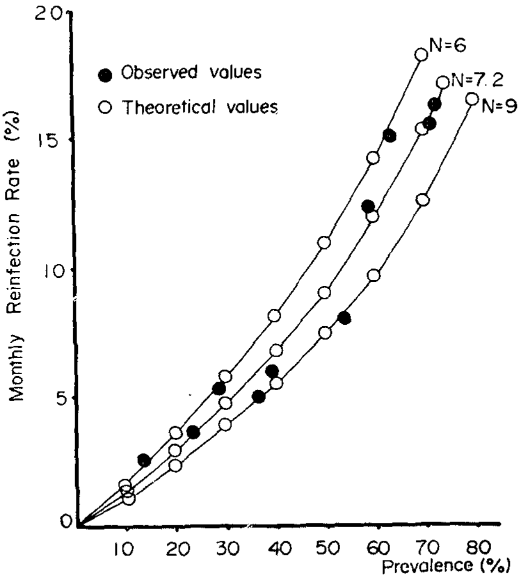

Fig. 1. Regression curve, $Y=1-(1-X)^N$, between prevalence (Y) and monthly reinfection rate (X) of *A. lumbricoides*, where 'N' is the constant value (6, 7.2 or 9) of time in month.

The author selected 7.2 as the representative one, hence, the finally established equation between prevalence and monthly reinfection rate in the surveyed communities was, $Y=1-(1-X)^{7.2}$, which roughly means that the time needed to attain equilibrium of *A. lumbricoides* infection is about 7.2 months after one time mass chemotherapy to whole inhabitants residing in an endemic area.

DISCUSSION

It was suggested that where the prevalence and intensity of *A. lumbricoides* infection are high the incidence (frequency) of reinfection would also be high (Morishita, 1972; Seo, 1983). In practice, Matsuzaki *et al.* (1954) reported that where the prevalence was 82~92% the monthly reinfection rate was 7.3~10.2%, while where it was 36% the monthly rate was 3.3~4.8%. The above study, however, was based on repeated egg examinations after treatment and not on the worm recovery. So, there seems to have been much discrepancy between the genuine and the observed rates, since it was pointed out that there is considerably much difference in figures between egg and worm positive rates in various endemic areas surveyed (Seo *et al.*, 1979).

In the present study, all of the values of epidemiological factors such as prevalence, worm burden and reinfection rate obtained were based on the worm recovery results after mass treatment with pyrantel pamoate. The values are considered to represent the genuine ones more closely. This is due to the high therapeutic efficacy of pyrantel pamoate (95~99% in cure rate) in treatment of *A. lumbricoides* infection (Rim *et* Lim, 1972; Seo *et al.*, 1972). The reinfection rate was determined by discriminating the cases who harboured young worms among examined, because young worms mean new infections during the previous 2 months (Cho, 1977; Seo *et* Chai, 1980a). According to them, almost all worms, not only 2~30 cm young or adult worms but also even as small as 1.2~1.9 cm in length during moulting stage, were collected from two days' whole stools after treatment with pyrantel pamoate.

The clear positive correlation between prevalence and average worm burden, *i.e.*, the higher the prevalence the higher the average worm burden, agreed well to Seo *et al.* (1979) who reported that the frequency (worm burden) distribution pattern of *A. lumbricoides* in rural inhabitants was changed toward lower worm burdens by the decrease of prevalence or endemicity. On this matter, a good correlation equation was proposed by Croll *et al.* (1982) and Anderson *et* May (1982), whose studies were based on the quantitative analysis of *A. lumbricoides* infection in Iran (Arfaa *et* Ghadirian, 1977). The present data of prevalence and worm burden will be analyzed in detail in separate paper, applying the equation proposed by the above authors.

From the correlation equation obtained in the present study, $Y=(1-X)^{7.2}$ between current prevalence 'Y' and monthly reinfection rate 'X', two interesting speculations were made. The one is on the epidemiological equilibrium of *A. lumbricoides* infection and another on the life span of worms in human host.

The value 'N', 7.2 in the equation, means that if the inhabitants in the surveyed areas are completely treated with an excellent drug such as pyrantel pamoate but reinfection continue thereafter, the prevalence of *A. lumbricoides* infection observed in this study will be attained after 7~8 months. So, if the point prevalence represents roughly the equilibrium state, the period 7~8 months, is considered the time required from one time mass treatment to return of the prevalence, *i.e.*, equilibrium of infection.

So far as the equation is concerned, the prevalence seems to increase continuously after reaching equilibrium because reinfection is persistent (Fig. 2A). However, it is practically not probable. It is suggested that while newly reinfected worms continue to grow, those as old as 7~8 months spontaneously expell, to

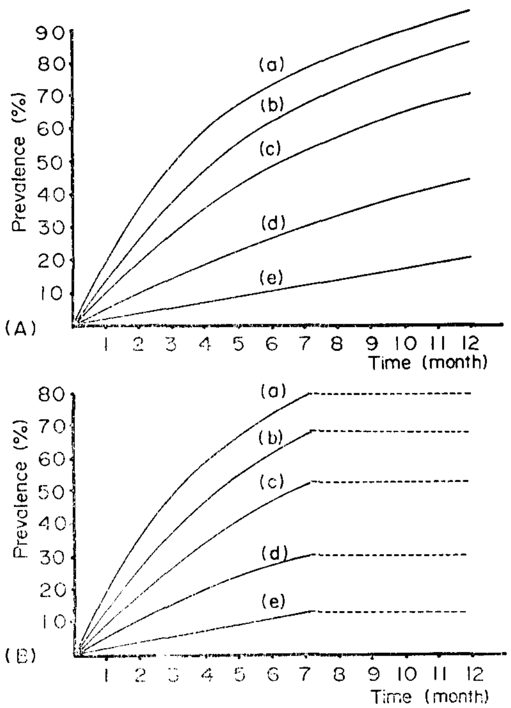

Fig. 2. Time-prevalence curves when monthly reinfection rates are variable. The equation is $Y=1-(1-X)^N$, where 'Y' is the prevalence and 'N' is time in month. (A) Continuous elevation of prevalence so far as the equation is concerned, (B) Suggested feature of maintenance of equilibrium in prevalence after 7~8 months. (a) when monthly reinfection rate (X) is 20%, (b) $X=15\%$, (c) $X=10\%$, (d) $X=5\%$ and (e) $X=2\%$.

maintain the prevalence within a certain range (equilibrium) (Fig. 2B). In other words, the period of 7~8 months may be related with the average life span of *A. lumbricoides.*

No exact information is available on the life span of this worm in human host. In textbooks, the life span varies according to the observers, from 9 months to a year (Chandler *et* Reed, 1981) or from 12 to 18 months (Brown *et* Neva, 1983). It was stated by Otto (1930) that there may be almost a complete turn-over of the worms each year. And Pan *et al.* (1954) also speculated that the life span may be considerably shorter than a year, since the egg production rate and amount which continued to increase after one time mass chemotherapy abruptly dropped after 6 months. The distribution pattern of the ages of worms collected from human, which were calculated from the chronological length growth curve (Seo *et* Chai, 1980a), revealed the majority of both male and female worms were younger than 250 days of age (Chai, 1983), which supports the speculation that the life span may be around 7~8 months. However, further study is needed to elucidate this point.

By this study, the currently applied nationwide control scheme of biannual mass chemotherapy on student group by KAPE (1982) may be justified. This interval, as a strategy of mass control, is considered much reasonable because it is shorter than the period required to attain equilibrium, until which state much more amount of eggs is produced and accumulates at surroundings. It was verified, by field study, that the schemes of mass chemotherapy at shorter intervals than 6 months, *i.e.*, bimonthly, triennial or biannual, were all effective to reduce the prevalence of *A. lumbricoides* infection, while annual scheme was entirely of no effects (Seo *et al.*, 1980; Seo *et* Chai, 1980b).

SUMMARY

The epidemiological relationship between the current prevalence and monthly reinfection rate of *Ascaris lumbricoides* was observed in rural communities in Korea by means of blanket mass chemotherapy and worm collection for measurement of the prevalence and reinfection rates. During the period from 1975 to 1980, a total of 4,466 inhabitants in 10 different localities were treated with 10 mg/kg of pyrantel pamoate and 2 days' whole stools were collected from 2,547 inhabitants. The stools were examined for the presence of expelled adult and/or young worms, which represent the prevalence and reinfection rates for past 2 months respectively. After then, the obtained rates were correlated each other applying the time-prevalence curve proposed by Hayashi.

It was observed that the prevalence (overall worm positive rate) and worm burden per individual ranged by areas from 13.6 to 72.3% and 1.4~10.2 respectively. The calculated monthly reinfection rates (X) (from young worm positive rates) according to areas were in the range, 2.6~16.2%, and clearly correlated with the current prevalence (Y) under the equation, $Y=1-(1-X)^{7.2}$ where 7.2 is time in month. The equation means that after one time mass chemotherapy the period needed to attain equilibrium of prevalence again would be about 7~8 months. And it is inferred that the majority of reinfected worms in human host turn over every 7~8 months.

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=國文抄錄=

韓國 農村地域의 蛔蟲再感染에 대한 疫學的 調査硏究

I. 現在感染率과 月再感染率의 相關關係

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(指導：徐 丙 卨 敎授)

우리나라 農村地域의 蛔蟲感染에 있어서 現在感染率(prevalence)과 月再感染率(monthly reinfection rate)의 상관관계를 알아보고자 하였다. 1975년부터 1980년까지 京畿道 華城郡 등 10個地域의 住民 總 4,466名에 대하여 蟲卵陽性여부에 관계없이 全員 pyrantel pamoate 10mg/kg을 投藥한 뒤 2,547名으로부터 投藥後 2日間의 全大便을 蒐集하였다. 蒐集된 大便으로부터 驅蟲되어 排出된 蛔蟲의 成蟲 및 幼若蟲(young worm)을 골라내고 蟲體蒐集檢査者中 蟲體陽性者 비율을 現在感染率로 표시하는 한편, 幼若蟲陽性者를 가려내어 지난 2個月동안의 누적再感染率로 표시하였다. 또 이로부터 月再感染率을 구한 뒤 現在感染率과의 상관관계를 분석하였다. 상관관계의 model은 Hayashi의 時間—感染率(time-prevalence) 관계곡선식을 응용하였다.

調査한 10個地域의 感染率 및 1人當 平均 感染量은 각각 13.6～72.3% 및 1.4～10.2의 범위에 있었고, 계산된 月再感染率은 地域에 따라 2.6～16.2%의 범위에 있었다. 感染率(Y)과 月再感染率(X)은 서로 깊은 陽性 상관관계를 나타내고 있었고, 상관곡선식은 $Y=1-(1-X)^{7.2}$로 나타났다. 數式中 數値 7.2는 이론적으로 蛔蟲感染이 一次投藥으로 完全治療된 후 다시 再感染되어 평형상태에 도달하기 위한 期間(個月)으로 해석되었다. 또, 蛔蟲이 再感染에 의해서 感染率이 지속적으로 상승하지 않고 7～8個月後 평형상태를 유지하게 된다는 것은 인체내에서 蛔蟲이 대략 7～8個月만에 새로운 蟲體에 의해서 바뀌어지고 있음을(turn over) 의미하는 것으로 생각되었다.