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Bathers as a possible source of contamination for swimming-associated illness at marine bathing beaches

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The results of a prospective, follow-up epidemiological study conducted at three Israeli coastal beaches in 1983 showed that enteric, respiratory and ear symptomatology were higher among swimmers than nonswimmers, especially for young children. The enterococcus levels and the swimming-associated rates for enteric and respiratory symptoms at one of the beaches (Gordon) were at least twice those at another beach (Rishon Lezion). The higher swimming-associated symptom rates at Gordon Beach, however, were largely attributable to individuals who swam on Saturdays, which are non-working days in Israel, as opposed to Fridays and Sundays. The absence of extrinsic sources of pollution, the restricted water exchange due to horizontal surf-breakers, the greater bather density and higher indicator levels (including those of *Staphylococcus aureus*) on Saturdays and the better correlation of *S. aureus* than enterococcus (or *Escherichia coli*) levels to swimming-associated enteric and respiratory symptoms, suggests that contamination from the bathers themselves is the source of the indicators and swimming-associated illness at Gordon Beach.

Key words: Epidemiology; bathing beaches; indicators; water quality; swimming-associated illness

Introduction

The bathers themselves are the sources of the infectious agents which may contaminate the water in swimming pools. The potential for infectious disease is increased because of minimal dilution under conditions of high bather density. Chlorination of the water is the major barrier in preventing person-to-person transmission of the agents via the bathing water; and it has been suggested by several investigations (Mallman 1962; Favero *et al.* 1964; Robinton and Mood 1966) that, aside from the measurement of chlorine residuals, the levels of staphylococci shed from the skin of the bathers is the best measure of water quality since this measurement considers both bather density and the effectiveness of chlorination.

It is reasonable to conclude, therefore, that under conditions of heavy usage and minimal water exchange, the bathers themselves may be the major source of the agents in natural bathing places as well. The results from three epidemiologic investigation at fresh water bathing beaches (Dallessio *et al.* 1981; Seyfried *et al.* 1985; Calderone *et al.* 1991) suggest the bathers themselves were the sources of the infectious agents responsible for swimming-associated illness. They also infer chlorination of the water at beaches in some small fresh water ponds is practiced to minimize bather-to-bather transmission of the

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agents via the water. In this report, we present the results of a prospective epidemiologic bathing beach study at some heavily used coastal, saltwater beaches which, because of the use of horizontal surf-breakers to reduce wave action, suggest the bathers themselves as the sources of the pathogens responsible for the excess of illness among swimmers relative to non-swimmers.

Materials and methods

The design of this 'mini' prospective epidemiological study was similar to that of Cabelli (1983). In general, it followed the recommendations for prospective epidemiological-microbiological studies as given by the World Health Organisation (WHO/UNEP 1977). There were three notable exceptions and all three of them could have influenced the results of the study. The first was that water exchange was markedly restricted at two of the beaches (Gordon and Sheraton) due to the effect of off-shore, horizontal surf-breakers (Fig. 1). The second exception was that beach interviews were not only conducted on Saturdays, which is not a working day in Israel, but on Fridays and Sundays as well. Beach usage was markedly greater on Saturdays than on other days

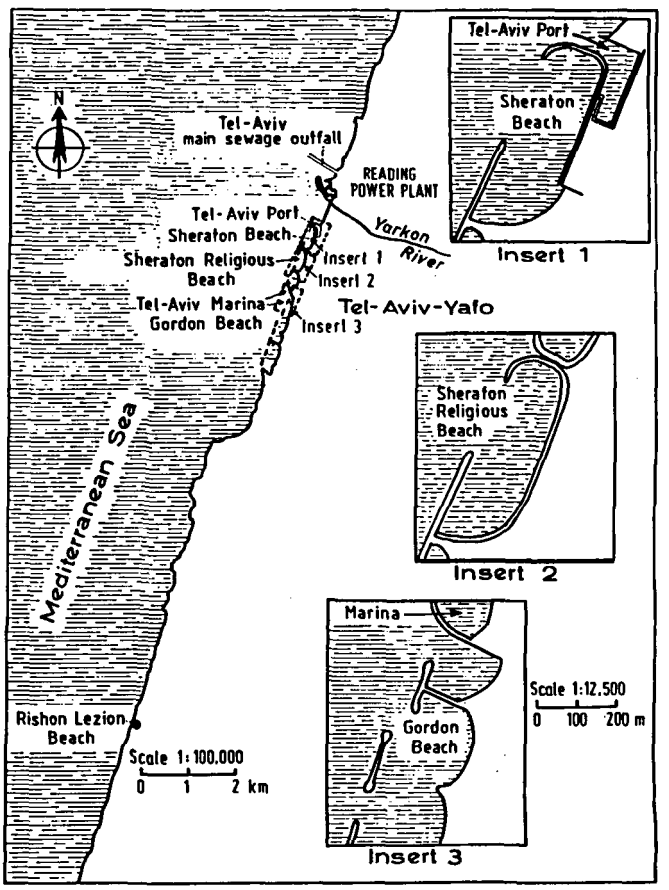

Fig. 1. Location of the study beaches.

except for a portion of the Sheraton beach which is used on Sundays by highly religious individuals. Therefore, the data from these individuals were not included in the initial analyses. The third was that the data from persons who swam in the five days prior to and following the beach interviews were not excluded from the analyses because monetary constraints limited the size of the study population.

Study sites and conditions

The study was conducted between May and August (1983). It was started at the beginning of the bathing season in order to include bathers who came to the beach for the first time that season. Three beaches in the greater Tel-Aviv area were chosen for the study, Sheraton, Gordon and Rishon Lezion (Fig. 1). Sheraton was actually two beach areas, one of which was used by religious individuals as noted above. Although the first two beaches are near what was the outfall for raw sewage from Tel-Aviv, both are south of the outfall and the prevailing current is from south to north. However, wind driven contamination from the outfall could have reached the beaches, albeit at very low levels. The Rishon Lezion Beach is located 15 km further south of the Tel-Aviv outfall. There is a very small municipal waste water discharge some 3–4 km south of the beach. All the beaches were approved for bathing by the Israeli Ministry of Health.

The study population

Potential participants were recruited at the beach and queried some 3–5 days later by telephone concerning symptomatology which developed subsequent to the swimming experience. A 3–5 day interval was considered satisfactory since the USA studies had shown that the mean incubation period for the most common swimming-associated, pollution-related illness, an acute gastroenteritis, was less than two days (Cabelli, 1983). An effort was made to select only families that came to the beach with at least one child less than 10 years of age. Families with no access to a telephone were not interviewed. The mother was usually chosen as the contact for beach and telephone interviews. A 'swimmer' was defined as any participant present at the beach whose head had been immersed in the water, who had swallowed seawater or whose face had been splashed by waves. A 'nonswimmer' was defined as any participant present at the beach who was not designated a swimmer.

The study population consisted of 1796 individuals. This number is smaller than that used in a preliminary analysis of the data Fattal *et al.* (1986) because data from two sources were eliminated from the initial analyses. They were those from the individuals at a beach which, for religious reasons, was used by men on some days and women on others and those in which both enterococcus levels in the water and follow-up illness information were not available. This left 23 study days as follows: Gordon 13 (Saturdays 7, Fridays or Sundays 6); Rishon Lezion 7 (Saturdays 5, Fridays 2); Sheraton 3 (Fridays 3). Demographic data obtained at the beach included age, sex, country of origin and socioeconomic status.

Symptomatology

Morbidity information was obtained from the respondents by telephone. Symptoms were categorized as total enteric (vomiting, diarrhea, abdominal pain or nausea), total respiratory (throat irritation, severe cough, or colds), skin complaints, earache or fever (temperature over 37.5°C).

Enteric or respiratory symptoms were considered highly credible if fever also was reported or if the individual was absent from work, school or kindergarten, or visited a nurse or physician for medical treatment (Cabelli 1983).

Bacteriological testing

Water samples were taken for bacteriological testing twice a day, once in the morning and once in the afternoon during the day of the beach interview. They were collected from below the surface of the water in sterile containers at a minimum of two locations where individuals were swimming. The samples were kept on ice, shipped to the laboratory and assayed within 6 h of collection. Equal quantities of the samples collected from different locations at a given time at a given beach were pooled just prior to assay. The levels of enterococci, *E. coli* and *S. aureus* were determined by the methods of Levin *et al.* (1975), Dufour *et al.* (1981) and Mintzer-Morgenstern and Katzenelson (1980) respectively. *S. aureus* assays were not performed for the first 7 trial days.

Statistical analyses

Illness rates for swimmers relative to non-swimmers were examined by the chi-square analysis. The log-transformed indicator levels were compared using the Student's t-test. Correlation of swimming-associated symptom rates to log-transformed indicator levels in the water was examined by linear regression. Each indicator level assigned to a given trial day was the geometric mean of the values obtained from the morning and afternoon samples.

Results

The success rate for the follow-up telephone calls was in excess of 90%. Of the 1796 individuals for whom usable follow-up information was obtained, 22% were young children (<5 years old). Only the data from two of the beaches, Gordon and Rishon Lezion, were used in most of the analyses for the reasons given. The percentages of young children at the two beaches were 21 and 23, respectively. The percentages of swimmers among the total population (70.3) and young children (65.4) at Gordon were significantly greater than the corresponding ones at Rishon Lezion (57.5 and 50.7, respectively). These differences are consistent with the much calmer waters at Gordon Beach and could have been responsible for the higher indicator levels in the water. The percentage of swimmers at Gordon on Saturdays (69.7) was not significantly different from that on other days (71.6).

All the symptom categories were found to be swimming-associated, although not necessarily pollution-related (Table 1). That is, the rates of all the symptom categories for swimmers were higher than those for nonswimmers when the total data set was examined. Only the rates for earaches and total enteric and respiratory symptoms for all ages and highly credible respiratory symptoms for the <5 years age group were significantly higher among swimmers. The swimming-associated rates for all symptom categories were highest among young children, but significance generally was not obtained, presumably because of the smaller number of individuals.

When the geometric mean indicator levels in the water at the three beaches were compared, those at Sheraton were not significantly different from those at the other two beaches. The enterococcus levels at Gordon and Rishon Lezion, however, were significantly different from each other (Table 2). Therefore, the swimming-associated

Table 1. Swimming-associated symptom rates

	Symptom rates per 1000 persons[b]					
	All ages			*< 5 years*		
Symptoms[a]	*S (1182)*[c]	*NS (614)*	*S–NS*	*S (241)*	*NS (152)*	*S–NS*
Total enteric	88.0	61.9	26.1*	170.1	111.8	58.3
HC enteric	35.5	29.3	6.2	74.7	65.8	8.9
Total respiratory	80.4	55.4	25.0*	186.7	131.6	55.1
HC respiratory	30.5	19.6	10.9	91.3	39.5	51.8*
Skin	30.5	27.7	2.8	83.0	52.6	30.4
Earache	18.6	1.6	17.0†	37.3	6.6	30.7

[a]Total enteric symptoms: vomiting, diarrhea, abdominal pain or nausea.
Total respiratory symptoms: colds, cough or throat irritation.
HC highly credible (see text for definition).
[b]S: swimmers; NS: non-swimmers; (S–NS): swimming-associated (see text for definition of swimmers).
[c]Number of usable responses.
*, †Rate for swimmers significantly different from that for non-swimmers at $p < 0.1$ and $p < 0.05$, respectively.

Table 2. Comparison of indicator levels by beach

	GM[a] *indicator level per 100 ml*		
Indicator	*Gordon*	*R. Lezion*	*Sheraton*
Enterococci	33.6 (13)[b]	11.2 (7)†	17.9 (3)
E. coli	24.0 (13)	13.7 (7)	19.2 (3)
S. aureus	23.5 (10)	20.1 (3)	13.4 (3)

[a]GM: geometric mean.
[b]Number of days (two samples per day).
†Significantly different from Gordon at $p < 0.05$.

symptom rates for all ages and young children at the two beaches also were compared (Table 3). The symptom rates generally were higher among swimmers than nonswimmers for all ages and young children at both beaches, but only at Gordon Beach were any of the differences significant. Included were those for total enteric symptoms (primarily because of diarrhea), total and highly credible respiratory symptoms, fever among all ages and total enteric symptoms (including diarrhea) among the young children.

The swimming-associated symptom rates among all ages at Gordon were more than about twice those at Rishon Lezion (Table 3), except for total respiratory symptoms, skin complaints and earaches. Among young children, only the rates for swimming-associated fever and enteric symptoms were appreciably higher at Gordon than at Rishon Lezion. It would appear that throat irritation and cough among adults were responsible for the higher swimming-associated rates for respiratory symptoms for all ages at Gordon as compared with Rishon Lezion. We have no explanation for this finding. Skin complaints

Table 3. Comparison of swimming-associated symptom rates for Gordon (G) and Rishon Lezion (RL) beaches

	Swimming-associated symptom rates per 1000 persons[a]					
	All ages			*< 5 years*		
Symptoms	*Gordon (700/296)*[b]	*R. Lezion (350/259)*	*G/RL*[c]	*Gordon (136/72)*	*R. Lezion (71/69)*	*G/RL*
Total enteric	34.9*	15.5	2.3	101.0*	24.9	4.1
HC enteric[d]	7.3	1.5	4.9	46.6	−31.0	>47
Vomiting	6.5	1.9	3.4	37.6	−0.4	>38
Diarrhea	28.6*	−11.0	>29[e]	84.2*	−31.0	>84
Abdominal pain	13.4	7.1	1.9	31.9	−0.3	>32
Nausea	6.0	>7.6	<0.8	>0.8	NC[f]	NC[f]
Total respiratory	28.4*	25.8	1.1	59.6	80.8	0.7
HC respiratory[d]	23.2*	6.3	3.7	67.8	55.1	1.2
Cough	12.6	2.4	5.3	32.7	54.3	0.6
Colds	15.2	23.4	0.6	44.1	82.5	0.5
Throat irritation	17.5	4.4	4.0	1.6	13.7	0.1
Fever	22.2*	2.4	9.3	46.6	−2.5	>47
Skin complaints	−5.2	5.4	0.2	−10.6	41.4	<0.0
Earache	13.8	>16.1	<0.9	8.2	>41.6	<0.2

[a]Rate for swimmers minus rate for non-swimmers.
[b]Study populations (swimmers/non-swimmers).
[c]Relative risk for swimming-associated symptoms at the two beaches.
[d]HC: highly credible symptoms (see text for definition).
[e]*Minus (−) values set at 1.0 in estimation of G/RL.*
[f]NC: could not be calculated.
*Rate for swimmers significantly different from that for non-swimmers at $p < 0.1$.

were not associated with swimming, with the possible exception of children at Rishon Lezion. To the extent that pollution levels were higher at Gordon than at Rishon Lezion, earaches were swimming-associated but not pollution-related. The greatest relative risks of swimming-associated illness at the two beaches were for enteric symptomatology and fever among young children at Gordon Beach.

Swimming-associated symptoms for the 16 beach-days when data were available for all three indicators were grouped by the indicator levels. Then, the rates for each group were regressed against the corresponding mean indicator levels. These analyses provided an important insight into the sources of contamination. *S. aureus* levels in the water were more positively correlated than those of the enterococci or *E. coli* to total and highly credible enteric and respiratory symptoms (Table 4). This observation suggested the possibility that the increased indicator levels and swimming-associated illness rates at Gordon Beach were due to contamination from the bathers themselves and not to extrinsic contamination with sewage from the outfall to its north (Fig. 1). This explanation was consistent with the virtual absence of wave action at Gordon Beach because of horizontal and 'T' surf-breakers.

Since the bather load at Gordon Beach was considerably higher on Saturdays than other days, the symptom rates on Saturdays at Gordon Beach were compared to those on other days at this beach and to all days at Rishon Lezion (Table 5). This analysis suffered

Table 4. Correlation coefficients for log indicator levels against swimming-associated symptom rates

	Correlation coefficients (r)			
	Total		*Highly credible*	
Indicator	*Enteric*	*Respiratory*	*Enteric*	*Respiratory*
Enterococci	−0.13	−0.72	−0.75	−0.47
E. coli	−0.24	−0.42	−0.64	−0.46
S. aureus	0.79	−0.42	0.15	0.22

Table 5. Comparison of swimming-associated symptom rates on Saturdays and other days

	Swimming-associated rates per 1000 persons					
			All ages			
	Gordon Beach		*Sheraton Beach*		*Rishon*	*< 5 years*[b]
			Religious	*Other*	*Lezion*	*Gordon*
	Saturday	*Other*	*Sunday*	*Friday*	*Saturday*	*Saturday*
Symptoms	*(498/216)*[a]	*(202/80)*	*(195/136)*	*(132/59)*	*(300/226)*	*(96/50)*
Total enteric	48.9†	9.2	26.8	−27.7	5.8	138*
HC enteric[c]	6.4	9.7	16.7	9.8	−1.0	75
Total respiratory	34.6	11.8	38.6	24.9	24.7	108*
HC respiratory	> 27.5†	−5.2	10.9	−11.2	4.6	> 105†
Earache	> 15.5*	−2.6	0.7	5.8	> 18.9	> 11.3
Skin complaints	0.3	−25.3	> 28.5*	36.1	11.2	−7.9

[a]Size of study populations (swimmers/non-swimmers).
[b]Size of study populations too small to calculate rates for all ages on other days at Rishon Lezion and for < 5 years age group for Gordon during other days (40/22) and Rishon Lezion during Saturdays (59/56) and other days (23/19). Rates for Gordon on Saturdays included only to show source of high rates in total population.
[c]HC: highly credible symptoms (see text for definition).
*, †Rates for swimmers significantly different from those for non-swimmers at $p < 0.1$ and $p < 0.05$, respectively.

from the small size of the study populations during days other than Saturday. It can be seen, however, that the higher swimming-associated symptom rates at Gordon relative to Rishon Lezion, generally were attributable to those for Saturdays at Gordon Beach. The rates for enteric and respiratory symptoms among young children on Saturdays at Gordon were more than five times those for the older individuals (data not shown).

Support for the possibility that contamination from the bathers themselves was responsible for swimming-associated illness at Gordon came from the data obtained from the beach used by religious individuals. This beach located between Sheraton and Gordon (Fig. 1), also is sheltered by horizontal breakers and has virtually no surf activity. The swimming-associated rates for enteric and respiratory symptoms were markedly higher than those for Gordon or Sheraton on 'other' days and comparable to those for Gordon on Saturdays (Table 5).

The levels of all three indicators were higher on Saturdays at Gordon Beach than on other days at this beach or Saturdays at Rishon Lezion (Table 6).

Table 6. Comparison of indicator levels on Saturdays and other days

	GM[a] indicator level per 100 ml			
	Gordon		*Rishon Lezion*	
Indicator	*Saturday*	*Other*	*Saturday*	*Other*
Enterococci	47.2 (7)[b]	22.6 (6)	14.1 (5)[c]	6.2 (2)[d]
E. coli	31.9 (7)	17.2 (6)	20.1 (5)	2.0 (2)
S. aureus	35.3 (5)	15.6 (5)	20.1 (3)	ND[e]

[a]GM: geometric mean.
[b]Number of days (two samples per day).
[c]Significantly different from Gordon on Saturday at $p < 0.05$.
[d]Significantly different from Gordon on other days at $p < 0.05$.
[e]Not determined.

Discussion

It is now clear from the results of several prospective epidemiological studies that contamination of bathing waters with municipal waste water discharges, even at levels which are aesthetically acceptable, results in an increased risk of swimming-associated illness, principally a relatively benign gastroenteritis (Cabelli *et al.* 1982; Centers for Disease Control 1982; Foulon *et al.* 1983; Dufour 1985; Brown *et al.* 1987) and less frequently shigellosis (Rosenberg *et al.* 1976).

There undoubtedly also is a risk of infectious disease at some natural bathing places in which the bathers themselves are the sources of the pathogens. Beaches in fresh water ponds and lakes which are both heavily used and subject to minimal water exchange are the most likely locations for this to occur. There have been several small outbreaks of swimming-associated shigellosis where this was suspected since there were no known extrinsic sources of human faecal contamination (Centers for Disease Control 1983). Contamination of the water from the bathers cannot be excluded as an explanation of the outbreaks of swimming-associated infections at fresh water beaches due to Coxsacki A (Denis *et al.* 1974), Coxsacki B (Hawley *et al.* 1973) and hepatitis A viruses (Bryan *et al.* 1974). In addition, the swimming-associated disease and/or symptomatology reported by Dallessio *et all.* (1981) and Seyfried *et al.* (1985) from epidemiological studies at fresh water beaches also may have derived from contamination due to the bathers.

The best explanation for the results obtained from this study is that the major source of faecal contamination at Gordon Beach, at least on Saturdays when the bather density is high, was the bathers themselves. This explanation is consistent with a number of observations. The only known source of faecal contamination was the main sewage outfall for Tel-Aviv which is located about 3 km north of the beach, but the current flow along the beach generally is from south to north (although wind-driven contamination from the outfall could reach the beach). The use of 'T' and horizontal breakers markedly reduces wave action and, presumably, water exchange at the beach. The highest swimming-associated rates at Gordon on Saturdays were among the <5 year old age group. We speculate that these very young children, who play at the waters edge, are subjected to the highest levels of contamination from each other and from other bathers.

Individuals who swam midweek before and after a Saturday, were retained in the study population in order not to further reduce its already small size. Their retention probably overstated the reported illness rates for 'other days' to the extent that the individuals also swam on Saturdays.

The better correlation of the swimming-associated enteric and respiratory symptom rates to *S. aureus* levels in the water also is consistent with the bathers themselves as the source of contamination. Seyfried *et al.* (1985) also found that *S. aureus* levels in the water generally were better correlated than those of enterococci or coliforms to illness among swimmers at some fresh water beaches. Our interpretation of their findings is that the major sources of contamination, at least during times of heavy beach usage, were the bathers themselves. More important, *S. aureus* levels in the water were correlated with both bather density and swimming-associated enteric symptoms (in the fresh water epidemiological study conducted by Calderone *et al.* (1991)). We assume that the source of the *S. aureus* is the skin of the bather since the organism can be isolated from that location in normal individuals and is not part of the faecal flora (Moore *et al.* 1974).

Unfortunately, neither bather density nor water exchange were measured in the present study. It was very obvious, however, that the bather density was higher on Saturdays than other days at Gordon Beach; and there was virtually no wave action within the breakers. These are measurements which should be made when the bather themselves are suspected to be a significant source of contamination.

The results of this study and the others noted have three implications of a somewhat more practical nature. The first is the paradox concerning the use of horizontal surf-breakers. While their use creates calm waters better suited for young children, it also increases the risk of illness, especially for this age group. the second issue is the validity of criteria based on sewage derived faecal indicators in situations where the bathers themselves are the major sources of the indicators and potential pathogens. The third is the applicability of monitoring data obtained in such situations to the prediction of swimming-associated illness rates or the classification of bathing beaches.

The susceptibility of a bathing population to infection should be no different whether the source of the agents is intrinsic or extrinsic to them. The ratios of indicators to pathogens in the water and the degree of exposure, however, could be quite variable when the source of the pathogens is the bathers themselves. If the data base is sufficiently large, the recreational water quality could be valid; but our inclination is against the development of criteria from data obtained when the source of the pathogens is primarily the bathers themselves.

The use of the monitoring data obtained in an instructive or regulatory mode is inappropriate because the risk of illness is not predictable and cannot be reduced by conventional source control. Therefore, water samples collected during compliance monitoring against the standards should be taken during times when the beach usage is minimal and at locations which are the least subject to contamination from the bathers themselves.

Conclusions

Firstly, bather-to-bather transmission of infective agents via the water can be an important means for the transmission of swimming-associated enteric and respiratory disease at marine bathing beaches under conditions of minimal water exchange and

heavy usage. *S. aureus* levels in the water is the best index for assessment of the risk of illness. Secondly, horizontal surf-breakers employed to reduce wave action should be used judiciously. Thirdly, bathing beach epidemiological studies should not be conducted in situations where the bathers themselves are the major source of contamination. Fourthly, water samples collected in a monitoring program to classify bathing beaches should be taken when beach usage is minimal.

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