RELATIONSHIP OF INTESTINAL PARASITES TO THE ENVIRONMENT AND TO BEHAVIORAL FACTORS IN CHILDREN IN THE BOLIKHAMXAY PROVINCE OF LAO PDR

Heio Hohmann[1], Sebastian Panzer[2], Chansy Phimpachan[3], Chanpeng Southivong[4], and Frank Peter Schelp[2]

[1]Lao-German Family Health Project, Ministry of Health, Lao PDR; [2]Department of Epidemiology, Institute of Social Medicine, Benjamin Franklin University Hospital, Free University Berlin, Germany; [3]School of Public Health, Ministry of Health, Vientiane, Lao PDR; [4]Council of Medical Sciences, Ministry of Health, Vientiane, Lao PDR

Abstract. From March to July 1998 the infection rates of 732 children aged below 15 years were assessed. The investigation was conducted in selected villages of the Bolikhamxai Province in Lao PDR. Socio-economic conditions and behavioral pattern were studied. The three soil-transmitted helminths, *Ascaris lumbricoides*, *Trichuris trichiura* and hookworm were found with prevalence rates of 67.14, 17.49 and 12.83%, respectively. Infection rates with other intestinal parasites were negligible. Of the children investigated, 56.7% harbored one and 20.45% more than one parasite. Except for hookworms, no statistically significant differences were found between genders. The probability of being infected with *A. lumbricoides* is associated with living in mountainous areas. For hookworms, infection is associated with staying in the plains. A river in the vicinity of the village is linked with the probability of being infested with *Trichuris trichiura*. Not to belong to a family with the ability to own expensive items increases the probability by almost two times of getting infested with *A. lumbricoides*. Unhygienic behavioral factors were important in increasing the probability of suffering from *A. lumbricoides* and *T. trichiura* infection. Behavioral factors did not seem to be related to hookworm infections. It was concluded that after mass treatment, besides promoting the construction of toilets, it is also important to improve personal hygiene so that a lasting impact on the infection rate of the most prevalent parasites in Lao PDR could be achieved. Measures to control parasitic infections do not have to be postponed until a marked improvement of the economic situation has occurred.

INTRODUCTION

The soil-transmitted helminths *Ascaris lumbricoides*, *Trichuris trichiura* and hookworms are one of the most widespread health problems found in the world, especially in developing countries (Bundy *et al*, 1992; Anonymous, 1996). Control programs are required to reduce the harmful effects of infection, such as chronic under-nutrition and anemia, and public health actions should also be taken in cases of mild and moderate intestinal infections because of the serious after-effects, such as impaired learning ability, observed in primary school children infected with these parasites (Nokes and Bundy, 1992, 1993; Sakti *et al*, 1999). Within the framework of a family health project, which is a joint venture of the Ministry of Health in Lao PDR and the Provincial Health Authority of the Bolikhamxay Province and supported by funds from the Federal Ministry of Economic Co-operation and Development (BMZ), Germany, through the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) Germany, an attempt was made to investigate the parasitic infestation in the Bolikhamxay Province. Emphasis was laid on assessing the overall situation and the underlying reasons for infections so that strategies could be developed to control all the major species at the same time (Bundy and de Siva, 1998).

MATERIALS AND METHODS

Study area and population

The investigation was carried out from

March to July 1998 in three districts of the Bolikhamxay Province, located south of the capital of Lao PDR, Vientiane. The total population of the province was estimated to be 170,000. The estimated child population below 15 years of age in the three districts, namely Khamkeut, Viengthong and Pakkading was 21,000, 7,300 and 13,000, respectively. Of these, 1.6% of the children in Khamkeut, 2.1% in Viengthong and 1.4% in Pakkading were included in this investigation. The study period corresponded with the end of the dry/ hot season and the beginning of the rainy season. The villages investigated in Pakkading can be reached by car within three hours from Vientiane. They are mainly located in the lowland areas and are inhabited predominantly by the Lao Loum ethnic group. The district of Viengthong is difficult to reach and accessible only by boat during the rainy season. It is mainly located in the hilly areas. All three ethnic groups can be found in this district. The district of Khamkeut can be reached by car in approximately six hours from Vientiane and it shares a common border with Vietnam. The villages in this district are located mainly in the hilly areas and can be reached in the rainy season only with some difficulties. All three ethnic groups are present in this district as well.

Sampling and study design

Selection of villages was based on the size of the community and whether they are representative of the population in the three districts in terms of physical environment and distribution of ethnic groups within the population. Also, only the villages with not more than 200 children were selected. This was because compliance from the villagers could only be achieved if all the children in that particular village were checked for parasites. The necessary information was obtained from a foregoing community survey conducted in the whole area. From the 12 villages selected for the survey, 3 villages were from the district of Pakkading, 2 from Vienthong and 7 from Khamkeut. Feces were obtained from all the children investigated and checked for intestinal parasites, using the Kato-Katz thick smear technique (Montresor, 1998) to assess infection. Blood was taken, either from the ear lobe or from a finger prick, to measure the hemoglobin concentration using a hemoglobin color scale (Stott and Lewis, 1995). To pierce the skin, only one Feather®, blood lancet was used for each child. Consent for piercing the skin was obtained from the father or the mother of the child.

Questionnaire

A "family questionnaire", which included questions concerning the socio-economic status of the family and behavioral pattern in relation to parasitic infections, was used. The questionnaire was translated from English into Lao and then back again into English. Before it was used for the study, the questionnaire was tested first in one village. Nearly two thirds of those persons interviewed were females. Others were either the father or a close relative of the child. For this report, only a selected number of variables were chosen as proxy indicators of the economic status and the behavioral pattern of the mothers and the children. A proxy indicator was chosen for families having an above average economic status in terms of possessing relatively expensive items, such as motorbikes, multipurpose agricultural machinery ("iron buffalo"), or some electronic item. Most families in the villages raise some animals and possess the necessities of daily living. It is assumed that the relative wealth of a family possessing relatively expensive items also reflects the intellectual ability either of both parents of the child, or one of them. The person interviewed was also tested for his/her ability to read and write. Most of the villagers answering the questionnaire were women. Since illiteracy is more common in women than in men, this variable was thought not to truly reflect the family's ability to respond to the challenges of life. Variables in connection with the behavioral pattern were selected under the assumption that they serve best as proxy indicators in relation to the parasites investigated, since they reflect best personal hygiene and food

Table 1
Gender and age of children of the Bolikhamxay Province infected with soil-transmitted helminths.

	Total No.	*A. lumbricoides*[b]		*T. trichiura*[b]		Hookworms[a,b]		Monoinfection[c]		Multiinfection	
		No.	%	No.	%	No.	%	No.	%	No.	%
Male	371	242	65.23	60	16.17	57	15.36	211	56.87	76	20.49
Female	338	234	69.23	64	18.93	34	10.06	191	56.51	69	20.41
Total	709	476	67.14	124	17.49	91	12.83	402	56.7	145	20.45
Age (years)											
0-1	71	27	38.0	1	1.4	[a]	[a]	28	39.4	[a]	[a]
2-5	176	129	73.3	27	15.3	17	9.7	111	63.1	32	18.2
6-11	354	251	70.9	75	21.2	62	17.5	201	56.8	92	26.0
12-15	93	58	62.4	21	22.6	11	11.8	50	53.8	21	22.6
Total											

[a]Significant differences (df 1; p<0.035) between gender.
[b]Significant differences(df 3 p<0,000) between age groups.
[c]Significant differences for mono- and multi-infection combined (df 8 p<0,000) between age groups. Calculated by c^2 test.

Table 2
Parasitic infection rates according to districts and ethnic groups.

	Total No.	*A. lumbricoides*[a,b]		*T. trichiura*[a,c]		Hookworms[a]		Monoinfection[b]		Multiinfection	
		No.	%	No.	%	No.	%	No.	%	No.	%
District											
Pakkading	153	60	39.22	39	25.49	58	37.91	53	34.64	52	33.99
Viengthong	189	109	57.67	[a]	[a]	26	13.76	107	56.61	15	7.94
Khamkeut	307	307	83.65	85	23.16	7	1.91	242	65.94	78	21.25
Ethnic groups											
Lao Loum	557	387	69.48	111	19.93	66	11.85	327	58.71	118	21.18
Lao Sung	119	60	50.42	[a]	[a]	21	17.65	61	51.26	11	9.24
Lao Thueng	33	29	87.88	13	39.39	4	12.12	14	42.42	16	48.48

[a]Significant differences (df 2; p<0,000) between districts. [b]Significant differences (df 4 p<0,000) for mono- and multi-infection combined (df 4 p<0,000) between districts and ethnic groups. [c]Significant differences (df 2 p<0,000) between ethnic groups. Calculated by c^2 test.

handling, *ie* washing vegetables before eating, washing hands before eating and after defecation, and cleaning after defecation.

Statistical evaluation

The software programs Minitab (State College, PA, Release 12.2), SPSS (Release 9.0) and BMDP (University of California, Release 7) were used for computing. Tables 1-4 present the results of the investigation in

Table 3
Probability of children becoming infected with different soil-transmitted helminths to be anemic.

	OR	95% CI
A. lumbricoides	1.94	1.41-2.68
T. trichiura	2.15	1.39-3.32
Hookworms	1.23[a]	0.77-1.94[a]
All infections	2.58	1.80-3.70

[a]95% CI includes 1, no statistically significant difference between infected and non-infected individuals.

Table 4
Proportion of children living in different environments and having particular behavioral patterns.

	Total no.	No.	%
Village location	709		
Plain		321	45.28
Mountainous		388	54.72
River in 200 m vicinity		414	58.39
Possession of expensive item[a]	649		
Yes (0)		234	36.06
No (1)		415	63.94
Washing vegetables	702		
Often (0)		487	69.37
Sometimes (1)		215	30.63
Behavior of child			
Washing hands before eating	703		
Always (0)		320	45.52
Sometimes or never (1)		383	54.48
Washing hands after defecation	707		
Always (0)		190	26.87
Sometimes or never (1)		517	73.13
Cleaning after defecation	709		
Water (0)		62	8.74
Stick, coconut shells, paper etc (1)		647	91.26

[a]Motorbike, multipurpose agricultural machinery ("iron buffalo"), television set, radio etc.

Table 5
Univariate probability[a] of becoming infected due to environmental and behavioral factors.

	A. lumbricoides		*T. trichiura*		Hookworms		All infections	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Sex	0.83	0.61-1.14	0.83	0.56-1.22	1.62[b]	1.03-2.55[b]	1.02	0.72-1.45
Plain	[a]	[a]	[a]	[a]	2.96[b]	1.85-4.74[b]	0.97	0.69-1.39
Mountainous	1.65[b]	1.21-2.27[b]	1.38	0.93-2.06	[a]	[a]	1.02	0.72-1.45
River	[a]	[a]	1.62[b]	1.08-2.45[b]	2.85[b]	1.69-4.79[b]	0.96	0.67-1.36
Possession	1.91[b]	1.37-2.67[b]	1.02	0.67-1.53	0.92	0.58-1.45	1.49[b]	1.03-2.15[b]
Washing vegetables	2.44[b]	1.67-3.57[b]	1.92[b]	1.29-2.86[b]	0.34[b]	0.17-0.63[b]	2.18[b]	1.42-3.36[b]
Washing hands before eating	2.95[b]	2.10-4.17[b]	2.87[b]	1.65-5.00[b]	0.59[b]	0.37-0.94[b]	3.34[b]	2.31-4.84[b]
Washing hands after defecation	2.99[b]	2.15-4.14[b]	1.40	0.94-2.08	0.27[b]	0.16-0.44[b]	2.25[b]	1.57-3.23[b]
Cleaning after defecation	3.67[b]	2.14-6.28[b]	2.57[b]	1.01-6.55[b]	2.25	0.80-6.36	4.24[b]	2.49-7.23[b]
Anemic	1.94	1.41-2.68	2.15	1.39-3.32	1.23	0.77-1.94	2.58	1.80-3.70[b]

[a]Exposed=1; unexposed=0 (see Table 3);
[b]95% CI not includes 1, statistically significant difference between infected and non-infected individuals.

Table 6
Final model of a step forward logistic regression with the dependent variable *A. lumbricoides*.

Independent variable	Rank	R^2 after inclusion	Wald statistics	Significant level	OR	95% CI
Mountainous	4	0.178	10.3700	0.0013	1.83	1.27-2.64
Possession	2	0.123	19.4029	0.0000	2.35	1.61-3.44
Age	6	0.203	5.6989	0.0170	1.34	1.05-1.71
Washing hands after defecation	5	0.193	8.8361	0.0030	2.03	1.27-3.25
Washing hands before eating	1	0.082	16.6737	0.0000	2.50	1.61-3.89
Cleaning after defecation	3	0.161	4.2836	0.0385	2.08	1.04-4.14

Table 7
Final model of a step forward logistic regression with the dependent variable *T. trichiura*.

Independent variable	Rank	R^2 after inclusion	Wald statistics	Significant level	OR	95% CI
River	3	0.131	19.9238	0.0000	2.81	1.79-4.43
Washing vegetables	4	0.150	8.6249	0.0033	2.01	1.26-3.19
Age	2	0.092	18.8573	0.0000	1.86	1.40-2.45
Washing hands after defecation	1	0.048	15.5923	0.0001	3.37	1.84-6.16

Table 8
Final model of a step forward logistic regression with the dependent variable hookworms.

Independent variable	Rank	R^2 after inclusion	Wald statistics	Significant level	OR	95% CI
Plain	1	0.087	47.4970	0.0000	6.62	3.87-11.34
Rivers	2	0.205	28.5354	0.0000	5.12	2.81-9.33
Male	5	0.269	5.5409	0.0331	1.75	1.04-2.92
Washing hands before eating	3	0.234	11.8564	0.0006	0.39	0.23-0.67
Cleaning after defecation	4	0.258	7.1620	0.0074	5.56	1.58-19.53

the form of simple proportions. For an univariate risk assessment, the conventional odds ratio with 95% confidence interval (CI) was calculated. To assess in greater detail the importance of the various independent variables, models were computed by applying a step forward logistic regression for the three parasites in question (Hosmer and Lemeshow, 1989) (Tables 6-8) and a cumulative forward polychotomous logistic regression with mono- and multi-infections (McCullagh, 1980) (Table 9). Conventionally, age and gender have to be added to the models together with the variables listed in Table 4. As far as the physical environment was concerned, for *A. lumbricoides,* only mountainous areas, for *T. trichiura*, only the variable "river in vicinity of village", and for hookworms, the two variables of the physical environment, *ie* "plains" and "river in vicinity of village" were added to the model. Tables 6 to 8 give the final model and the rank of inclusion into the model for the given variable. The Wald statistics is achieved conventionally by the formula, which considers the probability of infection divided by the probability of not being infected and the standard deviation. The

Table 9
Final model of a step forward logistic regression with the dependent variable taking all infections into consideration.

Independent variable	Rank	Wald statistics	Significant level	OR	95% CI
River	4	13.2026	0.0002	1.8	1.3-2.4
Washing vegetables	5	4.1459	0.0418	1.4	1.0-2.0
Possession	3	16.0400	0.0001	1.9	1.4-2.6
Age (years)	1		0.0000		
2-4		41.9640		6.8	3.8-12.0
5-11		67.4035		10.0	5.8-17.0
12-15		44.1504		9.1	4.7-17.0
Washing hands after defecation	2	33.2795	0.0000	3.2	2.1-4.7

tables also give the significant level for each independent variable, as well as the odds ratio with the 95% CI for the final model. In Table 6 to 8 the Nagelkerke R^2 at the time a given variable entered the model is listed. The R^2 gives an impression of how the model at the given stage fits the dependent variable. However, this has to be interpreted carefully, since the computation assumes a linear relationship between independent and dependent variable, which is not true for age for the models calculated here.

The study was approved by the Ministry of Health in Lao PDR and the provincial health authorities. All persons found infected were treated.

RESULTS

From a total of 732 children, only 23 (3.14%) children were infected with parasites such as *Opisthorchis viverrini* (14), *Strongyloides stercoralis* (3), *Enterobius vermicularis* (2), *Giardia intestinalis* (3) and *Entamoeba histolytica* (1). These 23 children were excluded from the statistical evaluation because of the small number of individuals suffering from these parasites that are not very common in the study area. Three soil-transmitted helminths, *Ascaris lumbricoides*, *Trichuris trichiura* and hookworms were found to be the parasites with the highest prevalence. Age and gender distribution of these helminths, calculated on the basis of 709 children, are given in Table 1. The prevalence was found to be 67.14, 17.49 and 12.83% respectively The rates of mono- and multi-infection are also listed. 56.7% of the children investigated harbored one and 20.45% more than one parasite. Except for hookworms, no statistically significant differences were found between genders. The infection rate was higher in boys (15.36%) than in girls (10.06%).

Statistically significant differences in infection rates were found in relation to age for all infections given in Table 1. High rates of infection (38.0%) were found in the group of children up to one year of age, almost exclusively due to *A. lumbricoides*. When the mono- and multi-infection rates of children in the age groups of 2 - 5 and 6 - 11 years were combined, 81.3% and 82.8% of them were found to be infested with the parasite respectively. The infection rates dropped slightly to 76.4% in children in the age group of 12 to 15 years. Infection rates on a rather lower level increased steadily with age. With 17.5%, hookworms rates were found to be highest among the children in the age group of 6 to 11 years.

Infection rates according to habitat and ethnic groups are given in Table 2. Statistically significant differences were found between the three districts included in the survey. Highest overall infection rates with 87.19% were found in the predominantly mountainous district of

Khamkeut. Almost no hookworm infections were found in the children in this district. The predominant parasite in this district was *A. lumbricoides* with an infection rate of 83.65%. The overall infection rates did not differ much for the two other districts, namely Pakkading and Viengthong, with 68.63% and 64.55%, respectively. Compared to the district of Khamkeut, hookworm infections were more and infections with *A. lumbricoides* less prevalent.

The number of children found in the Lao Thueng ethnic group (33) was rather low. Almost all of them were infected with parasites. The infection rate of the Lao Loum ethnic group (almost 80%) was higher than for the Lao Sung group (60.5%).

The median hemoglobin concentration with the 95% CI was 11 g/dl, irrespective of whether the children were infected or not. The rate of anemic children was then calculated for the different age groups. As cut-off points, the following values were selected: <1year - <10g/dl; <4 years - 11g/dl; <15 years - 15g/dl. The probability of becoming anemic while suffering from parasitic infection was assessed and is given in Table 3. *A. lumbricoides* increased the probability of anemia almost two times and *T. trichiura* more than two times. Overall infection increased the probability 2.58 times.

Table 4 shows important environmental factors including the behavioral pattern of the children. The figures in brackets, standing for unexposed (0) and exposed (1), were used further for risk assessments. Slightly less than 50% of the children were investigated in villages located in the lowland areas, and slightly more than 50% in the mountainous areas. Villages in the lowlands and in the hills may be located close to a river or stream. Almost 60% of the children investigated were living in such villages.

Thirty-six percent of the children belonged to families who could afford to purchase and possess relatively expensive items, such as motorbike, multipurpose agricultural machinery ("iron buffalo"), or some electronic item.

The parents interviewed were mostly the mothers. Sixty-nine percent of the mothers claimed that they often washed the vegetables before they are prepared as salads or included in the meals. Forty-five percent of the children were said to always wash their hands before eating, while 27% always washed their hands after defecation, and 9% cleaned themselves with water after defecation.

An univariate risk assessment was calculated with gender and the environmental factors, as listed in Table 4, were calculated as independent variables and the three major parasites as dependent variables (Table 5). Boys with an odds ratio of 1.62 run a higher risk of suffering from hookworm infections than girls. The probability of becoming infected with *A. lumbricoides* was associated with living in the mountainous areas and the harboring of hookworms was associated with staying in the plains. A river in the vicinity of the village was linked with the probability of becoming infested with *Trichuris trichiura*. Not to belong to a family who can afford to own expensive items increased the probability of becoming infected with *A. lumbricoides* almost two times. Unhygienic behavioral factors were found to be important in increasing the probability of suffering from *A. lumbricoides*. The probability of harboring *T. trichiura* was not linked to washing hands before eating and to cleaning with water after defecation. Behavioral factors did not seem to be related to hookworm infections. The findings are contradictory in that unhygienic behavioral factors, such as not washing hands before eating and after defecation, appeared to protect against hookworm infection.

The final model of the forward logistic regression for *A. lumbricoides* includes all three indicators of behavioral pattern connected with personal hygiene, physical environment, and the economic proxy variable "not possessing expensive items" and "age" (Table 6). These variables explain the model to 20% (see R^2 after inclusion of the variable "age").

Infection with *T. trichiura* also seemed to be dependent on behavioral pattern, such as "not always washing vegetables before eating" and "not washing hands after defecation" (Table

7). Physical environment and "age" also play a role. All the variables together explain the model to 15%.

Contrary to *A. lumbricoides* and *T. trichiura*, the model for hookworm infection includes only the "behavioral" variable of "not cleaning after defecation", besides the physical environment, which seems to be more important for hookworm infection than for the other two parasites tested here (Table 8). As computed in this model, it is contradictory that the unhygienic behavior of eating with dirty hands prevents hookworm infection. The model as a whole explains hookworm infection to 27%.

Table 9 shows the final model for the combination of infections with only one parasite and with two or more parasites. The model includes the physical environment "river in the vicinity of the village", the proxy indicator of economic status, age, and the two variables of unhygienic behavior, *ie* "not washing hands after defecation" and "not washing vegetables before eating".

DISCUSSION

The results of this study are in line with the results obtained by other investigations on parasitic infestation, in that ascariasis, trichuriasis and hookworms are the most common parasites found in Lao PDR (Kobayashi *et al*, 1996, Siharath *et al*, 2000). The environment in mountainous areas does not seem to favor the development of hookworm larvae. The humid soil often found in the lowland areas is more favorable. Difference in temperature did not seem to be a factor, since there was little difference in the temperatures in the two areas to have an impact on the development of the larvae. One study conducted in the area of a large irrigation dam also found *Opisthorchis viverrini* infection to be of some importance (Polsena *et al*, 1991). These findings also confirm those of a study done in only two villages, one in the hills and the other in the lowland, that ascariasis was highly prevalent in the hilly areas and hookworm prevalent almost exclusively in the lowland areas and at locations close to water (Siharath *et al*, 2000). Although also this investigation cannot claim to be a representative study of parasitic infestation in children in Lao PDR, at least this investigation and other studies published previously seem to give a realistic impression on the magnitude of *A. lumbricoides* and hookworm infection. In this study, however, *T. trichiura* infection was found to be quite low in Bolikhamxay province but higher in the other investigations. Unfortunately, due to limited resources and manpower, it was not possible to assess the worm load in this study. Judged by the fact that a direct relationship between hemoglobin values and hookworm infection could not be found, at least the worm load in hookworm infection did not seem to be heavy. To a certain extent, parasitic infections seem to have an impact, probably together with other factors, on the probability of suffering from anemia associated with all three parasites in question.

The results on parasitic infestations in ethnic groups had to be carefully interpreted. The number of individuals belonging to the Lao Sung and Lao Thung ethnic groups found in the districts of Viengthong and Khamkeut were higher than in the Pakkading district. Therefore, the results for ethnic groups are confounded by the location of the villages. The physical environment seemed to be more important for the probability of becoming infected than of whether or not a child belongs to a certain ethnic group.

Besides the physical environment of the villages, behavioral factors were also closely linked to the probability of becoming infected. The variable "possession of expensive items" is supposed to be as much an indicator of the economic status of the family as well as an indicator of understanding how to preserve the wellbeing of the family and provide protection against *A. lumbricoides*. The proxy indicator "washing hands before eating", which stands for personal hygiene, determines the probability of becoming infected with ascariasis. The other two indicators of personal hygiene seem to be cofounders to some extent and go along with the variable "washing hands before eating". An indicator for confounding is the distinct difference between the odds ratio for "washing hands after defecation" and "cleaning after defecation" between the univariate risk assessment and the outcome of the model computing for *A. lumbricoides* through logistic regression. The variable "washing vegetables" was not automatically added to the model by forward logistic regression. However, it should be kept in mind that infection with *A. lumbricoides* eggs which might be ubiquitous, can occur through contaminated food, dirty hands from playing on the ground and in the dust, and after defecation (Crompton and Savioli, 1993).

Indicators of personal hygiene, age and location were also important for *T. trichiura* infections. Besides location, overall infection is related to lack of personal hygiene, "not possessing expensive items" and age.

Indicators of personal hygiene did not seem to be important for hookworm infection in the study area. Instead, the physical environment of a particular village, which is located in the plains and close to a river, increases the probability of infection. Obviously, the physical environment provides favorable conditions for the development of the larvae. It must be noted that in the villages under study practically no latrines were found. The results that those villagers having a favorable attitude towards personal hygiene have a higher probability of becoming infected with hookworm are contradictory and need to be investigated further. Hypothetically, it might be assumed that those villagers with favorable behavior towards personal hygiene also tend to defecate away from the eyes of other villagers. They are more likely to hide behind bushes and other locations frequently used by others who are more conscious of their personal hygiene to defecate than those villagers who care less about their personal hygiene. Gender differences in hookworm infection rates need to be investigated further and cannot be explained here.

The results of this study clearly indicate the importance of improving personal hygiene after mass treatment to achieve a lasting impact on infection rate of the most prevalent parasites in Lao PDR. Measures to control parasitic infections do not have to be postponed until a marked improvement of the economic situation has occurred (Schelp, 1998).

ACKNOWLEDGEMENTS

The authors would like to express their sincere gratitude to the employees of all the institutions of the Ministry of Health, who contributed to the realization of this survey, *ie* The Mother and Child Health Center; Council of Medical Sciences; School of Public Health; Mahosot Hospital; and the provincial health service of Bolikhamxay Province and the districts involved. They also would like to thank Dr Dipl Math Ekkehart Dietz for this valuable statistical suggestions and advice.

REFERENCES

Anonymous. Intestinal parasitic infections. *World Health Forum* 1996; 17: 210-11.

Bundy DAP, Hall A, Medley GF, *et al*. Evaluating measures to control intestinal parasitic infections. *World Health Stat Q* 1992; 45: 168-79.

Bundy DAP, de Silva NR. Can we de-worm this wormy world? *Br Med Bull* 1998; 54: 421-32.

Crompton DWT, Savioli L. Intestinal parasitic infections and urbanisation. *Bull WHO* 1993; 71: 1-7.

Hosmer DW, Lemeshow S. Applied logistic regression. New York: John Wiley and Son, 1989.

Kobayashi J, Vannachone B, Xeutvongsa A, *et al*. Prevalence of intestinal parasitic infection among children in two villages in Lao PDR. *Southeast Asian J Trop Med Public Health* 1996; 27: 562-5.

McCullagh P. Regression models for ordinal data. *J R Stat Soc* 1980; B42: 109-42.

Montresor A, Crompton DWT, Bundy DAP, *et al*. Guidelines for the evaluation of soil-transmitted helminthiasis and schistosomiasis at community level. WHO Geneva. *WHO/CTC/SIP/98.1*, 1998.

Nokes C, Bundy DAP. *Trichuris trichiura* infection and mental development in children. *Lancet* 1992; 339: 500.

Nokes C, Bundy DAP. Compliance and absenteeism in school children: implications for helminth control. *Trans R Soc Trop Med Hyg* 1993; 87: 148-52.

Pholsena K, Sayaseng B, Hongvanthong B, *et al*. The prevalence of helminth infection in Ban Nanin Laos. *Southeast Asian J Trop Med Public Health* 1991; 22: 137-8.

Sakti H, Nokes C, Hertanto WS, *et al*. Evidence for an association between hookworm infection and cognitive function in Indonesian school children. *Trop Med Int Health* 1999; 4: 322-34.

Schelp FP. Nutrition and infection in tropical countries - implications for public health intervention-a personal perspective. *Nutrition* 1998; 14: 217-22.

Siharath K, Soukphathai S, Thongbai, T *et al*. Control of intestinal parasitic infection – a pilot project in Lao PDR. *Southeast Asian J Trop Med Public Health* 2000; 31 (suppl 2): 41-50.

Stott GJ, Lewis SM. A simple and reliable method for estimating hemoglobin *Bull WHO* 1995; 73: 369-73.