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Epidemiologic Studies of Virus Transmission in Swimming Waters

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EPIDEMIOLOGIC STUDIES OF VIRUS TRANSMISSION IN SWIMMING WATERS

by

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FOREWORD

The U. S. Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The primary mission of the Health Effects Research Laboratory in Cincinnati (HERL) is to provide a sound health effects data base in support of the regulatory activities of the EPA. To this end, HERL conducts a research program to identify, characterize, and quantitate harmful effects of pollutants that may result from exposure to chemical, physical, or biological agents found in the environment. In addition to valuable health information generated by these activities, new research techniques and methods are being developed that contribute to a better understanding of human biochemical and physiological functions, and how these functions are altered by low level insults.

This report provides an evaluation of the transmission of viral disease among swimmers at recreational areas. The results indicated that children who swam at public freshwater beaches or swimming pools were more likely to be shedders of virus in their stools and more likely to experience gastroenteritis, presumably of viral etiology, than were nonswimmers. Although not studied extensively, water quality data suggested that the infectious organisms had not originated from sewage contamination of the water but rather were transmitted from infected swimmers to other swimmers by the water medium.

These findings tend to underscore the everpresent potential of fecally contaminated water to be a transmitter of infectious disease and indicate that control measures may be required to prevent waterborne disease transmission in areas of heavy recreational use even when measures to prevent point source sewage contamination have been effective.

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ABSTRACT

Retrospective and prospective epidemiologic studies were conducted during the summers of 1976 and 1977 to determine if swimming activities increase the risk of acquiring enteroviral infection in children. The retrospective study consisted of a surveillance of recent swimming activities and clinical histories in 3,774 children who visited a pediatric clinic. Viruses consisting mainly of non-polio enteroviruses were recovered from 63 of 157 and 138 of 262 children with clinically apparent acute viral infections who were sampled during 1976 and 1977, respectively. On the other hand, non-polio enteroviruses were isolated from only 2 of 28 well children sampled during the second year. The relationship of swimming activities to enteroviral and other illnesses showed similar trends in both years, but because of more extensive sampling and surveillance efforts, the 1977 data showed greater significant associations. Most notably, there was a highly statistically significant increased rate of swimming activity among children who had enterovirus associated illnesses as compared to the well controls.

Additionally, in 1977, age-specific swimming rates of all ill children with enteroviral isolates and ill children who were not sampled were markedly higher than those of well children. The most striking difference was seen in the birth to 3 year old ill children with an enterovirus isolate who had an age-specific swimming rate that was 2.6 times greater than that of the well controls. No significant differences were seen in those who visited exclusively swimming pools, but a highly significant difference was seen in exclusive beach goers between those with enterovirus isolates and well children. The frequency of visits to swimming sites appeared to have no relationship to illnesses. Weekly age adjusted swimming rates generally showed greater differences during the periods when enterovirus activity was high.

The prospective study examined the relationship between swimming activities and enteroviral infections in 296 elementary school children. Sera were collected from the children at the beginning and end of the summer for neutralizing antibody tests for selected enterovirus serotypes. When the data were analyzed by two-week periods, swimmers had a two to more than three fold greater frequency of reported illnesses compared to nonswimmers. The difference was particularly striking during periods when enterovirus activity was high. These differences, however, were not significant as there was an insufficient number of volunteers. Swimming rates for the entire season showed no relationships to reported illnesses or rates of antibody conversions to selected Coxsackievirus B and echovirus serotypes. This lack of a relationship appeared to be the result of a failure to find enough

children who were infrequent or nonswimmers. Nevertheless, the trend toward a decreased illness rate in children who refrained from swimming for two weeks is consistent with the retrospective study results.

To our knowledge, this is the first study that has found a statistically significant association between exposure to recreational waters and an increased risk of enteroviral disease. Various internal consistencies of the data discussed in this report support the validity of the association and suggest that water served as the transmission medium.

This report was submitted in fulfillment of grant number R-804161 by the Enterovirus Research Laboratory, Department of Preventive Medicine, University of Wisconsin at Madison under the sponsorship of the U.S. Environmental Protection Agency. This report covers a period from February 1, 1976 to January 31, 1979, and work was completed as of April 30, 1979.

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ACKNOWLEDGEMENTS

The cooperation of the Pediatric Departments at Dean Clinic and Quisling Clinic, Madison, WI, is gratefully appreciated. We are particularly grateful to the pediatricians, nurses, technicians and clerical staff for their active participation during the three years of the project.

The cooperation of Madison Public Schools is also gratefully acknowledged. The interest and assistance of the school district's External Research Committee, principals and teachers provided for efficient recruitment and sampling of volunteers.

SECTION 1

INTRODUCTION

Virtually any virus that infects humans could be present in recreational waters and be transmitted to swimmers, but relatively few virus groups appear to be good candidates for this mode of transmission. The enteroviruses, which are the predominant viruses encountered during the summer in temperate climates, are prime candidates for swimmer-acquired waterborne infections. Certain enterovirus serotypes have been detected in swimming pools (1, 2, 3) and in swimming beach waters (4,5) and concurrently isolated from children who swam in these waters. This does not, however indicate that water transmission occurred; e.g. virus may have passed from infected individuals to the water but may not have been transmitted from water to the swimmers.

Several investigations of outbreaks of pharyngoconjunctival fever, caused by adenoviruses, have revealed common exposure to a swimming pool or small lake (6, 7, 8, 9). Although most attempts to isolate virus from the water were made long after exposure and therefore were unsuccessful, adenovirus was isolated from a water sample collected near a sewage outlet in a lake where persons who experienced pharyngoconjunctival fever had been swimming (7).

A series of three field studies explored the question of potential influence of bacteriologic quality of different bathing waters on the frequency of reported swimmer illnesses (10). An appreciably higher incidence of overall illness was observed in swimmers compared to nonswimmers regardless of the bacterial quality of the water. Those who swam in a river that had high coliform densities had a significantly greater incidence of gastrointestinal illnesses. More recently, Cabelli et al. (11) also observed a significantly higher incidence of gastrointestinal symptoms in swimmers compared to nonswimmers at a polluted New York City beach.

We conducted epidemiologic studies during two consecutive summers to determine if swimming activities increase the risk of acquiring enteroviral infection in children. These studies included both a retrospective and prospective approach to the question. Children who visited a pediatric clinic were studied retrospectively to compare recent swimming activities of ill children with the activities of those who were well and to seek a viral etiology of a selected sample of illnesses. Prospectively, elementary school children were surveyed longitudinally to compare the rates of illnesses and serologic conversions to certain enterovirus serotypes in swimmers and nonswimmers.

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

This investigation, using both cohort and case-control epidemiologic study designs, was meant to test the hypothesis that recreational water that is not subject to sewage plant effluent serves as a transmission route for viruses, in particular, the enteroviruses.

On the basis of the cohort study data, we think the following conclusions are valid:

1. Children between 6 and 10 years of age who visited swimming sites consistently reported more illnesses of apparent viral etiology, both respiratory and gastrointestinal, than those who refrained from these activities. The peak illness frequency in swimmers coincided temporally with peak enterovirus activity.

2. No association was apparent between the frequency of visits to swimming sites or location of lake, beach or pool, and the frequency of acute infectious illness.

The case-control study results permit somewhat more particular conclusions:

1. A statistically significant association between swimming activities and enteroviral illness was demonstrated. This association held for children from birth to 15 years of age.

2. Features of the data suggest that water served as the enterovirus transmission medium, although this study does not provide direct evidence on this point.

3. The results also suggest, although less strongly, that the risk of acquiring enteroviral illnesses may be greater at beaches than at swimming pools.

4. As in the cohort study, there was no apparent association between the frequency of visits to swimming sites and illness.

This study was initiated with the realization that there was no convincing evidence that recreational water plays a role in enterovirus transmission. Our investigation was, in part, meant to examine the feasibility of approaching this question by epidemiologic methods. We feel that our findings constitute the strongest evidence currently available for water transmission of the enteroviruses. They are not conclusive or detailed enough to serve as the basis for specific control measures. This step will require further investigation which appears to us to be fully justified on the strength of our findings to date.

To be profitable, further study of this question must involve a more detailed definition of the shedding of virus by infected individuals, chemical, bacteriologic and virologic characterization of specific swimming sites, and specific etiologic investigation of illnesses in swimmers using these sites.

1. Quantitation of virus shedding from infected individuals: The data reported here suggest that swimmers may serve as the source of water contamination. Enteroviruses proliferate and are shed from both the nasopharynx and gastrointestinal tract. Quantitation of the extent of virus shedding by infected children would be necessary to assess the likelihood that water users are the source of contamination.

2. Definition of the character of the recreational water: Additional study of this question would seem to require that the bodies of water under examination be characterized in terms of particulate and chemical composition. In swimming pools, free chlorine levels would have to be carefully defined. This kind of characterization would supplement careful bacteriologic monitoring. Most importantly, attempts should be made to recover and quantitate viruses from the recreational water.

3. An experimental epidemiologic study design: Assuming that there is an association between swimming and an increased risk of acquiring an enteroviral illness, one of the most difficult questions to decide is whether actual water transmission occurs or transmission is really via person-to-person contact at the swimming site. Our current study design did not allow direct examination of this question, although we feel there is evidence to suggest actual water transmission. Decisive study of this question is very difficult with any observational design. The most discerning approach to this question would be a study in which participants agreed to a random assignment to swimming or nonswimming categories. Achieving such agreement would be difficult but would make possible a crossover study and would be a very effective way to clarify the mode of transmission.

In summary, the data we will present suggest that swimming plays an important role in enterovirus disease. This is of sufficient public health importance to justify further study. If enterovirus water transmission is established, effective control measures might well be feasible.

SECTION 3

MATERIALS AND METHODS

CLINIC STUDY

Virology Samples

Dual specimens consisting of throat and rectal swabs were collected for isolation of viruses. Immediately after collection, the cotton swabs were immersed in 2.5 ml of Hanks' Balanced Salt Solution plus 0.25% gelatin, penicillin G (200 Units/ml), and streptomycin (100 μg/ml) and wrung out. The specimens were then refrigerated until the following morning when cell cultures were inoculated. A 10 cc blood sample was collected by venipuncture and allowed to clot and express serum.

Isolation of Viruses

Two tubes each of Wisl (a human embryonic lung diploid strain developed by the Wisconsin State Laboratory of Hygiene Virus Section) and HEp-2, and three tubes of primary rhesus monkey kidney (RMK) cell cultures were inoculated per specimen. One tube of each cell type received 0.2 ml of specimen while the others received 0.1 ml. The medium was changed after 2 hr and again after one week. Tubes were placed in a stationary position, incubated at 37 C, and examined microscopically for cytopathic effect at several intervals during a two-week period. One tube of RMK containing a throat culture was tested for hemadsorption with 0.25 ml of 0.25 percent guinea pig erythrocytes 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 hr old with 0.05 ml subcutaneously and 0.02 ml intracerebrally. Mice were observed daily for two weeks for development of paralysis.

Identification of Viruses

Viruses were identified with commercially obtained animal hyperimmune antisera (Microbiological Associates, Bethesda MD). Enterovirus-like agents were tested for neutralization (tube method) by type-specific Coxsackievirus B 1 to 5 and poliovirus 1 to 3 antisera and by intersecting pools containing echovirus and Coxsackievirus A9 antisera. Nine pools, each containing 6 to 8 monotypic antisera, were formulated in our laboratory in a manner similar to the Benyesh-Melnick scheme. The isolates were diluted to contain 32 to 320 $TCID_{50}$/0.1 ml and were tested with 20 units of antiserum. Agents not identified with any of these antisera were tested for stability to ether and acidity (pH 3) and declared to be "enterovirus-like agents" if they passed both tests.

Isolates from mice that developed a flaccid paralysis were declared to be group A Coxsackieviruses and were not identified further. Isolates obtained from throat specimens that were ether stable but acid labile were assumed to be rhinoviruses.

Adenoviruses were identified by neutralization tests using type-specific antisera (32 to 320 $TCID_{50}$ of virus and 20 units of antiserum). Herpes simplex virus was identified by the Wisconsin State Laboratory of Hygiene Virus Section using a direct fluorescent antibody test. Hemadsorbing agents were tested for hemadsorption-inhibition with parainfluenza 1 to 3 antisera but were not tested further. Agents not identified by the above procedures were tested for the presence of mycoplasma by the Wisconsin State Laboratory of Hygiene Immunology Section and, if negative, were declared to be "unidentified virus-like agents."

Serology

Available paired acute and convalescent sera from patients with isolates were tested for serum neutralizing antibody rises to infecting serotypes. In addition, paired sera from individuals without isolates were tested for neutralizing antibody rises to Coxsackieviruses B 1 to 5. The tube method (12) was employed for all virus groups except the Coxsackievirus B group which was used in a microtiter test that will be described below.

Statistical Analysis of Swimming vs. Infection

A log-linear model for the analysis of categorical data was used to analyze swimming versus infection data. The data were categorized by four variables.

(i) Illness
- well
- ill

(ii) Swimming
- didn't swim in the previous two weeks
- did swim (including beach or pool swimming)

(iii) Sex — male / female

(iv) Age — birth to 3 years old / 4-9 years old / 10-15 years old / more than 15 years old

Since a retrospective 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 odds ratio

p_I denotes the probability of swimming among ill children

p_W denotes the probability of swimming among well children

$e=1$ implies no relationship between swimming and illness

$e>1$ implies a positive relationship between swimming and illness

$e<1$ implies a negative relationship between swimming and illness

It is well known that if the prevalence of illness is relatively small, the odds ratio in a retrospective study approximates the relative risk of illness in swimmers versus nonswimmers. Each of the analyses that follow were done in two steps. First, a test for effect modification of age and sex was done. That is, we tested whether the odds ratio of illness and swimming was the same for each age-sex category or whether they differed significantly from category to category. Secondly, if there was no significant effect modification of age and sex then we tested whether the odds ratio was significantly different from 1.

SCHOOL STUDY

Paired acute and convalescent sera were tested for neutralizing antibody to Coxsackievirus B 1 to 5. In addition, sera collected in 1977 were tested for antibodies to echovirus 3, 6 and 11. All tests were performed using a microtiter procedure.

Sera were inactivated (56 C, 30 min) and 50 µl of two-fold dilutions (1:8 to 1:8,192) in growth medium were prepared in duplicate in 96-well tissue culture microtiter plates (Linbro Scientific, New Haven CT) using an automated microdiluter (Medimixer, Linbro). A 50 µl volume of growth medium containing 32 to 320 $TCID_{50}$ of virus was added to each well. A single row of serum dilutions containing no virus was prepared for each serum. A virus back titration (100-0.01 $TCID_{50}$/50 µl) was done in quadruplicate. Four wells containing only growth medium were included in each plate. The plates were gently agitated, then incubated at 37 C for 1 hr in a 5 percent CO_2 atmosphere. A suitable suspension of LLC-MK_2 cells (one flask of cells per five microtiter plates) was prepared in growth medium and 0.15 ml added to each well. The plates were gently agitated, re-incubated for six days, and examined microscopically for cytopathic effect.

SECTION 4

EXPERIMENTAL PROCEDURES

CLINIC STUDY

Overall Study Design

All children who visited two private pediatric clinics in Madison, Wisconsin were surveyed for histories of recent swimming activities, reasons for visiting the clinic, and current clinical syndromes. Children with clinically apparent acute viral infections and some well children were sampled for virus isolation and serology.

Study Area

Madison (population: 175,000) is the site of the state capital and the major campus of the University of Wisconsin System. Since the city is nearly devoid of heavy industry and is not located near other cities, a substantial portion of the population is comprised of state and university employees. Residents, therefore, enjoy a stable and above average standard of living.

Five lakes are located in Madison and the immediate surrounding area and three of these are partially or wholly within the city limits. The city alone has 14 municipally supervised swimming beaches in addition to numerous public and private swimming pools. Discharge of raw or treated human sewage into area lakes is prohibited, but run-off waters from farm land and storm sewer discharge reach the lakes and constitute the principal threat to water quality. The municipal drinking water supply is drawn exclusively from deep wells.

Study Periods

Children were sampled from June 7, 1976 to September 9, 1976 and from June 13, 1977 to September 1, 1977. The 1976 study began at just one clinic (Clinic A). Because sampling at this clinic was quite sporadic, a second clinic (Clinic B) joined the study on August 2, 1976. During 1977, sampling was conducted exclusively at Clinic B.

Clinic Questionnaires

All children visiting the two clinics in 1976 were given questionnaires that they or their parents were to complete if they were willing to cooperate. In the second year, questionnaires were distributed only to patients of the two pediatricians directly participating in the study. The surveillance was conducted by clinic staff nurses in the first year of the study, but during the second year this responsibility was assumed by a senior nursing student employed for the project. This resulted in more uniform and complete clinical and epidemiologic data collection.

One purpose of the questionnaire (Appendix A) was to determine if swimming sites were visited during the two weeks immediately preceding the clinic visit, where the activity occurred, and its frequency. For our purposes, swimming activity was defined as the act of going to a swimming site. The definition did not distinguish between the types of activity that the children participated in at the swimming area.

The other major purpose of the questionnaire was to identify those children visiting the clinic for reasons not related to infectious disease (e.g. physical examinations, injuries, immunizations, atopic allergies, chronic health problems, etc.) and distinguish them from children who had apparent acute infectious illnesses. The latter included illnesses with possible viral, bacterial, mycoplasmal, and other infectious etiologies.

A total of 3,962 children received questionnaires in 1976, including 1,497 at Clinic A and 2,465 at Clinic B. Questionnaires were distributed to 1,561 children in the following year. The smaller number in 1977 resulted because all patients at Clinic B which includes seven pediatricians were asked to complete questionnaires in 1976, whereas in 1977 questionnaires were distributed only to patients of the two cooperating physicians.

<u>Sampling</u>

Nearly all of the children who presented with an apparent viral illness were interviewed by the nursing student to obtain further clinical data. The clinic pediatricians were responsible for judging whether a child had signs and symptoms that would justify viral isolation attempts. Children with syndromes that were suggestive of non-enteroviral exanthems or bacterial/mycoplasmal infections were excluded from this group. Specimens were collected only if informed consent was provided.

A total of 157 patients, including 80 at Clinic A and 77 at Clinic B, were sampled in the first year. Well children were not sampled during this season. In 1977, 262 ill and 28 well children were sampled.

Throat specimens for viral isolation were collected from all of the 447 sampled children. Stool specimens were collected from all but 14 of these individuals. Paired acute and convalescent sera were obtained from 53 of the 157 patients (34 percent) in 1976 and 46 of the 290 patients (16 percent) in 1977.

SCHOOL STUDY

<u>Experimental Design</u>

Sera were collected from elementary school children in late May and early September of 1976 and 1977. During the intervening periods, the children or their parents kept a record of swimming activities and illnesses. The purpose of the study was to determine whether children who went swimming more frequently during the summer had more illnesses or serological conversions to selected enteroviruses than children who went swimming less frequently or not all.

Recruitment of Volunteers

Children in grades 1 through 5 (ages 6 through 10) were recruited from Madison Public Schools, Madison, Wisconsin. The characteristics of the study area have been described above. Three schools, each in a different geographical area of the city, were approached during the first year, whereas nine schools located throughout the city were involved in the second year. During the first and second summers, 149 and 147 children were recruited, respectively. A number of children participated in the study during both summers.

Surveillance

Surveillance of swimming activities and illnesses began just after the end of the school year (June 13) and concluded just before the beginning of the next school year (August 21). The 10 weeks of surveillance were divided into five equal periods.

Parents completed and returned post card questionnaires at the end of each two-week period (Appendix B). Reminders were sent whenever questionnaires were not returned. The questionnaire supplied information about whether the child went swimming, the location and frequency of swimming, and whether he or she had been ill during the two-week period.

Swimming again was defined as the act of going to a swimming site. Swimming frequency was listed by category: 0, 1 to 3, 4 to 6, 7 to 9, and greater than 9 days. These categories were assigned scores of 0 to 4.

When an illness was reported, the project nurse or physician telephoned the parents to obtain a clinical history. Illnesses were defined as acute episodes of at least 24 hr duration, consisting of signs and symptoms compatible with a viral etiology (excluding non-enteroviral exanthems). Each episode of illness was recorded only once and was assigned to the period corresponding with its onset.

After the conclusion of the study, questionnaires were distributed to obtain an approximation of the summer activities engaged in by volunteers (Appendix C). One purpose of this questionnaire was to determine if children with low average swimming scores tended to avoid group activities, had little sibling contact, or came from small families. These situations would greatly reduce opportunities for person-to-person transmission of viruses and might lead to a false conclusion that the lower infection rate was related to a low swimming exposure. Responses to the questionnaire were assigned scores that were weighted to reflect the relative importance of each factor in promoting person-to-person transmission (Appendix C). A second purpose of the questionnaire was to determine the types of activity that occurred at the swimming site.

BACTERIOLOGIC MONITORING OF SWIMMING WATERS

The City of Madison Public Health Department provided weekly reports of fecal coliform and enterococci counts at municipal beaches during the 1976 and 1977 study periods. Fecal coliform densities were determined by the membrane filter technique.

SECTION 5

RESULTS AND DISCUSSION

CLINIC STUDY

Viruses Isolated

The case control study of the relationship of swimming to enterovirus illnesses was carried out in two clinics, A and B, in 1976 but in only Clinic B in 1977. Viruses were recovered from 63 of 157 children (40 percent) sampled in 1976. Fifty of these isolates (32 percent) were non-polio enteroviruses. In 1977, 262 ill children were sampled and 138 viral isolations were made (53 percent). Of these, 120 (46 percent) shed non-polio enteroviruses. During 1977, 28 well children were sampled and nine shed viruses. However, only two (6 percent) of these isolates were non-polio enteroviruses while the other seven were polioviruses assumed to be vaccine strains (TABLE 1).

Group A Coxsackieviruses predominated in both years, but the other non-polio enteroviruses recovered differed markedly between the two seasons (TABLE 1). In 1976, among the Group B Coxsackieviruses, only types 3 and 4 were active whereas all five serotypes were isolated in 1977. The major difference between the two years was in the number of echoviruses isolated. There were four echovirus isolates in 1976, whereas in 1977, 40 isolates of six different serotypes were found. Isolation of agents other than enteroviruses totaled just 31 for both years and the mixture of adenoviruses, rhinoviruses, paramyxoviruses, and herpes simplex viruses was not surprising in the population sampled.

Serologic Confirmations

Paired acute and convalescent sera were available from 21 of the children in whom viruses were isolated, including 18 with enteroviral isolates. Significant titer rises (4-fold or greater) occurred in 13 (62 percent) of these 21 patients. In a number of children who did not have titer rises but had enteroviral isolates, the initial serum showed a fairly high titer which may account for our inability to demonstrate a greater percentage of significant rises. Acute and convalescent serum specimens from 25 children who had no isolates were available. These 25 serum pairs (all from children sampled in 1977) yielded no significant titer rises to any of the five Coxsackievirus B serotypes.

TABLE 1. VIRUSES ISOLATED FROM CHILDREN IN CLINICS A AND B (1976) AND CLINIC B (1977)

Viruses	Number of children with isolates* 1976	1977 Ill group	1977 Well group
Coxsackievirus A			
Mouse isolates	32	42	0
Type 9	2	3	0
Total	34	45	0
Coxsackievirus B			
Type 1	0	10	0
2	0	2	0
3	3	10	0
4	7	1	0
5	0	6	1
Total	10	29	1
Echovirus			
Type 3	0	12	0
5	0	1	0
6	0	6	0
7	0	2	0
11	0	16	1
18	1	0	0
22	0	3	0
30	3	0	0
Total	4	40	1
Poliovirus			
Type 1	1	0	6
3	0	1	0
Mixture	0	1	1
Total	1	2	7
Enterovirus-like Agents, untypeable	2	6	0
Adenovirus			
Type 2	2	2	0
3	0	6	0
5	0	2	0
Total	2	10	0

(continued)

TABLE 1 (continued)

Viruses	Number of children with isolates* 1976	1977 Ill group	1977 Well group
Rhinoviruses, nontyped	7	0	0
Myxovirus			
Parainfluenza Type 3	1	0	0
Unidentified	1	0	0
Total	2	0	0
Herpes simplex virus			
Type 1	0	1	0
2	0	1	0
Total	0	2	0
Unidentified virus-like agents	1	4	0
Total non-polio enteroviruses	50	120	2
Total isolates	63	138	9

*Number of children sampled: 1976, 157; 1977 ill group, 262; 1977 well group, 28.

Characteristics of the Study Population

Although the Clinic Study was begun in June 1976 in Clinic A, the sampling in that clinic was so variable and incomplete that the data derived do not bear analysis. Secondly, we excluded from analysis all children 16 years of age or older because they were few in number and, with a spread between 16 and the early 20's, differed significantly from the bulk of our sample. Furthermore, very few virus isolations were made in this group. Our study population then consisted of all children between birth and 15 years of age who were seen at Clinic B in 1976 and 1977 and agreed to participate in the study. The 1976 study population, which completed questionnaires at Clinic B from the first day of August through the subsequent six weeks, consisted of 2,402 children. The 1977 population consisted of 1,372 children who completed similar questionnaires at Clinic B (TABLE 2).

In both years, well children who appeared at the clinic for physical examinations or reasons other than illness comprised just under 50 percent of the study population (TABLE 2). Similarly about 22 percent of children in 1976 and 27 percent of children in 1977 had illnesses which appeared

TABLE 2. CATEGORIES OF THE CLINIC B PATIENT POPULATIONS, 1976 AND 1977

Patient category	1976 Patients No.	1976 Patients Percent	1977 Patients No.	1977 Patients Percent
Well children	1154	(48)	679	(50)
Ill children				
Viral-like illness				
Sampled	82	(34)	241	(18)
Not sampled	431	(18)	147	(11)
Nonviral-like illness	-		219	(16)
Other	621	(26)	46	(3)
Health status unknown	114	(5)	40	(3)
Total questionnaires completed	2402		1372	

to be viral in etiology on the basis of symptomatology, the 513 viral-like illnesses seen in 1976 at Clinic B again represent all of the participating children seen by the entire pediatric group. Of these illnesses, 82 children who were patients of the two cooperating pediatricians had samples taken for viral isolation. Sampling was much more complete and extensive in 1977 because of the daily presence of the senior nursing student in the clinic. This resulted in about two-thirds of the children with viral-like illnesses having specimens taken for viral isolation. Also, the more complete information in 1977 allowed the separation of the remaining illnesses into nonviral infections (e.g., otitis media, streptococcal pharyngitis, otitis externa) and non-infectious illnesses (asthma, atopic dermatitis and other acute and chronic diseases). Consequently, the 1976 "other" category in TABLE 2 contains a large number of both non-viral and non-infections illnesses which we were not able to distinguish on the basis of the information available. In 1977 we were able to reduce this "other" group significantly to include just those illnesses which were non-infectious in etiology. The "health status unknown" category includes patients who did not complete the questionnaire in sufficient detail to make a determination.

The age composition of the various diagnostic categories differed markedly (TABLE 3). Children in the 10-15 year group comprised from 30 percent in 1976 to 40 percent in 1977 of the well children seen. This age group comprised similar percentages of those who had viral samples but no virus isolated, viral-like illnesses who were not sampled, and those with nonviral-like illnesses. In contrast this age group comprised only 13 percent and 12 percent, respectively, of those who had viruses isolated in 1976 and 1977. In our virus isolate population in 1977, 47 percent of the children were in the birth to 3 year old group.

These marked differences in age composition between the virus isolation group and the other diagnostic categories resulted primarily because enterovirus infections and illnesses are most frequent in younger children. This is strikingly apparent in the age-specific isolation rates for 1976 and 1977 (TABLE 4). Isolation rates in the birth to 3 year old age group were 80 percent and 63 percent, respectively, for the two years with similarly high isolation rates in the 4 to 9 year olds. In contrast, only one-fourth of the 10 to 15 year olds who were sampled had virus isolates. Analysis of the distribution of virus isolates by age groups documents the aggregation of enterovirus isolations of all types in those children 9 years or younger, whereas the non-enterovirus isolates distributed themselves fairly uniformly over the three age categories (TABLE 5).

In 1976, the presenting syndromes of the sampled patients could only be distinguished on the basis of the symptomatology listed on the questionnaire (TABLE 6). Comparing those patients with a virus isolated versus those without, we found that there was very little difference in the percentage of children manifesting various syndromes. There were slightly fewer patients with viral isolates who had nonfebrile illnesses. The predominant syndrome involved the respiratory tract. Few illnesses were completely localized to the gastrointestinal tract.

Because of the interviews that were conducted by the nursing student in 1977, a somewhat finer clinical categorization of the patients and identification of children not sampled but who had viral-like illnesses was possible (TABLE 7). Again, there was little difference in the distribution of clinical syndromes between those sampled patients who did or did not have a virus isolate made. Infection of the respiratory tract again accounted for the predominant syndrome and there were slightly more nonfebrile patients among those who did not have a virus isolated. Of course, the nonsampled viral-like illness group represents an unknown mixture of etiologies. This group was notable in that it had a somewhat lower frequency of respiratory, respiratory-gastrointestinal, and gastrointestinal tract involvement compared to the other two groups and a greater concentration of patients with exanthems, conjunctivitis, and otitis media with possible viral involvement.

Seasonal Enteroviral Activity

Enteroviral activity in northern temperate climates is highly seasonal,

TABLE 3. AGE COMPOSITION OF THE VARIOUS DIAGNOSTIC CATEGORIES*, CLINIC B 1976 AND 1977

	Age in years												All Children	
	0 to 3				4 to 9				10 to 15					
	1976		1977		1976		1977		1976		1977		1976	1977
Patient	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	No.
Well children	340	(29)	162	(24)	442	(38)	228	(34)	372	(32)	289	(42)	1154	679
Sampled with virus isolated	12	(31)	63	(47)	22	(56)	55	(41)	5	(13)	16	(12)	39	134
Sampled with no virus isolated	3	(7)	36	(34)	25	(58)	33	(31)	15	(35)	38	(35)	43	107
Viral-like illness not sampled	182	(42)	48	(33)	170	(39)	52	(35)	79	(18)	47	(32)	431	147
Nonviral-like illness+	-		64	(29)	-		78	(36)	-		77	(35)	-	219
All categories	537		373		659		446		471		467		1667	1286

*Includes only well children and those ill children who had a suspected infectious disease.

+Because of limitations of data collected in 1976, nonviral-like infectious illnesses could not be distinguished.

TABLE 4. ISOLATION RATES AMONG AGE GROUPS AT CLINIC B, 1976 AND 1977

Age groups (years)	No. of virus isolate/No. tested			
	1976		1977	
	No.	%	No.	%
0 to 3	12/15	(80)	63/99	(64)
4 to 9	22/47	(47)	55/88	(63)
10 to 15	5/20	(25)	16/54	(30)
All Ages	39/82	(48)	134/241	(56)

TABLE 5. AGE SPECIFIC DISTRIBUTION OF VIRUS ISOLATES AMONG ILL PATIENTS AT CLINIC B, 1976 AND 1977

Viruses	Number of Children							
	Ages 0 to 3		Ages 4 to 9		Ages 10 to 15		All Children	
	1976	1977	1976	1977	1976	1977	1976	1977
Coxsackievirus A	9	21	13	17	2	7	24	45
Coxsackievirus B	1	9	9	17	0	3	10	29
Echovirus	1	20	0	17	1	2	2	39
Enterovirus-like agents, untypeable	1	6	0	0	0	0	1	6
Other	0	7	0	4	2	4	2	15
All Viruses	12	63	22	55	5	16	39	134

TABLE 6. SYNDROMES OF CLINIC B SAMPLED PATIENTS, 1976

Syndrome	Patients with virus isolated		Patients without virus isolated		Total Number of Patients
	No.	%	No.	%	
Respiratory					
Febrile	23	(59)	25	(58)	48
Nonfebrile	1	(3)	3	(7)	4
Respiratory-Gastrointestinal					
Febrile	5	(13)	3	(7)	8
Nonfebrile	0		2	(5)	2
Febrile Gastrointestinal	1	(3)	1	(2)	2
Undifferentiated	6	(15)	7	(16)	13
Unknown	3	(7)	2	(5)	5
All syndromes	39	100	43	100	82

TABLE 7. SYNDROMES OF CLINIC B SAMPLED PATIENTS AND NONSAMPLED VIRAL-LIKE ILLNESS PATIENTS, 1977

Syndrome	Patients with virus isolated		Patients without virus isolated		Patients with viral-like illness not sampled		Total Number of Patients
	No.	%	No.	%	No.	%	
Respiratory							
Febrile	51	(38)	41	(38)	7	(5)	99
Nonfebrile	14	(11)	14	(13)	16	(11)	44
Respiratory-Gastrointestinal							
Febrile	26	(19)	18	(17)	12	(8)	56
Nonfebrile	0		6	(5)	5	(3)	11
Gastrointestinal							
Febrile	15	(11)	6	(5)	3	(2)	24
Nonfebrile	0		1	(1)	4	(3)	5
Undifferentiated	26	(19)	18	(17)	8	(5)	52
Central Nervous System	2	(2)	3	(3)	0		5
Exanthem	0		0		24	(16)	24
Conjunctivitis	0		0		9	(6)	9

(continued)

TABLE 7 (continued)

Syndrome	Patients with virus isolated		Patients without virus isolated		Patients with viral-like illness not sampled		Total Number of Patients
	No.	%	No.	%	No.	%	
Otitis with possible viral	0		0		17	(12)	17
Other possible viral	0		0		21	(14)	21
Unspecified viral-like illness	0		0		21	(14)	21
All syndromes	134	100	107	99	147	99	388

with peak acitivity in July and August. This was apparent in the analysis of weekly isolation rates from the clinics (TABLE 8). In 1976, between the weeks of June 7 through July 26 when sampling was performed only in Clinic A, relatively few cultures were taken per week and no enterovirus isolations were made until the week of July 19. During the week of July 26, we received no specimens for viral isolation from Clinic A. Reportedly, there had been a marked increase in the number of ill children which so overloaded the staff that they felt they had no time to take cultures. Consequently, we requested that Clinic B join the study August 2 and the remainder of the 1976 isolation results in Table 8 reflect cultures taken at both Clinics A and B. From the sudden marked increase in ill patients during the week of July 26 at Clinic A and the peak number of viruses isolated during the weeks of August 2 and 9, we assume that the enterovirus season in 1976 was the period from July 26 through August 9 with a rapid decrease in activity after that time.

The 1977 enterovirus season was much more active, both in terms of number of cultures taken and the number and variety of enteroviruses isolated. Enterovirus isolations began during the first week of sampling, June 13, and activity persisted at steady levels through June and the first week of July. There was a sudden increase in the number of children sampled and isolations beginning July 11. Isolations persisted at high levels through the first week of August and then showed a sharp decline similar to that seen in 1976. However, during this period a 50 percent decrease in cultures and isolations occurred in the week of July 18. This resulted from one of the two participating physicians taking vacation that week. In contrast to the enteroviruses, isolation of other viruses persisted at low levels throughout the entire summer with little weekly variation in either 1976 or 1977.

To assess how accurately these weekly variations in virus isolations might represent the virus activity in Madison as a whole, we compared our clinic results to those of the Wisconsin State Laboratory of Hygiene Virus Diagnostic Section, which receives specimens for viral isolation from throughout the state (TABLE 9). Patients tested by the State Laboratory differ in a number of ways from ours. Specimens are received from adults as well as children and the patients generally have more severe illnesses which often require hospitalization. Despite these differences, the Virus Section results indicate that the enterovirus season in Wisconsin began about July 19, 1976, with few isolations prior to that time. This preceded by a week the beginning that we saw in the clinics. The 1976 season ran through August 23, or for two weeks following the decline in clinic isolations. The 1977 statewide enterovirus season was somewhat closer to the pattern that we saw in Clinic B. Enterovirus isolations began in early June, with the peak incidence of July 11 through the first week of August coinciding precisely with the peak isolation frequency seen in our clinic study. This comparison leads us to believe that the variation in numbers of our weekly clinic isolations accurately reflects enterovirus activity in Madison during the summers of 1976 and 1977 and that these data can be applied to the school study which will be reported below.

TABLE 8. VIRAL ISOLATIONS BY WEEK, CLINICS A AND B (1976) AND CLINIC B (1977)

Year	Week		No. of ill children sampled	No. of children with isolates*					
				Cox A	Cox B	Echo	All NP entero	Other viruses	All viruses
1976	June	7	4	0	0	0	0	1	1
		14	7	0	0	0	0	0	0
		21	2	0	0	0	0	2	2
		28	3	0	0	0	0	0	0
	July	5	2	0	0	0	0	1	1
		12	4	0	0	1	1	1	2
		19	7	3	0	0	3	2	5
		26	0+	-	-	-	-	-	-
	August	2	35	14	2	0	17	1	18
		9	51	12	2	2	17	4	21
		16	20	1	2	1	4	0	4
		23	11	1	0	0	1	1	2
		30	5	2	2	0	4	0	4
	Sept	6	6	1	2	0	3	0	3
1977	June	13	13	1	2	4	7	1	8
		20	24	5	2	4	11	0	11
		27	25	3	2	5	10	2	12
	July	4	20	1	3	3	7	1	8
		11	38	12	0	3	18	2	20
		18	17‡	3	0	4	7	2	9
		25	35	5	6	3	16	3	19
	August	1	38	4	9	5	18	3	21
		8	16	4	0	2	6	0	6
		15	16	3	2	4	9	3	12
		22	12	3	2	1	7	0	7
		29	8	1	1	2	4	1	5

*Abbreviations: Cox(Coxsackievirus); Echo(echovirus); NP entero(non-polio enterovirus).

+Patient loads increased so markedly in this week that clinic personnel didn't have time to sample children.

‡This marked decrease in specimens occurred because one of the cooperating physicians took a one-week vacation.

TABLE 9. NUMBER OF PATIENTS WITH NONPOLIO ENTEROVIRUS POSITIVE SPECIMENS DURING THE SUMMERS OF 1976 AND 1977, STATE LABORATORY OF HYGIENE VIRUS DIAGNOSTIC SECTION

Week of Onset	Number of patients with isolates			Total
	Cox A	Cox B	Echo	
1976				
June 7	0	0	0	0
14	0	0	0	0
21	2	0	0	2
28	0	1	0	1
July 5	2	0	0	2
12	0	0	0	0
19	3	5	0	8
26	1	2	0	3
Aug 2	0	1	2	3
9	1	2	2	5
16	1	0	7	8
23	3	4	3	10
30	0	1	2	3
Sept 6	0	5	0	5
Total	13	21	16	50
1977				
June 13	1	1	0	2
20	0	1	1	2
27	1	1	1	3
July 4	1	3	1	5
11	3	2	6	11
18	3	0	6	9
25	1	1	11	13
Aug 1	1	5	4	10
8	1	3	3	7
15	0	1	2	3
22	0	0	2	2
29	0	0	3	3
Total	12	18	40	70

Association Between Swimming and Enteroviral Illness

With the weekly variation in enterovirus isolations as a background, weekly age-adjusted swimming rates in the various diagnostic categories of clinic patients can be compared. Age-adjusted rates were computed by taking the weekly age-specific swimming rates for each diagnostic category and applying them to a standard population comprised of the total population surveyed during each summer. The 1976 weekly age-adjusted rates for Clinic B (TABLE 10) present some difficulty in that the sampled patients who did and did not have enteroviruses isolated were small in number. Nevertheless, some trends do appear. Considering that the peak enterovirus activity was already in progress during the first two weeks of August when Clinic B joined the study, the adjusted swimming rate in the enterovirus isolation group was 11 percent greater than the rate in the well group during the week of August 2. The rate for the isolate group dropped below the well controls during the week of August 9, and then exceeded the well group by 12 and 13 percent during the weeks of August 16 and 23. Similarly, the group of patients who had viral-like illnesses but had no samples taken showed age-adjusted weekly swimming rates considerably higher than the well controls throughout the entire test period. In contrast, those patients who had virus specimens taken but from whom no isolations were made had rates that were lower than those seen in the well controls for four of the six weeks of the study.

Since the age-adjusted data for 1977 (TABLE 11) are based on considerably larger numbers of sampled patients than in 1976, more consistent patterns are evident. The 1977 data also have the advantage of covering the entire summer season. Adjusted swimming rates of well children and those with enteroviruses isolated show almost no differences until the week of July 11, when there is a marked increase in the percent of swimming among the enterovirus isolate patients, exceeding the well controls by about 19 percent. This increased frequency of swimming persists for the enterovirus isolate group to a greater or lesser extent through the first week of August, which encompasses the peak enteroviral isolation activity. The weekly age-adjusted swimming rates among those sampled with no virus isolated, and the nonsampled possible viral illness group, show much more variation in comparison to the well controls and no consistent excess swimming during the period of peak enteroviral activity.

Finally, some interesting differences emerge when comparing age specific swimming rates by the various diagnostic categories over the entire summer (TABLE 12). In 1976, the age-specific rates for all those who were ill, those who had enteroviruses isolated, and those with viral-like illnesses who were not sampled, consistently exceeded those of the well children by as much as 10 to 14 percent. The only exception to this generalization occurred in 10-15 year olds with enterovirus isolates where the small number of children in that group went swimming about the same number of times as the well controls. Children sampled but with no isolations differed from the other ill categories. This group showed age-specific swimming rates which were indistinguishable or slightly lower than those of the well controls.

TABLE 10. WEEKLY AGE ADJUSTED RATES OF SWIMMING IN VARIOUS DIAGNOSTIC CATEGORIES, CLINIC B 1976

Week	Well patients		Patients with enterovirus isolates		Sampled patients with no isolates		Nonsampled patients with viral-like illnesses	
	Total no. of children	% swimmers	Total no. of children	% swimmers	Total no. of children	% swimmers	Total no. of children	% swimmers
August 2	198	46	11	57	9	100	118	60
August 9	232	51	14	43	18	32	113	60
August 16	360	42	5	65	7	39	84	52
August 23	211	43	1	59	5	56	60	61
August 30	104	47	3	41	1	0	35	51
September 6	47	28	3	59	3	0	14	40

TABLE 11. WEEKLY AGE ADJUSTED RATES OF SWIMMING IN VARIOUS DIAGNOSTIC CATEGORIES, CLINIC B 1977

Week	Well patients		Patients with enterovirus isolates		Sampled patients with no isolates		Nonsampled patients with viral-like illnesses	
	Total no. of children	% swimmers	Total no. of children	% swimmers	Total no. of children	% swimmers	Total no. of children	% swimmers
June 13	42	44	7	45	3	23	5	27
20	57	51	11	41	10	47	5	47
27	87	50	9	41	12	43	12	67
July 4	55	68	7	55	9	74	17	77
11	67	61	19	80	15	72	22	74
18	31	76	6	77	7	51	7	44
25	43	61	16	86	14	43	21	60
Aug. 1	63	58	18	62	15	68	19	66
8	34	55	6	53	9	63	7	71
15	55	44	9	37	4	0	14	53
22	91	24	7	35	5	24	11	33
29	49	18	4	83	4	25	7	15

TABLE 12. AGE SPECIFIC SWIMMING RATES BY DIAGNOSTIC CATEGORY, CLINIC B 1976 AND 1977

	Age groups (years)						Total	
	0 to 3		4 to 9		10 to 15			
Patient Category	Swimmers/ Total	% swimmers	Swimmers/ Total	% swimmers	Swimmers/ Total	% swimmers	Swimmers/ Total	% swimmers
1976								
Well children	66/340	19	244/442	55	239/372	64	549/1154	48
All ill children	58/197	29	138/217	64	71/97	73	267/511	52
Sampled with enterovirus isolate	4/12	33	15/22	68	2/3	67	21/37	57
Sampled with no isolate	0/3	0	12/25	48	10/15	67	22/43	51
Viral-like illness nonsampled	54/182	30	111/170	65	59/79	75	224/431	52
Other	65/261	25	147/214	69	99/146	68	311/621	50
1977								
Well children	27/162	17	142/228	62	175/289	61	344/679	51
All ill children	59/204	29	151/214	71	124/174	71	334/592	56
Sampled with enterovirus isolate	24/56	43	35/51	69	9/12	75	68/119	57

(continued)

TABLE 12 (continued)

	Age groups (years)							
	0 to 3		4 to 9		10 to 15		Total	
Patient Category	Swimmers/ Total	% swimmers	Swimmers/ Total	% swimmers	Swimmers/ Total	% swimmers	Swimmers/ Total	% swimmers
Sampled with no isolate	8/36	22	20/33	61	27/38	71	55/107	51
Viral-like illness nonsampled	13/48	27	37/52	71	33/47	70	83/147	57
Non-viral-like illness	14/64	22	59/78	76	55/77	71	128/219	58

The same patterns were evident in the more extensive and consistent 1977 data. The most striking differences seen were in the group with enteroviral isolates in the birth to 3 year old age group. In these children the age-specifc swimming rate was 2.6 times that of the well controls. Similarly, those in other age groups with viral isolations consistently exceeded the controls in swimming frequency. This same excess of swimming was evident in all ill patients, except for those who had samples taken but no virus isolated. Only the 10 to 15 year olds in this group had swimming rates higher than the well controls. The highest rate of excess swimming was seen among the 4 to 15 year old children who had nonviral-like illnesses. This seems clearly related to the frequency of otitis externa in this group; an infectious illness well known to be related to frequent swimming.

Statistical Analysis of Swimming versus Infection

In 1976, well children were compared with four illness categories: those with enteroviral isolates, those sampled with no isolate, those with viral-like illness not sampled, and all ill children (TABLE 13).

TABLE 13. RESULTS OF STATISTICAL ANALYSIS OF SWIMMING IN VARIOUS DIAGNOSTIC CATEGORIES, CLINIC B 1976

Patient Categories	Swimming vs. nonswimming*
Well children vs. ill with enterovirus isolates	E = 1.76 X^2= 2.39 P = not significant
Well children vs. ill with no isolate	E = .91 X^2= .08 P = not significant
Well children vs. viral-like illness not sampled	E = 1.47 X^2=11.85 P = <.005
Well children vs. all ill children	E = 1.47 X^2=11.85 P = <.005

*Symbols: E = estimate of odds ratio
X^2 = value of chi square test statistic
P = the probability value

The greatest odds ratio was seen in well children versus those with enteroviral isolates. However, because of small numbers, the difference was not significant. In contrast, those children who had no isolates had an odds ratio of less than one. Highly significant differences in the odds ratio were seen in well children versus those with viral-like illnesses not sampled, and well children versus all ill children groups. No significant effect modification by age or sex was apparent in any of the groups.

In 1977, the numbers were sufficient to analyze the effect of exclusive pool or beach swimming as well as swimming versus non swimming (TABLE 14). In the well children versus those with enterovirus isolations, there was no significant difference seen in exclusive pool swimming. However, there was a highly significant difference seen in beach swimming between these two groups as well as with all swimming. The exclusive beach swimmer analysis was the only category which showed an effect modification for age, with a very large odds ratio for children between the ages of birth and 3 years old who had enteroviral isolates (TABLE 14). In contrast, the comparison of swimming and illness in well children versus those sampled with no isolate, showed no significant difference in any of the categories of swimming. In nonsampled children with viral-like illnesses versus well children, no significant difference in odds ratios was seen for exclusive pool or beach swimmers, but the overall swimming variable showed a significant difference. Both exclusive beach and pool swimming differences were significant when all well children were compared to all ill children.

The data also were analyzed with regard to the location and frequency of swimming in the two weeks prior to the clinic visit. No differences in frequency of swimming were apparent between well and ill swimmers. Analyses of specific swimming sites were not meaningful because the total number of different beaches and pools was so high that there were insufficient numbers of children at any one site. However, sufficiently large numbers resulted when swimming was tabulated for the three major lakes within the city limits of Madison. Among the well children who swam at a beach, about 40 percent swam at one of the beaches on Lake Mendota which is the largest of the three city lakes. Thirty-four percent swam at beaches on Lake Monona and 19 percent swam at the only beach on Lake Wingra, the smallest and shallowest of the three lakes. On the other hand, 20 percent of the enterovirus isolate group swam at beaches on Lake Mendota and 40 percent swam at Lake Wingra.

SCHOOL STUDY

<u>Characteristics of the Population</u>

Over 90 percent of participants returned biweekly questionnaires in both years of the study. Activity profile questionnaires, which were completed at the end of the study, were returned by 80 percent of the children.

Respondents to the activity profile questionnaire were given a swimming score by their average swimming frequency per two-week period over the summer. About 50 percent swam at least 4 to 9 times per two weeks (i.e. swimming score of 2.0 or more) and only 17 percent averaged less than one swimming session per period (TABLE 15). On the basis of the average activity score computed as explained in Appendix C, the infrequent swimmers had as much contact with siblings and other children as did those who swam frequently. Information from questions related to the nature of swimming (TABLE 16) revealed that most swimming was done with friends and that most of the children considered themselves good swimmers. The profiles also

TABLE 14. RESULTS OF STATISTICAL ANALYSIS OF SWIMMING IN VARIOUS DIAGNOSTIC CATEGORIES, CLINIC B 1977

Patient Categories	Pool swimming vs non swimming*	Beach swimming vs non swimming	Swimming vs non swimming
Well children vs. ill with enterovirus isolated	E = 1.58 X^2= 2.64 P = not significant	E = 3.41† X^2= 8.07 P = <.005	E = 2.17 X^2=11.11 P = <.005
Well children vs. ill with no isolate	E = 1.25 X^2= .53 P = not significant	E = 1.53 X^2= .10 P = not significant	E = 1.28 X^2= 1.13 P = not significant
Well children vs. viral-like not sampled	E = 1.49 X^2= 2.61 P = not significant	E = 1.53 X^2= 1.91 P = not significant	E = 1.57 X^2= 4.81 P = <.05
Well children vs. all ill children	E = 1.60 X^2= 8.16 P = <.005	E = 1.66 X^2= 6.81 P = <.01	

*Symbols: E = estimate of odds ratio
X^2= value of chi square test statistic
P = the probability value

†This analysis was the only one showing a significant effect modification with age. In particular the estimates of the different odds ratios are:

E for ages 0 to 3 = 10.63
E for ages 4 to 9 = 1.05
E for ages 10 to 15 = 3.93

TABLE 15. DISTRIBUTION OF SCHOOL STUDY POPULATION OF 218 CHILDREN RESPONDING TO THE ACTIVITY QUESTIONNAIRE BY AVERAGE SEASON SWIMMING SCORE AND THE CORRESPONDING ACTIVITY SCORE*, 1976 AND 1977

Average swimming score	No. of children	% of children	Average activity score
0 to 0.4	18	8	59
0.5 to 0.9	15	7	72
1.0 to 1.9	58	27	64
2.0 to 2.9	57	26	63
3.0 to 4.0	70	32	60

* See Appendix C. The score is based on answers to questions 1-7 and 12, 13, 16.

TABLE 16. THE NATURE OF SWIMMING ACTIVITY BY 218 SCHOOL STUDY CHILDREN RESPONDING TO THE ACTIVITY PROFILE QUESTIONNAIRE 1976 AND 1977*

Question	Answer	No. of children choosing answer
8	a-group swimming	49
	b-occasional group swimming	22
	c-swims with friend	128
	d-swims alone	8
9	a-can't swim	9
	b-doesn't swim well	41
	c-good swimmer	167
10	a-seldom puts head under water	5
	b-occasionally puts head under water	22
	c-frequently puts head under water	190
11	a-spends most time out of water	6
	b-spends most time in water	177
	c-time spent half and half	35

*See Appendix C.

showed that the large majority of children frequently put their heads under water and that an equally large number spent most of the time during the swimming activity in the water.

Frequency of Illness Per Two-Week Period

The school study population was comprised of children living throughout Madison who used a large variety of different beaches and pools. The following findings were correlated with enterovirus activity as defined by the clinic study isolations which reflected the city-wide virus activity for reasons described in the previous section (TABLE 8). For the entire summer, the frequency of reported illnesses in swimmers was two fold higher in 1976 and more than three fold higher in 1977 (TABLE 17).

TABLE 17. FREQUENCY OF ILLNESSES BY TWO-WEEK PERIODS IN SWIMMERS AND NONSWIMMERS 1976 AND 1977

		Nonswimmers			Swimmers		
			Percent illness			Percent illness	
Season	Period	Number	Total	GI*	Number	Total	GI*
1976	June 13 to 26	30	--†	--	117	9	6
	June 27 to July 10	19	5‡	--	127	6	2
	July 11 to 24	24	8	--	119	6	3
	July 25 to Aug. 7	30	3‡	--	115	13	4
	Aug. 8 to 21	29	7	3	115	13	4
	Average	26	5	1	119	10	4
1977	June 13 to 26	19	--	--	125	9	—
	June 27 to July 10	9	11‡	--	135	8	2
	July 11 to 24	12	8‡	--	130	13	2
	July 25 to Aug. 7	20	--	--	122	14	5
	Aug. 8 to 21	47	2‡	2‡	97	7	1‡
	Average	21	3	1	122	10	2

*Gastrointestinal (either with or without accompanying respiratory symptoms).
†—no illnesses reported.
‡Represents only one illness.

The biweekly illness frequency data between the two groups revealed some recurring patterns. During the period starting June 13, 1976, there were no reported illnesses among nonswimmers but 6 percent of the swimming group reported a gastrointestinal illness accounting for the majority of swimmer illnesses during that period of time. At this time in the clinic study, we were isolating few viruses of any kind. No clue as to the possible etiology of this gastrointestinal illness could be determined from either our isolation data or that of the State Laboratory. From June 27 through July 24 of the same year, illness frequency was identical in the swimmer and nonswimmer groups. However, beginning July 25 through August 21, the illness rate in swimmers was 2 to 3 times greater than that of nonswimmers. July 25 also marked the increase of enteroviral activity noted in the clinic study. Therefore, the peak illness period in the school study coincided closely with the peak enteroviral activity in Madison in 1976. A similar pattern occurred in 1977, with peaks of swimmer illness frequency coinciding with clinic enterovirus isolations.

None of the differences in illness frequency between swimmers and nonswimmers either by two-week period or for the entire summer were statistically significant. The major difficulty was with the small number of nonswimmers, which averaged 26 per two-week period in 1976 and 21 per two-week period in 1977. Many of the biweekly illness rates in nonswimmers during both years were based on one ill person as noted in TABLE 17. A finding which should be noted is that gastrointestinal illnesses were reported by swimmers throughout virtually the entire summer season both years. However, this syndrome was not reported by nonswimmers except for the last two weeks of the study each year. Finally, swimmers reported a greater variety of illnesses than did nonswimmers. In addition to increased gastrointestinal and respiratory illnesses, there were also instances of otitis media and conjunctivitis. Nonswimmer illnesses were mostly confined to the respiratory tract.

Relationship of Swimming Frequency and Site to Illness Frequency

The frequency of swimming had no apparent effect on the rate of the reported illnesses (TABLE 18). Dividing swimmers for each period throughout both summers into those who swam 1 to 6 times per two weeks and those who swam 7 or more times, showed that the percent reporting illnesses in any period often varied widely but that the increased illnesses were just as likely to occur in the less frequent swimmers as in the more frequent swimmers.

Similarly, there was no consistent relationship between frequency of reported illness and the kind of recreational water where swimming occurred (TABLE 19). In 1976, the illness rate reported by children who swam exclusively at beaches was similar to that of nonswimmers. The highest rate of illness that year occurred in those who swam in both beaches and pools. However, in 1977, the location of swimming had very little effect on the frequency of reported illness. Differences fluctuated markedly by two-week periods and showed no consistent trends in either summer.

Relationship of Age and Sex to Illness Frequency

Increased frequency of illnesses in swimmers compared with nonswimmers held for every age category (TABLE 20). In 1976, the only illnesses reported in nonswimmers were in the 6 to 8 year olds and the illness frequency in swimmers was greatest in the 6 to 7 year olds, with a progressive decrease in percent ill through the 10 year olds. This trend was not apparent in 1977. Therefore, age did not appear to consistently affect illness differences between swimmers and nonswimmers.

Some consistent differences did occur when the population was analyzed by sex. Similar average illness rates were seen in male and female swimmers

TABLE 18. THE RELATIONSHIP OF SWIMMING FREQUENCY AND ILLNESS FREQUENCY, SCHOOL STUDY 1976 AND 1977

		Swimming score			
		1 to 2		3 to 4	
Season	Period	No. with score	% illnesses	No. with score	% illnesses
1976	June 13 to 26	63	10	54	9
	June 27 to July 10	58	7	69	4
	July 11 to 24	48	8	71	10
	July 25 to Aug 7	51	12	64	14
	Aug 8 to 21	66	17	49	8
	Average	62	8	70	11
1977	June 13 to 26	49	12	76	7
	June 27 to July 10	38	5	97	9
	July 11 to 24	44	11	86	14
	July 25 to Aug 7	59	12	63	16
	Aug 8 to 21	71	9	26	4
	Average	57	11	61	9

TABLE 19. AVERAGE FREQUENCY OF ILLNESS PER TWO-WEEK PERIOD ASSOCIATED WITH DIFFERENT TYPES OF SWIMMING, SCHOOL STUDY 1976 AND 1977

Season	Type of swimming	Average number of children per period	Percent illnesses
1976	None	26	5
	Pool	44	8
	Beach	17	5
	Pool and Beach	58	13
1977	None	21	3
	Pool	57	10
	Beach	25	11
	Pool and Beach	40	11

TABLE 20. AVERAGE FREQUENCY OF ILLNESS PER TWO-WEEK PERIOD IN DIFFERENT AGE GROUPS AND IN MALES AND FEMALES, SCHOOL STUDY 1976-1977

		Nonswimmers		Swimmers	
Season	Age (years) or sex	Average number per period	Percent with illnesses	Average number per period	Percent with illnesses
1976	6	5	8	16	18
	7	6	11	18	14
	8	6	3	25	8
	9	4	--*	30	9
	10	6	--	29	6
	Males	13	6	57	10
	Females	13	3	62	10
1977	6	<1	--	3	--
	7	6	3	31	14
	8	7	--	37	9
	9	7	3	33	7
	10	2	11	18	14
	Males	12	5	63	11
	Females	10	--	59	10

*-- No illnesses reported.

in each year of the study (TABLE 20). However, male nonswimmers had higher illness frequencies than did female nonswimmers. This was especially apparent in 1977 when there were no illnesses reported in female nonswimmers. Consequently, the differences between swimmer and nonswimmer illness rates were much greater in the females in both years of the study.

Relationship of Seasonal Swimming Frequency to Reported Illness and Serologic Conversions

Very few children in the study refrained from swimming during the entire 10 weeks of either summer. Children who were nonswimmers during one two-week period were likely to become frequent swimmers in the next period. Furthermore, children who averaged less than one episode of swimming per two-week period over the season represented less than 20 percent of the total population. Because there were too few children who could be considered nonswimmers for the season, children were divided into those with average season swimming scores above and below the median in each summer (TABLE 21).

TABLE 21. SEASON FREQUENCY OF ILLNESS AND SEROLOGIC CONVERSIONS TO GROUP B COXSACKIEVIRUSES (CB) AND ECHOVIRUSES (ECHO), SCHOOL STUDY 1976 AND 1977

			Percent of children with one or more			
				Serologic conversion to		
Season	Average swimming score	Number of Children	illness	CB 1-5	Echo 3,6,11	CB or echo
1976	<median*	70	31	6	--	6
	>median*	69	28	10	--	10
1977	<median†	69	36	26	25	39
	>median†	69	41	41	26	39

*Median = 1.8.
†Median = 2.4.

Those children with below median swimming scores reported illnesses about as frequently as those who were above the median. The frequency of serologic conversions during 1976 in those above the median was almost double that of the group below the median. This difference was not statistically significant because of the very low number of total conversions. A much higher rate of serologic conversions was seen in the 1977 study, but the frequency of conversions was identical for those above and below the median swimming frequency.

BEACH ATTENDANCE AND BACTERIOLOGIC QUALITY

The 14 city beaches located on the three lakes either wholly or partially within the city limits of Madison have varying usage (TABLE 22).

TABLE 22. RANKING OF BEACHES BY TOTAL SEASON ATTENDANCE*

Rank	Beach	Lake	Percent total attendance
1	Vilas	Wingra	32
2	Olbrich	Monona	16
3	Warner	Mendota	8
4	Tenney	Mendota	8
5	B.B. Clarke	Monona	7
6	Spring Harbor	Mendota	5
7	Marshall	Mendota	4
8	Willows	Mendota	3
9	South Shore	Monona	3
10	Olin	Monona	3
11	James Madison	Mendota	3
12	Brittingham	Monona	3
13	Esther	Monona	2
14	Lake Front	Monona	1

*Based on total attendance at all beaches from the first Saturday in June through Labor day, 1969 to 1973 (data obtained from the City of Madison Parks Department).

As determined by a weekly survey between 1969 and 1973, Vilas Beach is by far the most heavily used beach in the city. This is the sole swimming site on Lake Wingra which is the smallest and shallowest of the city lakes. Olbrich Beach, located on Lake Monona, is the second most frequently used with half the attendance of Vilas. Despite the wide variation in usage of the other beaches, when viewed collectively, each lake services almost exactly one-third of Madison beach swimmers, albeit with widely varying population densities per beach.

The City of Madison Health Department monitors each beach at least weekly for fecal coliforms and enterococci and provided us with these data for the summers of 1976 and 1977 (TABLES 23, 24, 25, 26). In 1976 (TABLES 23, 24) the counts of these organisms varied widely by week at the various beaches, with the highest geometric mean titers occurring in the first several weeks of June and generally low counts occurring during late July and the month of August. In 1977, the mean counts were noticeably higher than in 1976 and some individual beaches had periods of very high bacterial counts. In this year, the highest mean counts were seen during the weeks of July 18 and August 8. In 1977, Lake Wingra had persistently high counts which increased to very large numbers during the week of July 18 and the last two weeks of August. For the entire summer, Vilas Beach had the highest mean count of any of the beaches.

None of these lakes receive sewage effluent but are subject to the products of agricultural runoff and storm sewer drainage. The origin of the fecal coliforms and enterococci which repeatedly lead to the closing of individual beaches for short periods is not clear despite considerable investigation.

Discussion

There is continuing concern over the potential role of both drinking and recreational water in the transmission of viral infections, despite the paucity of evidence that transmission by this route constitutes a significant public health problem. Both Fox and Goldfield have recently presented analyses of the epidemiologic and clinical characteristics of the candidate virus infections as well as the continuing problems with disease surveillance. They have clearly outlined the difficulties inherent in studying this question, which may account largely for the lack of conclusive evidence in this area (13, 14). Only Hepatitis A virus is known to be regularly transmitted in drinking water, a route which constitutes only a small proportion of Hepatitis A transmission and which almost always results from gross sewage contamination of a drinking water supply (15, 16). The only viral disease consistently linked to transmission by recreational waters is pharyngoconjunctival fever of adenoviral etiology (7, 8, 9, 17, 18).

Surprisingly, despite the widespread belief that swimming represented a dangerous exposure during epidemics of paralytic poliomyelitis, there are only two episodes which are cited classically as possible evidence of waterborne transmission of poliovirus. In 1954, Little (19) described an explosive outbreak of poliomyelitis in Edmonton, Alberta that occurred late in the enterovirus season. He felt that a possible reservoir of infection was present at Devan, a town located 20 miles upstream from the Edmonton municipal water supply intake. Just before the outbreak of poliomyelitis in Edmonton, an outbreak of the disease had occurred in Devan. Devan's primary treatment sewage plant, which discharged its effluent into the river, had malfunctioned

TABLE 23. FECAL COLIFORM DENSITIES AT MADISON BEACHES, 6/7/76 to 9/6/76*

Beach	Number of Organism/100ml														Geometric
	6/7	6/14	6/21	6/28	7/5	7/12	7/19	7/26	8/2	8/9	8/16	8/23	8/30	9/6	mean
Lake Mendota															
Warner	710	4200	<10	2500	220	<10	620	430	10	20	<10	20	140	90	65
Tenny	140	80	20	10	80	<10	90	30	30	10	10	<10	10	10	17
James Madison	50	1670	1080	50	3200	<10	<10	220	260	<10	<10	130	<10	10	32
Willows	287	7000	20	40	10	20	60	60	190	20	<10	310	<10	<10	32
Spring Harbor	600	810	370	150	120	40	70	10	250	50	110	1250	100	10	122
Marshall	170	240	40	<10	10	10	<10	10	110	10	20	300	480	10	26
Geometric mean	229	956	43	44	94	4	25	51	86	11	5	82	20	10	39
Lake Monona															
Olbrich	180	17	30	1000	30	--	300	120	<10	<10	70	<10	120	360	38
Esther	270	70	<10	20	10,000	60	30	70	40	<10	10	10	70	50	36
Olin	100	230	20	<10	40	10	150	10	40	<10	<10	240	80	50	23
South Shore	20	140	40	10	1500	20	30	20	<10	<10	10	<10	<10	110	15
Brittingham	160	640	20	30	860	30	50	10	50	<10	10	<10	360	30	35
B.B. Clarke	80	40	10	20	70	<10	40	140	20	<10	10	<10	40	40	16
Lake Front	10	100	10	200	60	10	380	90	10	10	90	20	90	300	46
Geometric mean	74	100	13	30	252	12	85	41	11	1	13	5	51	86	48
Lake Wingra															
Vilas	120	370	<10	<10	<10	20	100	120	20	<10	<10	10	60	20	13
Geometric mean-all beaches	125	289	18	28	111	8	51	49	27	3	7	17	35	20	24

*Data obtained from the City of Madison Health Department.

TABLE 24. ENTEROCOCCI DENSITIES AT MADISON BEACHES, 6/7/76 to 9/6/76

Beach	Number of Organism/100ml														Geometric mean
	6/7	6/14	6/21	6/28	7/5	7/12	7/19	7/26	8/2	8/9	8/16	8/23	8/30	9/6	
Lake Mendota															
Warner	770	1520	<10	22,400	2230	<10	780	2410	70	40	<10	<10	360	130	103
Tenny	320	30	10	50	230	20	20	50	50	30	<10	40	<10	60	26
James Madison	390	280	19,500	420	1430	50	150	610	440	80	40	400	30	30	246
Willows	23	6400	<10	300	10	20	10	40	570	20	<10	820	50	<10	39
Spring Harbor	360	600	140	90	100	140	40	150	1020	90	170	1150	310	60	189
Marshall	230	1160	80	10	<10	100	90	70	280	30	70	430	520	10	64
Geometric mean	238	620	36	224	95	26	66	177	251	42	9	137	67	23	82
Lake Monona															
Olbrich	120	17	20	680	40	--	240	240	30	10	20	20	240	260	66
Esther	420	80	10	120	7600	90	30	160	180	10	40	50	100	130	97
Olin	100	300	20	20	170	20	100	140	190	<10	20	1610	50	70	62
South Shore	80	190	10	20	560	30	<10	90	70	<10	40	10	10	140	28
Brittingham	110	870	90	50	380	30	60	230	10	90	80	110	160	20	88
B.B. Clarke	40	100	10	3160	40	<10	60	300	140	<10	110	<10	60	70	36
Lake Front	30	150	110	490	170	40	1090	600	90	10	<10	30	360	40	80
Geometric mean	91	139	24	159	257	20	60	213	71	5	25	34	88	79	60
Lake Wingra															
Vilas	300	300	30	100	20	40	130	190	250	170	90	120	30	70	95
Geometric mean-all beaches	150	279	29	178	140	19	66	195	133	16	17	68	72	46	71

*Data obtained from the City of Madison Health Department.

TABLE 25. FECAL COLIFORM DENSITIES AT MADISON BEACHES, 6/13/77 TO 8/29/77*

Beach	Number of Organism/100 ml												Geometric mean
	6/13	6/20	6/27	7/4	7/11	7/18	7/25	8/1	8/8	8/15	8/22	8/29	
Lake Mendota													
Warner	80	30	40	270	540	330	10	40	350	<10	60	20	55
Tenny	10	70	<10	20	<10	110	10	170	630	150	10	20	25
James Madison	<10	80	640	30	10	1130	420	10	1200	70	10	210	70
Willows	210	20	20	--	--	870	600	100	70	<10	10	1100	71
Spring Harbor	<10	530	120	150	120	10,000	800	120	850	30	70	970	227
Marshall	80	20	80	30	30	50	20	90	1000	30	60	340	66
Geometric mean	23	57	41	59	29	511	86	65	501	15	25	177	67
Lake Monona													
Olbrich	<10	20	90	380	860	600	30	20	1200	80	110	6600	125
Esther	70	60	20	30	70	310	370	<10	170	10	670	<10	41
Olin	10	280	30	<10	50	410	30	210	420	350	360	190	83
South Shore	20	40	<10	<10	<10	400	<10	100	20	10	20	<10	8
Brittingham	110	60	50	<10	<10	1000	<10	20	<10	30	170	30	18
B.B. Clarke	20	50	30	50	<10	2500	<10	<10	8000	<10	80	60	27
Lake Front	120	70	170	40	330	2800	60	20	1370	10	80	180	123
Geometric mean	23	60	28	11	19	802	11	15	211	19	128	46	41
Lake Wingra													
Vilas	310	60	480	70	270	1600	120	100	140	420	1310	897	279
Geometric mean-all beaches	28	59	41	25	28	695	32	32	297	21	75	101	59

*Data obtained from City of Madison Health Department.

TABLE 26. ENTEROCOCCI DENSITIES AT MADISON BEACHES, 6/13/77 TO 8/29/77*

	Number of Organism/100 ml												
Beach	6/13	6/20	6/27	7/4	7/11	7/18	7/25	8/1	8/8	8/15	8/22	8/29	Geometric mean
Lake Mendota													
Warner	30	30	190	780	4300	2930	50	150	1890	10	30	50	163
Tenny	<10	170	<10	20	20	670	30	180	2200	80	10	30	41
James Madison	10	430	20	110	<10	1600	1050	100	5600	20	100	1000	127
Willows	120	10	10	--	--	670	270	80	760	10	30	1390	94
Spring Harbor	10	150	190	60	220	30,000	4560	50	2230	160	150	2410	349
Marshall	180	<10	50	30	260	490	10	90	990	310	50	450	88
Geometric mean	20	39	27	79	94	1771	164	100	1842	45	43	362	116
Lake Monona													
Olbrich	20	90	260	1020	1610	1940	60	70	470	20	60	1830	208
Esther	40	50	140	30	<10	1050	670	<10	540	30	580	180	68
Olin	20	440	30	20	30	730	10	10	690	160	40	50	61
South Shore	<10	10	50	20	<10	1430	40	1340	60	90	20	150	39
Brittingham	90	10	130	50	10	5540	40	10	100	150	180	70	73
B.B. Clarke	<10	10	520	50	10	6100	10	40	24,000	10	100	100	71
Lake Front	200	170	540	30	2510	18,000	160	10	9000	10	540	320	304
Geometric mean	16	44	153	51	28	2783	52	23	809	39	115	177	91
Lake Wingra													
Vilas	160	40	460	110	490	2570	40	50	290	140	6630	530	264
Geometric mean-all beaches	21	41	78	64	55	2280	83	46	1070	45	101	261	108

*Data obtained from City of Madison Health Department.

at that time. A second possible waterborne episode was described by Bancroft (20) in 1957 which involved an outbreak of poliomyelitis in a veterans low cost housing complex. There was a clear association between the distribution of illnesses and location of flush valve toilets not provided with vacuum breakers. There was also a consistent temporal correspondence between the outbreak and the occurrence of extreme fluctuations of pressure in the water mains. In neither of these studies was the suspected contaminated water source cultured for the presence of virus.

Another approach to the question of transmission of viruses in recreational water has been the surveillance of reported illness episodes in swimmers using waters of defined bacteriologic quality. The first such large scale field study compared swimmers using: two beach sites of varying bacterial contamination on Lake Michigan, an Ohio River swimming site and a nearby swimming pool, and two beaches on Long Island Sound (10). While close monitoring of the bacteriologic quality of the various swimming sites was done, illness incidence was determined by the report of the participating families and no attempt was made to establish etiologies for the illnesses reported. The investigators demonstrated that an appreciably higher overall illness incidence occurred in the swimming group as compared to the non-swimming group, regardless of bathing water quality. Secondly, they demonstrated an increased incidence of illness among swimmers that correlated with increasing levels of bacterial contamination, although the data on this question were not conclusive. Finally, those who swam in the river site with high coliform densities had a significantly greater incidence of gastrointestinal illnesses.

More recently, a study has been reported comparing illness experience in swimmers using a relatively bacteriologically clean versus a relatively dirty ocean beach in New York City (11). This study had some similarities to Stevenson's in that water quality was monitored closely, but the illness frequency and nature was defined by the report of the participants. The study was done on the weekends to isolate single water exposure and those who swam during the middle of the week were eliminated. Swimming was defined as submersion of the swimmer's head and each participant was carefully monitored for this activity. This study found a significant increase in gastrointestinal illnesses between swimmers who had definite contact with the water (i.e. head submerged) compared to those who did not. Differences in gastrointestinal illnesses between swimmers and nonswimmers were statistically significant only at the beach which had substantial bacterial contamination. Numerous indicator organisms were monitored through the two years of the study reported to date, and the density of fecal coliforms and enterococci showed the closest relationship with the frequency of gastrointestinal symptomatology.

A number of reports have dealt with the isolation of specific enteroviruses from different types of recreational waters in association with human infections. The earliest report involves an outbreak of disease of Coxsackievirus B1 etiology, an agent which had been undetected in the study area for the previous 14 years (1). This virus was concomitantly recovered from a city wading pool. A similar situation was described in Berlin in which virologic surveillance of the city swimming pool during one summer resulted in the recovery of Coxsackievirus B3 from 20 percent of the water samples. This virus was also the predominant agent recovered from clinical specimens obtained from children primarily manifesting meningitis or encephalitis (2). A final report dealing with swimming pools indicated that Coxsackievirus B1 was recovered from the children's section of two Moscow swimming pools during a two-month period with concomitantly proven human infections with this agent during the same period(3).

A small outbreak of Coxsackievirus A16 illness in five children occurred some days after they had been bathing in a lake(5). Coxsackievirus A16 was isolated from a 10-liter sample of lake water and from rectal swabs of two patients. A somewhat larger outbreak with accompanying isolation of the etiologic agent from a lake was reported by Hawley et al. in 1973 (4). This outbreak involved 21 identified cases of acute viral illnesses in children at a summer camp located on the shores of Lake Champlain. Coxsackievirus B5 was isolated from 62 percent of the clinical cases and 17 percent of sampled asymptomatic individuals. The same virus was also recovered from the water of the beach along the lakeshore which the camp used for its swimming activity. However, epidemiologic analysis of the outbreak fairly conclusively indicated that the principal mode of transmission was person-to-person, in that all but four cases were clustered in one cabin.

The lack of evidence of waterborne transmission in the Lake Champlain outbreak is similar to the findings of a summer camp study where virologic surveillance of the campers and environment was considerably more systematic (21). Over the course of the summer, 37 of 681 participating campers had virus isolates. None of the environmental samples, including those taken from the camp swimming pool on a weekly basis, resulted in the isolation of a virus. As in the Lake Champlain study, virus spread was shown to be primarily or solely by direct transmission, in that specific viruses tended to concentrate in groups of boys living in the same cabins. There was no apparent transmission of illnesses by swimming or by any other environmental exposures.

None of the above studies, including those that reported isolations of enteroviruses from recreational water, provide evidence that the swimming waters were to any extent a medium of transmission. They do establish several facts, however. It is clear that recreational waters not receiving sewage effluent can be contaminated with enteroviruses and that the serotype found in the water is likely to be the same one predominating in concomitant human infections. These studies provided the basis for questions we attempted to address in the investigations reported in this paper. If, in fact, recreational waters can be contaminated with enteroviruses either from the bathers using the water or from other undefined nonsewage sources, then recreational water transmission of enteroviruses might be examined more profitably as one of the regular transmission routes rather than the occasional source of recognizable outbreaks.

As is characteristic of north temperate climates, enterovirus activity in Wisconsin is highly seasonal with little circulation prior to June, a sharp peak of incidence in July and August, and then a decrease in activity through September and October (22). In most years a number of different serotypes circulate, although the predominance of a single serotype is not an uncommon occurrence. If recreational water transmission is a significant factor in this seasonal occurrence; examining the association between swimming and documented enteroviral infections, without regard for the site of swimming or the microbiologic characteristics of the swimming water, might be a useful approach to this question. Recognizing that person-to-person transmission is the primary mode of enterovirus spread, we realized fully that water transmission might not be discernible by epidemiologic study even if this mode occurred fairly commonly. Consequently, we simultaneously undertook a prospective (cohort) study offering the advantages of more complete and reliable exposure data and a direct determination of risk, and a case control study to ensure a sufficient number of cases for analysis.

The major logistic aspects of the prospective study in school children were very successful. Just under 150 children were recruited each year. Over 90 percent of the biweekly questionnaires were returned and there was an 80 percent response to the activity profile questionnaire distributed at the end of the study. Because each reported illness was followed up by phone interview to characterize the illness, we had additional confirmation of the accuracy of reporting.

The findings in this study based on reported illnesses confirmed those of Stevenson and Cabelli in that total illness and gastrointestinal illness among swimmers exceeded that of nonswimmers in eight of the ten two-week survey periods for the two summers. The average percent of total reported illnesses and of gastrointestinal illnesses for the two summers seasons showed a 2- to 3-fold increase in swimmers compared to nonswimmers. Equally significant were the peak illness rates among swimmers, which coincided closely with peak enteroviral activity in Madison as defined by isolation studies in our pediatric clinic population. Also notable was that gastrointestinal illnesses were reported by swimmers in nine of the ten periods for the two years combined, while in only two periods did nonswimmers report illness of the gastrointestinal tract.

The prospective study revealed no consistent association between illness frequency and the type of recreational water used (i.e. swimming pool or beach). Most surprisingly, we were unable to demonstrate any association between the frequency of swimming either by two-week period or for the summer as a whole and the incidence of either illness or significant serologic rise in neutralizing antibodies to the most frequently encountered Coxsackievirus B or echovirus serotypes. Finally, none of the differences between swimmers and nonswimmers in any of the analyses of the cohort study reached statistical significance.

The major and critical difficulty encountered in the school study was the inadequate number of nonswimmers recruited. Because of the starting date of the grant in 1976, there was only time to recruit children agreeable to entering the study. Under these conditions, there was an average of only 26 children per two-week period who did not swim. In 1977, vigorous effort was made to recruit volunteers who declared themselves to be infrequent swimmers. Despite this, the average number of nonswimmers by two-week period in 1977 was only 21. Computing swimming indexes for every child over each summer period revealed that only 17 percent of the children swam on the average of less than one time per period. The small size of our nonswimmer control group in the prospective study prohibited meaningful statistical analyses. Nevertheless, the results were all consistent with the hypothesis that swimming activity is associated with increased risk of apparent viral illness, both respiratory and gastrointestinal.

As anticipated, the case control study in the pediatric clinic did supply sufficient numbers for meaningful analysis. The information gathering and virologic sampling required by the study design was satisfactorily accomplished in Clinic B. This was not the case in Clinic A where the study was initiated in June 1976. The difficulties encountered in this clinic limited satisfactory data collection until the beginning of August and the first two weeks of September when Clinic B was added. This occurred just at the beginning of peak enteroviral activity that summer. Another design error in 1976 was the decision to collect questionnaire information on all patients seen by the seven pediatricians at Clinic B while only two of them were cooperating in collection of virologic samples.

These methodologic problems were corrected in the 1977 clinic study by the placing of a full-time member of our staff in the clinic and limiting data collection to the patients of the two cooperating pediatricians. As a result, we obtained a much more precise picture of the various diagnostic categories which comprised the study population and achieved a two-thirds sampling for virus isolation of those judged clinically to have viral-like illnesses.

The achievement of overall clinic isolation rates of 48 and 56 percent, respectively, in 1976 and 1977 provided sufficient numbers of etiologically defined cases. This was a central requirement in testing our hypothesis. There are several reasons to accept the etiologic significance of the enteroviral isolates made, even though relatively few acute and convalescent serum specimens were obtained from the isolate group. In 1977, 11 serum pairs were available on patients from whom a Coxsackievirus B or echovirus was isolated and in seven of these (63 percent) a 4-fold or greater rise in neutralizing antibody titer to the isolated serotype was documented. The four serum pairs not showing a significant rise all had acute serum titers of at least 1:24 and three of these four had an initial titer of 1:96 or above. Previous work has indicated that if the initial titer of neutralizing antibody is above 1:32, documentation of a significant rise is seldom achieved. This admittedly small set of paired serum specimens does suggest, however, that most of the isolations represent a true infection. More importantly, in ascertaining etiologic significance, is that in both years of the study, pharyngeal specimens were positive in 85 percent of the children with isolates. Kepfer et al. (23), have documented the importance of pharyngeal specimen isolation in the etiologic diagnosis of enteroviral infections compared to stool isolation alone. Finally, in the 1977 season we obtained viral isolation specimens from 28 well control children. This sample of controls was not representative. Nevertheless, non-polio enteroviruses were isolated from only two of the 28 controls (7 percent), which is very similar to the rate of enterovirus recovery found in asymptomatic children tested in other studies.

Statistical analyses of the Clinic B data when age adjusted revealed a significant association between swimming and illness in both years of the study. In 1976, statistical significance was seen for the nonsampled viral-like illnesses and total infectious illnesses verses the well group. The differences in swimming between those with enterovirus isolates and the well controls were not significant, but the odds ratio of this comparison was the highest seen in 1976. In contrast, the odds ratio in the sampled group with no isolates versus well controls was less than one.

The larger numbers generated in 1977 allowed statistical analyses of exclusive beach and pool swimmers, as well as total swimming, between the various diagnostic categories. As in 1976, the age adjusted rate of swimming among those with nonsampled viral-like illnesses was statistically significant. Similarly, exclusive beach and pool swimming was significantly greater in those with infectious disease-like illnesses. Both of these categories obviously contained undefined numbers of enterovirus infections. Those with known enterovirus illnesses swam significantly more frequently in the two weeks prior to the clinic visit than did well children, and the excess of exclusive beach swimmers in the enterovirus group was highly significant. The only ill group in 1977 with swimming rates the same as the well controls were those sampled with no isolate, a finding which recapitulated the 1976 data.

The case control clinic study then consistently demonstrated an age adjusted statistically significant association between swimming and infectious disease-like illness. More to the point, the statistical association is strongest for enteroviral disease. Since this study design cannot provide direct evidence that the association is causal, the results must be examined for confounding factors which might have produced either a spurious or indirect association between swimming activity and enterovirus illness.

In assessing the validity of our findings, several logistic aspects of the study must be considered. One of the major concerns of a case-control design is that exposure to the hypothesized causal factor must be determined by retrospection and is, therefore, subject to varying degrees of imprecision. We do not think this represents a serious problem in our study since the period in question encompassed only the two weeks prior to the clinic visit. Furthermore, statistically significant associations were found only on the question of whether or not the child had been swimming. There is no apparent reason that accuracy of reporting this event might have differed markedly and consistently between ill and well children. Information about the frequency and location of swimming could be expected to be less precisely recalled, but this information was not of central interest as will be discussed below.

A second concern is that we did not determine the extent of exposure to the water. Intuitively, recreational water transmission of viruses, especially the enteroviruses, seems most likely if water is taken into the mouth and some quantity is swallowed. This event seems most likely if there is frequent submerging of the swimmer's head. The case-control study provides no direct information on this question. However the results of the activity profile questionnaire in the school study indicate that the majority of children over six years of age could be expected to have had extensive water exposure. Furthermore, there is no prior reason to suspect that degree of exposure differed consistently between the various diagnostic categories. Finally, the greatest difference in swimming rates was seen between the enterovirus isolate group and the well controls below the age of three. Children this age can be assumed to have had the lowest frequency of head submersion. This age group, however, might be expected to put their hands in their mouths more frequently while engaging in activities at a swimming site.

Another aspect of this study which bears on its validity is that the results are biologically plausible. Work of others reviewed at the beginning of this discussion indicates that the enteroviruses, excreted both from the pharynx and intestinal tract, can contaminate and persist in bodies of recreational waters not receiving sewage effluent. Secondly, in 1977 the weekly age-adjusted swimming rates of the enterovirus isolate group did not exceed that of the well controls until the peak of enterovirus activity in Madison. Lastly, if the risk of acquiring an enteroviral illness is increased by swimming (or swimming place exposures), the effect of this transmission route might be most apparent in the age group with the highest incidence of enteroviral illnesses and the lowest swimming rate under normal circumstances. Our data confirm this postulation, showing the most markedly different age-specific swimming rates between the controls and enterovirus isolation group in the birth to 3 year age range.

Consistency of the demonstrated association between swimming and enteroviral illnesses is difficult to assess because there are no other reported studies that are similar enough to ours for comparison. Nevertheless, both years of our study demonstrated essentially similar results. In 1976, the differences between controls and the enterovirus isolation group were not statistically significant. This probably results, however, from the relatively small number in the latter group, since the odds ratio (relative risk) of this comparison was higher than any other comparison in that year.

Finally, do the data lend support to a specific association between swimming and an increased risk of enterovirus illness? This question really has two parts: 1) are the enteroviruses uniquely involved; 2) if swimming activity does have a role in enterovirus transmission, is water the medium or are viruses transmitted via person-to-person contact at the swimming site? Clearly this study design cannot provide conclusive evidence on these questions since the extent of water contact for each swimmer is not known and no attempts at virus recovery from the recreational waters were made. However, the data do provide some suggestions that the association was specific for the enteroviruses and that water served as a transmission medium.

The basis for these tentative conclusions rests largely on the results from those children who had specimens with no isolated viruses. We feel that this group was largely devoid of undiagnosed enteroviral infections since our enterovirus isolation rate was so high. In addition, this group's age composition was more similar to the well controls than the isolate group, and antibody testing of 25 serum pairs from this group revealed no Coxsackievirus B infections. Therefore, we feel that that the sampled group with no isolates, who had clinical syndromes that were very similar to the enterovirus isolate group, provides an ill control group for valid comparison.

In neither year of the study did the group of children with apparent but undefined viral illnesses show swimming activity that differed statistically from the well controls. In addition, they showed no consistent seasonal excess swimming patterns or age-specific swimming rate differences. This implies that there was not simply a nonspecific association between swimming and all apparent viral illnesses. Similary, the nonsampled viral-like illness group which undoubtedly contained some enteroviral illnesses showed a swimming association intermediate between the isolate and no isolate groups.

The two studies of viral infections in children's camps cited above (4,21) offered evidence against swimming water transmission of the virus infections detected in the campers. Significantly, the epidemiologic data spoke against other kinds of casual camp contacts, which would equal in intensity that which occurs at poolside. In both instances, transmission was clearly related to the family-like contact among cabinmates.

Our own work with the transmission of experimental rhinovirus infections (24) showed that even the intimate contact of married couples was not sufficient to transmit this strictly respiratory pathogen unless the transmitter was quite symptomatic and shedding large quantities of virus. Fox et al. (25) had previously observed this phenomenon in his virus watch family studies showing a markedly lower rate of transmission of respiratory infection (20 versus 70 percent) if the index case in the family was asymptomatic. In studies of intrafamilial person-to-person virus transmission such as those of Fox's group, an attack rate in susceptibles of 50 percent is considered high. Water containing any significant continuous level of enteroviral contamination might be as or more efficient a transmission route since our infectious dose study of polio type 1 vaccine shows a 50 percent infectivity rate with about 70 $TCID_{50}$ and a 100 percent rate at 150 $TCID_{50}$.

The one finding in both the school and clinic studies that does not support the association between enteroviral illness and swimming was the lack of a swimming frequency response. In the school study, illnesses were reported more frequently in swimmers than in nonswimmers, but no increase in illness frequency was seen as swimming frequency increased. Likewise, in the clinic study, well swimmers swam as frequently as did those in any of the ill groups. This was unexpected and unexplainable, yet it was a consistent finding in both years of both studies. If recreational water does serve as a transmission medium, this finding suggests an all or nothing phenomenon implying fairly constant viral contamination during peak enterovirus activity.

Finally, the prospective school study revealed no differences in illness frequency with either type of recreational water used, pool or beach water. The clinic study involved use of so many different swimming locations that systematic analysis was not possible. The 1977 clinic results, however, provide some intriguing, if inconclusive, findings. There was a statistically significant excess of beach swimmers with enterovirus isolates as compared to controls and this effect was most marked among those children in the birth to 3 year old group. Secondly, the enterovirus isolate group was twice as likely to have used the one beach on Lake Wingra than the controls. This beach is the most heavily used in Madison and in 1977 had the highest mean counts of fecal coliforms and enterococcus.

We feel that the data developed in this study of enterovirus transmission in recreational water have demonstrated the value of an epidemiologic approach to this question. The cohort study of school children has confirmed previous findings of increased respiratory and gastrointestinal illnesses in swimmers versus nonswimmers. However, differences were not statistically significant and the specific etiology of these illnesses could not be defined. The case-control clinic study has provided the first information we are aware of supporting the hypothesis that recreational water can play a role in enterovirus transmission. Not only was a statistically significant association demonstrated but the differences between various categories of ill children provide an internal consistency that leads validity to the statistical associations.

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Appendix A

Clinic Study Questionnaire

For: Teenagers, Children & Babies

The Quisling Clinic and the Dept. of Preventive Medicine, University of Wis. Medical School are studying the possibility of acquiring viral infections by swimming lakes or pools. The information requested below is important to the study. We would appreciate your cooperation in answering the following:

Child's Name ______________________ ________ ________
Age Sex

Address ______________________________ ________
Street City Date

1. In the past 2 weeks, my child swam: (circle one)
a) 0 times b) 1-3 times c) 4-6 times d) 7-9 times e) 10 or more times
Please list beaches or pools (not home backyard wading pools) he/she swam at during past 2 weeks and number of times:
______________________________ ______________
______________________________ ______________
______________________________ ______________

2. Is your child ill today or has he/she been ill in the past 2 weeks?
___ No ___Yes
Reason for seeing physician today: (check one or more)

___Common cold	___Fever	___Vomiting,	___Allergy injection
___Sore throat	___Sores in mouth	Stomach pain	___Gen'l physical exam
___Ear ache	___Persistent	or diarrhea	___Well-child check-up
___Rash	Headaches	___Injury	___Other:__________
		___Vaccination	______________

Thank you. Please return to receptionist.

Appendix B

School Study Post Card Questionnaire

For the 2 weeks
beginning Mon., ____________________

ending Sun., ______________________

Dear Parent:

As part of the virus-swimming study that you and your child are participating in, we would like to have you answer the following questions and mail this card as soon as possible.

Child's Name ____

1. In the past 2 weeks, my child swam _______________________days.

2. Please list beaches and/or pools used: _____________________________
____
____

3. Has your child been ill in the past 2 weeks? Yes___ No___

4. Phone number during the day: ___________________

Appendix C

Enterovirus Research Laboratory
Department of Preventive Medicine
University of Wisconsin
465 Henry Mall
Madison, Wi 53706

SWIMMER STUDY ACTIVITY PROFILE

Parents - Please help your child complete this questionnaire which will help us determine how much contact he or she has with other children during the summer.
Child's name ______________________________

Please circle the answer that best describes you while you were in our swimming study.

1. I have (a) one, (b) two, (c) three, (d) more than three, brothers and sisters who live at home.

2. I am (a) the oldest, (b) the youngest, (c) neither the oldest not the youngest, child living at home.

3. During the summer, I play with a brother or sister (a) once in awhile, (b) fairly often, (c) most of the time.

4. During the summer, I like best of all to play with (a) my brother or sister, (b) kids my age, (c) kids younger than me, (d) kids older than me, (e) just myself.

5. When I do things with other kids during the summer, I prefer doing them with (a) just one or two friends, (b) more than just one or two friends.

6. My favorite summer activities are (a) mostly indoors, (b) mostly outdoors, (c) about equally divided between the indoors and outdoors.

7. I (a) spend up to one week at a summer camp, (b) more than a week at a summer camp, (c) don't go to a summer camp.

8. I go swimming (a) with an organized group that meets regularly, (b) sometimes with an organized group, (c) usually with a friend or two, (d) mostly by myself.

9. I (a) can't swim, (b) don't swim very well, (c) am a good swimmer.

10. I (a) don't like to put my head under the water, (b) put my head under the water once in awhile, (c) put my head under the water frequently.

11. When I go swimming, (a) like to spend most of the time out of the water, (b) spend most of the time in the water, (c) divide my time equally between the water and out of the water.

Please complete the following (for the year you were in our study).

12. List your favorite summer-time activities (except for sports):

____________________ ____________________

____________________ ____________________

____________________ ____________________

13. What sports did you play in the summer?

____________________ ____________________

____________________ ____________________

____________________ ____________________

14. List any teams you played on:

____________________, met ________times per week

____________________, met ________times per week

15. List any organized swimming groups you belonged to (including lessons):

____________________, met ________times per week

____________________, met ________times per week

16. List any other organizations that you belonged to that held regular meetings:

____________________, met ________times per week

____________________, met ________times per week

____________________, met ________times per week

SWIMMER STUDY ACTIVITY PROFILE

Scoring Key

QUESTION	ANSWER	POINTS
1	only child	0
	a	5
	b	10
	c	20
	d	30
2	a	15
	b	5
	c	10
3	a	2
	b	4
	c	6
4	a	12
	b	6
	c	9
	d	3
	e	0
5	a	3
	b	6
6	a	0
	b	10
	c	5
7	a	15
	b	20
	c	0
12-13		0-10
16		0-15

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/1-80-006	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Epidemiologic Studies of Virus Transmission in Swimming Waters		5. REPORT DATE January 1980 issuing date
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) D.J. D'Alessio, T. E. Minor, D. B. Nelson, C. I. Allen, A.A. Tsiatis		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS University of Wisconsin Madison, Wisconsin 53706		10. PROGRAM ELEMENT NO. 1CC614
		11. CONTRACT/GRANT NO. R-804161 (Report #1)
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16. ABSTRACT

Retrospective and prospective epidemiologic studies were conducted to determine if swimming activities increase the risk of acquiring enteroviral infection in children. The retrospective study consisted of a surveillance of recent swimming activities and clinical histories in 3,774 children who visited a pediatric clinic. A highly statistically significant increased rate of swimming activity was found among children who had enterovirus associated illnesses as compared to the well controls.

The prospective study examined the relationship between swimming activities and enteroviral infections in 296 elementary school children. Swimming rates for the entire season showed no relationships to reported illnesses. This lack of a relationship appeared to be the results of a failure to find enough children who were infrequent or nonswimmers. Nevertheless, the trend toward a decreased illness rate in children who refrained from swimming for two weeks is consistent with the retrospective study results.

To our knowledge, this is the first study that has found a statistically significant association between exposure to recreational waters and an increased risk of enteroviral disease. Various internal consistencies of the data discussed in this report support the validity of the association and suggest that water served as the transportation medium.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
enterovirus public health water resources	Swimming and disease Recreation Gastroenteritis	57K 57U 06M 68D

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