Health Risks of Limited-Contact Water Recreation
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BACKGROUND: Wastewater-impacted waters that do not support swimming are often used for boating, canoeing, fishing, kayaking, and rowing. Little is known about the health risks of these limited-contact water recreation activities.

OBJECTIVES: We evaluated the incidence of illness, severity of illness, associations between water exposure and illness, and risk of illness attributable to limited-contact water recreation on waters dominated by wastewater effluent and on waters approved for general use recreation (such as swimming).

METHODS: The Chicago Health, Environmental Exposure, and Recreation Study was a prospective cohort study that evaluated five health outcomes among three groups of people: those who engaged in limited-contact water recreation on effluent-dominated waters, those who engaged in limited-contact recreation on general-use waters, and those who engaged in non–water recreation. Data analysis included survival analysis, logistic regression, and estimates of risk for counterfactual exposure scenarios using G-computation.

RESULTS: Telephone follow-up data were available for 11,297 participants. With non–water recreation as the reference group, we found that limited-contact water recreation was associated with the development of acute gastrointestinal illness in the first 3 days after water recreation at both effluent-dominated waters (adjusted odds ratio [AOR] 1.46; 95% confidence interval [CI]: 1.08, 1.96) and general-use waters (1.50; 95% CI: 1.09, 2.07). For every 1,000 recreators, 13.7 (95% CI: 3.1, 24.9) and 15.1 (95% CI: 2.6, 25.7) cases of gastrointestinal illness were attributable to limited-contact recreation at effluent-dominated waters and general-use waters, respectively. Eye symptoms were associated with use of effluent-dominated waters only (AOR 1.50; 95% CI: 1.10, 2.06). Among water recreators, our results indicate that illness was associated with the amount of water exposure.

CONCLUSIONS: Limited-contact recreation, both on effluent-dominated waters and on waters designated for general use, was associated with an elevated risk of gastrointestinal illness.

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Limited-contact water recreation activities are popular in the United States. An estimated 71 million people participate in fishing, 52 million in motor boating, 20.7 million in canoeing, 9.4 million in rowing, and 6.4 million in kayaking (Cordell et al. 2004). Some waters that have not attained the goal of the Clean Water Act (1972) to support “recreation in and on the water” are used for limited-contact recreation (e.g., fishing and boating) but not full-contact recreation (e.g., swimming and water skiing). Recently, site-specific standards for limited (or secondary) contact recreation have been explored in several U.S. states for waters that do not support full-contact recreation, generally because of high concentrations of bacteria [Illinois Pollution Control Board 2010; Missouri Department of Natural Resources 2011; Texas Commission on Environmental Quality 2009; U.S. Environmental Protection Agency (EPA) 2003; Utah Department of Environmental Quality 2008]. Large cohort studies (Colford et al. 2007; Wade et al. 2008, 2010) have evaluated the health risks of full-contact recreation, but little is known about the health risks of limited-contact recreation. The Chicago Health, Environmental Exposure, and Recreation Study (CHEERS), a prospective cohort study, was designed to estimate the risk of illness attributable to limited-contact water recreation. Additionally, we assessed the severity of illness reported by study participants.

Materials and Methods
Overview. The design and methods for the study presented here were adapted from those of the U.S. EPA’s National Epidemiological and Environmental Assessment of Recreational water (NEEAR) study (Wade et al. 2006, 2008, 2010). The CHEERS study, which was conducted by the University of Illinois at Chicago in the Chicago, Illinois, area between 2007 and 2009, included people who were engaged in limited-contact water recreation (defined as canoeing, fishing, kayaking, motor boating, or rowing) and people who were engaged in non–water recreational activities. After being screened for eligibility, participants underwent twice field interviews: a brief prerecreation interview that collected contact information; an interview immediately after recreation inquired about demographics, dietary and other exposures, symptoms at baseline, and the extent of water exposure during recreation. Barcoded wrist bands were applied to the wrist or ankle of participants to ensure correct matching of data from pre- and postrecreation interviews from individual participants. On approximately days 2, 5, and 21, the participants were contacted by telephone and asked about exposures (including water recreation), the development of health symptoms, and the severity of symptoms, since the previous interview. Computer-assisted interviews were conducted in the field and by telephone using Blaise version 4.7 (Statistics Netherlands; Heerlen, the Netherlands).

Setting. Participants were enrolled at Chicago-area locations where limited-contact water recreation takes place, including the Chicago Area Waterways System (CAWS). The CAWS, which includes the Chicago River, is engineered so that urban drainage and wastewater flow backward from Lake Michigan toward the Mississippi River. Two wastewater treatment plants that use an activated sludge process but no disinfection (such as chlorination) each discharge about 300 million gallons of treated wastewater per day into segments of the CAWS where limited-contact recreation (but not swimming) is permitted. Approximately 75% of the annual flow through the CAWS originates from the treatment plants (Rijal et al. 2011). In addition to the CAWS, recruitment took place at inland lakes, rivers, and Lake Michigan beaches designated by the state for swimming and other full-contact use, referred to here as general-use waters (GUW) (see Supplemental Material, Figure 1 [http://dx.doi.org/10.1289/ehp.1103934] for recruiting locations).

We recently reported that in the 2009 participant recruiting season (April through Address correspondence to S. Dorevitch, UIC School of Public Health, 2121 W. Taylor, M/C 922, Chicago, IL 60612 USA. Telephone: (312) 355-3629. Fax: (312) 413-9898. E-mail: sdoreviti@uic.edu

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Dorevitch et al. 2011a). Detection of *Giardia* and adenovirus type F was more frequent on the CAWS (86% and 65% of samples, respectively) than on the GUW (47% and 24%, respectively) waters. *Cryptosporidium* and enterovirus were each detected in about 30% of samples at both CAWS and GUW locations (Aslan et al. 2011; Dorevitch et al. 2011a).

**Participants.** Limited-contact recreators were enrolled into one of two water recreation groups, CAWS or GUW, depending on their location of recreation. People who were engaged in non–water recreational activities at locations adjacent to the CAWS and GUW water access locations, including cycling, jogging, rollerblading, team sports, and walking, were enrolled into the unexposed (UNX) group. People were not eligible for enrollment in CHEERS if they had engaged in surface-water recreation (not including pools or water parks) within the previous 48 hr, intended to swim during their index recreation event, or would not be available for telephone follow-up. People were not excluded from the study because of unintentional swimming (e.g., falling into the water while kayaking). After completing the day–21 telephone follow-up interview, participants were allowed to re-enroll. Recruitment took place in 2007 (August through November), 2008 (March through October), and 2009 (April through July).

**Exposure assessment.** Self-reported exposure to recreational water was evaluated in the post-recreation interview. Participants who reported any water contact were asked to evaluate, by recreation interview, participants were allowed to re-enroll. Recruitment took place in 2007 (August through November), 2008 (March through October), and 2009 (April through July).

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in each stratum. Stratified group effects were compared with the multivariate logistic result that did not include propensity score strata. All data analyses were performed using SAS, version 9.2.

Human subjects research. Participants (or a parent or guardian if < 18 years of age) provided written documentation of informed consent following a protocol approved by the Institutional Review Board of the University of Illinois at Chicago.

Results

Participants. A total of 11,733 sets of field interviews were completed, of which 11,297 (96.3%) were associated with telephone follow-up [for details about attrition, see Supplemental Material, Figure 2 (http://dx.doi.org/10.1289/ehp.1103934)]. Of the 11,297 sets of field and telephone interviews, 10,646 (94.2%) were obtained from individuals who participated one time, 4.6% were obtained from individuals who participated twice, and 1.1% were obtained from individuals who participated more than twice. Participants were enrolled on 390 location dates over 190 dates. The number of participants and the distribution of their ages were similar across the three groups (Table 1). Among the two water recreation groups, rowing and motor boating were more common among CAWS participants, whereas fishing and canoeing were more common among GUW participants.

Time periods of interest. In the first days after participation in the field study, the two water recreation groups had a higher proportion of incidence of AGI than did the UNX group (Figure 1), whereas starting at about day 7, AGI occurred more frequently among the UNX. Based on the log-negative–log survival curves, time-by-group interactions were present for AGI when dividing the follow-up period, for example, for days 0–2 versus days 3–21 and days 0–3 versus days 4–21 (i.e., the proportional hazards assumption was not valid). Curves for other end points did not suggest specific time windows for exposure outcome relations among participants (Table 1). Among CAWS, more days occurred among the UNX as the reference group.

Study group

Proportion remaining AGI-free

Day to onset of AGI

Figure 1. Kaplan–Meier curve of AGI survival, by study group.

Table 1. Demographic and water recreational activities of CHEERS participants [n (%)] by study group.

| Variable Category | CAWS n = 3,966 | GUW n = 3,744 | UNX n = 3,587 |
|-------------------|----------------|----------------|----------------|
| Race/ethnicity | White | 3,047 (76.9) | 3,077 (82.2) | 2,274 (63.5) |
| | Black/African American | 286 (7.2) | 126 (3.4) | 574 (16.0) |
| | Hispanic | 208 (5.2) | 246 (6.6) | 340 (9.5) |
| | Other/multiple | 422 (10.7) | 291 (7.8) | 392 (11) |
| Missing | 3 | 4 | 7 |
| Age (years) | 0–4 | 33 (0.8) | 37 (1.0) | 62 (1.7) |
| | 5–9 | 147 (3.7) | 182 (4.8) | 110 (3.1) |
| | 10–17 | 403 (10.1) | 369 (9.9) | 193 (5.4) |
| | 18–44 | 2,328 (58.7) | 1,279 (34.2) | 1,175 (32.8) |
| | 45–64 | 924 (23.3) | 1,279 (34.2) | 1,175 (32.8) |
| | ≥ 65 | 131 (3.3) | 147 (3.9) | 217 (6.0) |
| Sex | Female | 1,982 (50.0) | 1,512 (40.4) | 1,829 (51.0) |
| | Male | 1,984 (50.0) | 2,232 (59.6) | 1,758 (49.0) |
| Water recreation activity | Motor boating | 661 (16.7) | 232 (6.2) | |
| | Canoeing | 896 (22.3) | 1,202 (32.1) | |
| | Fishing | 425 (10.7) | 858 (22.9) | |
| | Kayaking | 1,355 (34.2) | 1,202 (32.1) | |
| | Rowing | 640 (16.1) | 252 (6.7) | |
| Face/head wetness | Not wet | 2,003 (50.5) | 2,506 (66.9) | |
| | Sprinkle/drops | 1,366 (34.4) | 721 (19.3) | |
| | Splash | 554 (14.0) | 376 (10.0) | |
| | Drenched | 28 (0.7) | 33 (0.9) | |
| | Submerged | 15 (0.4) | 108 (2.9) | |
| Swallowed water | None | 3,794 (95.7) | 3,614 (96.5) | |
| | Drops | 120 (3.0) | 78 (2.1) | |
| | Teaspoon | 43 (1.1) | 38 (1.0) | |
| | Mouthful | 9 (0.2) | 14 (0.4) | |

Other than race/ethnicity information, no data were missing.
Two potential modifiers of associations between group and outcome were significant at the $p = 0.1$ level. An interaction between age category and study group for the incidence of ARI was suggested ($p = 0.08$). Among those ≤ 10 years of age, the AOR for developing ARI for CAWS versus UNX was 1.90 (0.67, 21.56), whereas for those ≥ 11 years of age, the AOR was 0.89 (0.56, 1.42). An interaction between diabetes and study group and the incidence proportion of AGI was observed ($p = 0.04$); the AOR for developing AGI in the CAWS versus UNX group was 1.52 (1.12, 2.07) for those without diabetes and 0.62 (0.19, 2.02) for those with diabetes. However, given the unstable estimates for the two smaller groups—those < 10 years of age with ARI ($n = 13$ in the CAWS + UNX groups) and those with diabetes ($n = 14$ with AGI in CAWS + UNX groups)—these health outcomes were modeled without interaction terms to arrive at more interpretable results.

Among those who participated in limited-contact recreation, swallowing water was associated with the occurrence of AGI and ARI, face wetness score was associated with ear symptoms, and hand wetness score was associated with eye symptoms (Table 3).

Risk difference (RD) estimates based on G-computation indicated greater risks for both water recreation groups compared with the UNX groups. For the CAWS and GUW groups, the RD (95% CI) relative to the UNX group were 13.7 (3.1, 24.9) and 15.1 (3.1, 24.9), respectively, per 1,000 recreators. No suggestion of RD for AGI was apparent between study group and AGI were evaluated. Regardless of the definition of exposure, the AOR for group (CAWS vs. GUW) was approximately 1.0, confirming no difference between the adjusted odds of AGI for CAWS and GUW groups, as summarized in Supplemental Material, Table 3 (http://dx.doi.org/10.1289/ehp.1103934). Last, we attempted to run binomial models of health outcomes as was performed by Wade et al. (2008) in their analyses of the NEEAR study; however, models did not converge, as may be expected for uncommon (< 10% incidence) events (McNutt et al. 2003; Zou 2004).

**Symptom severity.** Of the 431 participants who developed AGI (including those who developed other symptoms along with AGI), there were no significant differences ($p > 0.05$) among exposure groups in the proportion who took over-the-counter medication or saw or spoke with a health care provider (45.2% and 12.5% for all participants combined). However, participants in the UNX group with AGI were more likely to report prescription medication use (9.4% compared with 4.3% and 4.4% in GUW and CAWS, respectively).
the CAWS and GUW groups; Fisher’s exact $p = 0.002$ and emergency department or hospital care [4.3% compared with 0% and 1% for CAWS and GUW (based on six cases of emergency department/hospital care), Fisher’s exact $p = 0.008$]. Among the 383 participants who developed eye symptoms, differences in severity by group were not apparent. Overall, 50.9% used over-the-counter medication, 5.7% used prescription medication, and 14.1% spoke with or saw a health care provider.

**Discussion**

We observed risks of gastrointestinal illness attributable to limited-contact water recreation that were comparable whether the recreation took place on effluent-dominated waters or GUW. A risk of eye symptoms after limited-contact water recreation on effluent-dominated waters only was apparent. Two cohort studies, both set on the same United Kingdom white-water canoeing slalom course fed by wastewater, reported associations between canoeing and the development of gastrointestinal illness (Fewtrell et al. 1992; Lee et al. 1997). However, substantial water contact, including capsize, occurred frequently (Lee et al. 1997), blurring the distinction between limited- and full-contact recreation. The risk of AGI after swimming at Great Lakes (Wade et al. 2006, 2008) and marine beaches (Wade et al. 2010) impacted by wastewater discharge, a marine beach not impacted by wastewater discharge (Colford et al. 2007), and an inland reservoir that does not directly receive wastewater discharge (although some of its tributaries do) have been described recently (Marion et al. 2010). Table 5 summarizes the unadjusted incidence proportion of illness and associations between exposure group and gastrointestinal illness in these studies and CHEERS.

Caution should be used in comparing estimates of association and risk across studies because of differences in protocols (we interviewed individuals rather than family units), the frequency and timing of health follow-up (days 2, 5, and 21 in CHEERS vs. a single follow-up interview between days 8 and 14, depending on the study), and differences in the definition of gastrointestinal illness. We identified a relatively brief time window during which differences among groups in the incidence proportion of AGI was maximized. It is possible that stronger associations between illness and swimming might have been obtained in the earlier studies had the day 0–3 time windows been used for defining gastrointestinal illness.

Given the above caveats, the risk of AGI attributable to limited-contact recreation appears to be within the range of attributable risk suggested by the above-noted studies of swimming. The incidence of AGI attributable to limited-contact water recreation was similar (about 14–15 cases/1,000) for the CAWS and GUW and groups, which is counterintuitive given that the CAWS is predominantly wastewater and that Cryptosporidium and adenovirus type F were more likely to be detected on CAWS compared with GUW locations (Aslan et al. 2011; Dorevitch et al. 2011a). This finding has potential policy implications, as the incidence proportion among GUW recr- eators is greater than the 8/1,000 targeted risk level at Great Lakes beaches established by the BEACH Act of 2004 amendments to the Clean Water Act (U.S. EPA 2004). Although CAWS and GUW recreators were equally likely to swallow a mouthful of water, GUW recreators reported head/surface submersion more frequently than did CAWS recreators (2.9% vs. 0.4%; $p < 0.001$). Thus, the average dose of ingested pathogens (pathogen density per unit volume of water × volume of water ingested) may have been comparable for the two groups, with CAWS recreators experiencing head immersion less frequently, but in waters with higher pathogen densities, whereas GUW recreators experienced head immersion more frequently, but in waters with lower pathogen densities.

The higher incidence proportion of eye symptoms among CAWS recreators, compared with either users of GUW or the non–water recreators, stands in contrast to other cohort studies of comparable or larger size that did not identify statistically significant associations between swimming and eye symptoms (Colford et al. 2007; Wade et al. 2008). Canoeing on a whitewater slalom course in the United Kingdom was not associated with eye symptoms (Lee et al. 1997), although that study had less statistical power because of a sample size that was about one-tenth of CHEERS. U.S. recreational waterborne disease outbreaks have identified cases of eye symptoms (Dizuban et al. 2006; Yoder et al. 2008); however, these outbreaks occurred at spas and water parks that use disinfectants and other eye irritants. In addition to the possibility that infectious agents in the CAWS were responsible for symptoms, another possibility is that endotoxin, a component of the cell walls of gram-negative bacteria, played a role. Endotoxin has been thought to cause a variety of symptoms, including eye symp- toms, among workers in wastewater treatment plants (Lee et al. 2007). Airborne gram-negative bacteria have been measured in the vicinity of one of the CAWS wastewater treatment plants (Scheff et al. 1981), although not specifically along the waterway.

Ambient water quality criteria have been established based on an estimated number of cases of illness attributable to swimming per 1,000 uses, rather than measures of association.
Ear, skin, and respiratory symptoms were not associated with limited-contact recreation. The occurrence of gastrointestinal, respiratory, eye, and ear symptoms was strongly associated with the degree of self-reported water exposure, suggesting that observed associations between water recreation and illness are causal.

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