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Health effects of white-water canoeing

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There is little quantitative information on the relation between water quality and disease attack rates after recreational activities in fresh water. We conducted a prospective cohort study to measure the health effects of white-water and slalom canoeing in two channels with different degrees of microbial contamination.

Site A, fed by a lowland river, showed high enterovirus concentrations (arithmetic mean 198 pfu per 10 litre and moderate faecal coliform concentrations (geometric mean 285/dl); at site B, from an upland impoundment, all samples were free of enteroviruses and the geometric mean faecal coliform concentration was 22/dl. Between 5 and 7 days after exposure canoeists using site A had significantly higher incidences of gastrointestinal and upper respiratory symptoms than canoeists using site B or non-exposed controls (spectators).

Like seawater bathers, fresh-water canoeists can be made ill by sewage contamination. The hazard of fresh water may be best measured by counting of viruses rather than bacteria.

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Introduction

Much use is made of inland waters by canoeists, water skiers, sailboarders, and casual bathers; and, as with seawater bathing, the effects of sewage contamination give cause for concern.[1,2] Opinions differ on whether the same microbiological safety standards should be applied to marine and fresh recreational waters.[2,3] Further, there is currently a debate about possible changes to the microbiological standards in the European Bathing Water Directive.[4] Although the UK maintains that this directive relates exclusively to coastal bathing waters, other member countries apply it to inland freshwater sites and its standards are used as a guide by recreational groups. Notwithstanding earlier research[5-7] there are insufficient data to determine the microbiological dose-response relation between water quality and disease attack rates for the various freshwater activities. We have used methods developed in epidemiological studies at marine bathing sites[8] to measure the health effects of canoeing in two slalom channels with different water quality.

Methods

At site A, an artificial concrete channel diverts water around a weir in the river's main channel and provides facilities for white-water and slalom canoeing. The water comes from a large lowland river receiving effluent from several sewage treatment plants upstream. Site B receives water from a pristine upland impoundment. Water samples were taken at each site during the event. Bacteriological analysis included counts of faecal coliforms,[9] faecal streptococci,[9] and total staphylococci.[10] Samples were also assessed for enteroviruses[11] by measurement of plaque forming units (pfu) with Buffalo green monkey kidney cells and the suspended cell method; poliovirus 2 was used as a control.

Subjects were recruited by advertising in the canoeing press and by approaching canoeists and spectators before the events. Data on age, sex, occupation, place of residence, water activities including canoeing, consumption of various foods, and illness were obtained on a structured questionnaire by trained interviewers, initially on arrival. Participants were interviewed a second time on leaving the site to determine water exposure, and 5–7 days later a third interview was conducted by telephone to record subsequent illness. A fourth questionnaire was sent by post so that subjects could record illness experienced between the second interview and 28 days.

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TABLE I—RESULTS OF ENVIRONMENTAL MICROBIOLOGICAL SAMPLING

Site A *Bacteria indicator*	Geometric mean	Log_{10} SD	Min	Max	N
Faecal coliform (/dl)	285	0·120	153	515	32
Faecal streptococci (/dl)	14	0·213	9	45	32
Total staphylococci (/dl)	14	0·506	9	1780	32
Virus indicator	Arithmetic mean	SD	Min	Max	N
Enterovirus (pfu/10 litre)	198·4	175·243	46	548	10
Site B *Bacteria indicator*	Geometric mean	Log_{10} SD	Min	Max	N
Faecal coliform (/dl)	22	0·517	9	475	36
Faecal streptococci (/dl)	13	0·366	9	240	36
Total staphylococci (/dl)	11	0·276	9	105	36
Virus indicator	Arithmetic mean	SD	Min	Max	N
Enterovirus (pfu/10 litre)	0·0	0·000	0	0	9

Differences in the bacteriological quality between the two sites were compared by the Mann-Whitney U test and virological differences by Student's *t* test. 2 × 2 tables were used to compare the frequencies of each of 33 symptoms in the exposed subjects from site A and site B with the combined non-exposed subjects from both sites; analysis for confounders was performed with the Mantel-Haenszel test. The frequencies of symptoms in those exposed at each site were compared in the same way with relative risks (RR) and confidence intervals (CI).

Results

Site A showed higher counts of faecal coliforms ($p < 0·001$) and faecal streptococci ($p < 0·05$) than site B. The arithmetic mean enterovirus concentration from site A (198 pfu/10 litre) was likewise significantly higher than the zero at site B ($p < 0·001$) (table I).

A total of 572 subjects were recruited—304 at site A and 268 at site B, of whom 160 and 218, respectively, engaged in canoeing. Information on exposure of 8 subjects from site A and 3 from site B was not obtained and these were excluded from further analysis. 516 subjects (90%) completed interviews at 5–7 days and 366 (64%) at one month.

Significantly different baseline results were as follows:

M/F ratios		
Exposed 328/378	Non-exposed 95/183	$p < 0·001$
Site A exposed 78/136	Site B exposed 17/47	$p < 0·05$
Age		
Exposed 25 (95% CI 23–26)	Non-exposed 28 (95% CI 26–29)	$p < 0·05$
Hamburger consumption		
Exposed 93/352	Non-exposed 27/173	$p < 0·01$

Canoeists at the two sites did not differ in M/F ratios or age; nor were there differences between any of the groups in frequency of self-reported illness before exposure.

At 5–7 days (table II) the frequency of self-reporting of 'flu and of respiratory and gastrointestinal (GI) symptoms was significantly higher in those exposed at site A than in the combined control group. At one month there was an excess of ear/eye symptoms (13/109 *vs* 5/131, $p < 0·05$: RR 3·12, 95% CI 1·15–8·49) and GI symptoms (40/109 *vs* 27/131, $p < 0·01$: RR 1·78, 95% CI 1·17–2·70). Site B exposed subjects reported a significant excess only of respiratory symptoms at 5–7 days.

When we compare canoeists at site A with those at site B the frequency in the reporting of all symptom groups was significantly higher at 5–7 days and this excess persisted at one month for GI symptoms (40/109 *vs* 24/126, $p < 0·01$: RR 1·93, 95% CI 1·25–2·98) and skin symptoms (14/109 *vs* 6/126, $p < 0·05$; RR 2·70, 95% CI 1·07–6·78).

In site-A participants the excess of illness at 5–7 days in the exposed group persisted when allowance was made for age, gender, and hamburger consumption. By contrast, at site B the excess of respiratory symptoms observed in the canoeing group was no longer significant when stratified by gender, although the relative risk was not much altered (RR 1·53 95% CI: 0·94–2·48). With controlling for age and gender, at one month the only significant difference between canoeists from the two sites was an excess of GI symptoms in site-A participants.

Discussion

The two sites represent the extremes of water quality encountered by white-water canoeists in the UK. The results suggest that microbiological contamination, as reflected by indicator bacteria and enteroviruses, is associated with an appreciable burden of illness in canoeists.

A weakness of the study design is that the exposed and non-exposed subjects were self-selected.[12] Thus, the canoeists were more likely to be male and eat hamburgers; however, accurate recording of potential confounding factors was possible and these do not explain the differences observed.

Because there were no significant differences in symptoms between any of the groups before exposure, the most plausible explanation for the post-exposure excess at site A is poor quality water. A further indication that this is so is the similarity between symptom frequencies in the two exposed groups on the study day compared with the excess confined to canoeists at site A at 5–7 days. Indeed, at site B only respiratory symptoms were reported significantly more frequently in the exposed than the non-exposed group. This may be a gender effect, but previous investigators[13] have suggested that certain symptoms developing after exposure at microbiologically uncontaminated sites are due to thermal shock, endogenous infection, or chemical irritation.

The response to the 4-week follow-up was low. These questionnaires were self-administered, unlike the previous interviews. However, the results are broadly consistent with

TABLE II—DIFFERENCES IN SYMPTOM FREQUENCY AT 5–7 DAYS IN SUBJECTS EITHER NOT EXPOSED OR CANOEING IN TWO FRESHWATER SITES OF CONTRASTING MICROBIOLOGICAL QUALITY*

Symptom	Site A n = 146	Site B n = 206	Unexposed n = 173	A *vs* unexposed RR (95% CI)	B *vs* unexposed RR (95% CI)	A *vs* B RR (95% CI)
'Flu	65	52	32	2·41† (1·68, 3·45)	1·36 (0·92, 2·02)	1·76† (1·31, 2·37)
Respiratory	47	44	23	2·42† (1·55, 3·79)	1·61† (1·01, 2·55)	1·51† (1·06, 2·14)
Ear/eye	10	4	5	2·37 (0·83, 6·78)	0·67 (0·18, 2·46)	3·53† (1·13, 11·03)
GI	61	29	17	4·25† (2·60, 6·94)	1·43 (0·82, 2·52)	2·97† (2·01, 4·37)
Skin	20	14	13	1·82 (0·94, 3·54)	0·90 (0·44, 1·87)	2·02† (1·05, 3·86)
Any	98	87	57	2·04† (1·60, 2·59)	1·28 (0·98, 1·67)	1·59† (1·31, 1·93)

*Full details are available from the authors.
†$p < 0·05$

those at 5–7 days and the persistent excess of GI symptoms in the exposed group at site A may represent infection with pathogens such as *Cryptosporidium* spp or *Giardia intestinalis*.

The finding that illness occurred more frequently after canoeing in fresh water at a site A receiving sewage effluent agrees broadly with results of sea bathing research in the UK.[8] Bacterial concentrations were not strikingly high by comparison with UK seawaters. The enterovirus concentrations, however, were considerably higher[14] than those recorded in marine waters with similar enteric bacterial concentrations.[8] This may be explained by the contribution from sewage works effluent. Sewage treatment produces greater attenuation of bacterial than viral concentrations.[15] Thus enteroviruses, although presumably not causing the symptoms, may provide a better indicator of fresh water quality than the bacteria measured.

White-water canoeing in poor quality water leads to a measurable amount of illness. Further studies are needed to determine whether there is a dose-response relation with microbial contamination. If so, knowledge of this relation would be valuable for both water quality standard formulation and public education.

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