

Water-contact patterns in relation to *Schistosoma haematobium* infection

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Water-contact observations were carried out on a population exposed to Schistosoma haematobium in a village situated on a man-made lake, Lake Volta, Ghana.

The observations were made over a period of 12 months prior to the introduction of control measures. A multiple regression analysis was performed on the results of observations on 132 individuals, with egg output as the dependent variable and various types of water-contact activity, as well as age and sex, as independent variables. In the analysis, specific activities, notably water-contact for domestic purposes and activities associated with fishermen's canoes, were found to be significantly related to schistosomiasis. Age was less important than degree of exposure as a contributory factor to variations in infection rates: the reduced intensity of infection of S. haematobium in the older age groups could be mainly due to a lower level of exposure to the cercarial population.

Water-contact studies can be a useful means of determining the principal human activities that create a high risk of exposure to schistosomiasis in areas where it is endemic (1). They also serve as a means of assessing possible reductions in human exposure to cercarial populations and subsequent worm burdens through control measures such as the installation of piped water supplies.

In the study described below, water-contact observations formed part of an investigation of different methods of schistosomiasis control on man-made lakes, which have become increasingly important as potential sources of schistosomiasis infection, thus posing new problems for developing countries. The immediate study area was Lake Volta, Ghana, where the infection rate for *Schistosoma haematobium* among the local population was high. Observations were carried out at a lakeside village about to receive a piped water supply that was expected to reduce human exposure to infection at local transmission sites. These have been followed up by a similar set of post-control observations. The objective of the study was to pinpoint those human activities involving the greatest risk of infection by *S. haematobium*, so that appropriate control strategies could be implemented.

The distribution of the infection in the area, and in the particular village under investigation, followed a pattern commonly found for *S. haematobium* elsewhere, i.e., a rise in egg output with age until the second decade of life, followed by a decline (see Fig. 5, page 424) (2).

In addition to problems of control, the study was concerned with the extent to which the distribution of infection by age was related to variations in water-contact patterns and an analysis was made of the correlation between the observed amount of water contact of 132 exposed individuals in the study village and the egg output of each individual.

MATERIALS AND METHODS

Study area

Fatem (population approximately 200) is situated on the extreme end of the Pawmpawmnya arm of Lake Volta, and is one of numerous schistosomiasis-infected hamlets scattered along the western bank of Lake Volta. The village is inhabited both by Ewe fishermen and their families, who have migrated in great numbers from the lower Volta since the Akosombo Dam was constructed in 1966, and by indigenous Krobo farmers who lived in the area prior to the creation of the lake. It is also a market town and consists of clusters of dwellings from which paths descend to the lake shore about 200 m away. At the

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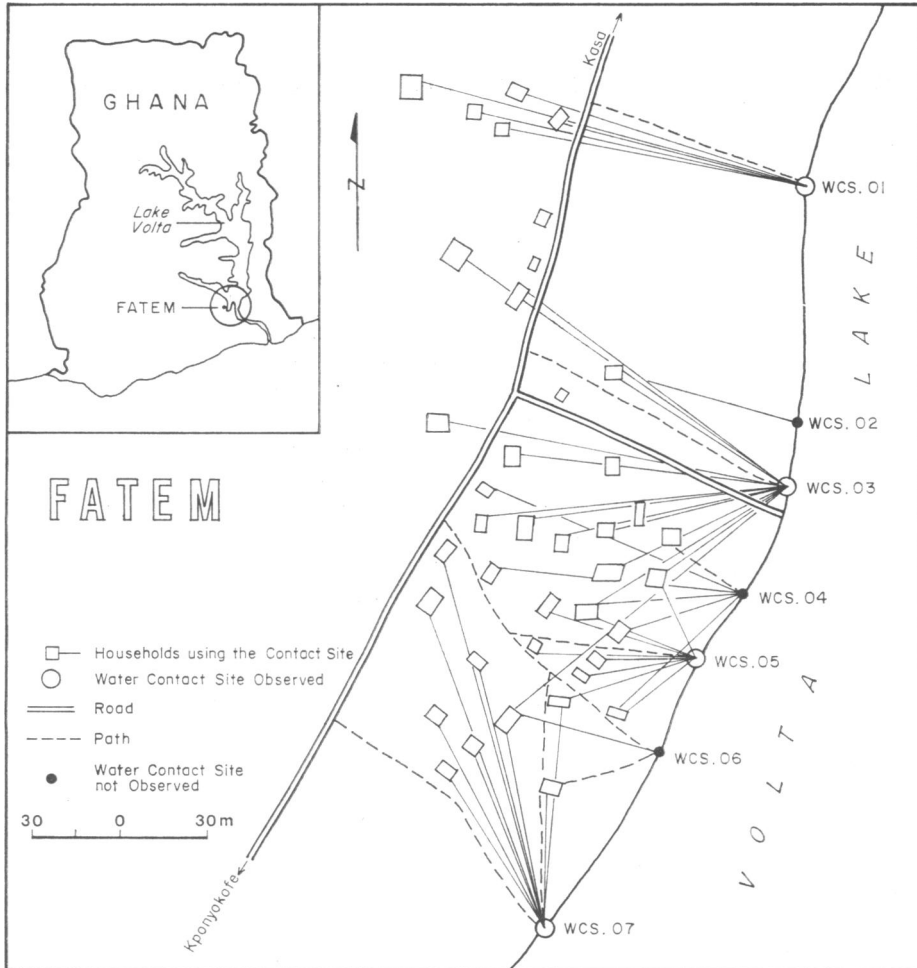


Fig. 1. The village of FATEM showing the houses in relation to the water-contact sites.

time of the study, the villagers walked down to the lake to obtain or use water for domestic and other purposes (Fig. 1). Children often played at the edge of the lake especially in and around fishermen's canoes. Most of the contact with the water (apart from bathing) consisted of standing in it up to the ankles or knees and inserting one or both arms to the elbows.

Surveys on population movements in the area revealed that, while there was a high degree of movement both within the area and between the lake and the Ewe home villages on the lower Volta, most water contact occurred at lakeside sites.

Contact during fishing was not important: biological studies by a WHO team showed that most

S. haematobium transmission was through the freshwater snail *Bulinus rohlfsi* and took place within 5 m of the shore at sites which were classified according to their physical shape and location within different zones of vegetation (3).

"Pocket-" and "channel-" shaped sites are confined by emergent vegetation and are therefore particularly favourable to cercarial transmission. "Open beach" sites, by contrast, are formed mainly during low-water periods and are relatively free from vegetation and snails.

The sites at FATEM were initially "open beach" but changed to "pocket" sites as the lake level rose. There were seven water-contact sites, four major and three minor (Fig. 1).

Experimental design

In order to reduce the effect of site and seasonal variation at Fatem a 4×4 Latin square with three replicates was used. Human water contact was observed at each of the 4 major sites for 4 days in each of 3 "seasons" of 4 months' duration. Activities were observed from 06 h 00 to 18 h 00 by local observers who were well known to the villagers. The following information was collected: name, sex, age, type of water activity, and frequency and duration of contact in minutes. The distance to which villagers waded out into the lake was also recorded.

Activities were: "domestic", i.e., taking fish home, usually from the canoes, fetching water for the household, and washing clothes and other household articles; "economic", i.e., loading or unloading the canoes, cleaning or washing them, setting up fishing gear, and selling fish from the canoes; "recreational", i.e., swimming, bathing, and playing in the lake. In addition there was a group of activities associated with the canoes berthed in and around the water contact sites. These were: "arriving in canoe", which usually involved fishermen or visitors stepping out of the canoe in shallow water before coming ashore; "departing in canoe", which involved stepping into the lake to board the canoe; "entering canoe", which largely consisted of young people stepping in and out of the canoes for no obvious purpose—it was sometimes difficult to distinguish this activity from "recreational" activity.

Observers

Activities inevitably overlapped; and difficulties occurred whenever a site became crowded. To avoid the problem, two observers were used at each site. Their accuracy was tested by random spot-checks and by comparing the relative distribution of contact by age and sex with a similar set of observations being carried out simultaneously in nearby villages. These comparisons showed a similar distribution of contacts at each site with respect to the frequency and proportion of time devoted to the various activities by sex and age group, suggesting that the performance of the observers was consistent.

Parasitology (quantitative)

Urine specimens were collected from all those present in every household in the settlement, each person being assigned a number; specimens were collected between 09 h 00 and 14 h 00. In Fatem, specimens were taken from 66% of the population

Table 1. Frequency and duration of water contacts of 132 residents of Fatem, by site

Site	Total frequency ^a	Total duration (min) ^a
S1	511 (22)	3 686 (22)
S3	689 (30)	5 074 (30)
S5	538 (23)	5 277 (31)
S7	591 (25)	2 871 (17)
Total	2 329 (100)	16 908 (100)

^a Figures in parentheses indicate percentage of total.

resident in the village at the time of the parasitology survey.

A 5-ml sample of urine taken after thorough mixing was introduced into a universal bottle containing a similar amount of 1% aqueous solution of carbol fuchsin and filtered. To facilitate examination, the filter circle was covered with a graticule and examined for the presence of *S. haematobium* ova.

The parasitological results used in the analysis described below were obtained 2–3 months before the water-contact observations began.

RESULTS

An analysis of the results of the observations over 12 months shows that daily and seasonal variations in the frequency and duration of water contact by humans were not significant. Much more important were the differences between the sites frequented, the frequency and duration of contact for different types of activity, and variations by sex and age. A discussion of each factor separately will be followed by a multiple regression analysis to determine primary relationships between types of contact and the degree of infection.

Site variation

Site 3 was the most popular water-contact site, being used more than all the others and providing nearly a third of the number and total duration of contacts. It was also an important secondary site for many residents, since fishermen berthed their canoes there, especially on market days, and crowds, including many visitors, gathered round the boats to buy fish. Site 5, the next most important site, was frequented by people from nearby households (see Table 1 and Fig. 1).

Table 2. Frequency and duration of water contacts of 132 residents of Fatem, by sex

Sex	No. of persons observed	Total frequency ^a	Total duration (min) ^a
Male	71	1 238 (53)	10 637 (63)
Female	61	1 091 (47)	6 271 (37)
Total	132	2 329 (100)	16 908 (100)

^a Figures in parentheses indicate percentage of total.

Sex

For females the frequency of contact was slightly lower than for males, and the total duration markedly lower (Table 2).

Age

Children aged 5–9 years had the highest rates for contact with the lake (frequency as well as duration), followed by those aged 10–19 years. Contact rates were low both for frequency and for duration, among those aged 0–4 years (especially the females) and over 40 years (Table 3).

Activities

Domestic activities accounted for the highest proportion of contacts, i.e., nearly half the total frequency and a third of the total duration. The next most important activities for both frequency and total duration of contact were “entering canoe” and “recreational”. “Economic” contact was the least

Table 3. Distribution of frequency and duration of water contacts of 132 residents of Fatem, by age

Age groups (years)	No. of persons observed	Total frequency ^a	Total duration (min) ^a
0–4	25	153 (7)	1 992 (12)
5–9	33	632 (27)	6 312 (37)
10–19	18	466 (20)	3 500 (21)
20–29	21	465 (20)	2 423 (14)
30–39	21	367 (16)	1 751 (10)
> 40	14	246 (11)	930 (6)
Total	132	2 329 (100)	16 908 (100)

^a Figures in parentheses indicate percentage of total.

Table 4. Frequency and duration of water contacts of 132 Residents of Fatem, by activity

Activities	Total frequency ^a	Total duration (min) ^a
Domestic	1 113 (48)	5 518 (33)
Economic	51 (2)	782 (5)
Recreational	225 (10)	3 652 (22)
Departing canoe	131 (6)	478 (3)
Arriving canoe	381 (16)	2 173 (13)
Entering canoe	428 (18)	4 305 (25)
Total	2 329 (100)	16 908 (100)

^a Figures in parentheses indicate percentage of total.

important for frequency and “departing canoe” for total duration (Table 4).

Interaction between factors

Significant associations ($P < 0.05$) have been found between most of the variables under consideration (see Table 6).

Age and site. The two most active age groups—5–9 years and 10–19 years—were most active by both frequency and duration, at site 3. Frequentation of the four sites by the those aged 4 years and under was negligible, except at site 5 (Fig. 2).

Age and type of activity. The importance of domestic activities was again demonstrated in the analysis of activity by age. Except for those aged 0–4 years, the most important type of activity for all age groups was “domestic”. This was followed by “entering canoes” especially for those aged 5–9 years and 10–19 years. The least important types of activity by age were “economic” for those aged 0–4 years and over 40 years and “recreational” for those over 40 (Fig. 3).

Sex and activity. The most important type of activity for young females was “domestic”; for young males, however, “entering canoe” was more important and, while domestic activities accounted for a higher total duration and frequency of contact than “entering canoe”, the mean contact rate for “entering canoe” was considerably greater. Young females had frequent short contacts with the lake (mostly fetching water) whereas males spent some time playing round the canoes (see Table 5 and Fig. 4).

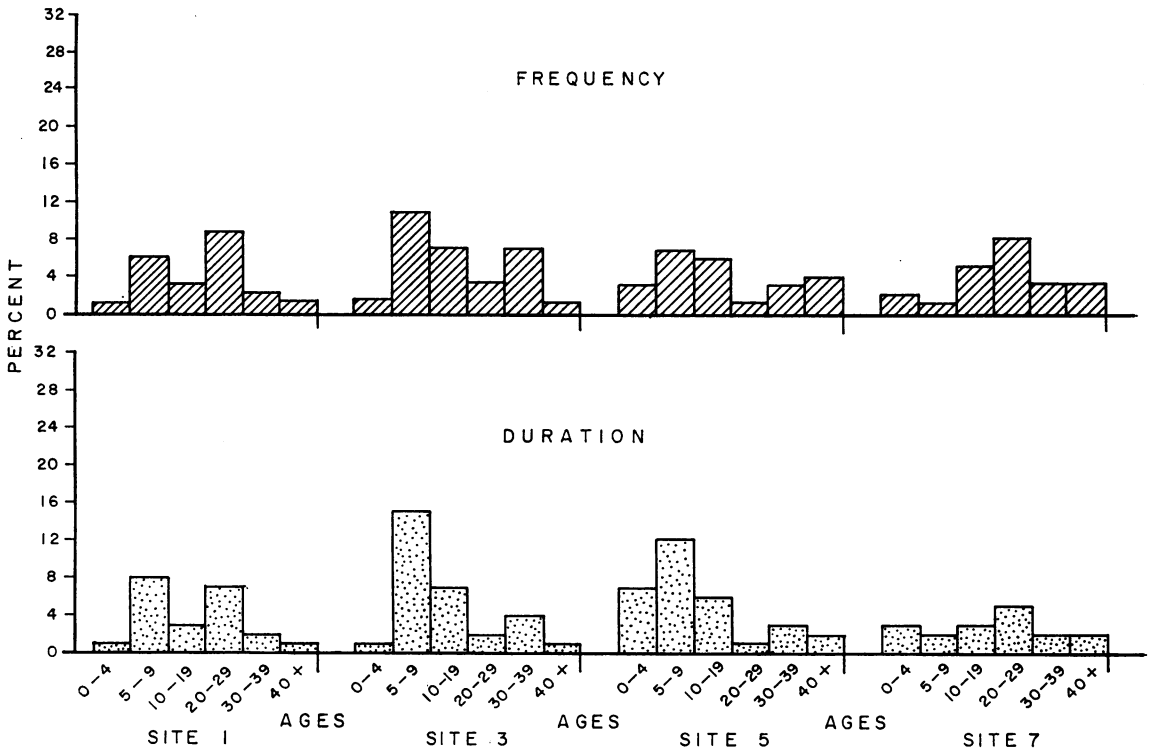


Fig. 2. The relative proportion of water contact by age at the observed water-contact sites (frequency and duration).

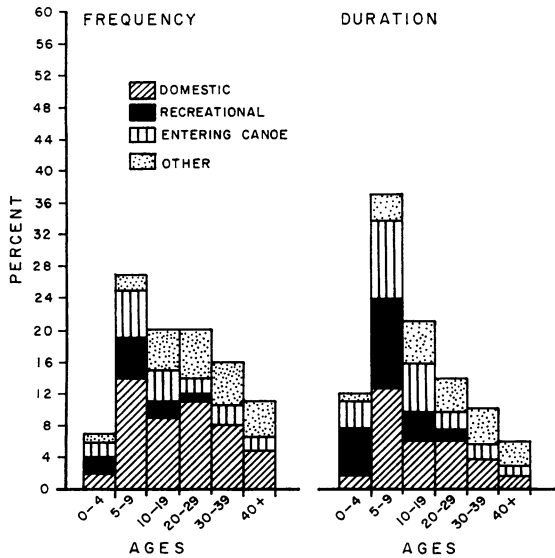


Fig. 3. The relative proportion of the different water-contact activities by age (frequency and duration). The category "other" includes "economic", "canoe departure", and "canoe arrival" activities.

Relationship of water-contact activities to egg count

There is a close correlation between water-contact activities and the intensity of infection. Table 6 gives the results of a correlation analysis of the contact

Table 5. Mean duration (min) of each water contact of 132 residents of Fatem for different activities, by age and sex

Age group (years)	Domestic		Recreational		Entering canoe		Other	
	M	F	M	F	M	F	M	F
0-4	5.0	5.0	29.5	5.3	11.1	27.2	4.7	0.0
5-9	4.9	7.8	16.2	10.6	12.7	13.7	10.7	6.2
10-19	5.5	4.7	17.0	13.6	8.6	13.3	14.9	5.1
20-29	2.7	4.2	11.1	2.5	13.5	3.5	5.2	5.1
30-39	3.2	3.9	9.3	14.5	7.0	8.1	4.5	7.4
> 40	3.5	2.6	7.1	0.0	4.3	7.0	4.1	4.7
All ages	4.6	5.0	15.0	10.3	6.7	8.6	6.1	5.6

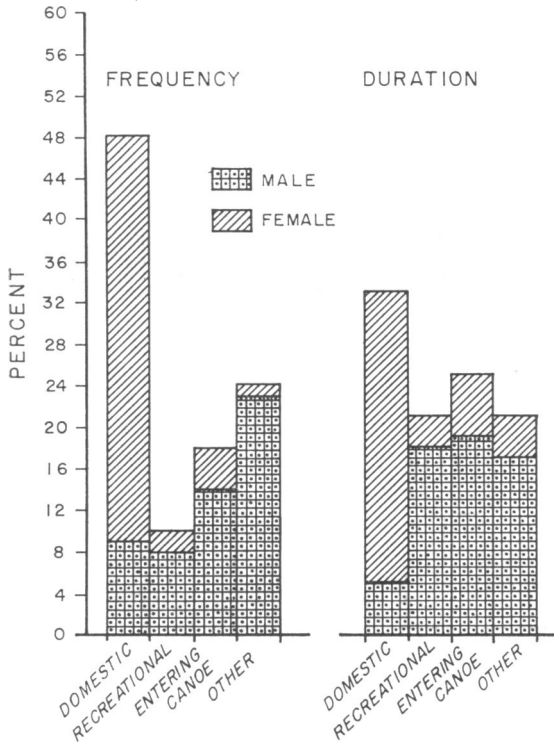


Fig. 4. The relative proportion of the different water-contact activities by sex (frequency and duration).

variables, egg output, age and sex. The correlations shown are those that are significant at the 0.05 level.

An examination of the distribution of egg excretion in a sample of 132 Fatem residents shows that the geometric mean reaches a peak among those aged 10–19 years and then declines as does the mean duration of contact. The geometric mean of egg output, except in the case of persons aged 0–4 years and over 40 years, is lower for females than for males in all age groups, and the mean duration of contact is correspondingly lower for females, except for those aged 30–39 years (Fig. 5).

Multiple regression analysis

In order to assess more closely the relationship between various types of water-contact activities, multiple regression analysis was applied. A computer programme prepared by one of the authors (DP) was used to give a multiple linear regression equation. As it provided more significant simple correlations than the actual number of eggs, the logarithm of the egg count plus one of the 132

individuals was used as the dependent variable; the various observed activities of each individual, as well as age and sex, were the independent variables. These variables were entered in the equation and the least significant contributors were removed one at a time until a model with only the most significant variables was left. The advantage of this technique is that it is possible to determine the contribution of each individual variable, while holding the contribution of the other, independent variables constant.

The final regression equation obtained was:

$$\log(\text{egg count} + 1) = 1.63 + 0.004(\text{domestic duration}) + 0.054(\text{canoe-entering frequency}) - 0.049(\text{sex}).$$

The multiple correlation coefficient was 0.28, the standard error of the estimate 0.995, and the F-test statistic 6.40, which was significant at the 0.01 probability level.

The model shows that the simplest way to predict infection from the data available is to bear in mind that it is likely to increase with the duration of domestic water contact and the frequency of contact from entering canoes and that it is more common in males even when the different contact pattern is taken into consideration. The frequency of visits to the lake for domestic purposes and the length of time spent on canoe activities were the least important factors. Age was the last of the less significant variables to be removed from the model.

DISCUSSION

It has been established that there is a definite ratio between egg output and the worm burden of the human host (4, 5). An understanding of the relationship between the egg excretion and water-contact patterns of infected individuals therefore permits an estimate of the potential worm burden of the population through a study of the human environment. In examining this relationship, water-contact studies and epidemiological studies of populations infected with schistosomiasis have brought out two significant points:

- (a) The level of water contact is usually lower for older people.
- (b) Egg output is also usually much lower for older people.

Some researchers have suggested that acquired immunity may be responsible for this lower egg output (6, 7, 8, 9). Here, there is, however, no need to postulate some mechanism such as immunity as playing a significant role in the distribution of

Table 6. Correlation coefficients between variables ^a

	Age	Egg count	Log (egg count + 1)	(D) { Frequency Duration	(E) { Frequency Duration	(R) { Frequency Duration	(CD) { Frequency Duration	(CA) { Frequency Duration	(CE) { Frequency Duration	(T) { Frequency Duration	Sex
Age	—										
Egg count	—	—									
Log (egg count + 1)	0.60	—	—								
Domestic (D)			—	{ frequency duration	—						
Economic (E)			0.79	{ frequency duration	—						
Recreational (R)	-0.27			{ frequency duration	0.91 — 0.37 0.34 —	—					
Canoe departure (CD)	-0.27			{ frequency duration	0.42 0.42 0.80 —	—					
Canoe arrival (CA)	0.34			{ frequency duration	-0.24 -0.23	—	0.52 —				
Canoe entering (CE)	0.38			{ frequency duration	-0.26 -0.24	0.26	0.83 0.47 —				
Total (T)	0.23			{ frequency duration	-0.22 -0.21	0.65 0.68 0.79 —	0.65 0.68 0.79 —	0.24 0.25 0.83 —			
Sex		0.22	0.28	{ frequency duration	0.59 0.56 0.49 0.55	0.33 0.23 0.41 0.34 —	0.33 0.23 0.41 0.34 —	0.24 0.25 0.83 —	0.24 0.25 0.83 —		
		0.25	0.25	{ frequency duration	0.62 0.58 0.48 0.55	0.30 0.30 0.30 0.30	0.30 0.30 0.30 0.30	0.34 0.26 0.60 0.45 —	0.34 0.26 0.60 0.45 —		
		-0.20	0.23	{ frequency duration	0.59 0.62 0.61 0.73	0.61 0.73	0.27	0.31 0.75 0.77 0.68 —	0.31 0.75 0.77 0.68 —		
		0.27	0.27		-0.23 -0.24 -0.44 -0.23	-0.44 -0.23 -0.49 -0.40	-0.23 -0.24 -0.44 -0.23	-0.23 -0.24 -0.44 -0.23	-0.23 -0.24 -0.44 -0.23		
		0.56	0.54								

^a Only the values for significant correlations (P < 0.01) are shown.

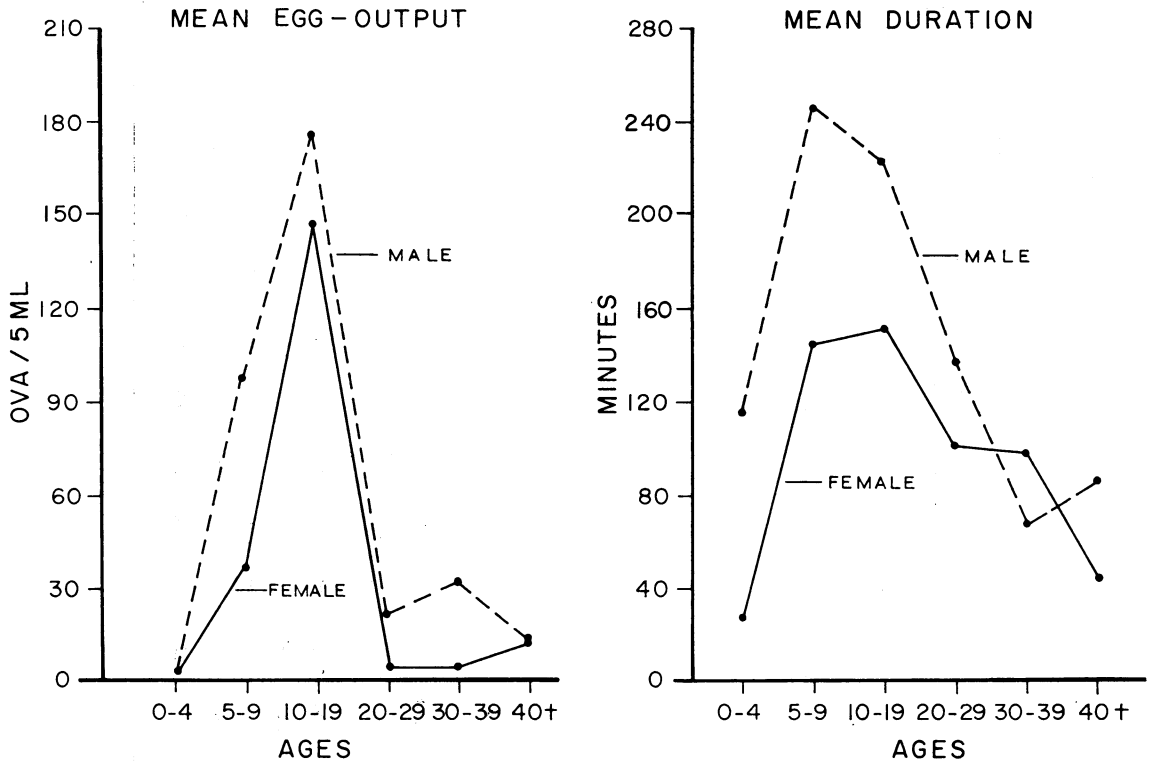


Fig. 5. The geometric mean of egg output and the arithmetic mean of the total duration of contact of a sample of 132 residents of Fatem, by age and sex.

infection by age. The reduction in egg output was closely related to a lower level of water contact for older people, thus providing a simpler explanation than that of intrinsic immunity. By observation it has also been possible to identify which human activities carried the greatest risk. Duration of domestic activities for females and "entering canoe" frequency for young males were the factors showing the highest correlation with the egg output of the exposed population.

The elimination, or reduction in intensity, of these particular activities by control measures may be the best means of reducing the output of eggs in human urine, and hence the worm burden of the population. Provision of a piped water supply would appear to be the most logical method of obviating lengthy lakeside domestic activities, especially that of fetching water—this measure would be of particular benefit to the female population.

On the other hand it probably would have little or

no effect on the activities of males round the canoes; in respect of duration these are the most important of their activities involving water contact, and it is the males who acquire the heaviest infections (Fig. 4). It is interesting to note that, overall, egg outputs are lower for young females than for young males (Fig. 5). Table 5 shows that the mean duration of each contact was higher for young males entering canoes than for females engaged in domestic activities (the most important of their activities involving water contact) so that the cercarial uptake is greater for males than for females (10, 11). Supplementary measures such as the provision of ramps to enable the fishermen to avoid the heavily infected shallow water at the lake edge and of paddling-pools for the boys should therefore be taken. In the long term, success would depend mainly on the level of community motivation, and health education should be used to reinforce measures against the activities carrying the highest risk.

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RÉSUMÉ

RELATION ENTRE DIVERS TYPES DE CONTACT AVEC L'EAU ET L'INFECTION A *SCHISTOSOMA HAEMATOBIIUM*

Des observations ayant trait au contact avec l'eau ont été faites pendant les douze mois qui ont précédé la mise en service d'un système de distribution d'eau sous canalisation dans un village de pêcheurs au bord du lac Volta (Ghana). Le taux d'infection par *Schistosoma haematobium* était élevé parmi les quelque 200 habitants du village, en particulier chez les jeunes. C'est en des points bien définis du rivage du lac, où une abondante végétation fournit un habitat au mollusque hôte intermédiaire, *Bulinus rohlfsi*, que les villageois étaient exposés à l'infection. Ils s'y rendaient à diverses fins — tâches domestiques, activités d'ordre économique ou récréatif — mais surtout pour se livrer à la pêche, qui comporte un certain nombre d'actes dans lesquels les pirogues jouent un rôle important. Celles-ci étant amarrées au point de contact avec l'eau ou à proximité, on peut simplement « monter dans la pirogue », ou bien « gagner la pirogue à partir du rivage » ou, inversement, « quitter la pirogue pour gagner le rivage ».

Pour chaque type d'activité en cause, le niveau de contact avec l'eau et le risque d'infection variaient selon le groupe d'âge. Ainsi, on observait chez les jeunes du sexe féminin une fréquence totale et une durée totale de contact à des fins domestiques relativement élevées, la

durée moyenne du contact étant cependant assez réduite. Chez les jeunes mâles, dont l'activité principale consistait à jouer autour des pirogues de pêcheurs, la fréquence totale du contact était moins élevée mais sa durée moyenne était supérieure, de même que l'excrétion d'œufs.

Une analyse à régression multiple portant sur 132 villageois, dans laquelle le logarithme du nombre d'œufs + un était la variable dépendante tandis que les résultats des observations concernant les différentes activités ainsi que l'âge et le sexe constituaient les variables indépendantes, a montré que le contact était un facteur plus important que l'âge dans l'excrétion d'œufs.

On a construit, par étapes successives, un modèle optimum dans lequel le logarithme de l'excrétion d'œufs + un présentait une corrélation maximale avec le contact à des fins domestiques, la montée dans les pirogues et le sexe.

Les théories avancées pour expliquer par l'immunité acquise la réduction de l'excrétion d'œufs dans les groupes d'âge supérieurs ont été battues en brèche par cette étude, les variations du niveau relatif d'exposition des divers groupes d'âge qui ont été notées fournissant une explication plus satisfaisante du tableau de l'infection selon l'âge.

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