Estimates of the severity of illnesses associated with bathing in marine recreational waters contaminated with domestic sewage

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Background During the summers of 1989–1992 we conducted four randomized intervention trials at four separate UK bathing locations judged of acceptable quality under current USEPA and EU criteria. The results showed bathers to be at increased risk of gastroenteritis, acute febrile respiratory illness (ICD-9 461–466, 480), ear and eye infections relative to non-bathers. The public health significance of these findings has been questioned based upon the unproven assumption that these illnesses are minor in nature and thus of questionable public health significance.

Methods The severity of these illnesses or ailments in terms of duration of illness, percentage of participants seeking medical treatment, and number of days of lost normal daily activity among study participants reporting specific illnesses or ailments were assessed. In addition the attributable proportion of illness among the exposed (bathers) was calculated for each illness or ailment.

Results Average duration of illness ranged from approximately 4 days to approximately 8 days depending on the specific illness reported. The percentage of study participants seeking medical treatment ranged from 4.2% to 22.2% while the percentage reporting the loss of at least one day of normal daily activity ranged from 7.0% to 25.9% depending on the illness reported. The overall percentage of each illness that can be directly attributable to exposure to marine waters contaminated with domestic sewage ranged from a low of 34.5% for gastroenteritis to a high of 65.8% for ear infections.

Conclusions To our knowledge, this is the first study to assess and report the severity of illnesses associated with bathing in recreational waters contaminated with domestic sewage. Illness associated with bathing in marine waters contaminated with domestic sewage can no longer be viewed as minor, and indeed can have a substantial impact on the public health.

Keywords Recreational water quality, indicators of water quality, illness severity, microbiology

Accepted 21 November 1997

The possible transmission of infectious disease via primary contact with recreational waters contaminated with domestic sewage has been the subject of 11 previously published epidemiological studies. The results reported in these studies suggest that bathing in such waters results in an excess of risk of gastroenteritis, respiratory ailments, ear, eye and skin ailments. Unfortunately, there has been large disparity both in terms of the particular illnesses of which bathers are at higher risk and the estimates of such risk reported among these previously published epidemiological studies.

Major weaknesses in epidemiological study design have contributed to this disparity of findings, and have been discussed elsewhere. Briefly, these weaknesses include: (1) failure to relate bacteriological water quality indices (Indicator Organism Density) directly to the individual bather; (2) failure to incorporate water quality sampling regimes that control for the substantial amount of temporal and spatial variation in indicator
organism densities shown to occur at marine bathing water locations;\textsuperscript{14} (3) failure to control for the large amount of nondifferential measurement error bias caused by the limited precision of current techniques of indicator organism enumeration;\textsuperscript{15} and (4) failure to adequately control for non-water-related risk factors and/or confounders for the illnesses studied.\textsuperscript{13}

During the summers of 1989 through 1992, we conducted four randomized intervention follow-up studies at four beaches located throughout the UK. These series of intervention follow-up studies were specifically designed to address the methodological weaknesses inherent in previously conducted epidemiological studies. Although the methods used and results obtained from these studies have been reported elsewhere,\textsuperscript{16,17} a brief explanation follows.

Four separate study locations located within the UK were used. The study locations were sufficiently distant from one another so that possible site-specific differences in the risk of bathing-associated illnesses could be assessed. All study locations met European Community mandatory bacteriological marine bathing water quality criteria as well as US Environmental Protection Agency criteria.\textsuperscript{18,19} Adult volunteers (>18 years) were recruited in population centres close to specific study locations. There was no duplication of volunteer cohorts between study locations. Ethical clearance for all four studies was granted by the Royal College of Physician’s Committee for Research on Healthy Volunteers. Informed consent was obtained from all study volunteers in such a manner as to keep volunteers blinded to the outcome illnesses under study. Four separate studies (Trials) were conducted on four successive bathing seasons during the summers of 1989–1992. Each Trial took about 3 hours to complete.

Healthy volunteers were randomized into bather and non-bather groups; the duration and place of individual bather exposure was rigorously controlled: indicator organism exposure was assigned to individual bathers within 15 minutes of actual exposure and within a maximum of 10 m of the actual point of exposure; and extensive pre- and post-trial-day interviews designed to identify, quantify, and control for non-water-related risk factors and/or possible confounders for the outcome illnesses under study was administered to each volunteer. (Initial interview 2–3 days prior to each trial, trial-day interview, first follow-up interview at 7 days, and second follow-up at 3 weeks post-trial day). All study subjects did not know their exposure status (bather or non-bather) until they reported to the beach.

Bathers were encouraged to spend at least 10 minutes in the water and were required to completely immerse their heads three times during exposure. No bathing caps, or other ‘protective gear’ was allowed. ‘Beach Supervisors’ recorded the duration of exposure of each individual bather. Non-bathers were kept in a roped-off area distant from the water, and ‘beach supervisors’ ensured that no non-bather entered the water.

Water quality sampling was conducted at 30-minute intervals for the following five bacteriological indices of water quality: total coliform, faecal coliform, faecal streptococci, total staphylococci, and \textit{Pseudomonas aeruginosa}. Samples were collected in the surf zone; in waters approximately 1 m in depth; and in waters approximately 1.3–1.4 m in depth (chest depth). At each of these three sampling locations, samples were taken 30 cm below the surface. It should be noted that ‘chest’ depth was the actual location where bather exposure took place. Geometric mean (GM) indicator organism counts (per 100 ml of sample) and ranges at the actual point of bather exposure over the four study trials were as follows: total coliform GM = 89, range 0–812; faecal coliform GM = 71, range 0–662; faecal streptococci GM = 24, range 0–159; \textit{Pseudomonas aeruginosa} GM = 2, range 0–137; and total staphylococci GM = 326, range 0–2801.

A total of 1216 participants (548 bathers and 668 non-bathers) comprised the final combined study cohort. The mean age of the final bather cohort was 31.65 years versus 32.12 years for the final non-bather cohort. Of the bathers, 54% were male, while 46.5% of non-bathers were male.

The public health significance of these findings have been questioned based on the unproven assumption that these illnesses are minor in nature, and thus of questionable public health significance.\textsuperscript{21–23} Therefore, we now report our findings regarding the severity of illness suffered by bathers participating in the four randomized intervention follow-up studies we conducted, along with estimates of the overall percentage of each outcome illness among bathers that can be directly attributed to bathing in marine waters contaminated with domestic sewage.

**Methods**

Three outcome measures were used to ascertain the severity of the four illnesses or ailments of which we observed bathers to be at a higher risk relative to non-bathers. These measures are duration of illness, whether or not the individual sought medical treatment, and the number of days of normal activity lost due to the particular ailment.

All study participants were asked to indicate the duration of any symptoms suffered, whether or not they sought medical attention for these symptoms, and the amount of time lost from normal activities as a result of their illness. This information was obtained at structured follow-up interviews administered by trained interviewers 7 days after the actual trial day, and via a self-administered questionnaire that covered the time period from 8 days post-trial day to 21 days post-trial day. In both instances, duration of illness was obtained by showing each participant a calendar that reflected the appropriate follow-up period, and asking the participant to identify their symptom/s and circle each day these symptoms persisted.

Prior to any analysis, individual symptoms were grouped together to form the following classifications of illness:\textsuperscript{16,17}

**Gastroenteritis**

This included all cases of vomiting or diarrhoea or all cases of nausea, indigestion, diarrhoea or vomiting that was accompanied by a fever. Diarrhoea was defined as having \textgeq3 runny stools within a 24-hour period. The grouping of symptoms in this manner was undertaken both to minimize possible bias due to inter-individual variations in the perception of what constitutes a case of gastroenteritis, and to provide compatibility with the definition of gastroenteritis used by Cabelli \textit{et al.}\textsuperscript{3} in their large prospective cohort study, the results of which form the basis of current USEPA criteria governing marine recreational waters.

**Acute febrile respiratory illness**

Previously published studies have failed to define respiratory symptoms according to some known classification of disease. It
was therefore decided to classify respiratory symptoms according to the criteria set forth in the American Public Health Association's Manual of Communicable Diseases. The disease entity 'Acute Febrile Respiratory Illness (AFRI)', ICD-9 461–466, 480 was chosen.20 The infectious agents responsible for this disease classification are numerous viral agents. Among these viral agents are enteroviruses and adenoviruses known to be discharged in human faeces, which have been implicated in outbreaks of this illness among people bathing in swimming pools.20 According to the American Public Health Association's classification criteria, study participants were classified as having AFRI if they experienced at least one of the symptoms listed in each of the following categories: (a) fever; (b) headache and/or bodyaches and/or unusual fatigue and/or anorexia; (c) sore throat and/or runny nose and/or dry or productive cough. Therefore, in order to be a study participant to be classified as having AFRI, the participant must have reported at least one symptom from each of these three categories.

**Ear ailments**

This included any clinical evidence of ear infection or inflammation noted at the medical examination given to each study participant at the 7-day post-trial follow-up interview, or any reported incidence of ear pain, with or without accompanying discharge.

**Eye ailments**

This included any reported incidence of sore, red eyes with or without concurrent discharge.

In order to ensure that each individual symptom reported was part of a single illness, all symptoms comprising a particular illness must have been reported within a single follow-up interval (i.e. all symptoms comprising a specific ailment reported at the follow-up interview that occurred 7 days post-trial date or all symptoms reported on the postal questionnaire which covered the follow-up interval of between 8 and 21 days post-trial). It should be noted that all illness classifications were decided upon prior to any data analysis.16,17

With regard to the severity of each of these illnesses, we report the mean and median duration, an estimate of the number of days of normal activity lost, and an estimate of the percentage of bathers and non-bathers who sought medical treatment for each of the outcome illnesses described above. In order to be conservative, if any of these data were missing for a particular study participant, the participant was regarded as having an illness duration of less than one day (coded as 0 duration), or having no loss of normal daily activity, or not seeking medical treatment depending on which measure of severity lacked data. In this manner, the estimates of disease severity we report should be considered conservative. In order to assess possible differences in these parameters among bathers versus non-bathers, χ² analysis was used when testing categorical data, while t-test procedures were used for continuous data.

With respect to the estimation of the overall percentage of each illness or ailment among bathers that could be attributed to the exposure (bathing in marine waters contaminated with domestic sewage), the attributable proportion among the exposed was computed according to the method described by Rothman.24

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**Table 1** Rates of illness among bathers versus non-bathers

<table>
<thead>
<tr>
<th>Illness</th>
<th>Bathers Rate/100</th>
<th>Bathers n³</th>
<th>Non-bathers Rate/100</th>
<th>Non-bathers n³</th>
<th>ρb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gastroenteritis</td>
<td>14.8</td>
<td>507</td>
<td>9.7</td>
<td>605</td>
<td>0.018</td>
</tr>
<tr>
<td>AFRI</td>
<td>5.0</td>
<td>546</td>
<td>3.0</td>
<td>665</td>
<td>0.10</td>
</tr>
<tr>
<td>Ear ailments</td>
<td>8.2</td>
<td>525</td>
<td>2.8</td>
<td>636</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Eye ailments</td>
<td>4.5</td>
<td>538</td>
<td>2.1</td>
<td>658</td>
<td>0.044</td>
</tr>
</tbody>
</table>

³ Sample size differs between symptoms due to numbers of volunteers having the specific illness on the trial day and excluded from further analysis.

b P-value from Mantel-Haenszel summary statistic for all four study locations.

c Acute febrile respiratory illness.

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**Table 2** Duration of illness (measured in days) among bathers and non-bathers

<table>
<thead>
<tr>
<th>Illness</th>
<th>Bathers Mean (SD) Median</th>
<th>Bathers n³</th>
<th>Non-bathers Mean (SD) Median</th>
<th>Non-bathers n³</th>
<th>ρb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gastroenteritis</td>
<td>4.1 (5.1) 2.75</td>
<td>75</td>
<td>3.9 (4.1) 3.5</td>
<td>59</td>
<td>0.84</td>
</tr>
<tr>
<td>AFRI</td>
<td>5.7 (5.7) 5.27</td>
<td>27</td>
<td>5.1 (5.0) 3.5</td>
<td>20</td>
<td>0.73</td>
</tr>
<tr>
<td>Ear ailments</td>
<td>8.1 (9.1) 6.43</td>
<td>43</td>
<td>5.4 (3.5) 5.8</td>
<td>18</td>
<td>0.11</td>
</tr>
<tr>
<td>Eye ailments</td>
<td>4.5 (3.1) 3.5</td>
<td>24</td>
<td>5.8 (5.5) 4.4</td>
<td>14</td>
<td>0.42</td>
</tr>
</tbody>
</table>

³ Actual number of participants with illness or ailment.

b Tests the hypothesis that the duration of illness or ailment among bathers equals the duration among non-bathers.

c Acute febrile respiratory illness

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**Results**

Table 1 shows the rates of gastroenteritis, AFRI, ear and eye ailments among bathers versus non-bathers after exclusion of those subjects having any of the specific outcome illnesses on the actual trial day. Inspection of Table 1 shows bathers to have statistically significantly higher rates (P < 0.05) of gastroenteritis, ear and eye ailments relative to non-bathers. With respect to the occurrence of AFRI, Table 1 shows bathers to have a nearly statistically significant increase in the occurrence of this illness (P = 0.10). (It should be noted that this difference reached statistical significance when bathers exposed to >60 faecal streptococci were compared with non-bathers, P < 0.001.)

Table 2 shows the mean (SD) and median duration of illness among bathers and non-bathers along with the P-value resulting from a test of the hypothesis that there is no difference in the average duration of illness among bathers versus non-bathers (t-test). Inspection of Table 2 shows that, on the average, bathers acquiring gastroenteritis were ill for approximately 4 days; bathers suffering from AFRI were ill for approximately 6 days; bathers contracting ear ailments were ill for approximately 8 days; and that bathers acquiring an eye ailment were ill for approximately 4 days. Table 2 further shows no statistically significant (P > 0.05) difference in the duration of any of these outcome illnesses among bathers versus non-bathers. This finding is not surprising given the fact that non-bathers represented a sample of the unexposed population that generated the pathogenic organisms contained in the sewage discharged into the waters in which bather exposure took place. Since the vast majority of study participants were local residents, our findings suggest that possible issues of local immunity did not prohibit...
excess illness among bathers. Further, it is extremely doubtful given the substantial surf and tidal activity observed at our marine water study locations, the strict supervision of bather exposure, and the distance between exposure points (approximately 20 m), that possible contamination induced by the bathers themselves could have influenced our findings.

Among bathers acquiring a specific illness or ailment, the following percentage sought medical treatment: gastroenteritis 12.0%; AFRI 22.2%; ear ailments 20.9%; and eye ailments 4.2%.

With respect to time lost from normal activities, 14.7% of bathers reporting gastroenteritis reported a loss of at least one day; 4.0% reporting losing 2 days; and 1.4% reported losing 3 days. Of those bathers classified as having AFRI, 25.9% reported losing at least one day of normal activity. Of this 25.9%, 7.4% reported losing one day; 14.8% reported losing 2 days; and 3.7% reported losing 3 days of normal activity. With respect to ear ailments, 7.0% of bathers acquiring this ailment reported the loss of at least one day of normal activity (2.3% reported losing one day, 2.3% reported a loss of 2 days, while 2.3% reported a loss of 3 days). And lastly, among bathers reporting an eye ailment, 12.5% reported losing at least one day of normal activity. Of this 12.5%, 4.2% reported losing a day of one day, while 8.3% reported losing 2 days. It should be noted that non-bathers did not differ significantly (P > 0.05) from bathers both in terms of the illness specific percentages seeking medical treatment or in the amounts of time lost from normal daily activities. Again, this is to be expected under the hypothesis that the non-bather cohort represent a sample of the unexposed population generating the pathogens contained in the sewage to which the bather cohort was exposed.

Table 3 shows the attributable fraction of illness among the exposed (bathers). Inspection of Table 3 shows that the percentage of each outcome illness acquired by bathers that can be directly attributable to the exposure (i.e. bathing in marine waters contaminated with domestic sewage) ranged from a low of 34.4% for gastroenteritis to a high of 65.8% for ear ailments.

**Table 3 Attributable proportion of illness among the exposed (bathers)**

<table>
<thead>
<tr>
<th>Illness</th>
<th>Attributable proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gastroenteritis</td>
<td>34.4%</td>
</tr>
<tr>
<td>AFRI</td>
<td>40.0%</td>
</tr>
<tr>
<td>Ear ailments</td>
<td>65.8%</td>
</tr>
<tr>
<td>Eye ailments</td>
<td>53.3%</td>
</tr>
</tbody>
</table>

* Acute febrile respiratory illness.

The estimates shown in Table 3 indicate that from 34.4% to 65.8% of the illnesses reported by our bather cohort can be attributed to bathing in marine waters contaminated by domestic sewage. The fact that this large burden of illness occurred in marine waters meeting both current USEPA criteria governing marine bathing waters and current European criteria questions the appropriateness of such criteria.

Since this is the first study to report estimates of disease severity and the proportion of illness among bathers attributable to bathing in marine waters contaminated with domestic sewage, more research is needed to confirm the results reported herein.

**References**

15. Fleisher JM. The effects of measurement error on previously reported mathematical relationships between indicator organism density and swimming associated illness: A quantitative estimate of the resulting bias. *Int J Epidemiol* 1990;19:1100-06.


