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A STUDY OF THE PROPORTIONS OF SWIMMERS AMONG WELL CONTROLS AND CHILDREN WITH ENTEROVIRUS-LIKE ILLNESS SHEDDING OR NOT SHEDDING AN ENTEROVIRUS

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Children between the ages of <1 year and 15 years who visited a pediatric clinic in Madison, Wisconsin, from June 13 through September 1, 1977, were surveyed for the frequency and location of swimming they had done in the two weeks prior to the clinic visit. The study population consisted of 679 well controls, and 296 children with enteroviral-like syndromes. Throat and rectal swab specimens were collected from 241 of the ill patients and from 27 well children. Non-polio enteroviruses were recovered from 119 ill and two well individuals. Other viruses were recovered from an additional 13 ill patients. The majority of viral-like syndromes were respiratory, with or without fever and gastrointestinal symptoms. Exclusive beach swimmers had significantly ($p < 0.0005$) increased relative risk (odds ratio estimate 3.41) of enterovirus illness. The highest relative risk (10.63) of enterovirus illness occurred in children less than 4 years old who were exclusive beach swimmers. Swimming in pools exclusively carried no significantly increased risk of enterovirus illness. Children with apparent viral illnesses based on clinical findings, who had no virus isolated, did not differ from well controls in the type of swimming exposure (either beaches or pools) in the two weeks prior to their clinic visit.

bathing beaches; enterovirus infections; swimming; swimming pools; virus diseases

A series of studies in the early 1950s by Stevenson (1) and a more recent study by Cabelli et al. (2) demonstrated an appreciably greater frequency of reported illness in swimmers versus non-swimming controls. These differences were statistically significant only for gastrointestinal disorders in swimmers using waters with relatively high coliform densities. Neither study attempted etiologic diagnosis of the reported illnesses. Similarly, a recent outbreak of gastrointestinal illness in-

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volving at least 239 persons was epidemiologically linked to swimming in a lake (3). The occurrence of a high secondary attack rate suggested an infectious etiology, probably viral, but no agent was recovered from either patients or lake water. From the transient nature of the problem, sewage contamination was suspected but not documented.

Recreational water transmission of a viral agent is more solidly supported in the case of pharyngoconjunctival fever of adenovirus etiology. A number of studies (4–6) have epidemiologically linked outbreaks to swimming exposures. Virus recovery from the water was attempted in these studies but occurred some time after exposure and was unsuccessful. In two instances, however, adenovirus was isolated from lake water near a sewage outlet (7) and from a swimming pool (8) used by persons with pharyngoconjunctival fever.

In the past decade, a number of investigators have reported the isolation of non-polio enteroviruses from unpolluted beaches and pools. In three reports, group B Coxsackieviruses were isolated from wading or swimming pools (9–11). In each instance, the serotype isolated from water concurrently predominated in human infections in the same locale, but there was no evidence of definite association of the cases with exposure to the contaminated water. Similarly, in an outbreak of illness in five children, Coxsackievirus A16 was isolated from two of the children and from a sample of water from the lake in which they swam several days previously (12).

Hawley et al. (13) reported a larger outbreak at a summer camp involving 21 cases, 62 per cent of whom had Coxsackievirus B5 isolated. The same virus was recovered from a water specimen from the camp beach. Epidemiologic analysis indicated fairly clearly, however, that transmission was principally person-to-person since all but four cases clustered in one cabin.

None of these studies document enterovirus transmission via recreational water. They do indicate that recreational water not receiving sewage effluent may be contaminated by the swimmers themselves. This paper reports a case-control study in children to assess whether swimming in non-polluted beaches and pools increased the risk of acquiring enterovirus illnesses.

Materials and methods

Study area. Madison, with a population of 175,000, is the capital of the state of Wisconsin, and it contains the campus of the University of Wisconsin-Madison. The state government and the University are major employers and the general community socioeconomic status is above average and fairly homogeneous.

Three lakes lie partially or wholly within the city limits. Fourteen municipally supervised swimming beaches edging these lakes are monitored at least weekly for bacteriologic quality by the city health department. Discharge of raw or treated sewage into the lakes is prohibited, but storm sewer discharge enters the lakes as well as run-off water from surrounding farm lands. There are no municipal swimming pools but there are numerous private ones in all areas of the city.

Study population. Between June 13, 1977, and September 1, 1977, we sought the cooperation of all patients seen by two of seven pediatricians in a private group practice. Participating children or an accompanying adult completed a questionnaire to obtain 1) demographic information, 2) reason for the clinic visit, 3) prominent symptomatology in ill patients, 4) whether the child had been swimming in the two weeks prior to the clinic visit, 5) the frequency of swimming and 6) the location of swimming.

The test group from whom specimens for virus diagnosis were sought were chil-

dren with predominantly febrile illnesses of the respiratory and/or gastrointestinal tract or central nervous system, or those with undifferentiated febrile illnesses. These syndromes were judged most likely to be of enteroviral etiology. The control group consisted of 679 children attending the clinic for routine examinations, immunizations or treatment of acute minor injuries.

The term "swimmer" will be used to denote children who made at least one beach or pool visit in the two weeks preceding the clinic visit, while "non-swimmer" will be used to indicate no such beach or pool visit in the two weeks prior to the clinic visit. Questionnaire information was not sought concerning the nature and duration of recreational water contact by swimmers.

Virus isolation and identification. Pharyngeal and rectal swabs were collected from all but seven patients who had only pharyngeal specimens taken. Paired acute and convalescent sera were obtained from only 32 patients. In addition, pharyngeal and rectal swabs were collected from 27 volunteer well children who were not a representative sample.

Immediately after collection, swabs were immersed in 2.5 ml of Hanks' Balanced Salt Solution plus 0.25 per cent gelatin, penicillin G (200 units/ml) and streptomycin (100 ug/ml) and wrung out. Specimens were refrigerated until the following morning when cell cultures were inoculated.

Two tubes of Wisl (14) and HEp-2, and three tubes of primary rhesus monkey kidney cell cultures were inoculated per specimen. One tube of each cell type received 0.2 ml of specimen, the others 0.1 ml. The medium was changed after two hours and again after one week. Tubes were kept stationary, incubated at 37 C, and examined microscopically for cytopathic effect several times during a two-week period. One tube of monkey kidney cells inoculated with pharyngeal specimen was tested for hemadsorption with 0.125 ml of 0.25 per cent guinea pig erythrocyte suspension after one and two weeks of incubation. Suspected viral isolates were passed in appropriate cell cultures.

Each specimen that did not yield a viral isolate in cell culture was tested for the presence of group A Coxsackieviruses by inoculating six albino mice (HA/ICR) that were less than 24 hours old, with 0.05 ml subcutaneously and 0.02 ml intracerebrally. Mice were observed daily for two weeks for development of flaccid paralysis. Mouse isolates were not identified further.

Enterovirus- and adenovirus-like isolates were identified by neutralization tests with animal hyperimmune antisera (Microbiological Associates, Bethesda, MD), using 32–320 $TCID_{50}$ (50 per cent tissue-culture-infective doses) per 0.1 ml and 20 units of antiserum (15, 16). Type-specific antisera used in these tests included poliovirus 1–3, Coxsackievirus B1–5, and adenovirus 1–7. The identification of echoviruses and Coxsackievirus A9 was facilitated by the use of nine intersecting pools, each of which contained 6–8 type-specific antisera. "Enterovirus-like agents" were viruses untypeable by the above methods which were stable to ether and pH 3.5 treatments.

One isolate was identified as a herpes simplex type 1 virus by a direct immunofluorescence technique. Four agents could not be identified by any viral or mycoplasma identification procedures.

Serology. Acute and convalescent sera from patients with isolates were tested for serum neutralizing antibody rises to the isolated serotypes by a microtiter technique (17).

Statistical model. Tests for statistical significance utilized a log-linear model (18) for the analysis of categorical data. Data were categorized by diagnostic groups, swimming activity, sex and age. Since a case-control design was used, the

natural index in the analysis is the odds ratio of illness and swimming. That is

$$e = \left(\frac{p_I}{1 - p_I} \right) / \left(\frac{p_W}{1 - p_W} \right),$$

where e denotes the odds ratio; p_I denotes the probability of swimming among the ill; p_W denotes the probability of swimming among the well; $e = 1$ implies no relationship between swimming and illness; $e > 1$ implies a positive relationship between swimming and illness; and $e < 1$ implies a negative relationship between swimming and illness.

The first step in the analysis was to determine if there was an effect modification (19) by age and sex, that is, whether the odds ratio of swimming and illness varied by age and sex. Following this, the odds ratio was tested by the chi square method to determine if it was significantly different from 1. In a case-control study, if the frequency of illness is relatively low and exposure high in the general population, the odds ratio approximates the relative risk of illness in this case in swimmers versus non-swimmers (20).

Results

Virologic studies. During the study period, there were 296 children judged clinically to have enterovirus-like illnesses, of whom 241 (81 per cent) had specimens taken for virus culture (table 1). The predominant syndrome of the sampled group was febrile respiratory illness with or without gastrointestinal involvement. The overall isolation rate was 55 per cent (134 isolates) and the syndromes distributed about equally between those with and without isolates. Culture specimens were not obtained in 55 of the 296 children for a variety of reasons, e.g., refusal by the patient, decision of the pediatrician or scheduling difficulties. This non-sampled group did not differ notably from the sampled patients in age, sex or swimming characteristics.

Of the 134 virus isolations, 119 (90 per cent) were non-polio enteroviruses with group A Coxsackieviruses the most numerous (table 2). The 13 non-enterovirus and two poliovirus isolate patients will not be considered further in this report. Throat swab specimens were posi-

TABLE 1

The distribution of clinical syndromes among children with enterovirus-like illnesses, Madison, Wisconsin, June 13–September 1, 1977

Syndrome	Patients with virus isolated		Patients with no virus isolated		Total	
	No.	%	No.	%	No.	%
Respiratory						
Febrile	51	38	41	38	92	38
Nonfebrile	14	11	14	13	28	12
Respiratory/Gastrointestinal						
Febrile	26	19	18	17	44	18
Nonfebrile	0	–	6	5	6	2
Gastrointestinal						
Febrile	15	11	6	5	21	9
Nonfebrile	0	–	1	1	1	0.5
Undifferentiated febrile illness	26	19	18	17	44	18
Central nervous system	2	2	3	3	5	2
Total	134		107		241	

TABLE 2

Isolation results from patients with enterovirus-like illness by virus type and age groups, Madison, Wisconsin, June 13–September 1, 1977

Viruses	No. of patients with isolates			
	<1–3 years (N* = 99)	4–9 years (N = 88)	10–15 years (N = 54)	All ages (N = 241)
Group A Coxsackieviruses	21	17	7	45
Group B Coxsackieviruses	9	17	3	29
Echoviruses	20	17	2	39
Untypable enterovirus-like	6	0	0	6
Adenoviruses	3	3	2	8
Other viruses†	4	1	2	7
Total isolates (isolation rate)	63 (64)	55 (63)	16 (30)	134 (56)

* *N* = number of children sampled.

† Includes four unidentified agents, one herpes simplex type 1 virus, and two poliovirus isolates.

tive in 80 per cent of patients with enterovirus isolates and no group A Coxsackievirus was recovered exclusively from rectal swab specimens. The study population then consisted of 679 well controls, 119 ill children with enterovirus isolates and 107 ill children who were culture negative.

Paired sera were available in only 14 children with enterovirus isolates, nine of which showed a four-fold or greater rise in neutralizing antibody to the isolated serotype. Finally, two of the 27 well children sampled shed a non-polio enterovirus (these children are not included in table 2).

Swimming and illness. The group of ill children from whom an enterovirus was isolated differed in both age composition and swimming exposure from the well controls and ill children with no enterovirus isolate (table 3). Almost half of the children in the enterovirus isolate group were three years old or less, and 90 per cent were under 10 years of age. In the well controls, only 24 per cent were three years of age or under, and the largest proportion were 10 to 15 years of age. The ill children with no isolate were distributed equally among the three age groups.

There was a similar difference in the proportion of swimmers between the diagnostic categories. In each age group, the proportion of swimmers in the enterovirus isolate category was larger than in the well controls. This was particularly striking in the <1–3 year age group in which those with an isolate had a 2.5-fold greater swimming exposure than similar age controls (43 vs. 17 per cent). The ill children with no isolate had proportions of swimmers nearly the same as controls except for a higher percentage in the 10–15 years age group.

Analysis of the swimming data by type of recreational water used—pool or lake beach—revealed that the proportion of beach swimmers in the enterovirus isolate group was twice that of the controls. This difference was largest in the comparison of children <1–3 years of age in the two groups. The no isolate group was identical to the control group in the proportions of swimmers using beach, pool, or both.

This difference in exclusive beach swimming between the enterovirus isolate group and well controls was statistically highly significant (tables 4 and 5). The odds ratio (relative risk) for an enterovirus isolate beach swimmer was 3.41 and an age effect modification was evident in this group. The relative risk for the <1–3 years age category was 10.63. Pool swimmers in the enterovirus isolate group did not incur increased risk of illness from such exposure and there was no significant difference in swimming be-

TABLE 3

Age composition and proportion of swimmers among well controls and children with enterovirus-like illness shedding or not shedding an enterovirus, Madison, Wisconsin, June 13–September 1, 1977*

Diagnostic category	Age group (years)										
	<1–3			4–9			10–15			Total all ages	
	No.	% of total group	% swimmers	No	% of total group	% swimmers	No	% of total group	% swimmers	No	% swimmers
Well children	162	24	17	228	34	62	289	43	61	679	51
Enterovirus-like illness											
Children with enterovirus isolates	56	47	43	51	43	69	12	10	75	119†	57
Children with no isolate	36	34	22	33	31	61	38	36	71	107	51

* Swimmer refers to a child who made at least one visit to a swimming site in the two weeks prior to visiting the pediatric clinic.

† Fifteen children from whom viruses other than non-polio enteroviruses were recovered are not included in this tabulation.

TABLE 4

Comparison of swimming among the diagnostic categories by age and pool or beach use, Madison, Wisconsin, June 13–September 1, 1977

	Well children					Ill children with enterovirus isolates					Ill children with no isolate				
	No. by age (years)			Total no.	%	No. by age (years)			Total no.	%	No. by age (years)			Total no.	%
	<1–3	4–9	10–15			<1–3	4–9	10–15			<1–3	4–9	10–15		
No swimming	135	85	110	330	49	32	16	3	51	43	28	12	11	51	48
Exclusive pool swimming	14	75	91	180	27	4	24	5	33	27	2	11	17	30	28
Exclusive beach swimming	7	38	36	81	12	17	8	4	29	24	4	3	1	8	7
Pool and beach swimming	4	23	40	67	10	0	1	0	1	<1	2	5	8	15	14
Swimming at unknown site	2	6	8	16	2	3	2	0	5	4	0	1	1	2	2
Total				674*					119					106†	

* Five children lacked swimming information and could not be categorized.

† One child lacked swimming information and could not be categorized.

TABLE 5

Statistical analysis of pool or beach swimming by diagnostic category, Madison, Wisconsin, June 13–September 1, 1977*

Well children versus those	Exclusive pool swimming			Exclusive beach swimming			All swimming		
	E	χ^2	*p*	*E*	χ^2	*p*	*E*	χ^2	*p*
Ill with enterovirus isolate	1.58	2.64	>0.05	3.41†	8.07	<0.0005	2.17	11.11	<0.005
Ill with no enterovirus isolate	1.25	0.53	>0.05	1.53	0.10	>0.05	1.28	1.13	>0.05

* E = odds ratio, χ^2 = value of chi square, p = probability.

† This analysis was the only one that showed an effect modification with age. The odds ratios for <1–3 years = 10.63, 4–9 years = 1.05, 10–15 years = 3.93.

tween controls and the ill children with no virus isolated.

Swimming at specific beaches and at pools within the city was examined for aggregation of specific enteroviral serotypes at the various sites. Because of the large number of swimming sites, numbers of swimmers were too small at any given site for analysis. Also, while ill children with enterovirus isolates had a significantly greater swimming exposure, no dose-response effect was apparent. That is, considering only the swimmers in each diagnostic category, the mean number of swimming episodes on an age-adjusted basis was no different.

DISCUSSION

There is no published evidence of outbreaks of enterovirus illness arising from unpolluted recreational water transmission similar to that for adenoviral pharyngoconjunctival fever (4–8). The reports of enterovirus recovery from both beaches and pools uncontaminated by sewage strongly suggest, however, that swimmers can contaminate the water that they use (9–13). If this is true, transmission of enteroviruses via recreational water might make a regular contribution to the usual enterovirus disease patterns yet be indiscernible because discrete, recognizable outbreaks do not occur. Our study was designed to examine this hypothesis.

Our findings indicate that swimmers using Madison lake beaches in the summer of 1977 incurred an increased relative risk of enteroviral illness more than three-fold overall and ten-fold in children aged 3 years or younger. Children with similar viral-like disease from whom no enterovirus was isolated had no increase in relative risk of illness from either beach or pool swimming. Compromises with ideal design were necessary in several aspects of this study but none serious enough to make the association between beach swimming and enterovirus illness a spurious one.

Our definition of a case of enteroviral illness was the isolation of an enterovirus from a child with a compatible illness. This definition could be questioned because, although virus recovery establishes infection, we did not have sufficient numbers of paired sera from cases to establish that the infection exactly coincided with the illness. This is the usual criterion to establish an enterovirus etiology. Despite this, we feel that most of the enterovirus isolate group did have illnesses of enterovirus etiology since throat swab specimens were positive in 80 per cent (21). Further, Kogon et al. (22) have estimated from their careful family studies that of those infected with a non-polio enterovirus, 25 per cent at a minimum and 50 per cent at a maximum will develop an illness. Therefore, if expo-

sure to swimmer contaminated recreational water increases enterovirus infections, increased enteroviral disease can also be expected.

Another question which might be raised is the extent of undetected enterovirus infections in the control group, since only a non-representative sample of 27 controls had specimens taken for virus culture. To the extent that recreational water transmission of enterovirus infections does occur, large numbers of undetected infections among the controls would result in a decreased difference in proportions of swimmers between test and control groups and would make our findings conservative. This same consideration holds for the ill children with no isolates.

A final concern in any case-control design is imprecise or biased exposure determination which we feel did not present a major problem. We asked about swimming activity only for the two-week period prior to the clinic visit. Swimming exposure was determined only from questionnaire responses in both ill patients and well controls, and virtually all patients attending the practice completed the questionnaire. There is no apparent reason to suspect systematic over- or under-reporting between well and ill groups. We did not, however, define the swimming episodes by time spent in the water and the extent of head submersion and/or water ingestion. Since the extent of actual swimming by the swimmers was unknown, the association observed could have resulted either from virus transmission by water or person-to-person contact at the swimming site.

We do not have direct evidence on this point but the data favor water transmission. If person-to-person transmission accounts for the association observed, it is difficult to explain why this occurred at beaches but not pools. An obvious explanation of this finding if water transmission is postulated is that the pools were sufficiently well chlorinated to keep enterovirus concentration below the level necessary for transmission. A second difficulty with the person-to-person transmission hypothesis is that no swimming association was seen in children with clinically apparent viral illnesses from whom no enterovirus was isolated.

Finally, although the data are not shown, the total fecal coliform and enterococci counts done at least weekly at each beach gave no evidence of significant water contamination. Occasionally, counts would be high at an individual beach resulting in its closure for several days but this was unusual. This suggests that if swimmers contaminate the unchlorinated water they use heavily enough to result in waterborne transmission, this is not reflected in the bacteriologic monitoring usually done.

This study, then, shows a significantly increased risk of enterovirus illness in children swimming at unpolluted Madison beaches with suggestive evidence of waterborne transmission. Conclusive evidence and generalizable data will require simultaneous virologic study of both swimmers and the water they use. This study represents a necessary first step which we feel justifies a more direct investigation of a possibly substantial public health problem.

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