[Jap. J. Parasit., Vol. 19, No. 5, 508-522, 1970]

Studies on endemic hookworm : 1. Survey and longitudinal observation in Taiwan

HSIEN-CHEN HSIEH

Department of Parasitology, Kaohsiung Medical College, Taiwan Republic of China

(Received for publication ; August 18, 1970)

Introducion

About 21% of the world population was estimated to be infected with hookworm by Stoll (1947). Despite numerous investigations on hookworm which have been made, there is a great gap in our understanding of the natural history of endemic hookworm in man. Therefore, the author in association with Dr. N. R. Stoll, Professor Emeritus (Parasitology) of The Rockefeller University in New York, and other co-workers, has made inquiries into this subject in Liberia, West Africa, since 1964. For comparison, another study on endemic hookworm was undertaken by the author in Taiwan from 1965 to January 1969. This paper gives the results of these studies together with hookworm data gathered during the course of the study on Taiwan ascariasis control financially supported by the World Health Organization.

Background Information on Hookworm in Taiwan

In Taiwan Nagano (1910) firstly described the endemic status of *Ancylostoma duodenale*. Ōi (1915) later reported the presence of *Necator americanus*. S. Yokogawa & Nishigori (1927) reported the third species of hookworm infective to man from cats. They referred to the species as "*A. braziliense* (*A. ceylanicum*)" in the first report. Apparently *A. ceylanicum* was then treated as the synonym of *A. braziliense*. When S. Yokogawa (1928) re-described this species, he referred to it as "*A. braziliene*". Huang *et al.* (1957) reported 67% of *A. braziliense* in 290 stray dogs examined in northern Taiwan. However, M. Yokogawa & Hsieh (1961) reported a case of *A. ceylanicum* infection directly from man in south Taiwan. In the same article, they critically reviewed the previous reports concerning *A. braziliense* infections in man in Taiwan, Ryukyu (Okinawa) and Japan and stated that *A. ceylanicum* is more appropriate name than *A. braziliense* for the species reported by Yokogawa & Nishigori (1927) and Yokogawa (1928).

Yoshida *et al.* (1968) reported more human infections of *A. ceylanicum*. As to the relative prevalence of two common species, Hsieh *et al.* (1965 c) reported that *A. duodenale* predominates over *N. americanus* by simple test-tube culture method. The highest prevalence of *A. duodenale* and *N. americanus* infections in their series reached 88% and 63% respectively and the majority of *N. americanus* infections were found in association with *A. duodenale*. Hsieh (1965 a, b) also reviewed available publications on hookworm in Taiwan and discussed hookworm prevalence together with his own unpublished survey record. He concluded that the hookworm prevalence is high in most of the rural areas but is usually below 10% in the municipal center, Peng-hu Hsien (Pescadores) and other off-shore islands, and in the mountainous areas of 1,000 meters or more above the sea level.

Hookworm intensity has been estimated

This study was undertaken with research grants kindly awarded by the World Health Organization.

among Taiwanese soldiers by Frick *et al.* (1956); among coal-miners by Huang *et al.* (1958); among school children by Chiu & Kao (1958), Huang *et al.* (1965), Hsieh (1965b), Tseng (1963), and Chen (1964); and among village people in different age groups by Hsieh (1965a). The mean EPG (egg-count per ml or gram of feces) obtained by Hsieh (1965b) in the rural villages in South Taiwan was as the follow: a) below 1,000 for school children, b) from 2,293 to 2,904 for men and from 1,719 to 2,616 for women, and c) 3,000 of more for about 9% of the rural population of all ages.

Hsieh (1965a) estimated hookworm population among 10,843 people according to age group and sex in Jenwu Hsiang and its vicinity in the Kaohsiung area in South Taiwan. The result gave, on the average, 17 hookworms (estimation based on 63 EPG per worm) to every person investigated. The number of hookworms in each age group significantly varied. Only 319 or 0.2% of the total hookworm population were in the age groups under five years although this age group consisted of 17% of the total human population in the area. The 46.3% of the total human population was under 15 years and they harboured 12.6% of the total hookworm population. However, the adult age groups consisting 53.7% of the total human population carried 87.4% of the total hookworm population.

Study Area

The study area is located at the rural section of the Nan-tzu District and Niao-sung Hsiang in the Kaohsiung area in Taiwan. The inhabitants are indigenous and engaged in agriculture. The paddy rice is grown twice from January to April and from June to September. Many kinds of vegetables are grown all the year around but the area of vegetable gardens varies by season. Between the Spring and Autumn rice cultivation seasons; peas, beans, peanuts, cucumbers, and other vegetables are widely cultivated. Sugarcane and sweet potatoes are also popularly planted. Chemical fertilizers are generally used for the rice plantation, but the nightsoil of man and domestic animals is used as fertilizers especially for vegetables and sweet potatoes etc. The water supply system and latrine-construction are generally inadequate. Promiscuous defecation of people, especially children, around premises is not uncommon. Irrigation canals and ditches run from large streams to rice-fields and vegetable gardens.

Table 1 Monthly rainfall, rainy days, relative humidity, and mean monthly temperature at Chiao-tou, the nearest weather station of the study area, 1960-1964

Month	Rainfall (mm)	Rainy days	Relative humidity (%)	Temperature (°C)		
				Mean	Max.	Min.
January	8	5	82	16.3	23.4	10.8
February	5	4	83	18.0	25.1	12.5
March	65	5	84	20.9	27.3	15.8
April	36	5	85	24.2	29.2	19.6
May	50	6	85	26.8	32.0	22.4
June	320	17	90	26.9	31.2	23.4
July	326	15	91	26.7	31.6	23.3
August	491	19	91	26.7	31.6	23.5
September	161	13	91	26.9	31.7	23.6
October	20	4	87	24.9	31.0	20.4
November	9	2	87	22.5	29.1	17.6
December	5	2	83	18.9	25.8	13.3

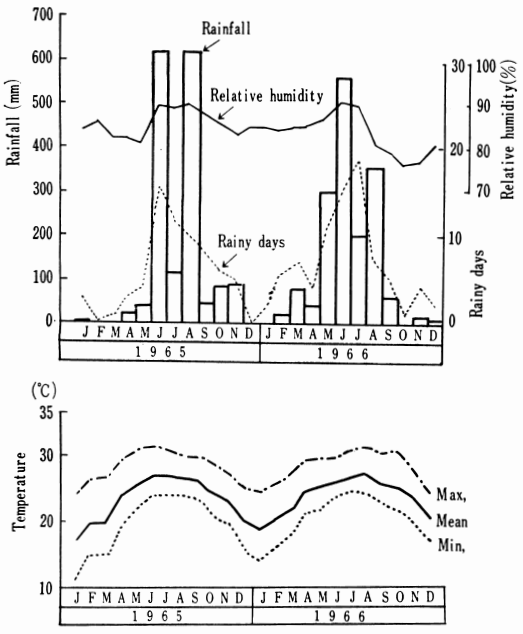

Fig. 1 Monthly rainfall, rainy days, relative humidity, and temperature at Chiao-tou, nearest weather station of the study area, 1965-1966.

Therefore the degree of wetness on cultivated lands is not always related to the amount of the rainfall in the area. The annual rainfall reached 1,636 mm in 1966.

The monthly climatic data for the period from January 1960 to 1966 were obtained from a nearest weather station at Chiao-tou. The summary of climatic data from 1960 to 1964 was given in Table 1. The monthly climatic data for 1965 and 1966 were given in Fig. 1. In 1966, 1,419 mm or 87% of the total annual rainfall fell in the 4-month period between May and August. The months with more than 10 rainy days were May to July. Monthly relative humidity ranged from 76 to 91%. From January 1965 to December 1966, the lowest monthly mean temperature, 16.8°C, was recorded in January 1965 and the highest, 27.5°C, in August 1966.

A. lumbricoides, *T. trichiura*, and *E. vermicularis*, were often found in association with hookworm. *E. histolytica* was not very common. Malaria was very prevalent before the DDT residual house spraying program started in 1953. However, by 1965 the World Health

Table 2 The relative prevalence of *A. duodenale* (Ad) and *N. americanus* (Na) examined by simple test-tube culture method in 3,619 people, male and female, according to age group. See Fig. 2.

Age group (gear)	Population	Total exam.	Hookworm positive per cent♯					
			Total	*Na* only	*Na* & *Ad*	*Ad* only	*Na* total	*Ad* total
0- 4	823	619	15	*	3	12	3	15
5- 9	853	638	43	1	8	34	9	42
10-14	750	539	53	2	12	39	14	51
15-19	509	306	64	2	20	42	22	62
20-24	345	183	72	2	21	49	23	70
25-29	369	255	71	2	22	47	24	69
30-34	328	205	65	4	20	41	24	61
35-39	297	195	62	1	25	36	26	61
40-44	269	203	69	3	24	42	27	66
45-49	199	147	73	3	35	35	38	70
50-54	163	115	70	2	27	41	29	68
55-59	127	88	64	2	21	41	23	62
60 or more	181	126	75	5	23	29	28	52
Total	5,213	3,619	52	2	15	35	17	50

*: Less than 1 % ♯: Percentages given to nearest whole value.

Organization was able to declare the eradication of malaria from Taiwan.

Study Method

The age, sex and occupations of the village population were based on the census record kept by the local Government except those of school children which were taken from the registration book in each school.

The prevalence of *A. duodenale* and *N. americanus* was determined by simple test-tube culture method (Hsieh, 1963) and hookworm intensity was estimated by the dilution egg-counting method (Stoll, 1962). Consistency of each fecal sample was noted and the egg-counts were finally brought to "Basis F". This was done by multiplying the EPG from soft-formed specimens by one and half, from mushy specimens by two, and formed specimens by one and half, from mushy specimens by two, and from mushy-diarrhoeic specimens by 3. The diarrhoeic specimens were not used. EPG for children of 2 years or below was discounted by 75%, and for children of 3 and 4 years by 50%.

Results

Relative prevalence of *A. duodenale* and *N. americanus* in all age groups as obtained by the simple test-tube culture method is

Table 3 The relative prevalence of *A. duodenale* (Ad) and *N. americanus* (Na) examined by simple test-tube culture method in 1,760 male and 1,859 female according to age group

Age group (year)	Sex	Population	Total exam.	Hookworm positive per cent#					
				Total	*Na* only	*Na* & *Ad*	*Ad* only	*Na* total	*Ad* total
0- 4	M	430	310	15	1	3	11	4	14
	F	393	309	16	0	2	14	2	16
5- 9	M	428	319	50	1	11	38	12	49
	F	425	319	36	1	5	30	6	35
10-14	M	375	277	56	3	10	43	13	53
	F	375	262	51	2	14	35	16	49
15-19	M	268	148	66	2	19	45	21	64
	F	241	158	62	3	20	39	23	59
20-24	M	143	66	76	2	21	53	23	74
	F	202	117	69	2	21	46	23	67
25-29	M	177	116	75	1	21	53	22	74
	F	192	139	68	3	23	42	26	65
30-34	M	170	97	62	2	20	40	22	60
	F	158	108	67	6	19	42	25	61
35-39	M	150	81	59	0	21	38	21	59
	F	147	114	63	2	27	34	29	61
40-44	M	140	97	66	2	19	45	21	64
	F	129	106	72	4	28	40	32	68
45-49	M	115	83	70	0	34	36	34	70
	F	84	64	77	6	38	33	44	71
50-54	M	85	60	74	2	27	45	29	72
	F	78	55	66	2	27	37	29	64
55-59	M	62	41	61	0	15	46	15	61
	F	65	47	66	4	26	36	30	62
60 or more	M	89	65	67	5	23	39	28	62
	F	92	61	46	5	23	18	28	41
Total	M	2,632	1,760	53	1	15	37	16	52
	F	2,581	1,859	50	2	16	32	18	48

#: Percentages given to nearest whole value.

summarized in Tables 2-3 and Fig. 2.

The average prevalence of hookworm reached 52% among 3,619 peole of all ages examined; with a demonstration of 50% for *A. duodenale* and 17% for *N. americanus*. The youngest age group of 4 years or below showed the lowest prevalence. As the majority of *N. americanus* infections was concurrently infected with *A. duodenale*, the prevalence curve of *A. duodenale* was almost parallel to that of all hookworm cases. In the age group under 20 years, the prevalence of the two species rose with increase of age. However, in the latter age groups the prevalence of *A. duodenale* did not increase beyond the highest level reached in the age group of 20-24 years, although the prevalence of *N. americanus* slowly continued rising and

Table 4 The mean and the maximum EPG according to sex and age group

Age groug (year)	Sex	Population	Total exam.	EPG	
				Mean	Maximum
0- 4	M	430	252	74	3,000
	F	393	250	54	1,600
	M & F	823	502	64	3,000
5- 9	M	428	278	345	7,800
	F	425	268	255	11,550
	M & F	853	546	301	11,550
10-14	M	375	241	422	12,200
	F	375	224	391	6,075
	M & F	750	465	407	12,200
15-19	M	268	126	616	7,200
	F	241	121	756	11,000
	M & F	509	247	685	11,000
20-24	M	143	58	1,171	15,200
	F	202	103	1,248	15,600
	M & F	345	161	1,220	15,600
25-29	M	177	94	636	5,800
	F	192	116	854	5,500
	M & F	369	210	757	5,800
30-34	M	170	84	937	14,400
	F	158	98	854	9,600
	M & F	328	182	892	14,400
35-39	M	150	79	516	5,800
	F	147	97	1,058	14,600
	M & F	297	176	815	14,600
40-44	M	140	80	763	7,800
	F	129	91	642	9,400
	M & F	269	171	698	9,400
45-49	M	115	67	1,437	13,400
	F	84	49	1,488	9,600
	M & F	199	116	1,459	13,400
50-54	M	85	50	1,456	25,600
	F	78	50	1,119	20,200
	M & F	163	100	1,288	25,600
55-59	M	62	33	1,797	39,900
	F	65	36	883	7,300
	M & F	127	69	1,320	39,900
60 or more	M	89	56	1,643	16,200
	F	92	48	594	6,800
	M & F	181	104	1,159	16,200
Total	M	2,632	1,498	616	39,900
	F	2,581	1,551	595	20,200
	M & F	5,213	3,049	605	39,900

reached the highest level in the age group of 45–49 years.

On the whole, the hookworm prevalence steadily increased until the age group of 20–24 years but it appeared to be arrested in the older groups in spite of their continuous living in the endemic area where hookworm re-infection must have constantly occurred. As shown in Table 3 the prevalence in male groups appeared to be slightly higher than in female groups.

The egg-counts in all age groups are shown in Tables 4–6. The relationship of the prevalence to mean egg-counts is compared in Fig. 2. Generally, the curve of egg-counts follows that of the prevalence in each age group, increasing from the youngest, and producing a peak in the age group of 20–24 years. However, among the middle age groups from 25 to 44 years, the level of egg-counts was apparently lower than that of the young adult group. As shown in Table 5 only 6% of 3,049 people examined by the Stoll's dilution egg-counts produced 3,000 or more EPG. Table 6 shows percentages of people with different degrees of hookworm intensity by age group and sex. Hookworm infections were found in infants of 12 month or below. Among the 7 infants shown in Table 7, *A. duodenale* was the only hookworm identified by simple test-tube culture method. The egg-counts of these infants were generally low. The youngest infant with hookworm was 2-month old boy. Among these cases, the possibility of either fomite-borne infection (Loughlin & Stoll, 1947) or transmammary transmission (Stone & Girardeau, 1968) could not be excluded.

Longitudinal studies of hookworm infection were made in the following groups of schoolchildren.

A group: 143 children of from 7 to 9 years were consecutively examined once every other month from January 1965 to January 1967. A hundred and two children, or 71%, were found positive for hookworm eggs at least once in 13 examinations. The result of bi-monthly egg-counts is shown in Table 8 and Fig. 3 and relative prevalence of *A. duodenale* and *N. americanus* in Table 9.

B group: 100 children of 6 and 7 years were consecutively examined once a month from October 1965 to October 1966. Fifty-nine were found positive for hookworm eggs at least once in 13 examinations. The result of monthly egg-counts is shown in Table 10 and relative prevalence of *A. duodenale* and *N. americanus* in Table 11.

As shown in Tables 8 and 10, there was apparent seasonal variation of the egg-counts in the two groups. Not all hookworm cases did steadily increase their egg-counts month after month in spite of their continuous living in the endemic area throughout the

Table 5 Percentages and cumulative percentages of people among different degrees of hookworm infection. Percentages given to nearest whole value

EPG	Male (*1,498 persons*)		Female (*1,551 persons*)		Both sexes (*3,049 persons*)	
	%	Cumulative %	%	Cumulative %	%	Cumulative %
10,000 or more	1	1	*	*	1	1
5,000–9,999	2	3	2	2	2	3
3,000–4,999	3	6	4	6	3	6
1,000–2,999	11	17	10	16	10	16
400– 999	12	29	10	26	11	27
1– 399	17	46	15	41	16	43
0	54	100	59	100	57	100

*: Less than 1 %

Table 6 Percentages of people with different degrees of hookworm infection (EPG) by age group and sex. Percentages given to nearest whole value

Age group (year)	Sex	Total exam.	EPG						
			0	1–399	400–999	1,000–2,999	3,000–4,999	5,000–9,999	10,000 or more
0– 4	M	252	87	8	3	2	*	0	0
	F	250	85	11	2	2	0	0	0
	M & F	502	86	10	2	2	*	0	0
5– 9	M	278	59	18	12	10	1	*	0
	F	268	70	16	8	5	1	0	*
	M & F	546	64	17	10	8	1	*	*
10–14	M	241	55	19	14	10	1	0	1
	F	224	61	14	12	10	2	1	0
	M & F	465	58	17	13	10	2	*	*
15–19	M	126	50	20	11	12	4	3	0
	F	121	49	17	11	16	4	2	1
	M & F	247	50	18	11	14	4	3	*
20–24	M	58	31	24	12	23	5	3	2
	F	103	44	17	11	11	6	10	1
	M & F	161	39	20	12	15	6	7	1
25–29	M	94	35	21	24	16	3	1	0
	F	116	47	12	16	12	11	2	0
	M & F	210	41	16	20	14	8	1	0
30–34	M	84	46	21	10	16	1	4	2
	F	98	47	14	13	19	3	4	0
	M & F	182	47	18	11	17	2	4	1
35–39	M	79	54	14	13	15	3	1	0
	F	97	52	11	13	14	5	3	2
	M & F	176	53	13	12	15	4	2	1
40–44	M	80	50	16	11	11	8	4	0
	F	91	43	23	12	18	2	2	0
	M & F	171	46	20	12	14	5	3	0
45–49	M	67	36	18	13	16	6	9	2
	F	49	35	17	12	16	12	8	0
	M & F	116	35	17	13	16	9	9	1
50–54	M	50	46	12	16	16	0	6	4
	F	50	48	18	16	4	6	6	2
	M & F	100	47	15	16	10	3	6	3
55–59	M	33	46	18	12	15	6	0	3
	F	36	56	6	14	14	5	5	0
	M & F	69	51	12	13	14	6	3	1
60 or more	M	56	39	14	14	16	9	2	6
	F	48	58	15	13	8	4	2	0
	M & F	104	48	14	13	13	7	2	3
Total	M	1,498	56	17	11	11	2	2	1
	F	1,551	59	15	10	10	4	2	*
	M & F	3,049	57	16	11	10	3	2	1

*: Less than 1 %

study period. A high percentage of hookworm infection; 81% in A group (Table 8) and 86% in B group (Table 10), persistently remained at the low level of the egg-count below 1,000 EPG. It should be noted that this lightly infected group did not contribute to the marked seasonal variation of the whole group. The 8% in A group and 2% in B group produced one or two marked seasonal peaks of egg-counts 3,000 or more EPG. This small portion of severe hookworm cases eventually contributed to the seasonal

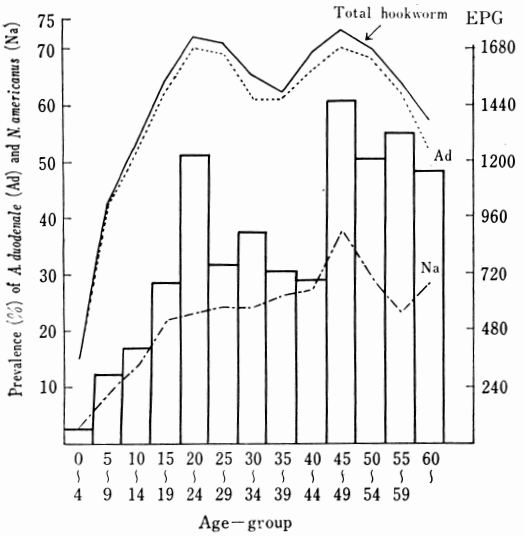

Fig. 2 The relative prevalence of *A. duodenale* (Ad) and *N. americanus* (Na) in 3,619 people, male and female, according to age-group, as determined by simple test-tube culture method. See Tables 2 & 4.

Table 7 Hookworm infections of infants examined by simple test-tube culture method in several villages, South Taiwan. Only *A. duodenale* was found

Serial No.	Village	Age (month)	Sex	EPG
13108	Ta-hua	2	Male	0
00886	Chin-fong	6	Male	450
02369	Chung-yang	7	Female	0
26016	Niao-sung	9	Female	0
00699	Ching-fong	10	Female	250
02103	Ta-hua	11	Male	0
02934	Cnung-yang	12	Male	200

variation of the egg-count in the whole group. More severe cases of hookworm infections in the two groups were found before and during the rainy season covering the period from March to September.

The variations of the prevalence and egg-counts of endemic hookworm observed according to age group in South Taiwan might be due to several complicating factors: eco-

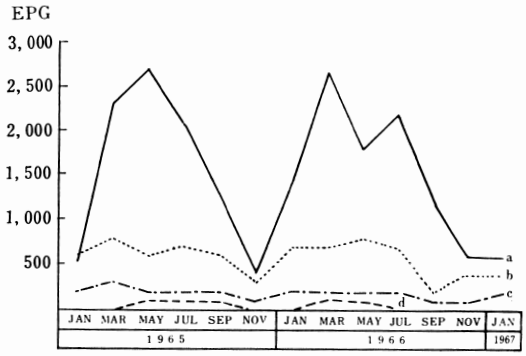

Fig. 3 The variations of 13 bi-monthly egg-counts in 4 sub-groups of hookworm infections among 143 schoolchildren. See Table 8.

logical conditions; frequency of re-infection; numbers of infective larvae to which exposed; numbers of larvae successfully invading host; the hookworm species involved; associated helminths and other diseases; duration of existing infection; nutritional status, age, and resistance or immunity of the host, and so on. Also the variations might be due to the acquisition and loss of hookworms in the host.

Discussion

WHO Expert Committee on Helminthiasis held at Rio de Janeiro in August 1963 gave the collective views on the age resistance in human hookworm infection that the maximum incidence occurs somewhere between the ages of 15 and 25, and that in the age group 0–10 years thers is a markedly lower egg output.

However, the observation made by the author in South Taiwan has revealed that there are two peaks of hookworm prevalence and egg-counts, the first peak among young adults and the second peak among old adults. The second rise in hookworm prevalence and egg-counts among old adults may not be a reflection of greatly increased exposure to hookworm larvae. The rural people of middle ages are observed to be more frequently engaged in agricultural pursuits than older ages in South Taiwan.

Table 8 The variations of 13 bi-monthly egg-counts in each degree of hookworm infections examined among 143 schoolchildren (A-group). See Fig. 3.

Sub-group	Highest egg-count reached at least once	No. of cases	% of cases in infected group#	EPG												
				1965						1966						1967
				JAN	MAR	MAY	JULY	SEPT	NOV	JAN	MAR	MAY	JULY	SEPT	NOV	JAN
a	3,000 or more	8	8	500	2,300	2,700	2,100	1,300	400	1,400	2,700	1,800	2,100	1,200	600	600
b	between 1,000-2,999	19	19	600	800	600	700	600	300	600	600	700	600	200	400	400
c	between 400- 999	37	36	200	300	200	200	200	100	200	200	200	200	100	100	200
d	below 400	38	37	0	0	100	100	100	0	0	100	100	0	0	0	0
e	0	41		0	0	0	0	0	0	0	0	0	0	0	0	0
Total	infected cases	102		238	438	407	390	284	130	316	408	376	350	199	176	180
Total	cases examined	143		170	313	290	278	203	92	226	291	268	249	142	126	128

#: Percentages given to nearest whole value.

Table 9 The bi-monthly hookworm prevalence (%), according to species, in 143 schoolchildren of A-group examined by the Stoll and simple test-tube culture methods.
Percentages given to nearest whole value

Hookworm present	1965						1966						1967	From JAN '65 to JAN '67
	JAN	MAR	MAY	JULY	SEPT	NOV	JAN	MAR	MAY	JULY	SEPT	NOV	JAN	
A. duodenale only	34	48	46	34	38	35	30	30	30	35	34	30	25	48
N. americanus only	1	0	1	0	1	0	1	4	1	0	1	2	0	0
Mixed infections	1	0	1	6	4	6	2	6	5	6	3	6	1	23
Total cases	36	48	48	40	43	41	33	40	36	41	38	38	26	71

Table 10 The variations of 13 monthly egg-counts in each degree of hookworm infections examined among 100 schoolchildren (B-group)

Sub-group	Highest egg-count reached at least once	No. of cases	% of cases in infected group#	EPG												
				1965			1966									
				OCT	NOV	DEC	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT
a	3,000 or more	1	2	100	900	900	800	400	100	100	100	4,200	1,700	1,000	200	300
b	between 1,000-2,999	8	14	300	500	500	500	500	500	500	900	900	500	400	300	400
c	between 400- 999	19	32	200	300	200	100	100	100	100	200	200	200	100	100	200
d	below 400	31	53	0	0	0	0	0	0	0	0	100	0	0	0	0
e	0	41		0	0	0	0	0	0	0	0	0	0	0	0	0
Total	infected cases	59		102	197	156	131	134	114	127	210	281	193	137	97	124
Total	cases examined	100		60	116	92	77	79	67	75	124	166	114	81	57	73

#: Percentages given to nearest whole value.

Table 11 The monthly hookworm prevalence (%), according to species, in 100 schoolchildren of B-group examined by the Stoll and simple test-tube culture methods

Hookworm present	1965			1966										From OCT '65 to OCT '66
	OCT	NOV	DEC	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	
A. duodenale only	21	22	22	22	18	20	26	22	24	22	23	23	24	41
N. americanus only	2	2	2	0	1	5	2	3	4	3	2	1	0	0
Mixed infections	5	6	2	2	7	4	3	4	6	4	5	2	4	18
Total cases	28	30	26	24	26	29	31	29	34	29	30	26	28	59

As suggested by experimental infections with nematodes in animals, the age resistance to hookworm infection in man may also be attributed to the changing physiological pattern from youth to age, involving the glycoprotein barrier, the antibody-forming mechanism, endocrine balnce and mucus production in the alimentary tract etc.

There have been divided opinions regarding the acquisition and natural loss of hookworm infection in man. Smillie (1922) considered that hookworm infection was slowly acquired and slowly lost. However Chandler (1926) believed that hookworm infection was relatively rapidly lost when reinfection did not occur. Cort *et al.* (1929) reported from their study in Panama that the group with the best sanitation showed much less rapid reinfection with hookworm about six months after treatment than the people living in houses without latrines or where the latrines were only partially in use. Caldwell & Caldwel (1931) studied the inmates of an institution where re-infection was considered impossible, and members of a rural community during a period unfavorable for infection to occur. They also kept under observation for a period of four years a case of laboratory infection, and the results were the same in all three series, that is, there was no apparent loss of infection as measured by egg counts. Payne & Payne (1931) examined three hookworm cases very frequently for periods varying from about five weeks in the shortest to three months in the longest, and they found no significant differences. Maplestone (1930, 1932) expressed his agreement with the findings of Caldwell & Caldwell (1931) and Payne & Payne (1931). Maplestone (1932) however believed from his work in Bengal, India, that there was a distinct annual variation of the egg-counts which indicated a variation in the number of worms and that this variation was in close association with the rainfall. The principal factor in limiting the amount of hookworm infection was presumably the excessive rain in the monsoon and not the dry time of the year. Maplestone (1932) raised the suggestion of Dr. W. C. Sweet of the Rockefeller Foundation that the extra worms picked up by people during the April-June period failed to become properly established. Maplestone (1932) introduced a speculation of Dr. J. B. McVail that perhaps hookworm lay more eggs during the early monsoon period than during the rest of year, but gave no proof. Chandler (1935) later added to the above discussion : "Since hookworm infections in any stable community eventually reach an equilibrium and do not markedly change from year to year, it follows that the rate of loss and acquisition of worms must proceed at approximately equal rates as soon as this equilibrium has been reached, regardless of whether the exchange of old worms for new takes place rapidly or slowly. It does not necessarily follow, however, that these rates remain the same when the equilibrium is disturbed ".

Maplestone (1930) suggested that acquisition of infection is reflected in egg-counts some six months later instead of two months. Kendrick (1934) held that a longer time than had been believed is required for hookworm to reach the height of their egg laying powers. Kendrick's experiment with ancylostomes and necators showed that eggs first appeared about three months or more after infection, and that thereafter there was a further rise until a peek was reached fifteen to eighteen months after infection. After this peak there was a rapid fall, presumed due to loss of worms rather than to a diminution in egg output.

In the endemic areas each year new infections are superimposed on old ones. There is strong evidence from experimental work on hookworm in dogs and on other nematodes, that superimposed infections are affected by the resistant forces of the host much earlier than are primary infections. It is possible (but not proven) that in superimposed infections eggs would not appear in numbers in less than three months, and it is not improbable that the falling off in egg production would occur much earlier, causing the peak to appear at six months instead of

fifteen of eighteen.

Chandler (1935) also suggested that in communities where an equilibrium has been reached there is no marked increase in egg output until about six months after reinfection has occurred and that as soon as the egg production of the new worms has reached a high point, it falls off again very rapidly, presumably, due to the host's resistance beginning to operate on the six-months'-old worms, causing their expulsion at a rapid rate.

The result and discussion of these studies in South Taiwan could be concluded as follows :

a) Among people living in the highly endemic villages of *A. duodenale* and *N. americanus*, the prevalence and egg-counts of hookworm were higher as ages increased before 20 years.

b) For those who lived continuously in the same area, the prevalence and egg-counts of hookworm in the middle age groups of men and women, were, lower than the high levels reached by the young adult groups.

c) The prevalence and egg-counts of hookworm reached the highest level among old men above 44 years. However, among old women the highest level in the age group of 45–49 years was gradually reduced in the older age groups.

d) Rising egg-counts were not maintained for months. The rapid rise of egg-counts might be due to increased worms in susceptible individuals, especially during the transmission season. The rapid falling of egg-counts, however, might be due to self-cure and protection mechanism mobilized by the host as no chemotherapeutic treatment was given to them in these study groups.

e) Variations of hookworm infections, especially changes of egg-counts may not be due entirely to environmental and other external factors. Instead either the host protective reaction or host resistance may be involved in seasonal fluctuation of the egg-counts. In the majority of hookworm cases, they may develop an effective grade, over a period of about 20 years, of host protective reaction or host resistance due to repeated infections that eliminates the excessive numbers of worms and prevents other worms from colonizing the intestine. This could serve to protect middle age people, who seemed to be more frequently exposed to the infections in South Taiwan.

f) The host resistance might be gradually raised by repeated heavy infections or/and continuous light infections. However, a second rise of the prevalence and egg-counts among people in old age groups might suggest breakdown of the host protective mechanism. The low egg-counts might then be considered to be at the stage before heavy acquisition or after the great loss of hookworm.

Summary

1. The high prevalence of human hookworm in South Taiwan was confirmed to be constituted predominantly by *A. duodenale* though *N. americanus* was often in association.

2. Adult age groups showed higher prevalence and heavier egg counts of hookworm than children. From infants to children and then to younger adults up to 20 years, there was sharp rise of the egg counts corresponding to the rising curve of the prevalence. Among adult groups 20 years or older, prevalence varied little but the egg-counts significantly fell in the middle age groups and rose again in the old age groups.

3. Hookworm prevalence and egg-counts in children of 5–9 years were shown to be increasing. Results of longitudinal studies in the same area, showed seasonal variation instead of steady rising of the egg-counts month after month in this age group.

4. Variations of the hookworm prevalence and egg-counts in the longitudinal studies were found to be due to the rapid rise and fall of hookworm in a small number of heavy infections instead of the general rising of egg-counts in each group. The possibility of host protective reaction related to the prevalence and egg-counts of hookworm was discussed.

Acknowledgements

The author is most grateful to Dr. N. R. Stoll, Professor Emeritus (Parasitology) of The Rockefeller University for his critical review and helpful comments given to this manuscript.

The author is also grateful to Dr. E. R. Chen, Associate Professor, and all members of the Department of Parasitology, Kaohsiung Medical College for their laboratory and field assistance. The continuous cooperation to this study extended by teachers of the primary schools and the officers in the Health Bureau of Kaohsiung Hsien and Kaohsiung City si greatly appreciated. This study was undertaken during the course of study on Taiwan ascariasis control which was financially supported by the World Health Organization.

References

1) Caldwell, F. C. and Caldwell, E. L. (1931) : The rate of loss of hookworms in the absence of reinfestation. J. Parasitol., 17, 209-222.
2) Chandler, A. C. (1926) : The rate of loss of hookworm in the absence of re-infection. Ind. J. Med. Res., 13, 625-634.
3) Chandler, A. C. (1935) : A review of recent work on rate of acquisition and loss of hookworm. Amer. J. Trop. Med., 15, 357-370.
4) Chen, E. R. (1964) : A study of soil-transmitted helminthic infections and health in pre-schoolchildren of rural villages in South Taiwan. J. Formosan Med. Assoc., 63, 517-531.
5) Chiu, J. K. and Kao, C. T. (1958) : The incidence of intestinal parasites among the elementary school children in Hualien prefecture, Taiwan. J. Formosan Med. Assoc., 58, 101-114.
6) Cort, W. W., Schapiro, L. and Stoll, N. R. (1929) : A study of reinfection after treatment with hookworm and *Ascaris* in two villages in Panama. Amer. J. Hyg., 10, 614-625.
7) Frick, L. P., Moon, A. P. and Lin, S. S. (1956) : Parasitologic studies in the Far East XV. A preliminary survey for parasitism in Southern Formosa. Metabolism, 5, 302-308.
8) Hsieh, H. C. (1963) : Test-tube filter-paper method for the diagnosis of *Ancylostoma duodenale*, *Necator americanus*, and *Strongyloides stercoralis*. WHO Technical Report Series, 255, 27-30.
9) Hsieh, H. C. (1965 a) : A comparative study on worm populations (hookworm, *Ascaris* and *Trichuris*) among various age-groups of rural people in South Taiwan. J. Formosan Med. Assoc., 64, 138-145.
10) Hsieh, H. C. (1965 b) : The incidence and intensity of common soil-transmitted helminthic infections in Taiwan. J. Formosan Med. Assoc., 64, 222-238.
11) Hsieh, H. C., Kuo, M. and Shih, C. C. (1965 c) : Studies on the relative prevalence of *Ancylostoma duodenale* and *Necator americanus* in Taiwan with reference to employment of test-tube filter-paper cultivation method. J. Formosan Med. Assoc., 64, 358-366.
12) Huang, W. H., Chiu, J. K. and Kao, C. T. (1957) : A survey of the endoparassite fauna of stray dogs in northern Taiwan. J. Formosan Med. Assoc., 56, 614.
13) Huang, W. H., Kao, C. T., Hsu, M. C. and Huang, C. C. (1958) : Observations on hookworm diseases among coal miners in Taiwan. II. A pre-treatment survey of intestinal parasite infections in the workers of coal miners : especially of the intensity of hookworm infection. J. Formosan Med. Assoc., 57, 710-735.
14) Huang, W. H., Chiu, J. K. and Kao, C. T. (1960) : The present status of intestinal helminthic infections among the elementary school children in the central part of Taipei, Taiwan. J. Formosan Med. Assoc., 59, 385-398.
15) Kendrick, J. F. (1934) : The length of life and the rate of loss of the hookworms, *Ancylostoma duodenale* and *Necator americanus*. Amer. J. Trop. Med. 14, 363-379.
16) Loughlin, E. H. and Stoll, N. R. (1947) : Fomite-borne ancylostomiasis. Amer. J. Hyg., 45, 191-203.
17) Maplestone, P. A. (1930) : Seasonal variation in hookworm infection. Ind. J. Med. Rer., 18, 685-698.
18) Maplestone, P. A. (1932) : Further observations on seasonal variation in hookworm infection. Ind. J. Med. Res., 19, 1145-1151.
19) Nagano, Z. (1910) : Ten years in Taiwan. Kyolinsha, Tokyo, page 317-326.
20) Ōi, T. (1915) : The intestinal parasites survey in central Taiwan. J. Formosan Med. Assoc., 154, 816-825.
21) Payne, G. C. and Payne, F. R. (1931) : Observations on rate of loss of *Necator americanus*. Amer. J. Hyg., 14, 149-155.

22) Smillie, W. G. (1922) : Studies on hookworm infection in Brazil 1918-1920. Hookworm infection slowly acquired and slowly lost. The Rockefeller Institute for Medical Research Monograph No. 17, pages 34-55.
23) Soil-Transmitted Helminths. Report of a WHO Expert Committee on Helminthiasis (1964). WHO Technical Report Series No. 277.
24) Stoll, N. R. (1947) : This wormy world. J. Parasitol., 33, 1-18.
25) Stoll, N. R. (1962) : For hookworm diagnosis is finding an egg enough? Ann. N. Y. Acad. Sci., 98, 712-724.
26) Stone, W. M. and Girardeau, M. (1968) : Transmammary passage of *Ancylostoma caninum* larvae in dogs. J. Parasitol., 54, 426-429.
27) Tseng, P. T. (1963) : Personal communication.
28) Yokogawa, S. and Nishigori, M. (1927) : On *Ancylostoma braziliense* (*A. ceylanicum*) found in Japan for the first time. Taiwan Igakkai Zasshi, 26, 1183.
29) Yokogawa, S. (1928) : The discovery in Japan of the Brazilian hookworm infesting the human body. Trans. Jap. Pathol. Soc., 18, 510-511.
30) Yokogawa, M. and Hsieh, H. C. (1961) : A critical review of human infections of *Ancylostoma braziliense* in Taiwan, Ryukyu (Okinawa) and Japan. Jap. J. Parasitol., 10, 329-335.
31) Yoshida, Y., Okamoto, K. and Chiu, J. (1968) : *Ancylostoma ceylanicum* infection in dogs, cats, and man in Taiwan. Amer. J. Trop. Med. & Hyg., 17, 378-381.

地方病性鉤虫に関する研究
1. 台湾における調査ならびに連続的観察による研究*

謝　　献　　臣
高雄医学院　寄生虫学科
中華民国　台湾省高雄市

地方病性鉤虫感染の自然発育史研究の一環として著者は1964年以来，鉤虫感染の連続観察に依る研究を熱帯アフリカのリベリヤ共和国と台湾両地で行なつた，本文は1965年から1969年1月までに南台湾で得られた連続観察と同一地方の一般調査の成績を比較考察した．

南台湾における一般調査では鉤虫の感染率は可なり高くヅビニ鉤虫の分布が優先であるがアメリカ鉤虫がしばしば混合感染することが確認された．成年層は子供よりも平均感染率ならびに平均 EPG が明らかに高い．乳児にも鉤虫感染陽性者があるが乳児から児童群，それから更に成年層と年齢が増加するにつれて平均感染率と平均 EPG は略ぼ平行して急速に増加している．20歳から上の成年層の各年齢群では平均感染率の変動は僅かであるが，25歳から44歳の約20年間の年齢群では平均 EPG は著明に減少し，45歳以後の年齢群に達して，再び増加する傾向がみられた．以上の様な鉤虫の高度浸淫地に継続居住した243名の5-9歳年齢群の学童を1乃至2年の期間にわたつて毎月又は一個月置きの連続観察を行なつたところ，毎度の平均 EPG は観察期間が延びるにつれて増大するのではなく，季節的増減のあることが認められた．然しこれは大幅な EPG の増減を示した極めて少人数に依るものであることが判明した．此の事実から地方病性鉤虫の感染率と EPG が人体宿主防御作用に関連する可能性があることを考察した．

* 本研究の一部は W.H.O 研究補助によつて行なわれた．記して謝す．