

Swimming in the USA: beachgoer characteristics and health outcomes at US marine and freshwater beaches

Sarah A. Collier, Timothy J. Wade, Elizabeth A. Sams, Michele C. Hlavsa, Alfred P. Dufour and Michael J. Beach

ABSTRACT

Swimming in lakes and oceans is popular, but little is known about the demographic characteristics, behaviors, and health risks of beachgoers on a national level. Data from a prospective cohort study of beachgoers at multiple marine and freshwater beaches in the USA were used to describe beachgoer characteristics and health outcomes for swimmers and non-swimmers. This analysis included 54,250 participants. Most (73.2%) entered the water; of those, 65.1% put their head under water, 41.3% got water in their mouth and 18.5% swallowed water. Overall, 16.3% of beachgoers reported any new health problem. Among swimmers, 6.6% reported gastrointestinal (GI) illness compared with 5.5% of non-swimmers (unadjusted $\chi^2 p < 0.001$); 6.0% of swimmers and 4.9% of non-swimmers reported respiratory illness ($p < 0.001$); 1.8% of swimmers and 1.0% of non-swimmers reported ear problems ($p < 0.001$); and 3.9% of swimmers and 2.4% of non-swimmers experienced a rash ($p < 0.001$). Overall, swimmers reported a higher unadjusted incidence of GI illness and earaches than non-swimmers. Current surveillance systems might not detect individual cases and outbreaks of illness associated with swimming in natural water. Better knowledge of beachgoer characteristics, activities, and health risks associated with swimming in natural water can improve disease surveillance and prioritize limited resources.

Key words | gastrointestinal illness, health outcomes, healthcare utilization, natural waters, recreational water, swimming

Sarah A. Collier (corresponding author)
Michele C. Hlavsa
Michael J. Beach
 Centers for Disease Control and Prevention,
 Mailstop C-09, 1600 Clifton Road,
 Atlanta,
 GA 30333,
 USA
 E-mail: SCollier@cdc.gov

Timothy J. Wade
Elizabeth A. Sams
 United States Environmental Protection Agency,
 Office of Research and Development,
 Chapel Hill,
 NC,
 USA

Alfred P. Dufour
 United States Environmental Protection Agency,
 Office of Research and Development,
 Cincinnati,
 OH,
 USA

INTRODUCTION

Swimming is a favorite US pastime. A census report estimated that in 2009 swimming was the fourth most popular sports activity (Bureau of the Census 2012). Another study estimated that 88 million of those 16 years of age or older (41% of the US population) swim in natural waters (e.g., oceans, lakes, rivers, or streams) each year (NSRE 2004). Swimming is associated with many health benefits (Broman *et al.* 2006; Bartels *et al.* 2007; Chase *et al.* 2008; Rotstein *et al.* 2008; Cox *et al.* 2010), but swimming in waters contaminated by human or animal feces (Schoen *et al.* 2011) or natural environmental pathogens can pose a variety of health risks, including gastrointestinal, respiratory, ear, eye, and skin infections (Springer & Shapiro 1985; van

Asperen *et al.* 1995; Wade *et al.* 2006, 2008, 2010; Yoder *et al.* 2008; Hlavsa *et al.* 2011, 2014; Hilborn *et al.* 2014).

Current waterborne disease surveillance systems underestimate the burden of recreational water-associated illness, particularly for large beaches that draw visitors from a wide radius. As beachgoers disperse and return to their homes, epidemiologic links among cases of illness associated with swimming in natural water could go unrecognized and thus outbreaks could go undetected. For example, higher rates of gastrointestinal illness were observed among swimmers in several surveys at freshwater and marine beaches with evidence of fecal contamination, but outbreaks of gastrointestinal illness associated with these sites were

neither detected nor reported to the national Waterborne Disease and Outbreak Surveillance System (WBDOSS) (Cabelli *et al.* 1979, 1982; Haile *et al.* 1999; Wade *et al.* 2006, 2008, 2010; Colford *et al.* 2007). Since US national reporting or recreational water-associated outbreaks began in 1978, only one Great Lakes beach-associated outbreak has been reported to WBDOSS (Yoder *et al.* 2004). This represents a burden of disease that has gone largely undocumented.

Quantifying the US national burden of disease due to swimming can help advocate for and prioritize limited prevention resources. Estimates of the burden of foodborne disease in the USA (Mead *et al.* 1999; Scallan *et al.* 2011a, b) have been used to allocate resources, set public health goals, and measure the economic impact of disease (Hoffmann *et al.* 2012). An effort to quantify the burden of waterborne disease in the USA is underway and has produced estimates of the frequency and cost of hospitalizations due to illnesses caused by waterborne pathogens (Collier *et al.* 2012) and the frequency of emergency department (ED) and outpatient visits for acute otitis externa (swimmer's ear) (CDC 2011).

Before the US national burden of disease due to swimming can be estimated, the characteristic behaviors of swimmers and swimming locations should be better described. The characteristics of US beachgoers, their activities at the beach, and swimmers' health outcomes have not been previously described and the burden of disease associated with swimming in natural water has not been quantified. These descriptive data are needed to estimate the overall burden of disease resulting from swimming-related exposures and could be used to inform further analyses. For example, a quantitative microbial risk assessment might use the proportion of beachgoers who enter the water, the proportion of swimmers who put their head under water, and the risk of illness in swimmers to calculate the expected number of ill beachgoers.

One objective of the National Epidemiologic and Environmental Assessment of Recreational Water (NEEAR Water) study was to better understand beachgoer characteristics and behaviors and health outcomes in swimmers and non-swimmers. As a result, it provides a needed epidemiologic snapshot describing marine and freshwater swimming and its health impact in the USA. Data from the study can improve disease surveillance, provide data

for risk assessment and modeling, and inform efforts to quantitate disease burden and impact. This information is needed as a foundation for future regulatory, beach management, and health promotion planning to improve swimmer use and health at US lakes, rivers, and beaches. The goal of this paper is to present a comprehensive, descriptive analysis of the characteristics and behaviors of beachgoers and health outcomes of swimmers in the USA, using one of the largest surveys of beachgoers ever completed.

METHODS

Methods for the NEEAR Water study have been previously described in detail (Wade *et al.* 2006, 2008, 2010, 2011). The study was a prospective cohort study of beachgoers at multiple marine and freshwater beaches in the USA, which employed a water quality evaluation, an in-person beachgoer survey, and a telephone follow-up interview 10–12 days later that asked about any new health problems experienced since the trip to the beach. This study protocol was approved by the Institutional Review Board of the US Centers for Disease Control and Prevention (Protocol #3544).

Study sites

A total of 54,250 beachgoers were included in the study, which was conducted at four freshwater beaches and five marine beaches (2003–2009). The freshwater beaches included in the study were: West Beach (studied in 2003, located on Lake Michigan in Indiana, within the Indiana Dunes National Seashore); Huntington Beach (2003, on Lake Erie near Cleveland, Ohio); Silver Beach (2004, on Lake Michigan near St Joseph, Michigan); and Washington Park Beach (2004, on Lake Michigan in Michigan City, Indiana) (Wade *et al.* 2006, 2008). The marine beaches were: Edgewater Beach (2005, located in Biloxi, Mississippi); Goddard Beach (2007, located in Goddard Memorial State Park in West Warwick, Rhode Island); Fairhope Municipal Beach (2007, in Fairhope, Alabama); Boquerón Beach (2009, located in southwest Puerto Rico); and Surfside Beach (2009, located in South Carolina south of Myrtle Beach) (Wade *et al.* 2010, 2011). Seven of the beaches were selected because they were located close to treated sewage

outfalls. Boquerón Beach was selected because it was a tropical beach located near treated sewage outfall. Finally, Surfside Beach was selected because it was primarily affected by runoff from nearby urban areas ('non-point source' contamination) rather than point-source contamination from treated sewage outfalls. Each site showed variability in water quality but all generally met local and federal guidelines.

Behavior and health assessments

For this analysis, surveys and follow-up interviews were used to examine characteristics and behaviors of beachgoers. Participants completed a brief initial interview upon arrival at the beach that asked about demographic data (gender, race, and ethnicity of household members), and illness and swimming activity prior to the beach visit. Participants also completed a survey at the end of the day asking about behavior during the beach visit (contact with water, time spent in the water, use of nose and earplugs, participation in water-related activities including rafting or snorkeling, contact with sand and algae, and other beach activities including sunscreen use and consumption of food and drinks). The follow-up phone interviews were conducted 10–12 days after the beach visit and inquired about any swimming activity and symptoms or illness that developed after the beach visit, including gastrointestinal symptoms, coughs and colds, eye and ear problems, etc. For respondents who became ill after the beach visit, the interview asked about time lost from work, school or daily activities; over-the-counter (OTC) and prescription medicines; and healthcare utilization.

Statistical methods

Frequencies of beachgoer demographics and behaviors including water exposure, water activities, other exposures (e.g., contact with sand and algae), and use of goggles or masks, earplugs and noseplugs were calculated and cross-tabulated by beach and by age group.

Frequencies of new health problems were also tabulated by beach, by age group, and by swimming status. Marine and freshwater beaches were compared. Because the purpose of analysis was to describe the health and demographic

characteristics of beachgoers, results were not adjusted for potentially confounding factors such as age, sex, and other exposures.

Health effects examined included gastrointestinal (GI) illness, defined as any of the following: diarrhea (three or more loose stools in a 24-hour period); vomiting; nausea and stomach ache; or nausea or stomach ache with interference with regular activities (i.e., missed time from work, school, or other regular activities as a result of the illness), upper respiratory illness (URI, defined as reporting any two of the following: sore throat, cough, runny nose, or cold or fever), ear problems (including earache, ear infection, or discharge or drainage from ears), eye problems (either eye infection or watery eyes), rash, and urinary tract infection (UTI). Health outcomes were defined as in previous studies (Wade *et al.* 2008). Reports of illness within the 3 days before the baseline beach interview were excluded from tabulation for that particular health effect (e.g., respondents who had a cold during the baseline interview were not counted in the upper respiratory category but were included in the denominator, and possibly the numerator, for other illnesses and symptoms).

The effects of illness after a beach visit were also tabulated. Respondents were asked, for each reported health problem, about related time lost from work, school, or daily activities, use of OTC and prescription medicines, doctor's office and ED visits, and hospitalizations. These events were totaled by respondent for each reported health problem.

RESULTS

Beachgoer characteristics

A total of 54,250 beachgoers participated in the study (Table 1). About a third (33.4%) of beachgoers were 30–49 years of age, while those under 20 years of age represented 33.6% of beachgoers. The majority of beachgoers at the study beaches were white (59.5%) and non-Hispanic (65.4%). About one-third (34.6%) of participants were Hispanic, but this was driven by a high proportion of Hispanic visitors at Boquerón Beach in Puerto Rico (99.3%). Excluding Boquerón Beach, 8.2% of beachgoers

Table 1 | Beachgoer characteristics, by beach. NEEAR Water Study, 2003–2009

| | BB n (%) | EB n (%) | FB n (%) | GB n (%) | SSB n (%) | Marine n (%) | HB n (%) | SB n (%) | WB n (%) | WP n (%) | Freshwater n (%) | Overall n (%) |
|-------------------|---------------------|---------------------|---------------------|---------------------|----------------------|-------------------------|---------------------|---------------------|---------------------|---------------------|-----------------------------|--------------------------|
| Participants | 15,726 (29.0) | 1,351 (2.5) | 2,022 (3.7) | 2,977 (5.5) | 11,159 (20.6) | 33,235 (61.3) | 2,840 (5.2) | 10,921 (20.1) | 2,877 (5.3) | 4,377 (8.1) | 21,015 (38.7) | 54,250 (100.0) |
| Age of beachgoers | | | | | | | | | | | | |
| 0–4 years | 908 (5.9) | 75 (5.7) | 241 (11.9) | 238 (8.1) | 647 (5.9) | 2,109 (6.4) | 185 (6.6) | 909 (8.6) | 214 (7.5) | 344 (8.1) | 1,652 (8.1) | 3,761 (7.1) |
| 5–9 years | 1,208 (7.8) | 121 (9.1) | 287 (14.2) | 269 (9.2) | 921 (8.4) | 2,835 (8.6) | 268 (9.5) | 1,225 (11.6) | 261 (9.1) | 492 (11.6) | 1,793 (8.8) | 5,052 (9.5) |
| 10–14 years | 1,490 (9.6) | 103 (7.8) | 189 (9.4) | 167 (5.7) | 886 (8.1) | 2,648 (8.1) | 230 (8.2) | 920 (8.7) | 232 (8.1) | 411 (9.7) | 1,808 (8.8) | 4,628 (8.7) |
| 15–19 years | 1,365 (8.8) | 134 (10.1) | 111 (5.5) | 153 (5.2) | 885 (8.0) | 5,776 (17.6) | 163 (5.8) | 987 (9.3) | 357 (12.5) | 301 (7.1) | 3,321 (16.2) | 4,456 (8.4) |
| 20–29 years | 3,039 (19.6) | 331 (25.0) | 275 (13.6) | 504 (17.2) | 1,627 (14.8) | 10,687 (32.6) | 418 (14.8) | 1,661 (15.7) | 709 (24.8) | 533 (12.6) | 7,142 (34.8) | 9,097 (17.1) |
| 30–49 years | 5,129 (33.1) | 450 (34.0) | 600 (29.7) | 952 (32.4) | 3,556 (32.3) | 2,806 (8.6) | 1,071 (37.9) | 3,702 (35.0) | 865 (30.2) | 1,504 (35.6) | 2,246 (11.0) | 17,829 (33.4) |
| 50–69 years | 2,113 (13.6) | 103 (7.8) | 266 (13.2) | 518 (17.6) | 2,259 (20.5) | 5,259 (16.0) | 427 (15.1) | 1,087 (10.3) | 215 (7.5) | 584 (13.8) | 2,313 (11.3) | 7,572 (14.2) |
| 70+ years | 260 (1.7) | 8 (0.6) | 52 (2.6) | 138 (4.7) | 227 (2.1) | 685 (2.1) | 61 (2.2) | 89 (0.8) | 12 (0.4) | 60 (1.4) | 222 (1.1) | 907 (1.7) |
| Race | | | | | | | | | | | | |
| White | 65 (0.4) | 798 (59.1) | 1,320 (65.3) | 1,882 (63.2) | 10,513 (94.2) | 14,578 (43.9) | 2,554 (89.9) | 9,543 (87.4) | 2,091 (72.7) | 3,499 (79.9) | 17,687 (84.2) | 32,265 (59.5) |
| Black | 13 (0.1) | 375 (27.8) | 546 (27.0) | 154 (5.2) | 235 (2.1) | 1,323 (4.0) | 51 (1.8) | 198 (1.8) | 121 (4.2) | 226 (5.2) | 596 (2.8) | 1,919 (3.5) |
| Other | 15,648 (99.5) | 178 (13.2) | 156 (7.7) | 941 (31.6) | 411 (3.7) | 17,334 (52.2) | 235 (8.3) | 1,180 (10.8) | 665 (23.1) | 652 (14.9) | 2,732 (13.0) | 20,066 (37.0) |
| Ethnicity | | | | | | | | | | | | |
| Non-Hispanic | 105 (0.7) | 1,208 (89.6) | 1,935 (95.7) | 2,221 (74.7) | 10,874 (97.7) | 16,343 (49.3) | 2,671 (94.3) | 10,150 (93.3) | 2,325 (81.6) | 3,886 (89.1) | 19,032 (90.9) | 35,375 (65.4) |
| Hispanic | 15,609 (99.3) | 141 (10.5) | 87 (4.3) | 751 (25.3) | 253 (2.3) | 16,841 (50.8) | 162 (5.7) | 734 (6.7) | 524 (18.4) | 478 (11.0) | 1,898 (9.1) | 18,739 (34.6) |

Marine beach abbreviations: BB = Boquerón Beach, PR; EB = Edgewater Beach, MS; FB = Fairhope Beach, AL; GB = Goddard Beach, RI; SSB = Surfside Beach, SC. Freshwater beach abbreviations: HB = Huntington Beach, OH; SB = Silver Beach, MI; WB = West Beach, IN; WP = Washington Park, IN.

were Hispanic. The median distance traveled to the beach was 20 miles (interquartile range [IQR]: 3–55 miles), but 10.5% of participants traveled over 100 miles to go to the beach.

Beachgoer water exposure, activities, and protective behaviors

Most participants (73.2%) reported at least some water contact, although the proportion of participants entering the water varied by beach (range: 46.0–84.3%; [Table 2](#)). Goddard Beach, RI and Huntington Beach, OH were the only beaches where a minority of participants entered the water (46.7% and 46.0%, respectively). Most swimmers (65.1%) reported immersing their head. This proportion varied considerably by beach. At Boquerón Beach, 79.9% of swimmers put their head under water, compared with 44.5% of swimmers at Edgewater Beach, MS and 40.2% of swimmers at Huntington Beach. Among swimmers, 41.3% (range: 25.1–52.5%) reported getting water in their mouth and 18.5% (range: 9.1–24.1%) reported swallowing water. About a third (34.8%) of beachgoers reported digging in sand and 6.7% reported burying their body in sand. Few swimmers used a mask or goggles (8.7%), ear plugs (1.2%), or nose plugs (0.3%). Water contact varied by age ([Table 3](#)). Children entered the water more frequently than adults and were more likely to get water in their mouth and swallow water. Children between 5 and 14 were the most likely to immerse their heads.

Health outcomes

Overall, 16.6% of swimmers and 13.5% of non-swimmers reported at least one new health symptom in the 10–12 days after a beach visit ($p < 0.001$). Gastrointestinal illness was significantly elevated in swimmers (6.6% compared with 5.5% in non-swimmers, $p < 0.001$), as was respiratory illness (6.0% in swimmers, 4.9% in non-swimmers, $p < 0.001$), ear problems (1.8% in swimmers, 1.0% in non-swimmers, $p < 0.001$) and rash (3.9% in swimmers, 2.4% in non-swimmers, $p < 0.001$) ([Table 4](#)). Among beachgoers, children under 5 years of age had the highest incidence of earache, while adults aged 20–29 years of age were most likely to experience eye problems and UTIs. Age is likely

to confound several of the unadjusted associations between swimming and health. For example, younger age was strongly associated with both respiratory illness and swimming ([Table 5](#)). Among swimmers, children under 5 years and adults 20–29 years of age had the highest incidence of GI and respiratory illness and rash. At baseline, 2.1% of beachgoers reported a GI illness within the past 3 days, 0.9% reported vomiting, 1.3% reported an ear problem, 0.6% reported eye problems, 2.3% had a rash, and 0.6% had a UTI. Baseline illnesses were excluded from reports of post-beach illness, as described in the Methods section.

Healthcare utilization

Of the 16.3% of beachgoers with any new health outcome, 69.7% utilized the healthcare system (defined as calling or visiting their healthcare provider, visiting the ED, or being admitted to hospital), missed work or daily activities, or took prescription or OTC drugs ([Table 6](#)). Healthcare utilization and medication use differed by syndrome. People with GI illness were most likely to miss daily activities (42.8%), while people with a respiratory infection were most likely to take an OTC drug (64.7%). People with a UTI were most likely to visit a doctor (33.2%) and obtain prescription drugs (40.0%).

DISCUSSION

The NEEAR Water study enrolled nearly 55,000 participants and is the largest study of beachgoers, to date, looking at beachgoers and beach use, health outcomes, and healthcare utilization. The median distance traveled to the beach was 20 miles; over 10% of participants traveled 100 miles or more. Most participants (73.2%) reported getting in the water. Among swimmers, 65.1% put their head under water; 41.3% reported getting water in their mouth; and 18.5% reported swallowing water, underscoring the high levels of water exposure. Children were more likely to swim, immerse their heads, get water in their mouth and swallow water compared to adults, which may result in higher rates of illness ([Wade *et al.* 2006, 2008, 2010](#)). Few swimmers used protective equipment including masks or goggles, ear plugs, or nose plugs. These data could

Table 2 | Beachgoer recreational water exposure, other activities, and protective behaviors, by beach. NEEAR Water Study, 2003–2009

| | BB n (%) | EB n (%) | FB n (%) | GB n (%) | SSB n (%) | Marine n (%) | HB n (%) | SB n (%) | WB n (%) | WP n (%) | Freshwater n (%) | Overall n (%) |
|---|---------------------------|---------------------------|---------------------------|---------------------------|----------------------------|-------------------------------|---------------------------|---------------------------|---------------------------|---------------------------|-----------------------------------|--------------------------------|
| Any water contact | | | | | | | | | | | | |
| Any | 12,615 (80.8) | 966 (71.8) | 1,163 (57.7) | 1,389 (46.7) | 9,358 (84.3) | 25,491 (77.1) | 1,305 (46.0) | 7,502 (69.0) | 2,155 (74.9) | 3,091 (71.1) | 14,053 (67.1) | 39,544 (73.2) |
| None | 2,995 (19.2) | 380 (28.2) | 853 (42.3) | 1,584 (53.3) | 1,748 (15.7) | 7,560 (22.9) | 1,535 (54.1) | 3,374 (31.0) | 722 (25.1) | 1,257 (28.9) | 6,888 (32.9) | 14,448 (26.8) |
| Water exposure among swimmers (any water contact) | | | | | | | | | | | | |
| Immersed head | 10,074 (79.9) | 429 (44.5) | 646 (55.6) | 779 (56.3) | 6,406 (68.5) | 18,334 (72.0) | 524 (40.2) | 3,946 (52.8) | 1,211 (56.5) | 1,698 (55.1) | 7,379 (52.7) | 25,713 (65.1) |
| Water contact but did not immerse head | 2,536 (20.1) | 535 (55.5) | 517 (44.5) | 605 (43.7) | 2,952 (31.5) | 7,145 (28.0) | 781 (59.9) | 3,529 (47.2) | 932 (43.5) | 1,383 (44.9) | 6,625 (47.3) | 13,770 (34.9) |
| Got water in mouth | 5,614 (45.1) | 368 (38.7) | 488 (42.0) | 490 (35.8) | 4,906 (52.5) | 11,866 (47.0) | 326 (25.1) | 2,257 (31.3) | 548 (25.8) | 1,030 (35.0) | 4,161 (30.7) | 16,027 (41.3) |
| Swallowed water | 2,632 (21.3) | 164 (17.3) | 280 (24.1) | 223 (16.4) | 2,103 (22.5) | 5,402 (21.5) | 118 (9.1) | 922 (13.1) | 197 (9.4) | 471 (16.6) | 1,708 (12.9) | 7,110 (18.5) |
| Other activities | | | | | | | | | | | | |
| Touched/played with algae | 2,499 (16.0) | 42 (3.1) | 95 (4.7) | 168 (5.7) | 403 (3.6) | 3,207 (9.7) | 43 (1.5) | 161 (1.5) | 54 (1.9) | 115 (2.7) | 373 (1.8) | 3,580 (6.6) |
| Body buried in sand | 640 (4.1) | 106 (7.9) | 110 (5.5) | 111 (3.7) | 441 (4.0) | 1,408 (4.3) | 136 (4.8) | 1,019 (9.4) | 389 (13.6) | 678 (15.6) | 2,222 (10.6) | 3,630 (6.7) |
| Dug in sand | 3,699 (23.7) | 506 (37.6) | 766 (38.0) | 601 (20.2) | 3,991 (35.9) | 9,563 (28.9) | 910 (32.0) | 4,925 (45.3) | 1,327 (46.2) | 2,069 (47.5) | 9,231 (44.1) | 18,794 (34.8) |
| Collected shells, rocks, or feathers | 2,330 (14.9) | 211 (15.7) | 433 (21.5) | 630 (21.2) | 3,383 (30.5) | 6,987 (21.2) | 618 (21.8) | 1,296 (11.9) | 582 (20.3) | 624 (14.3) | 3,120 (14.9) | 10,107 (18.7) |
| Used raft, body/boogie board, or snorkel | 21 (0.2) | 141 (14.6) | 13 (1.1) | 11 (0.8) | 383 (4.1) | 569 (2.2) | 135 (10.3) | 1,123 (15.0) | 259 (12.2) | 427 (13.9) | 1,944 (13.9) | 2,513 (6.4) |
| Protective behaviors | | | | | | | | | | | | |
| Used ear plugs | 207 (1.7) | 20 (2.1) | 17 (1.5) | 34 (2.5) | 98 (1.1) | 376 (1.5) | 9 (0.7) | 63 (0.9) | 9 (0.4) | 35 (1.1) | 115 (0.8) | 491 (1.2) |
| Used nose plugs | 30 (0.2) | 5 (0.5) | 6 (0.5) | 13 (0.9) | 39 (0.4) | 93 (0.4) | 4 (0.3) | 18 (0.2) | 13 (0.6) | 8 (0.3) | 43 (0.3) | 136 (0.3) |
| Used a mask or goggles | 1,967 (15.7) | 44 (4.6) | 63 (5.4) | 59 (4.3) | 571 (6.1) | 2,704 (10.7) | 32 (2.5) | 436 (5.8) | 109 (5.1) | 139 (4.5) | 716 (5.1) | 3,420 (8.7) |

Marine beach abbreviations: BB = Boquerón Beach, PR; EB = Edgewater Beach, MS; FB = Fairhope Beach, AL; GB = Goddard Beach, RI; SSB = Surfside Beach, SC. Freshwater beach abbreviations: HB = Huntington Beach, OH; SB = Silver Beach, MI; WB = West Beach, IN; WP = Washington Park, IN.

Table 3 | Beachgoer recreational water exposure, other activities, and protective behaviors, by age group. NEEAR Water Study, 2003–2009

| | 0–4 years n (%) | 5–9 years n (%) | 10–14 years n (%) | 15–19 years n (%) | 20–29 years n (%) | 30–49 years n (%) | 50–69 years n (%) | 70+ years n (%) | Overall n (%) |
|---|--------------------|--------------------|----------------------|----------------------|----------------------|----------------------|----------------------|--------------------|------------------|
| Total participants | 3,761(7.1) | 5,052(9.5) | 4,628(8.7) | 4,456(8.4) | 9,097(17.1) | 17,829(33.5) | 7,572(14.2) | 907(1.7) | 53,302(100.0) |
| Any water contact | | | | | | | | | |
| Any | 3,052(81.7) | 4,664(92.9) | 4,119(89.4) | 3,371(76.1) | 6,473(71.4) | 12,177(68.5) | 4,605(61.1) | 363(40.2) | 38,824(73.2) |
| None | 684(18.3) | 355(7.1) | 487(10.6) | 1,057(23.9) | 2,589(28.6) | 5,593(31.5) | 2,936(38.9) | 539(59.8) | 14,240(26.8) |
| Water exposure among swimmers (any water contact) | | | | | | | | | |
| Immersed head | 1,925(63.3) | 3,872(83.2) | 3,494(85.1) | 2,573(76.4) | 4,091(63.2) | 6,835(56.2) | 2,293(49.8) | 143(39.5) | 25,226(65.1) |
| Water contact but did not immerse head | 1,118(36.7) | 784(16.8) | 614(15.0) | 794(23.6) | 2,378(36.8) | 5,326(43.8) | 2,311(50.2) | 219(60.5) | 13,544(34.9) |
| Got water in mouth | 1,735(57.9) | 2,882(64.1) | 2,262(57.0) | 1,491(45.3) | 2,368(36.9) | 3,755(31.1) | 1,225(26.8) | 60(16.7) | 15,778(41.3) |
| Swallowed water | 1,170(39.7) | 1,565(35.8) | 1,092(28.1) | 574(17.6) | 866(13.5) | 1,294(10.8) | 408(8.9) | 22(6.1) | 6,991(18.5) |
| Other activities | | | | | | | | | |
| Touched/played with algae | 248(6.6) | 476(9.5) | 434(9.5) | 263(6.0) | 666(7.4) | 1,080(6.1) | 336(4.5) | 28(3.1) | 3,531(6.7) |
| Body buried in sand | 601(16.1) | 1,086(21.6) | 637(13.8) | 226(5.1) | 323(3.6) | 567(3.2) | 110(1.5) | 11(1.2) | 3,561(6.7) |
| Dug in sand | 2,679(71.7) | 3,903(77.7) | 2,441(53.0) | 1,163(26.3) | 2,260(25.0) | 4,684(26.4) | 1,195(15.9) | 83(9.2) | 18,408(34.7) |
| Collected shells, rocks, or feathers | 1,285(34.4) | 2,246(44.7) | 1,237(26.9) | 535(12.1) | 980(10.8) | 2,551(14.4) | 1,042(13.8) | 67(7.4) | 9,943(18.7) |
| Used raft, body/boogie board, or snorkel | 201(6.9) | 661(14.2) | 515(12.6) | 185(5.5) | 205(3.2) | 540(4.4) | 130(2.8) | 5(1.4) | 2,451(6.3) |
| Protective behaviors | | | | | | | | | |
| Used ear plugs | 58(1.9) | 72(1.6) | 55(1.3) | 48(1.4) | 67(1.0) | 116(1.0) | 63(1.4) | 3(0.8) | 482(1.2) |
| Used nose plugs | 9(0.3) | 31(0.7) | 23(0.6) | 11(0.3) | 17(0.3) | 33(0.3) | 11(0.2) | 1(0.3) | 136(0.4) |
| Used a mask or goggles | 134(4.4) | 780(16.8) | 590(14.4) | 196(5.9) | 497(7.7) | 867(7.2) | 284(6.2) | 15(4.1) | 3,363(8.7) |

Table 4 | Beachgoers reporting new health problems, by beach and recreational water exposure. NEEAR Water Study, 2003–2009

| | BB n (%) | EB n (%) | FB n (%) | GB n (%) | SSB n (%) | Marine n (%) | HB n (%) | SB n (%) | WB n (%) | WP n (%) | Freshwater n (%) | Overall n (%) | χ^2 p-value ^a |
|--------------------------------|--------------------|--------------------|--------------------|--------------------|---------------------|------------------------|--------------------|--------------------|--------------------|--------------------|----------------------------|-------------------------|----------------------------------|
| Total participants | 15,726 (29.0) | 1,351 (2.5) | 2,022 (3.7) | 2,977 (5.5) | 11,159 (20.6) | 33,235 (61.3) | 2,840 (5.2) | 10,921 (20.1) | 2,877 (5.3) | 4,377 (8.1) | 21,015 (38.7) | 54,250 (100.0) | |
| GI illness | | | | | | | | | | | | | |
| Overall | 719 (4.7) | 121 (9.2) | 163 (8.3) | 138 (4.8) | 667 (6.2) | 1,808 (5.6) | 274 (10.0) | 678 (6.4) | 232 (8.2) | 313 (7.4) | 1,497 (7.3) | 3,305 (6.3) | |
| No contact | 123 (4.3) | 31 (8.3) | 63 (7.7) | 65 (4.3) | 79 (4.7) | 361 (5.0) | 127 (8.7) | 164 (5.0) | 33 (4.7) | 73 (6.0) | 396 (6.0) | 758 (5.5) | Ref |
| Any water contact ^b | 587 (4.8) | 89 (9.6) | 99 (8.8) | 73 (5.4) | 587 (6.5) | 1,435 (5.8) | 147 (11.6) | 512 (7.0) | 199 (9.4) | 237 (7.9) | 1,095 (8.0) | 2,530 (6.6) | <0.001 |
| Contact, no head immersion | 127 (5.2) | 44 (8.6) | 41 (8.1) | 32 (5.4) | 182 (6.3) | 426 (6.1) | 79 (10.4) | 239 (7.0) | 85 (9.3) | 104 (7.8) | 507 (7.9) | 933 (7.0) | |
| Immersed head | 460 (4.7) | 45 (10.8) | 58 (9.4) | 40 (5.4) | 405 (6.5) | 1,008 (5.7) | 68 (13.2) | 271 (7.0) | 114 (9.6) | 132 (8.0) | 585 (8.1) | 1,593 (6.4) | |
| Respiratory illness | | | | | | | | | | | | | |
| Overall | 998 (6.9) | 67 (5.3) | 104 (5.4) | 111 (3.9) | 500 (4.7) | 1,780 (5.7) | 193 (7.2) | 581 (5.7) | 123 (4.5) | 236 (5.7) | 1,133 (5.7) | 2,913 (5.7) | |
| No contact | 158 (5.8) | 24 (6.6) | 40 (5.0) | 45 (3.0) | 73 (4.4) | 340 (4.8) | 93 (6.5) | 146 (4.6) | 27 (4.0) | 55 (4.7) | 321 (5.0) | 661 (4.9) | Ref |
| Any water contact ^b | 827 (7.2) | 43 (4.8) | 64 (5.8) | 66 (5.0) | 426 (4.8) | 1,426 (6.0) | 100 (8.1) | 434 (6.2) | 96 (4.7) | 180 (6.2) | 810 (6.1) | 2,236 (6.0) | <0.001 |
| Contact, no head immersion | 181 (8.0) | 20 (4.0) | 23 (4.7) | 31 (5.4) | 130 (4.6) | 385 (5.8) | 57 (7.7) | 201 (6.1) | 44 (5.0) | 81 (6.2) | 383 (6.1) | 768 (5.9) | |
| Immersed head | 645 (7.0) | 23 (5.7) | 41 (6.7) | 35 (4.7) | 296 (4.8) | 1,040 (6.1) | 43 (8.5) | 232 (6.29) | 52 (4.5) | 98 (6.1) | 425 (6.1) | 1,465 (6.1) | |
| Ear problems | | | | | | | | | | | | | |
| Overall | 271 (1.8) | 15 (1.1) | 24 (1.2) | 38 (1.3) | 214 (2.0) | 562 (1.7) | 30 (1.1) | 130 (1.2) | 35 (1.2) | 72 (1.7) | 267 (1.3) | 829 (1.6) | |
| No contact | 40 (1.4) | 3 (0.8) | 9 (1.1) | 14 (0.9) | 20 (1.2) | 86 (1.2) | 10 (0.7) | 30 (0.9) | 4 (0.6) | 14 (1.1) | 58 (0.9) | 144 (1.0) | Ref |
| Any water contact ^b | 227 (1.8) | 12 (1.3) | 15 (1.3) | 24 (1.8) | 193 (2.1) | 471 (1.9) | 20 (1.6) | 100 (1.4) | 31 (1.5) | 58 (1.9) | 209 (1.5) | 680 (1.8) | <0.001 |
| Contact, no head immersion | 48 (1.9) | 4 (0.8) | 6 (1.2) | 5 (0.8) | 31 (1.1) | 94 (1.4) | 14 (1.8) | 38 (1.1) | 6 (0.6) | 27 (2.0) | 85 (1.3) | 179 (1.3) | |
| Immersed head | 179 (1.8) | 8 (1.9) | 9 (1.4) | 19 (2.4) | 162 (2.5) | 377 (2.1) | 6 (1.2) | 62 (1.6) | 25 (2.1) | 31 (1.8) | 124 (1.7) | 501 (2.0) | |
| Eye problems | | | | | | | | | | | | | |
| Overall | 550 (3.6) | 41 (3.1) | 54 (2.7) | 79 (2.7) | 202 (1.8) | 926 (2.8) | 107 (3.8) | 288 (2.7) | 92 (3.2) | 126 (2.9) | 613 (2.9) | 1,539 (2.9) | |
| No contact | 111 (3.8) | 15 (4.0) | 29 (3.4) | 42 (2.7) | 27 (1.6) | 224 (3.0) | 68 (4.5) | 95 (2.8) | 23 (3.2) | 33 (2.7) | 219 (3.2) | 443 (3.1) | Ref |
| Any water contact ^b | 433 (3.5) | 26 (2.7) | 25 (2.2) | 36 (2.6) | 175 (1.9) | 695 (2.8) | 39 (3.0) | 193 (2.6) | 69 (3.2) | 93 (3.0) | 394 (2.8) | 1,089 (2.8) | 0.0517 |
| Contact, no head immersion | 111 (4.5) | 17 (3.2) | 13 (2.5) | 11 (1.8) | 62 (2.1) | 214 (3.0) | 27 (3.5) | 100 (2.9) | 32 (3.5) | 47 (3.4) | 206 (3.1) | 420 (3.1) | |
| Immersed head | 322 (3.2) | 9 (2.1) | 12 (1.9) | 25 (3.2) | 113 (1.8) | 481 (2.7) | 12 (2.3) | 93 (2.4) | 37 (3.1) | 46 (2.7) | 188 (2.6) | 669 (2.6) | |
| Rash | | | | | | | | | | | | | |
| Overall | 675 (4.2) | 60 (4.6) | 44 (2.2) | 89 (3.1) | 430 (4.0) | 1,298 (4.0) | 70 (2.5) | 275 (2.6) | 90 (3.2) | 122 (2.9) | 557 (2.7) | 1,855 (3.5) | |
| No contact | 91 (3.2) | 15 (4.0) | 16 (1.9) | 37 (2.4) | 38 (2.2) | 197 (2.7) | 34 (2.3) | 67 (2.0) | 12 (1.7) | 31 (2.5) | 144 (2.1) | 341 (2.4) | Ref |
| Any water contact ^b | 580 (4.7) | 43 (4.6) | 28 (2.4) | 52 (3.9) | 391 (4.3) | 1,094 (4.4) | 36 (2.8) | 208 (2.8) | 78 (3.7) | 90 (3.0) | 412 (3.0) | 1,506 (3.9) | <0.001 |
| Contact, no head immersion | 156 (6.4) | 25 (4.8) | 14 (2.7) | 21 (3.6) | 103 (3.6) | 319 (4.6) | 25 (3.3) | 94 (2.7) | 33 (3.6) | 43 (3.2) | 195 (3.0) | 514 (3.8) | |
| Immersed head | 424 (4.3) | 18 (4.4) | 14 (2.2) | 31 (4.1) | 288 (4.7) | 775 (4.4) | 11 (2.2) | 113 (2.9) | 45 (3.8) | 46 (2.8) | 215 (3.0) | 990 (4.0) | |
| UTI | | | | | | | | | | | | | |
| Overall | 184 (1.2) | 17 (1.3) | 17 (0.9) | 19 (0.6) | 62 (0.6) | 299 (0.9) | 19 (0.7) | 61 (0.6) | 17 (0.6) | 26 (0.6) | 123 (0.6) | 422 (0.8) | |

(continued)

Table 4 | continued

| | BB n (%) | EB n (%) | FB n (%) | GB n (%) | SSB n (%) | Marine n (%) | HB n (%) | SB n (%) | WB n (%) | WP n (%) | Freshwater n (%) | Overall n (%) | χ^2 p-value ^a |
|--------------------------------|--------------|-------------|-------------|-------------|--------------|-----------------|-------------|--------------|-------------|-------------|---------------------|------------------|----------------------------------|
| No contact | 34 (1.2) | 8 (2.1) | 10 (1.2) | 10 (0.6) | 13 (0.8) | 75 (1.0) | 12 (0.8) | 24 (0.7) | 4 (0.6) | 6 (0.5) | 46 (0.7) | 121 (0.8) | Ref |
| Any water contact ^b | 150 (1.2) | 9 (0.9) | 7 (0.6) | 9 (0.7) | 49 (0.5) | 224 (0.9) | 7 (0.5) | 37 (0.5) | 13 (0.6) | 20 (0.7) | 77 (0.6) | 301 (0.8) | 0.3673 |
| Contact, no head immersion | 35 (1.4) | 6 (1.1) | 3 (0.6) | 1 (0.2) | 14 (0.5) | 59 (0.8) | 3 (0.4) | 17 (0.5) | 7 (0.8) | 11 (0.8) | 38 (0.6) | 97 (0.7) | |
| Immersed head | 115 (1.2) | 3 (0.7) | 4 (0.6) | 8 (1.0) | 35 (0.6) | 165 (0.9) | 4 (0.8) | 20 (0.5) | 6 (0.5) | 9 (0.5) | 39 (0.5) | 204 (0.8) | |
| Any outcome | | | | | | | | | | | | | |
| Overall | 2,589 (16.5) | 245 (18.1) | 304 (15.0) | 360 (12.1) | 1,714 (15.4) | 5,212 (15.7) | 556 (19.6) | 1,637 (15.0) | 469 (16.3) | 680 (15.5) | 3,342 (15.9) | 8,554 (16.3) | |
| No contact | 422 (14.1) | 69 (18.2) | 125 (14.7) | 159 (10.0) | 210 (12.0) | 985 (13.0) | 277 (18.1) | 438 (13.0) | 85 (11.8) | 160 (12.7) | 960 (14.0) | 1,945 (13.5) | Ref |
| Any water contact ^b | 2,138 (17.0) | 173 (17.9) | 178 (15.3) | 200 (14.4) | 1,500 (16.0) | 4,189 (16.4) | 279 (21.4) | 1,197 (16.0) | 384 (17.8) | 515 (16.7) | 2,375 (16.9) | 6,564 (16.6) | <0.001 |
| Contact, no head immersion | 492 (19.4) | 88 (16.4) | 69 (13.4) | 86 (14.2) | 417 (14.2) | 1,152 (16.1) | 161 (20.6) | 559 (15.8) | 169 (18.1) | 230 (16.6) | 1,119 (16.9) | 2,271 (16.5) | |
| Immersed head | 1,645 (16.3) | 85 (19.8) | 109 (16.9) | 113 (14.5) | 1,083 (16.9) | 3,035 (16.6) | 118 (22.5) | 635 (16.1) | 215 (17.8) | 283 (16.7) | 1,251 (17.0) | 4,286 (16.7) | |

Marine beach abbreviations: BB = Boqueron Beach, PR; EB = Edgewater Beach, MS; FB = Fairhope Beach, AL; GB = Goddard Beach, RI; SSB = Surfside Beach, SC. Freshwater beach abbreviations: HB = Huntington Beach, OH; SB = Silver Beach, MI; WB = West Beach, IN; WP = Washington Park, IN. Ref.: Referent category.

^aChi-square p-values are unadjusted and might be confounded by differences in age or other characteristics of swimmers.

^bThe sum of 'contact, no head immersion' and 'immersed head' is sometimes slightly smaller than the total for any water contact because a small number of respondents said they had water contact but could not recall if they put their head under water (i.e., had a response for water contact but missing data for head immersion).

prove useful in developing appropriate health promotion materials (e.g., tailoring communications to specific age groups), and in informing risk assessment models about water exposures and beach activities that might increase risk (e.g., as has been postulated for exposure to beach sand (Heaney *et al.* 2009)).

Overall, 16.7% of swimmers reported some type of health outcome in the 10–12 days after a beach visit compared with 13.6% in non-swimmers ($p < 0.001$). Swimmers were significantly more likely to report GI illness, respiratory illness, earache, and rash than non-swimmers. However, the unadjusted associations reported in this analysis (in particular respiratory illness) might be confounded by differences in age or other characteristics of swimmers, who tended to be younger than non-swimmers. Since the goal of this analysis was to describe the characteristics of beachgoers, no adjustments were made for age, sex, or other potential confounders. Accordingly, care should be taken in attributing causal relationships to the associations reported.

Strengths of this analysis included the large sample size and the inclusion of geographically and environmentally diverse study sites. However, sites were specifically selected because of their known proximity to point or non-point source contamination and might not be representative of all natural water swimming sites in the USA. In particular, only one non-point source impacted beach was included in the study and results may be more representative of point-source impacted beaches. Additionally, health outcomes were self-reported and could have been under- or over-estimated by respondents.

Beachgoers were from a wide surrounding area and dispersed after their visits. This suggests that current locality-based, passive surveillance systems are insufficient for detection of outbreaks and sporadic illness from natural waters. This is supported by the infrequent national reports of beach visit-associated outbreaks (Hlavsa *et al.* 2011) and the finding that no outbreaks of illness were reported at these studied beaches despite elevated levels of illness in swimmers. The data underscore that regardless of water type (fresh or marine) or geographic location, many health symptoms appear to be elevated in swimmers compared to non-swimmers. Among participants reporting a new health problem after the beach visit, 69.7% reported utilizing the healthcare system, missing daily activities, or taking

Table 5 | Beachgoers reporting new health outcomes, by age group and water exposure. NEEAR Water Study, 2003–2009

| | 0–4 years | 5–9 years | 10–14 years | 15–19 years | 20–29 years | 30–49 years | 50–69 years | 70+ years | Overall |
|--------------------------------|------------|-----------|-------------|-------------|-------------|-------------|-------------|-----------|-------------|
| GI illness | | | | | | | | | |
| Overall | 322 (8.9) | 349 (7.1) | 234 (5.2) | 251 (5.8) | 642 (7.4) | 1,096 (6.3) | 341 (4.6) | 26 (2.9) | 3,261 (6.3) |
| No contact | 35 (5.4) | 23 (6.7) | 14 (2.9) | 56 (5.5) | 159 (6.5) | 339 (6.2) | 112 (3.9) | 16 (3.1) | 754 (5.5) |
| Any water contact ^a | 284 (9.6) | 322 (7.1) | 219 (5.4) | 193 (5.9) | 481 (7.7) | 755 (6.4) | 228 (5.1) | 10 (2.8) | 2,492 (6.6) |
| Contact, no head immersion | 102 (9.5) | 55 (7.2) | 30 (5.0) | 50 (6.5) | 188 (8.2) | 363 (7.0) | 129 (5.7) | 5 (2.3) | 922 (7.0) |
| Immersed head | 181 (9.7) | 266 (7.0) | 188 (5.5) | 143 (5.7) | 293 (7.4) | 391 (5.9) | 99 (4.4) | 5 (3.5) | 1,566 (6.4) |
| Respiratory illness | | | | | | | | | |
| Overall | 366 (10.5) | 310 (6.6) | 231 (5.3) | 229 (5.6) | 652 (7.8) | 816 (4.9) | 266 (3.7) | 15 (1.7) | 2,885 (5.8) |
| No contact | 53 (8.2) | 20 (6.1) | 26 (5.7) | 57 (5.9) | 189 (7.9) | 215 (4.1) | 84 (3.0) | 12 (2.3) | 656 (4.9) |
| Any water contact ^a | 310 (11.0) | 285 (6.5) | 205 (5.3) | 171 (5.5) | 458 (7.7) | 599 (5.2) | 182 (4.1) | 3 (0.9) | 2,213 (6.1) |
| Contact, no head immersion | 128 (12.3) | 44 (6.1) | 22 (3.8) | 50 (6.9) | 161 (7.4) | 267 (5.3) | 86 (3.9) | 0 (0.0) | 758 (6.0) |
| Immersed head | 181 (10.2) | 241 (6.7) | 181 (5.5) | 121 (5.0) | 297 (7.9) | 332 (5.2) | 96 (4.4) | 3 (2.3) | 1,452 (6.1) |
| Ear problems | | | | | | | | | |
| Overall | 81 (2.2) | 99 (2.0) | 97 (2.1) | 55 (1.3) | 159 (1.8) | 238 (1.4) | 87 (1.2) | 3 (0.3) | 819 (1.6) |
| No contact | 11 (1.6) | 6 (1.7) | 8 (1.7) | 7 (0.7) | 32 (1.3) | 54 (1.0) | 23 (0.8) | 2 (0.4) | 143 (1.0) |
| Any water contact ^a | 69 (2.3) | 92 (2.0) | 88 (2.2) | 48 (1.5) | 126 (2.0) | 184 (1.5) | 63 (1.4) | 1 (0.3) | 671 (1.8) |
| Contact, no head immersion | 20 (1.8) | 6 (0.8) | 6 (1.0) | 13 (1.6) | 44 (1.9) | 60 (1.1) | 26 (1.1) | 1 (0.5) | 179 (0.0) |
| Immersed head | 49 (2.6) | 86 (2.2) | 82 (2.4) | 35 (1.4) | 82 (2.0) | 124 (1.8) | 37 (1.6) | 0 (0.0) | 501 (1.9) |
| Eye problems | | | | | | | | | |
| Overall | 85 (2.3) | 116 (2.3) | 98 (2.1) | 112 (2.5) | 325 (3.6) | 533 (3.0) | 229 (3.1) | 29 (3.2) | 1,527 (2.9) |
| No contact | 8 (1.2) | 9 (2.6) | 7 (1.5) | 36 (3.4) | 97 (3.8) | 171 (3.1) | 91 (3.1) | 21 (3.9) | 440 (3.1) |
| Any water contact ^a | 76 (2.5) | 106 (2.3) | 90 (2.2) | 76 (2.5) | 226 (3.5) | 361 (3.0) | 137 (3.0) | 8 (2.2) | 1,080 (2.8) |
| Contact, no head immersion | 24 (2.2) | 20 (2.6) | 11 (1.8) | 25 (3.2) | 84 (3.6) | 171 (3.2) | 77 (3.4) | 5 (2.3) | 417 (3.1) |
| Immersed head | 52 (2.7) | 86 (2.2) | 79 (2.3) | 51 (2.0) | 142 (3.5) | 190 (2.8) | 60 (2.6) | 3 (2.1) | 663 (2.7) |
| Rash | | | | | | | | | |
| Overall | 153 (4.2) | 193 (3.9) | 161 (3.6) | 149 (3.5) | 380 (4.3) | 560 (3.2) | 210 (2.9) | 16 (1.8) | 1,822 (3.5) |
| No contact | 26 (4.0) | 8 (2.3) | 4 (0.8) | 32 (3.1) | 69 (2.8) | 130 (2.4) | 62 (2.2) | 9 (1.7) | 340 (2.5) |
| Any water contact ^a | 126 (4.3) | 185 (4.1) | 156 (3.9) | 117 (3.6) | 309 (4.9) | 427 (3.6) | 147 (3.3) | 7 (1.9) | 1,474 (3.9) |
| Contact, no head immersion | 45 (4.1) | 34 (4.5) | 19 (3.2) | 24 (3.1) | 127 (5.5) | 176 (3.4) | 75 (3.3) | 6 (2.8) | 506 (3.8) |
| Immersed head | 80 (4.3) | 151 (4.0) | 137 (4.0) | 93 (3.7) | 181 (4.6) | 251 (3.8) | 72 (3.2) | 1 (0.7) | 966 (3.9) |
| UTI | | | | | | | | | |
| Overall | 27 (0.7) | 25 (0.5) | 13 (0.3) | 30 (0.7) | 109 (1.2) | 156 (0.9) | 56 (0.8) | 3 (0.3) | 419 (0.8) |
| No contact | 3 (0.4) | 4 (1.1) | 4 (0.8) | 8 (0.8) | 25 (1.0) | 51 (0.9) | 22 (0.8) | 3 (0.6) | 120 (0.9) |
| Any water contact ^a | 24 (0.8) | 21 (0.5) | 9 (0.2) | 22 (0.7) | 84 (1.3) | 105 (0.9) | 34 (0.8) | 0.0 | 299 (0.8) |
| Contact, no head immersion | 6 (0.5) | 3 (0.4) | 4 (0.7) | 4 (0.5) | 30 (1.3) | 34 (0.6) | 15 (0.7) | 0.0 | 96 (0.7) |
| Immersed head | 18 (0.9) | 18 (0.5) | 5 (0.1) | 18 (0.7) | 54 (1.3) | 71 (1.1) | 19 (0.8) | 0.0 | 203 (0.8) |

(continued)

Table 5 | continued

| | 0–4 years | 5–9 years | 10–14 years | 15–19 years | 20–29 years | 30–49 years | 50–69 years | 70+ years | Overall |
|--------------------------------|------------|------------|-------------|-------------|--------------|--------------|-------------|-----------|--------------|
| Any health outcome | | | | | | | | | |
| Overall | 774 (20.6) | 890 (17.6) | 669 (14.5) | 677 (15.2) | 1,754 (19.3) | 2,697 (15.1) | 917 (12.1) | 71 (7.8) | 8,449 (15.9) |
| No contact | 102 (14.9) | 56 (15.8) | 54 (11.1) | 155 (14.7) | 447 (17.3) | 766 (13.7) | 310 (10.6) | 44 (8.2) | 1,934 (13.6) |
| Any water contact ^a | 663 (21.7) | 825 (17.7) | 611 (14.8) | 520 (15.4) | 1,299 (20.1) | 1,924 (15.8) | 603 (13.1) | 27 (7.4) | 6,472 (16.7) |
| Contact, no head immersion | 240 (21.5) | 132 (16.8) | 74 (12.1) | 135 (17.0) | 499 (21.0) | 845 (15.9) | 303 (13.1) | 16 (7.3) | 2,244 (16.6) |
| Immersed head | 421 (21.9) | 692 (17.9) | 535 (15.3) | 385 (15.0) | 799 (19.5) | 1,078 (15.8) | 300 (13.1) | 11 (7.7) | 4,221 (16.7) |

^aThe sum of 'Contact, no head immersion' and 'Immersed head' is sometimes slightly smaller than the total for any water contact because a small number of respondents said they had water contact but could not recall if they put their head under water (i.e., had a response for water contact but missing data for head immersion).

Table 6 | Healthcare utilization among all beachgoers reporting new health outcomes, by syndrome. NEEAR Water Study, 2003–2009

| | HCGI n = 3,305 (%) | Respiratory infections n = 2,913 (%) | Earache n = 829 (%) | Eye problems n = 1,539 (%) | Rash n = 1,855 (%) | UTI n = 422 (%) | Any outcome n = 8,554 (%) |
|---|-----------------------|--|------------------------|-------------------------------|-----------------------|--------------------|---------------------------------|
| Used OTC drugs | 1,427(43.4) | 1,875(64.7) | 337(40.6) | 717(46.6) | 933(50.3) | 152(36.0) | 4,620(54.0) |
| Obtained RX drugs | 336(10.2) | 601(20.7) | 257(31.0) | 258(16.8) | 177(9.5) | 169(40.0) | 1,453(17.0) |
| Missed daily activities | 1,412(42.8) | 910(31.3) | 201(24.3) | 278(18.1) | 165(8.9) | 90(21.3) | 2,485(29.1) |
| Missed work | 257(7.8) | 232(8.5) | 40(4.8) | 77(5.0) | 27(1.5) | 116(27.5) | 605(7.1) |
| Other household members missed daily activities | 153(4.6) | 159(5.5) | 30(3.6) | 47(3.1) | 22(1.2) | 14(3.3) | 326(3.8) |
| Called doctor | 238(7.2) | 256(8.8) | 122(14.7) | 108(7.0) | 119(6.4) | 83(19.7) | 788(9.2) |
| Visited doctor | 372(11.3) | 588(20.3) | 235(28.3) | 211(13.7) | 162(8.7) | 140(33.2) | 1,323(15.5) |
| Visited emergency room | 128(3.9) | 107(3.7) | 36(4.3) | 28(1.8) | 18(1.0) | 26(6.2) | 262(3.1) |
| Admitted to hospital | 0(0.0) | 1(0.0) | 0(0.0) | 0(0.0) | 0(0.0) | 0(0.0) | 1(0.0) |
| Any utilization | 551(16.7) | 776(26.6) | 317(38.2) | 341(22.2) | 285(15.4) | 210(49.8) | 1,967(23.0) |

OTC: over-the-counter (non-prescription); RX: recreational.

prescription or OTC drugs, underscoring the potential economic impact that these health outcomes have on individuals and the healthcare system.

These data are consistent with the billions of dollars of pathogen-specific healthcare costs associated with primarily or potentially waterborne pathogens (Collier *et al.* 2012). With an estimated 88 million adults swimming in natural waters each year (NSRE 2004), even a small health effect can result in a large population health impact and burden. Although this descriptive analysis did not account for potential confounding variables, the unadjusted estimates suggest up to 2.7 million excess illnesses (3.1%; the difference between non-swimmer and swimmer levels of illness after

the beach visit) might occur and result in over 500,000 healthcare visits and 1.1 million instances of lost work or activity time. These data provide a glimpse into the large impact that swimming in natural waters may have on swimmer health and the US healthcare system. For instance, an estimated 2.4 million healthcare visits for acute otitis externa ('swimmer's ear', a preventable infection) occur each year in the USA and require 600,000 ambulatory care clinician hours at a cost of almost \$500 million (CDC 2011); many of these infections might be related to natural water use. These data should be used to inform development of more sophisticated swimming-associated illness burden and impact estimates that can be used to inform public

health/healthcare professionals and policymakers seeking to prevent future infections and reduce healthcare costs.

CONCLUSIONS

Lake and ocean swimmers experience a variety of exposures and health symptoms which current surveillance systems may not detect. Better knowledge of beachgoer characteristics and health risks can advocate for and prioritize limited resources. An estimation of the burden of illness related to beach visits, in part developed using numbers reported here, could be used to guide and prioritize efforts to ensure needed water quality and improve the health and safety of beach visits.

ACKNOWLEDGMENTS

The authors would like to acknowledge Dr Rebecca Calderon (deceased) for her inspiration, dedication, and vision; Westat, Inc. especially Karen Della Torre and Kurt Patrizi; and all field study staff, participants, interviewers, and water sample collectors. The views expressed in this paper are those of the authors and do not necessarily reflect the views or policies of the Centers for Disease Control and Prevention or US Environmental Protection Agency.

REFERENCES

- Bartels, E. M., Lund, H., Hagen, K. B., Dagfinrud, H., Christensen, R. & Danneskiold-Samsoe, B. 2007 Aquatic exercise for the treatment of knee and hip osteoarthritis. *Cochrane Database Syst. Rev.* **4**, CD005523.
- Broman, G., Quintana, M., Lindberg, T., Jansson, E. & Kaijser, L. 2006 High intensity deep water training can improve aerobic power in elderly women. *Eur. J. Appl. Physiol.* **98**, 117–123.
- Bureau of the Census. 2012 *Statistical Abstract of the United States, 2012*. Bernan Press, Lanham, MD.
- Cabelli, V. J., Dufour, A. P., Levin, M. A., McCabe, L. J. & Haberman, P. W. 1979 Relationship of microbial indicators to health effects at marine bathing beaches. *Am. J. Public Health* **69**, 690–696.
- Cabelli, V. J., Dufour, A. P., McCabe, L. J. & Levin, M. A. 1982 Swimming-associated gastroenteritis and water quality. *Am. J. Epidemiol.* **115**, 606–616.
- CDC 2011 Estimated burden of acute otitis externa—United States, 2003–2007. *MMWR Morb. Mortal. Wkly Rep.* **60**, 605–609.
- Chase, N. L., Sui, X. & Blair, S. N. 2008 Swimming and all-cause mortality risk compared with running, walking, and sedentary habits in men. *Int. J. Aquatic Res. Educ.* **2**, 213–223.
- Colford Jr, J. M., Wade, T. J., Schiff, K. C., Wright, C. C., Griffith, J. F., Sandhu, S. K., Burns, S., Sobsey, M., Lovelace, G. & Weisberg, S. B. 2007 Water quality indicators and the risk of illness at beaches with nonpoint sources of fecal contamination. *Epidemiology* **18**, 27–35.
- Collier, S. A., Stockman, L. J., Hicks, L. A., Garrison, L. E., Zhou, F. J. & Beach, M. J. 2012 Direct healthcare costs of selected diseases primarily or partially transmitted by water. *Epidemiol. Infect.* **140**, 2003–2013.
- Cox, K. L., Burke, V., Beilin, L. J. & Puddey, I. B. 2010 A comparison of the effects of swimming and walking on body weight, fat distribution, lipids, glucose, and insulin in older women—the Sedentary Women Exercise Adherence Trial 2. *Metabolism* **59**, 1562–1573.
- Haile, R. W., Witte, J. S., Gold, M., Cressey, R., McGee, C., Millikan, R. C., Glasser, A., Harawa, N., Ervin, C., Harmon, P., Harper, J., Dermand, J., Alamillo, J., Barrett, K., Nides, M. & Wang, G. 1999 The health effects of swimming in ocean water contaminated by storm drain runoff. *Epidemiology* **10**, 355–363.
- Heaney, C. D., Sams, E., Wing, S., Marshall, S., Brenner, K., Dufour, A. P. & Wade, T. J. 2009 Contact with beach sand among beachgoers and risk of illness. *Am. J. Epidemiol.* **170**, 164–172.
- Hilborn, E. D., Roberts, V. A., Backer, L., DeConno, E., Egan, J. S., Hyde, J. B., Nicholas, D. C., Wiegert, E. J., Billing, L. M., DiOrio, M., Mohr, M. C., Hardy, F. J., Wade, T. J., Yoder, J. S. & Hlavsa, M. C. 2014 Algal bloom-associated disease outbreaks among users of freshwater lakes – United States, 2009–2010. *MMWR Surveill. Summ.* **63**, 11–15.
- Hlavsa, M. C., Roberts, V. A., Anderson, A. R., Hill, V. R., Kahler, A. M., Orr, M., Garrison, L. E., Hicks, L. A., Newton, A., Hilborn, E. D., Wade, T. J., Beach, M. J. & Yoder, J. S. 2011 Surveillance for waterborne disease outbreaks and other health events associated with recreational water – United States, 2007–2008. *MMWR Surveill. Summ.* **60**, 1–32.
- Hlavsa, M. C., Roberts, V. A., Kahler, A. M., Hilborn, E. D., Wade, T. J., Backer, L. C. & Yoder, J. S. 2014 Surveillance for waterborne disease outbreaks and other health events associated with recreational water – United States, 2009–2010. *MMWR Surveill. Summ.* **63**, 6–10.
- Hoffmann, S., Batz, M. B. & Morris Jr, J. G. 2012 Annual cost of illness and quality-adjusted life year losses in the United States due to 14 foodborne pathogens. *J. Food Prot.* **75**, 1292–1302.
- Mead, P. S., Slutsker, L., Dietz, V., McCaig, L. F., Bresee, J. S., Shapiro, C., Griffin, P. M. & Tauxe, R. V. 1999 Food-related illness and death in the United States. *Emerg. Infect. Dis.* **5**, 607–625.
- NSRE 2004 *National Survey on Recreation and the Environment 2000–2002. The Interagency National Survey Consortium Coordinated by the USDA Forest Service Recreation*

- Wilderness and Demographics Trends Research Group and the University of Tennessee Human Dimensions Research Laboratory*. University of Tennessee, Knoxville, TN.
- Rotstein, A., Harush, M. & Vaisman, N. 2008 The effect of a water exercise program on bone density of postmenopausal women. *J. Sports Med. Phys. Fitness* **48**, 352–359.
- Scallan, E., Griffin, P. M., Angulo, F. J., Tauxe, R. V. & Hoekstra, R. M. 2011a Foodborne illness acquired in the United States—unspecified agents. *Emerg. Infect. Dis.* **17**, 16–22.
- Scallan, E., Hoekstra, R. M., Angulo, F. J., Tauxe, R. V., Widdowson, M. A., Roy, S. L., Jones, J. L. & Griffin, P. M. 2011b Foodborne illness acquired in the United States—major pathogens. *Emerg. Infect. Dis.* **17**, 7–15.
- Schoen, M. E., Soller, J. A. & Ashbolt, N. J. 2011 Evaluating the importance of faecal sources in human-impacted waters. *Water Res.* **45**, 2670–2680.
- Springer, G. L. & Shapiro, E. D. 1985 Fresh water swimming as a risk factor for otitis externa: a case-control study. *Arch. Environ. Health* **40**, 202–206.
- van Asperen, I. A., de Rover, C. M., Schijven, J. F., Oetomo, S. B., Schellekens, J. F., van Leeuwen, N. J., Colle, C., Havelaar, A. H., Kromhout, D. & Sprenger, M. W. 1995 Risk of otitis externa after swimming in recreational fresh water lakes containing *Pseudomonas aeruginosa*. *BMJ* **311**, 1407–1410.
- Wade, T. J., Calderon, R. L., Sams, E., Beach, M., Brenner, K. P., Williams, A. H. & Dufour, A. P. 2006 Rapidly measured indicators of recreational water quality are predictive of swimming-associated gastrointestinal illness. *Environ. Health Perspect.* **114**, 24–28.
- Wade, T. J., Calderon, R. L., Brenner, K. P., Sams, E., Beach, M., Haugland, R., Wymer, L. & Dufour, A. P. 2008 High sensitivity of children to swimming-associated gastrointestinal illness: results using a rapid assay of recreational water quality. *Epidemiology* **19**, 375–383.
- Wade, T. J., Sams, E., Brenner, K. P., Haugland, R., Chern, E., Beach, M., Wymer, L., Rankin, C. C., Love, D., Li, Q., Noble, R. & Dufour, A. P. 2010 Rapidly measured indicators of recreational water quality and swimming-associated illness at marine beaches: a prospective cohort study. *Environ. Health* **9**, 66.
- Wade, T. J., Sams, E. A., Haugland, R., Brenner, K. P., Li, Q., Wymer, L., Molina, M., Oshima, K. & Dufour, A. P. 2011 *Report on 2009 National Epidemiologic and Environmental Assessment of Recreational Water Epidemiology Studies*. Environmental Protection Agency Reports. US Environmental Protection Agency, Office of Research and Development, Washington, DC.
- Yoder, J. S., Blackburn, B. G., Craun, G. F., Hill, V., Levy, D. A., Chen, N., Lee, S. H., Calderon, R. L. & Beach, M. J. 2004 Surveillance for waterborne-disease outbreaks associated with recreational water – United States, 2001–2002. *MMWR Surveill. Summ.* **53**, 1–22.
- Yoder, J. S., Hlavsa, M. C., Craun, G. F., Hill, V., Roberts, V., Yu, P. A., Hicks, L. A., Alexander, N. T., Calderon, R. L., Roy, S. L. & Beach, M. J. 2008 Surveillance for waterborne disease and outbreaks associated with recreational water use and other aquatic facility-associated health events – United States, 2005–2006. *MMWR Surveill. Summ.* **57**, 1–29.

First received 4 April 2014; accepted in revised form 6 September 2014. Available online 9 October 2014