Original Contribution

Sporadic Gastroenteritis and Recreational Swimming in a Longitudinal Community Cohort Study in Melbourne, Australia

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The relation between sporadic gastroenteritis and recreational swimming was examined in a cohort of 2,811 people in Melbourne, Australia, over a 15-month period (September 1997–February 1999). Data from a prospective community-based study of gastroenteritis were used for a Poisson analysis of temporality between reported swimming (in public or private pools/spas and in marine or freshwater settings) and a highly credible gastroenteritis (HCG) event. Overall, HCG events were more likely in participants who had swum in a public pool/spa (incidence rate ratio (IRR) = 1.25, 95% confidence interval (CI): 1.10, 1.42; \( P = 0.001 \)) or river/lake/dam (IRR = 1.77, 95% CI: 1.13, 2.79; \( P = 0.014 \)) during the previous week or had swum in a public pool/spa (IRR = 1.29, 95% CI: 1.13, 1.46; \( P < 0.001 \)) during the previous 2 weeks. Subanalysis by age showed that HCG episodes were also more likely in adults who had swum in a private pool/spa (IRR = 1.56, 95% CI: 1.02, 2.39; \( P = 0.042 \)) during the previous week or swum at an ocean/beach (IRR = 1.78, 95% CI: 1.12, 2.81; \( P = 0.014 \)) during the previous 2 weeks, demonstrating significant associations between all swimming locations and gastrointestinal symptoms. This study showed that although the incremental risk of recreational swimming is significant, it is relatively small.

bathing beaches; fresh water; gastroenteritis; gastrointestinal diseases; population surveillance; swimming; swimming pools

Abbreviations: CI, confidence interval; HCG, highly credible gastroenteritis; IRR, incidence rate ratio; OR, odds ratio.

Community gastroenteritis is a common illness in developed countries, and it causes significant associated morbidity and economic costs through visits to medical practitioners and time taken off from work (1). Communicable disease surveillance predominantly focuses on outbreaks of gastroenteritis rather than on sporadic cases (2). To facilitate targeting of interventions designed to reduce the prevalence of community gastroenteritis, a better understanding of the common sources of sporadic gastroenteritis is required (1).

Recreational swimming can lead to gastrointestinal disease, as demonstrated by many published outbreak studies (3–12). Fecally transmitted pathogenic microorganisms that can cause gastroenteritis are often found in fresh and marine water settings because of contamination from sewage effluent, livestock, urban runoff, and wildlife (13), especially after rainfall (14; http://www.epa.vic.gov.au/water/threats/default.asp). In recreational swimming venues, including swimming pools and spas, such microorganisms may also be derived from human use of the water (through defecation and/or shedding) (13).

Several epidemiologic studies have shown recreational swimming to be a significant risk factor for sporadic gastroenteritis (15–20). Retrospective and prospective cohort studies and randomized controlled trials have shown that a specific episode of contact with marine or fresh water can increase the risk of gastroenteritis (21–23). Several case-control studies have also demonstrated swimming to be a risk factor for infection by specific pathogens (15–19). To date, however, no studies have examined the relation between self-reported sporadic/endemic gastrointestinal illness in a community cohort (both children and adults) and exposure to a variety of different swim settings over a long period of time.
Our aim in this study was to examine the temporal association between highly credible gastroenteritis (HCG) and recreational swimming, using data from a large, prospective, longitudinal community-based cohort study of gastroenteritis. Previous analysis of this cohort showed that both age and time elapsed since the start of the study (a steady decline in reported HCG occurred during the course of the study) were related to reported HCG episodes (24). We felt that an analysis of the role of swimming over and above these factors might provide additional information about the burden of sporadic gastroenteritis caused by recreational swimming in the community.

MATERIALS AND METHODS

The Water Quality Study was a large community-based study in Melbourne, Australia, that assessed the relation between drinking water quality and gastroenteritis. Information was gathered from 600 families in Melbourne from about September 1997 to February 1999, with each household consisting of at least 4 members comprising 2 or more children aged 1–15 years. Full details on the study and the methods used have been reported previously (24). In brief, the study families completed a health diary each week in which they recorded information about their recreational swimming activity, illness, medication, contact with pets, and travel. All participants were requested to collect stool samples within 1 week of the onset of any gastroenteritis episode experienced during the study. Data recording was suspended for 4 weeks during the 2 Christmas holiday periods (which occur in summer in Australia), splitting the study observation period into 3 segments of 98, 336, and 42 days.

Ethics approval and informed consent

Approval for the Water Quality Study was granted by the Monash Standing Committee on Ethics in Research Involving Humans. Written informed consent was obtained from all adult participants at enrollment and from an adult parent or guardian for all children participating in the study (24).

Definitions

Participants were considered to have had an episode of HCG if, during a 24-hour period, they had 2 or more loose stools; 2 or more episodes of vomiting; 1 loose stool plus abdominal pain or nausea or vomiting; or 1 episode of vomiting plus abdominal pain or nausea. Episodes of HCG were deemed to be distinct if the participant had been symptom-free (of vomiting, diarrhea, nausea, and abdominal pain) for 6 days or more.

Recreational swimming settings were defined as a public pool/spa, a private pool/spa, an ocean/beach, or a river/lake/dam. Participants were asked to record whether they had swum during the week, on what days, and in which setting. No information was recorded regarding the length of swimming, how many times the participant had entered the water, or whether the participant had put his/her head underwater.

Data analysis

Taking an ecologic approach, we compared the reporting of at least 1 HCG event during the study with the participant’s number of swimming episodes in each recreational swimming setting, using logistic regression. We accounted for clustering of participants within households by using robust standard errors.

The temporal association between swimming and gastroenteritis was analyzed with a case-cohort approach. First, for each of the 476 days of data collection and for each participant, we evaluated the participant’s history of swimming in the prior 7 days. The same thing was done for 14-day swimming history. Secondly, we identified days on which an HCG episode had begun, and other days of that episode were excluded. Thirdly, using Poisson regression, we compared the swimming history of days that were not the start of an HCG episode with the swimming history of days that were the start of an episode. Where there were missing days in health records or in 7-day or 14-day swimming history, those days were excluded—for example, immediately after the Christmas holiday break. We accounted for repeated days of recording by participants and clustering of participants within households by using robust standard errors at the household level of clustering.

To ensure that the associations found in the analyses were not being unduly influenced by a particular subgroup of participants, we performed separate analyses according to age group, sex, and the frequency of reported swimming and HCG events (participants were categorized into 4 groups based on their being frequent swimmers (≥10 swims or not) and reporting frequent HCG events (≥2 or not) during the study period).

To allow analysis of occasions on which participants swam while suffering an HCG episode, we created additional variables for occasions when participants swam on the same day as the start of an HCG episode, within 7 days of the start of an episode, or within 14 days of the start of an episode. Logistic regression analysis was used to determine odds ratios.

Two-sided $P$ values of $\leq 0.05$ were considered significant. All analyses were undertaken in Stata (Stata Statistical Software, release 10; Stata Corporation, College Station, Texas).

RESULTS

Participants

Of the 2,811 participants, 1,440 (51%) were male; 648 (23%) were under age 6 years, 928 (33%) were between the ages of 6 and 15 years, and 1,235 (44%) were aged 16 years or older. Out of a possible 191,148 person-weeks of health diary data, a total of 173,298 person-weeks of data (91%) were recorded. Seventeen participants returned no health diaries for the entirety of the study, which left 2,794 participants for whom data were received.

Gastroenteritis

There were 2,669 cases of HCG during the study (0.80 cases/person/year), with 1,387 (49%) participants reporting...
no episodes, 749 (27%) participants reporting 1 episode, 579 (21%) reporting 2–4 episodes, and 79 (3%) reporting 5 or more (up to 14) episodes. The age of a participant was significantly associated with HCG events ($P < 0.001$). HCG episodes were reported for 70% of participants aged 0–5 years but only 47% of participants aged 6–15 years and 43% of participants aged ≥16 years. There was weak evidence that being an adult female was associated with reporting an HCG episode during the study period ($P = 0.16$) and with the number of HCG episodes reported ($P = 0.05$).

**Swimming episodes/habits of participants**

The number of days on which each participant swam ranged from 0 to 320, with 2,366 (85%) participants recording swimming on at least 1 day. Public pools/spas were the most popular swimming setting (Figure 1).

Overall, patterns of swimming frequency were similar for males and females, but statistically they differed significantly across age groups. Young participants (age <16 years) swam more frequently than others. Considering swim settings separately, young participants also swam more often in a public swimming pool/spa. Participants aged 6–15 years swam more often in private swimming pools/spas, the ocean/beaches, and rivers/lakes/dams than did other participants (Figure 1).

More participants swam in rivers/lakes/dams, at the ocean/beaches, and in private pools/spas during the warmer seasons and months, but the pattern of swimming in public pools/spas differed and did not rise as significantly over the summer months (Figure 2).

**Swimming-gastroenteritis relation, by participant**

In univariate analysis, swimming at an ocean/beach and swimming in a private or public pool/spa were associated with reporting of at least 1 HCG episode (Table 1). When the results were adjusted for age and sex, the number of swims in a public or private pool/spa remained significantly associated with having developed an HCG episode (Table 1).

**Temporal association between swimming and gastroenteritis**

Univariate Poisson analysis confirmed factors related to the risk of an HCG episode, including age (previously established), sex, and season. Children aged 0–5 years (incidence rate ratio (IRR) = 2.12, 95% confidence interval (CI): 1.88, 2.38; $P < 0.001$) and female participants (IRR = 1.12, 95% CI: 1.01, 1.24; $P = 0.025$) were significantly more likely to have a reported HCG event, and participants who swam during summer (IRR = 0.76, 95% CI: 0.97, 0.86; $P < 0.001$) or winter (IRR = 0.72, 95% CI: 0.62, 0.84; $P < 0.001$) were less likely to have a reported HCG event. All swimming exposures were found to be associated with HCG in univariate analysis (Table 2). Adjusting for age, sex, season, and the amount of time that had elapsed in the study made little difference in these associations, except for swimming in a public pool/spa; this latter change was attributable largely to confounding by age (Table 2, “Adjusted 1” results). Additional adjustment for other swimming exposures (Table 2, “Adjusted 2” results) revealed that, except for swimming in a public pool/spa, the risk of HCG following swimming in a specific setting was influenced by a person’s history of swimming in other settings. This analysis revealed that participants were at significantly increased risk of an HCG episode if they had swum in a public pool/spa or river/lake/dam during the previous 7 days or in a public pool/spa during the previous 14 days (Table 2, “Adjusted 2” results). Similar results were observed for all analyses, regardless of whether we were examining swimming during the 7 days prior to HCG onset or swimming during the 14 days prior to HCG onset.
The results of subgroup analyses were broadly similar to those presented in Table 2. They showed that adults had an increased risk of commencing an HCG episode during the week following swimming in a private pool/spa (IRR $= 1.56$, 95% CI: 1.02, 2.39; $P = 0.04$) and during the 2 weeks following swimming at the ocean/beach (IRR $= 1.78$, 95% CI: 1.12, 2.81; $P = 0.01$).

Of 2,623 HCG episodes recorded during the study, on 140 occasions a participant swam on the same day as the start of an HCG episode; on 218 occasions, the participant swam within the following 7 days, and on 229 occasions the participant swam within the following 14 days. Compared with adults, children aged 0–5 years had an increased likelihood of reportedly swimming on the same day as the start of an HCG event (odds ratio (OR) $= 1.84$, 95% CI: 1.15, 2.94; $P = 0.011$) or within the next 7 days (OR $= 1.87$, 95% CI: 1.24, 2.83; $P = 0.003$) or 14 days (OR $= 1.87$, 95% CI: 1.24, 2.82; $P = 0.003$). Participants aged 5–16 years also had an increased likelihood of reportedly swimming on the same day as the start of an HCG event (OR $= 1.96$, 95% CI: 1.20, 3.22; $P = 0.008$) or within the next 7 days (OR $= 2.39$, 95% CI: 1.60, 3.58; $P < 0.001$) or 14 days (OR $= 2.65$, 95% CI: 1.78, 3.95; $P < 0.001$).

DISCUSSION

To our knowledge, this was the first prospective longitudinal cohort study to examine the temporal association between community gastroenteritis and swimming over a 15-month period. The findings from this study confirm that recreational swimming in treated, fresh, and marine water is associated with an increased risk of episodes of HCG. The results revealed the most significant association between HCG and swimming to occur among participants who had...
swum in a river/lake/dam during the prior 7 days or in a public pool/spa during the prior 7 or 14 days (Table 2). Analysis by age group also revealed a significant association between HCG and swimming among adults who had swum in a private pool/spa in the prior 7 days or at the ocean/beach in the prior 14 days.

Although the association between sporadic community-based gastroenteritis and recreational swimming is not a new finding, previous studies have largely been prospective or retrospective cohort studies (21, 22, 25) or randomized controlled trials (23) that have focused only on the effects of 1 specific swimming episode in a marine or freshwater environment on the risk of gastroenteritis. Several case-control studies have also been performed, but those studies have only considered gastroenteritis patients with laboratory-confirmed infections (15–19). This study was unique in that it was a prospective cohort study carried out over a 15-month period involving both children and adults.

Table 2. Likelihood of Reporting At Least 1 Episode of Highly Credible Gastroenteritis, by Recency of Swimming and Swim Setting, in Unadjusted and Adjusted Poisson Analysis, Melbourne, Australia, September 1997–February 1999a

<table>
<thead>
<tr>
<th>Recency of Swimming and Swim Setting</th>
<th>Unadjusted</th>
<th>Adjusted 1b</th>
<th>Adjusted 2c</th>
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<tr>
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<td>IRR 95% CI</td>
<td>P Value</td>
<td>IRR 95% CI</td>
</tr>
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<tr>
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<td>1.34 1.18, 1.51  &lt;0.001</td>
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<td>1.54 1.13, 2.10  0.007</td>
<td>1.11 0.75, 1.64  0.598</td>
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<td>1.0</td>
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<td>1.31 1.05, 1.64  0.016</td>
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<tr>
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<td>1.48 1.31, 1.68  &lt;0.001</td>
<td>1.29 1.14, 1.47  &lt;0.001</td>
<td>1.25 1.10, 1.42  0.001</td>
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<td>River/lake/dam</td>
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<td>1.0</td>
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<tr>
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<td>2.27 1.63, 3.16  &lt;0.001</td>
<td>1.77 1.13, 2.79  0.014</td>
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<td>1.35 1.19, 1.52  &lt;0.001</td>
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<tr>
<td>Ocean/beach</td>
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<tr>
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<tr>
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<td>1.56 1.23, 1.98  &lt;0.001</td>
<td>1.29 0.96, 1.75  0.093</td>
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<td>1.17 0.95, 1.44  0.131</td>
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<tr>
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<td>1.0</td>
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<td>1.31 1.15, 1.48  &lt;0.001</td>
<td>1.29 1.13, 1.46  &lt;0.001</td>
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<td>River/lake/dam</td>
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<tr>
<td>No</td>
<td>1.0</td>
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<td>Yes</td>
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<td>1.67 1.24, 2.24  0.001</td>
<td>1.14 0.77, 1.70  0.504</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; IRR, incidence rate ratio.

a All analyses accounted for clustering by household.

b Results were adjusted for amount of time in the study, sex, age group, and season.

c Results were adjusted for amount of time in the study, sex, age group, season, and swimming in other settings.
adults, and it considered multiple swimming exposures (public and private pools/spas and marine and freshwater settings).

The study relied on self-reported gastroenteritis symptoms. We acknowledge that self-reporting may have produced over- or underestimation of the true number of HCG events because of misclassification of symptoms not due to infectious gastroenteritis; however, the use of a relatively stringent definition for HCG should have minimized this (24). In addition, the rate of sporadic gastroenteritis detected in the study (0.80 cases/person/year) was consistent with rates found in other community-based studies (26–29).

The risks of reporting an HCG event were similar regardless of the swim setting. However, only for the most commonly reported swim setting, swimming in a public pool/spa, was the association between swimming and HCG events found to be significant in all age groups and both sexes. Swimming is only 1 of multiple risk factors for sporadic gastroenteritis. Certain foods and drinking-water sources (18), person-to-person contact (19), and travel (17, 30) have all been associated with sporadic gastroenteritis as well. Therefore, it is unsurprising that although we found that recreational swimming in public/private pools, fresh water, and marine water were all significant predictors of an HCG episode, the size of the association was not large.

Participants generally had only a 1–2 times’ increased likelihood of reporting an HCG event during the 7 or 14 days following swimming in any setting.

We considered the effects of several factors on the swimming-HCG association during the study, including age, sex, season, and history of swimming in other settings. The risk of HCG following swimming in a public pool/spa was influenced by age, with a high percentage of children aged 0–5 years swimming in public pools/spas and, as previous research has found (25, 28, 29, 31, 32), younger age groups being the most likely to suffer from HCG events. For all other swim settings, however, the risk of an HCG event following swimming was most influenced, in our analysis, by a participant’s history of swimming in other settings (Table 2, “Adjusted 2” results). A participant’s history of swimming in public pools/spas, for example, contributed to the unadjusted association seen between all other swimming exposures and HCG. This is perhaps not surprising, given its status as the most common exposure; however, adjusting for river/lake/dam swimming also partly explained the association. As can be seen in Figure 2, increased river/lake/dam swimming coincided with increases in both ocean and private pool/spa swimming over the summer months, whereas public pool/spa exposure followed a different pattern throughout the study period. There does not appear to have been a significant increase in public pool use during summer, as there was for other recreational settings; this may have been due to the relatively high proportion (56%) of children under age 16 years in our study and the fact that many Australian children take swimming lessons in public pools during the school year (and then cease over the summer holidays). Alternatively, it may be that some participants preferred to swim in outdoor settings, such as the beach/ocean, during summer and at indoor public pools at other times of the year. In addition, the information recorded during summer was limited because data recording was suspended for 4 weeks over the 2 Christmas holiday periods. We recognize that much recreational swimming may have occurred during this time; however, we expected that many people would be away from home during this period, so the decision was made to suspend recording.

The relation between sporadic gastroenteritis and swimming is likely to be complex. As the World Health Organization noted in its recreational water guidelines, the risk of “infection or disease depends upon the specific pathogen, the form in which it is encountered, the conditions of exposure, and the host’s susceptibility and immune status” (13, p. 53). For these reasons, a straightforward linear association between swimming events and HCG is not expected and was not seen in our study. The extent to which prior immunity affects the swimming-gastroenteritis association is uncertain; more frequent water use may increase the overall level of exposure, but it may also confer some resistance to infection on a per-event basis (33). Additionally, the duration of water exposure and other factors, such as whether water was swallowed, can play a role in the relation (34); however, our study did not include collection of such detailed information.

Other studies have found Cryptosporidium and Giardia to be most often associated with treated water such as swimming-pool water (8, 35–37), and freshwater and marine venues have a higher proportion of outbreaks caused by bacterial and viral etiologic agents (3). No recreational water quality testing was performed in our study. Although microbiologic analyses of fecal samples were performed, samples were collected for only 27% of HCG events, and pathogens were detected infrequently in laboratory testing (25% of samples submitted). Therefore, we did not attempt to analyze the data for associations between swimming events and specific pathogens. The incubation periods for the most common pathogens reported to cause or be associated with gastroenteritis and recreational water exposure, as well as the precedent set by other studies (38, 39), led us to consider swimming activity that occurred both 7 days and 14 days before an HCG event as significant. Overall, results obtained using these 2 time intervals were similar.

One outbreak of cryptosporidiosis was identified during the study from contamination of a public swimming pool. This outbreak occurred during February and March of 1998 and has been previously reported (40). The 11 cases of cryptosporidiosis in this outbreak were not identified by routine communicable disease surveillance, and no affected person visited a medical practitioner; rather, the cases were identified as an outbreak by the study investigators only because submission of fecal specimens was encouraged as part of the study. Since linkage of the cases would not have been identified under normal surveillance conditions, these cases were treated as if they were sporadic and were not excluded from the analysis. Indeed, many cases of gastroenteritis that are classified as sporadic may actually be part of unidentified clusters or outbreaks. It is well recognized that most cases of gastroenteritis do not come to the attention of health-care providers or surveillance units, as surveillance has low sensitivity for detection of gastroenteritis.
outbreaks (41). Since an outbreak is usually defined as 2 or more cases linked to a common source or event, it may only take 1 case of gastroenteritis remaining unreported for an outbreak to be missed (42, 43).

While potentially confounding factors such as household clustering, age, sex, and swimming in other settings were taken into account during analysis, we acknowledge that there may have been other possible confounding influences that we were not able to consider. Since most participants lived in a defined area and all of them were of similar socioeconomic status, we were unable to consider the effect of socioeconomic factors. In addition, adjustment for child day care and animal contact was not performed. It is also conceivable that certain behaviors that are associated with swimming at recreational water venues may have affected gastroenteritis risk. Increased person-to-person contact, consumption of certain foods, use of public facilities, and even contact with intertidal beach sand (44), for example, are all potential sources of pathogens that may have confounded the relation.

Another acknowledged limitation of the study is that, as Figure 2 shows, the rate of reported HCG declined throughout the study, for an unknown reason. However, the rate of participant reporting for other factors, including swimming, did not decline; thus, although diminishing participant motivation may have contributed to the decline in reported HCG events, it is also possible that fewer events were experienced (24).

Using temporal information on HCG episodes and swimming activity, we were able to reveal that on many occasions participants swam while they were ill. Younger participants, in particular, were significantly more likely to swim on the same day as the start of an HCG episode (although a limitation of our data was that we were unable to know whether a participant swam before or after the onset of symptoms on that day) or within the following 7 or 14 days. Depending on the causative organism, the infectious period may begin prior to the onset of symptoms, may peak during the symptomatic period, and may continue for days or weeks after symptoms have resolved. It is important that public education about the importance of avoiding swimming during gastrointestinal illness be reinforced (3).

The quality of recreational water in Melbourne is controlled using a preventive risk management approach to “assure safety at [the] point of use” (45, p. 1-1) and prevent the occurrence of waterborne gastrointestinal disease. Public health authorities in Melbourne generally recommend that people suffering from diarrhea not use public pools until at least 1 week after their symptoms have cleared. If someone is known to have had cryptosporidiosis or giardiasis as the cause of diarrhea, they are advised not to swim for at least 2 weeks after symptoms have resolved. However, levels of compliance with this advice are unknown. Additionally, there are no specific recommendations regarding gastroenteritis and swimming in oceans, beaches, rivers, or dams.

In conclusion, this study showed that recreational swimming in a variety of settings may contribute to the risk of sporadic gastroenteritis; however, the incremental risk is relatively small. Given the likely association between sporadic gastroenteritis and swimming and the health benefits that recreational swimming confers (46), it is important that these preventive efforts be continued in all swim settings. The likely increase in extreme weather events due to climate change (47)—sea-level rise and an increased frequency of floods and heavy precipitation—may lead to an increased risk of waterborne disease through an increase in contaminated stormwater runoff and challenges to existing infrastructure (48). Thus, preventive efforts for ensuring recreational water quality will remain important in the future.

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