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Prevalence, Worm Burden and Other Epidemiological Parameters of *Ascaris lumbricoides* Infection in Rural Communities in Korea

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INTRODUCTION

Ascariasis is, even at present, one of the important helminthiases all over the world (Peters, 1978; WHO, 1981). Although its prevalence has been remarkably decreasing in Korea, greatly owing to national control activities since one or two decades ago (Seo *et al.*, 1983), the present status is not much satisfactory and further studies are needed on its epidemiology and control problems.

In the population biology and epidemiology of *Ascaris lumbricoides* infection, it is known that the parasites are distributed among host population according to negative binomial pattern (Seo *et al.*, 1979a; Croll *et al.*, 1982); a skewed, over-dispersed distribution of individual worm burdens, *i.e.*, in general the lower the worm burden the more the frequency of cases and *vice versa*. It was further suggested by Seo *et al.* (1979a) that there should be a close correlation between the prevalence and worm burden; in its average value as well as figure of negative binomial distribution. According to them, as the prevalence decreases, heavy infection cases should shift to light infections (1-4 in worm number) and light infections to uninfected, to result in a rather constant proportion of lightly infected cases. Such an epidemiological relationship between prevalence and worm burden of *A. lumbricoides* was more realistically analyzed by Croll *et al.* (1982) and Anderson *et* May (1982) with the data obtained in Iran, a hyperendemic area of ascariasis. They proposed several equations applicable to understand the relationships of epidemiological parameters such as prevalence, mean worm burden, degree of worm aggregation in host population ('$1/k$' by negative binomial index), density-dependent constraints on worm fecundity, basic reproductive rate of parasites, *etc.* According to them, those equations appeared useful for evaluation of the epidemiological status as well as the effect of control activities.

In this connection, this study was undertaken to evaluate the epidemiological status of ascariasis in several rural areas in Korea, through observation of such parameters, especially prevalence, worm burden and basic reproductive rate.

MATERIALS AND METHODS

1. Stool Examination and Worm Collection

The data from 6 villages already studied by Seo *et al.* (1979a) and from 2 villages in the present study were subjected to a detailed analysis. At first the stool specimens of inhabitants were examined qualitatively and quantitatively, and brief infection status of *A. lumbricoides* in each village was estimated.

In the next step, to count individual worm burdens including worm burden '0', a blanket mass treatment with 10 mg/kg of pyrantel pam-

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oate was performed to whole inhabitants irrespective of the results of stool examination and immediately after then their 24-hour stools were collected in vinyl envelope for 2 or 3 consecutive days. The stool specimens were carried to our laboratory and washed individually through a sieve. All of the specimens of *A. lumbricoides*, young or mature, male or female, were collected either by naked eye or under stereomicroscopy. They were fixed in 10% formalin, sexed, and counted in number by each person.

2. Mathematical Models and Parameters

The basic formula of negative binomial distribution is $(q-p)^{-k}$, where $q-p=1$. The values of parameters (p, q and k) were calculated as described by Bliss *et* Fisher (1953). In helminthic infections, 'k' means inverse measurement of the degree of worm aggregation among host population (Seo *et al.*, 1979a; Anderson *et* May, 1982).

Two basic equations proposed by Anderson *et* May (1982) were applied for the present analysis; $p=1-(1+M^*/k)^{-k}$ and $R=[M(1-z)/k+1]^k+1$, where 'p' is prevalence, 'M^*' equilibrium average worm burden, 'k' the negative binomial parameter, 'R' basic reproductive rate of parasites, and 'z' density-dependent constraints on worm fecundity.

The prevalence 'p' means the *sensu stricto* prevalence measured by recovery of worms rather than by eggs. The equilibrium worm burden 'M^*' is measured through an examination of people who had not received any of control measures including chemotherapy within a year. The basic reproductive rate 'R' denotes the average number of female offsprings produced by a female worm through its life which successfully infect other host and attain its sexual maturity. The density-dependent constraints on worm fecundity 'z' represents the degree of suppression of egg production by females when the host is heavily infected, and the value of 0.96 reported in Iran (Anderson *et* May, 1982) was adopted in this study.

RESULTS

1. Results of Stool Examination and Distribution Pattern of Worm Burdens

In 8 villages subjected, total 978 inhabitants were examined both for eggs and worms of *A. lumbricoides* (Table 1). By villages, the egg positive rate ranged from 3.3% (Kangjin; area code A) to 66.7% (Jinyang; area code H). The respective worm positive rates were in the range from 16.5% (code A) to 79.5% (code H), being 9~18% higher than the egg positive rate. The average worm burden among the examined inhabitants was also remarkably different by areas and in the range from 0.21 to 8.44.

The distribution pattern of individual worm burdens in 8 villages generally revealed a similar pattern to one another; the lower the worm burden the more its frequency of cases while the

Table 1. Studied areas and epidemiological indices for *Ascaris lumbricoides* infection

Area(Code*)	No. exam.	Egg posit. rate (%)	Worm collection results		
			No.posit.(%)	Total No. worms	Average No./inhabitant
Kangjin I(A)	91	3.3	15(16.5)	19	0.21
Namhae(B)	34	11.8	7(20.6)	10	0.29
Hwaseong(C)	540	23.9	211(39.1)	572	1.06
Macheon-dong(D)	136	40.4	79(58.1)	429	3.15
Hoengseong(E)	32	46.9	19(59.4)	74	2.31
Changheung(F)	47	46.8	29(61.7)	136	2.89
Kangjin II(G)	59	59.3	42(71.2)	321	5.44
Jinyang(H)	39	66.7	31(79.5)	329	8.44

* Data from Code C-H were the results in 1975~1979 and presented by Seo *et al.* (1979a).
Areas of Code A & B were examined in 1984~1985.

Table 2. Distribution of cases by worm burdens in each area

No. worms per case	Number of inhabitants in each area								
	A	B	C*	D*	E*	F*	G*	H*	Total
0	76	27	329	57	13	18	17	8	545
1	13	5	108	21	5	7	6	3	168
2	1	1	39	15	3	4	7	1	71
3	0	1	22	7	3	6	5	5	49
4	1	0	12	8	3	6	3	2	35
5	0	0	9	11	2	1	3	0	26
6	0	0	4	2	0	1	3	4	14
7	0	0	4	1	1	2	2	2	12
8	0	0	5	2	0	0	2	1	10
9	0	0	0	1	0	0	0	1	2
10	0	0	1	1	0	0	1	3	6
11 & over	0	0	7	10	2	2	10	9	40
Total	91	34	540	136	32	47	59	39	978

*Data were presented by Seo *et al.* (1979a)

Table 3. Negative binomial* indices for the distribution of individual worm burdens of *A. lumbricoides*

Area Code	Mean worm burden (M)	p	k**	p/q
A	0.21	0.55	0.38	0.35
B	0.29	0.55	0.53	0.36
C	1.06	2.92	0.36	0.75
D	3.15	7.95	0.40	0.89
E	2.31	4.27	0.54	0.81
F	2.89	5.77	0.50	0.85
G	5.44	13.57	0.40	0.96
H	8.44	15.57	0.54	0.94

*$(q-p)^{-k}$ distribution $(q-p=1)$

**Inverse measurement of the degree of worm aggregation in host individuals

higher the burden the less its frequency (Table 2). In areas A and B no case revealed higher worm burden than 5, while considerably many cases harboured 10 or more worms in areas C, D, E, F, G and H. The calculated values of 'k' in each village, however, were not much different one another, to be in the range of 0.38～0.54, representing approximately same degrees of worm aggregation among the inhabitants.

2. Relationships of Epidemiological Parameters

In order to assure whether the relationship between prevalence (p) and average worm burden (M^*) of *A. lumbricoides* in rural Korean villages could be expressed to be $p=1-(1+M^*/k)^{-k}$ in accordance with Anderson *et* May (1982)'s model, theoretical prevalences were calculated with known values of 'M^*' and 'k' obtained in each village, and compared with the observed ones (Table 4). The theoretical prevalences were in the range from 15.4% to 78.1% and revealed

Table 4. Theoretical prevalence (worm) and basic reproductive rate (R) according to Anderson *et* May (1982)'s model

Area Code	Mean worm burden	Worm prevalence (%)		R*
		Observed	Theoretical	
A	0.21	16.5	15.4	1.03
B	0.29	20.6	20.7	1.03
C	1.06	39.1	39.0	1.16
D	3.15	58.1	58.2	1.47
E	2.31	59.4	59.3	1.28
F	2.89	61.7	61.6	1.37
G	5.44	71.2	65.8	1.84
H	8.44	79.5	78.1	2.11
		$p>0.995$		

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

a high degree identity wtth the observed values ($p>0.995$).

As a next step, adopting 0.96 as an estimate of '*z*' (Anderson *et* May, 1982), the values of '*R*', representing the transmission potential of *A. lumbricoides*, were calculated in each village (Table 4). It was as high as 2.11 in area H where the prevalence and worm burden were remarkably high, while it was only 1.03 in areas A and B where the endemicity was relatively low.

DISCUSSION

Anderson *et* May (1982)'s equation for epidemiological parameters, such as prevalence and worm burden, of *A. lumbricoides* was highly useful for analysis of our data obtained from rural villages in Korea. The observed worm prevalences in 8 areas were almost identical with the theoretical ones obtained from their equation. It seems evident, therefore, that the prevalence, average worm burden as well as its distribution pattern among host population should be determined never incidentally but absolutely following certain biological and/or epidemiological rules.

The parameter '*R*' (basic reproductive rate) in 8 surveyed villages was calculated in the range from 1.03 up to 2.11. They are much lower values than 4.3 of Iran (Croll *et al.*, 1982). It is presumed that, in the present villages, one female *A. lumbricoides* was being succeeded by 1-2 females out of numerous eggs produced during the lifetime of the former. Epidemiologically, the value '*R*' is determined by several variables such as birth, death and/or turn-over rate of parasites in the host, and their transmission rates in the community (Croll *et al.*, 1982). The condition 'R'$=1$ defines a transmission threshold below which *A. lumbricoides* is unable to maintain itself in the human population. In other words, the threshold is a breakpoint of reinfection (Anderson *et* May, 1982).

In this context, '*R*' can be applied to determine whether control programs of ascariasis in an area should be continued or not; continued until the value of '*R*' becomes below the breakpoint. In Korea, it seems true that areas such as A and B, most recently surveyed, are nearly approaching to the breakpoint of reinfection. However, other areas where 'R' is higher than the breakpoint need further control measures. According to some workers in Korea (Yun *et al.*, 1979; Chai, 1983; Chai *et al.*, 1983), the reinfection of *A. lumbricoides* was still frequent and intense in some rural and suburban areas. In such areas, it was presumed that only about 7.2 months were required for the prevalence to return back to the previous level, due to reinfection, after a blanket mass treatment (Chai, 1983).

Another point to mention is the problem of false egg negative results in stool examination for *A. lumbricoides*. About 9-18% discrepancy was observed between the egg and worm positive rates in the present study. Such a remarkable discrepancy is a more important problem in lower endemic communities such as areas A and B in the present study, where the prevalence was only 3.3% and 11.8% by eggs while it was as high as 16.5% and 20.6% by worms, respectively. Biological reasons for such false negative results were reported either of the followings; male worm(s) infection alone, infection by immature female(s) with/without male(s), or other unknown reason (Seo *et al.*, 1979b). According to them, such cases were all light infection cases who harboured not more than 4 or 5 worms. Since general endemicity of ascariasis becomes lower in Korea, the false egg negative cases should not be overlooked, finally to eradicate successfully this nematode infection.

SUMMARY

The epidemiological status of ascariasis was analyzed in 8 rural villages in Korea, through observation of its epidemiological parameters such as prevalence, worm burden and basic reproductive rate. Total 978 inhabitants were subjected to stool examination and recovery of worms after chemotherapy with pyrantel pamoate.

The results were as follows:

1. The worm positive rate in each village was 16.5～79.5%, while the egg positive rate was 9～18% lower, 3.3～66.7%. The average worm burden (among all inhabitants) ranged from 0.21 to 8.44 by villages and the frequency of cases with each worm burden showed negative binomial distributions with 'k' values of 0.38-0.54.

2. The prevalence rates (worm) in each village was almost identical with the theoretical ones from Anderson and May's equation; $p=1-(1+M^*/k)^{-k}$, where 'p' is worm prevalence and 'M^*' equilibrium average worm burden. The basic reproductive rate 'R' was calculated from 1.03 to 2.11.

It is suggested that, although 'R' in lower endemic areas is approaching to the breakpoint of reinfection ($R=1$), control programs of ascariasis in Korea should be continued until it becomes below the level nationwidely.

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=국문초록=

한국 농촌지역의 蛔蟲 감염율, 감염량 및 疫學的 變數

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우리나라 8개 농촌지역의 蛔蟲 감염율, 감염량 및 기초산란율(basic reproductive rate)등 疫學的 變數의 상관관계를 관찰함으로써 우리나라 蛔蟲感染 실태를 분석하였다. 이들 감염율, 감염량 등은 대변검사는 물론 pyrantel pamoate투여후 蟲體 회수결과에 의해 측정하였으며 그 결과는 다음과 같다.

1. 각 조사지역의 蟲體陽性率(감염율)은 16.5~79.5%의 범위에 있었고 이것은 대변검사에 의한 蟲卵陽性率 3.3~66.7%보다 9~18%가 높은 수치이었다. 조사대상 주민의 평균 蛔蟲 感染量은 지역에 따라 0.21에서 8.44로 나타났고 개인별 감염량 분포는 'k'値가 0.38~0.54인 負二項分布(negative binomial distribution)를 보였다.

2. 이 조사에서 나타난 蟲體陽性率은 Anderson과 May의 數式 $p=1-(1+M^*/k)^{-k}$ (p : 蟲體陽性率, M^* : 평형상태의 평균 감염량)에 의해 구한 이론치와 거의 일치하여 우리나라 농촌지역의 蛔蟲感染率과 感染量의 상관관계는 이 數式에 의해 매우 정확히 표현됨을 알 수 있었다. 또 蛔蟲 암컷 1마리가 평생 산출하는 무수한 충란중 다음 숙주에 성공적으로 감염되고 성숙되는 암컷의 수를 표시하는 기초산란율(R)은 지역에 따라 1.03에서 2.11까지인 것으로 나타났다.

이상의 결과로 보아 'R'値가 1에 가까운 지역은 疫學的으로 再感染의 breakpoint에 도달하고 있는 것으로 관경되므로 蛔蟲 박멸이 매우 희망적이지만 전국적으로 'R'値가 1이하로 될 때까지 우리나라 蛔蟲管理事業은 계속되어야 할 것으로 생각된다.