Web-based investigation of water associated illness in marine bathers

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Abstract

Internet-based methods of disease investigation have proven useful for drinking water and foodborne illness but have not been applied to recreational water illness (RWI) in marine bathers. We analyzed responses to a web-based survey posted by Surfrider Foundation over the period 1996–2005. Subjects (\(n = 1895\)) were recruited by self-selection via website visitation. Complaints were screened to meet inclusion criteria (\(n = 1190\)). Demographic characteristics of respondents were assessed as well as the types and severity of their symptoms. Geographic information systems (GIS) were used to examine spatial patterns in survey data. Illness complaints were commonly received in summer from heavily used California beaches. A strong correlation was observed between water quality impairment and the number of illness complaints in coastal counties (\(r = 0.96, p < 0.01\)). Respondents most commonly complained of gastrointestinal symptoms, infections of the sinuses and other upper respiratory ailments. Certain severe symptoms, such as high fevers, severe vomiting and/or diarrhea, seizures, swollen glands, and infections that did not heal properly were also reported. Approximately one-third of respondents sought the care of a physician for their symptoms; however, less than 1% reported being hospitalized. Our findings concerning the nature of the described symptoms as well as the observed seasonal and spatial patterns in the data are consistent with previously published findings of RWI in ocean bathers exposed to sewage and urban runoff. This method of rapid RWI data collection over the web could easily be adopted by health agencies for coordinated disease surveillance.

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1. Introduction

Marine bathers exposed to pathogens in contaminated seawater may experience a wide range of symptoms including: gastroenteritis, infections of the eyes, ears and sinuses, and skin rashes (Fleisher et al., 1993, 1996; Pruss 1998; Mugglestone 2000; Zmirou et al., 2003). Bathers may become ill from accidental swallowing or inhalation of water contaminated with viral, bacterial, protozoan, or helminthic pathogens (Henrickson et al., 2001; Harrington et al., 1993). Illnesses associated with bathing contact in contaminated recreational water are collectively known as recreational water illness (RWI).

Sewage and urban runoff are two major sources of pathogenic microorganisms in seawater. Swimmers may contract diarrheal disease from contact with human sewage polluted waters (Cabelli et al., 1982; Saliba and Helmer 1990). Fecal wastes of animals may be transported in stormwater runoff (Calderon et al., 1991). Ocean swimmers exposed to seawater contaminated by storm drain runoff are at elevated risk for a number of ailments compared to bathers who swim farther away from drains (Haile et al., 1999). Contact with polluted runoff has also been linked to RWI in surfers (Dwight et al., 2004).

Swimmers are the subjects of the majority of published epidemiological studies on health risks to marine bathers (e.g. Fleisher et al., 1993; Kay et al., 1994; Fattal et al., 1986; Corbett et al., 1993; Cheung et al., 1990). Indeed, standards for marine water contact in the United States (Cabelli et al., 1982) and the United Kingdom (Kay et al., 2004) are based upon risk to swimmers. Surfers may have higher exposure than swimmers by virtue of more frequent
and longer contact with fecal contaminated water (Schiijven and de Roda Husman 2006). At the same time, surfers may comprise a disproportionately large fraction of marine bathers, particularly in some regions (County Sanitation Districts of Orange County, 1996). The routes of exposure to waterborne pathogens are identical for surfers and swimmers (Dwight et al., 2004).

Simulation models based upon epidemiologic evidence provide strong justification for the need for disease surveillance. An estimated 2500–95,010 excess gastrointestinal (GI) illnesses in marine bathers were likely to have occurred along a 13 km stretch of northern Orange County, California, over an 18-month period (Turbow et al., 2003). The economic burden of disease associated with those GI illnesses alone was estimated at $3.3 million per year (Dwight et al., 2005). Given et al. (2006) calculated 627,800–1,479,200 excess GI’s are likely to occur annually along the 160 km coastline of Orange and Los Angeles counties in Southern California.

Disease surveillance of marine bathers is not a required or routine activity of health agencies (Yoder et al., 2004). Recreational waterborne disease surveillance is a passive activity carried out by local, territorial, and state authorities (Frost et al., 1995; Craun et al., 2006). Local and state agency voluntary efforts to quantify RWI are hindered by underreporting (Yoder et al., 2004; Otto, 2006). Disease surveillance is needed for a more comprehensive understanding of the public health burden of coastal water quality impairment.

The challenge of quantifying the burden of waterborne and foodborne illness is formidable due to the paucity of epidemiologic data. The number of individuals in the exposed population may be orders of magnitude higher than the number of confirmed cases (Mead et al., 2000; National Center for Infectious Diseases, 2005).

The internet has been useful to investigate foodborne and waterborne illness (Wethington and Bartlett, 2006; Fox et al., 2005; Kuusi et al., 2004). For example, an internet-based survey was used to effectively conduct communitywide GI outbreak investigations (Kuusi et al., 2004). Internet-based questionnaires were also used to coordinate a Cryptosporidiosis outbreak investigation (Fox et al., 2005). These studies suggest that health data can be collected in a more complete manner over the worldwide web than through telephone calls with health representatives (Wethington and Bartlett, 2006). Internet-based surveys can also offer considerable time savings compared to mail-in and telephone-based survey methods (Pealer and Weiler, 2000). The quick turnaround time for web-based form submission can facilitate intervention on the part of health agency officials (Fox et al., 2005).

Furthermore, a web-based survey can be made accessible to a large population on the world wide web, allowing investigators to explore a health issue in respondents from geographically disparate regions at a low cost (Pealer and Weiler, 2000). The drawbacks of internet-based methods include the possibility of acquiring a biased sample of web users and an inability to control for repeat entries (Eysenbach and Wyatt, 2002; Lenert and Skoczen, 2002). Nevertheless, the goal of this research was to demonstrate the utility of a web-based survey to rapidly collect illness data on surfers and swimmers for the purposes of surveillance.

2. Materials and methods

2.1. Ocean illness data sources and survey design

Data used in this study were collected through Surfrider Foundation’s self-reported illness database between 1996 and 2005. The database is a repository of information gathered through its “ocean illness survey”, an instrument designed to collect information from subjects who experienced adverse health outcomes after surfing or swimming at the beach (http://www.surfrider.org/oceanillness.asp). The survey elicits demographic information, beach-going day, time and location of water recreation, and information about presumed water recreation-related illness symptoms experienced by beachgoers. Respondents submitted responses to an open-ended survey item, “Describe your illness and physical symptoms”. Respondents were also asked, “Did you see a doctor?” for which a “yes” or “no” binary response was prompted.

Surfrider Foundation maintains a worldwide base of survey responses. However, our quantitative analysis of the data set concerning illness types and frequency was limited to the United States. We chose to further the spatial examination of illness responses to California beaches.

2.2. Water quality impairment

The beach mile days (BMD) reported for each coastal county in California were used as an index of water quality impairment. BMD is a term used by the State Water Resources Control Board (SWRCB) and county agencies to indicate the total number of days and miles of shoreline along ocean or bay waters closed due to a sewage spill or are under health advisory (commonly known as posting) for a violation of California’s Ocean Water-Contact Sports Standards. BMDs are calculated by multiplying the number of days of a closure or posting by the number of miles of beach affected. BMD assessment provides a standardized measure of closures/postings, facilitating county to county comparisons as well as assessments over time. BMD analysis thus provides more information than merely the total number of closure or posting events in a given region. County-level BMD health advisory data for the years 1999–2005 used in this study were provided by the SWRCB. We analyzed water quality impairment data starting in 1999 because it was coincident with changes in monitoring standards (State of California, 1998).

2.3. Subject recruitment

The subject pool was comprised of individuals who visited Surfrider Foundation’s website. Subjects were recruited by self-visititation to the website. Potential subjects were not required to be paid members of the organization to participate. During the timeframe of data collection, a link to the survey was also included on Surfline.com, a privately operated website that provides weather and oceanographic data to surfers and other recreational users of coastal waters. Unique site visitation to Surfline.com is estimated at 50,000 per day, and the combined daily web visitation for both sites is currently estimated to exceed one million per month worldwide (www.surfline.com).

2.4. Data sorting and statistical analysis

Survey responses were first sorted for spatial analysis using a state code. Of 1895 submissions received, 1788 were originated from within the US.
Only responses originating from the US were analyzed. Data were then sorted by year and month of entry, followed by age of the respondent. Submissions containing insufficient information about the year, location and/or nature of the symptoms (~33%) were removed from further analysis. A total of 1190 data points deemed valid were included in the final analysis.

Illness symptoms described by respondents were coded into the following categories: sinus infection, cough, diarrhea, vomiting, nausea, upset stomach, malaise, fever, chills, eye infection, sore throat, headache, ear infection, skin rash and "other". We classified complaints of symptoms, such as high fevers, swollen glands and severe or persistent infections that did not heal as the "other" category. For each response, symptoms were then re-coded into different variables with a "1" for "yes" and "0" for "no". Responses to the item concerning whether or not doctor’s care was sought for illnesses (yes/no) were recoded into a different variable with a "1" for "yes" and "0" for no. We used responses to this item as a proxy for the severity of symptoms.

2.5. Data processing for GIS mapping

We created GIS maps to examine the spatial distribution of illness complaints received from the State of California. Coastal zip codes were adapted from beach areas and cities listed by survey respondents. Zip codes were obtained from the Monga Bay website (URL: http://www.mongabay.com/igapo/zip_codes/CA.htm), as well as county and state beach websites. Ambiguous survey entries were discarded.

California Census 2000 zip code and county shape files were used to generate GIS maps. All coast-bordering zip code areas were selected to create a layer of relevant zip codes. After illness complaints were geocoded by zip code, locations of individual responses were spatially joined to the coastal zip code layers. Chloropleth maps were generated to display illness complaint counts.

3. Results

3.1. Spatial and temporal distribution of survey results

Respondents from more than 20 countries in the world completed the ocean illness survey via the worldwide web. Approximately 96% of responses were submitted from within the US. Among US responses, California accounted for 85% of entries (Fig. 1). The age of respondents ranged from 2–65 with a mean of 28.1 years (SD = 10.8). Respondents in the 21–30 years age group accounted for 35% of the total entries (see Fig. 2). Parents and grandparents submitted responses on behalf of young children. Roughly 1.9% of respondents (n = 23) failed to report their age.

Starting from the first year of analysis in 1996, the total number of annual illness complaints increased, to a peak in the year 2000 followed by dips in 2001 and 2002 (Fig. 3). The number of annual illness complaints rebounded in 2003 and 2004. It should be noted that the number of illness complaints for the year 2005 was incomplete, as only January through September data were available at the time of analysis.

A seasonal peak in illness complaints during the summer beach use-season (June–September) became apparent when data were viewed for all locations combined over the entire study period (Fig. 4). Illness complaints received in July and August accounted for 16.1% and 13.4% of total complaints, respectively.

3.2. Water quality impairment and illness complaints

Coastal water quality was clearly more impaired in Southern California counties than in Northern California counties during the period 1999–2005 (Fig. 5). The highest number of advisory BMDs over the study period was consistently observed in Orange County (480), San Diego County (300), and Los Angeles County (163). By contrast, each of the northernmost counties, Del Norte, Humboldt, and Mendocino, was affected by less than one advisory BMD over the study period. There was a strong correlation between the number of illness complaints received from each county in California and the number of annual advisory BMD’s in each county (r = 0.96, p < 0.001) (Fig. 5).

3.3. GIS Maps of complaint hot spots

GIS maps show most illness complaints were concentrated in Southern California beaches (Fig. 6). Malibu Beach in Los Angeles County, Huntington Beach in Orange County, and La Jolla/Mission Bay in San Diego County may be considered “hot spots” for illness complaints (Fig. 6). Analysis of spatially disaggregated
data from Southern California revealed a pattern of heightened illness complaint submissions in summer, echoing the observed seasonal pattern for the entire data set (data not shown).

3.4. Frequency and severity of symptoms

Fig. 7 shows the frequency of individual symptom complaints as a percentage of total illness complaints received. Roughly 42% of respondents submitted complaints about sinus-related symptoms. For the purpose of our analysis, we categorized complaints of nasal congestion, runny nose, and any non-specific flu-like symptoms into the “sinus” category. In addition to sinus-related symptoms, complaints of other upper respiratory problems, such as cough (16%) and sore throat (23%) were also common. Approximately 45% of respondents complained of GI-related symptoms. GI symptoms were calculated as a sum total of the following individual symptoms: diarrhea (11%), vomiting (8%), stomach ache (14%), and nausea (12%). Slightly more than 10% of respondents reported skin rashes. Less frequently reported
ailments included eye infections (6%). These adverse health effects are representative of those previously reported in the literature (Fleisher et al., 1996; Cabelli et al., 1982; Dwight et al., 2004). Approximately 15% of respondents complained of fever and 4% reported chills. We calculated the occurrence of symptoms independently due to the possibility of multiple symptoms per complaint. Thus, the cumulative percentage of individual symptoms exceeds 100%.

Approximately 35% of respondents sought the care of a physician for their ailments. There was a significant relationship between age and likelihood to seek a physician’s care.

Fig. 5. Relationship between annual average coastal water quality impairment and total illness complaints originating from California coastal counties during the period 1999–2005. *Note: water quality impairment is expressed in units of beach mile days (BMD) Advisory posted for each county.

Fig. 6. Spatial patterns of illness complaints received in the State of California (1996–2005) as revealed by Geographic Information Systems (GIS) mapping. *Note: distribution of illness complaints originating from Southern California coastal counties are displayed on the right-hand side of the figure.
care for symptoms. Respondents 35 years of age or older were significantly more likely than respondents under the age of 35 to seek the care of a physician for symptoms \(X^2(1, N = 1152) = 7.016, p = 0.008\). The vast majority of responses concerned non-life threatening symptoms. However, a small percentage of respondents (0.8%) reported they were hospitalized for their symptoms. Hospitalization related complaints commonly involved severe vomiting and/or diarrhea with bloody stools, seizures, swollen glands, severe skin infections (e.g. cellulitis), and infections with presumed waterborne bacterial etiology.

4. Discussion

In this study, there was a seasonal trend of heightened complaints in summer. Both the observed seasonal trends and geographical patterns of illness complaints were consistent with previously derived simulation model estimates of RWI for beaches in Southern California. Higher estimated illnesses in summer may be attributable to heightened number of exposed individuals and contact with water despite higher fecal indicator bacteria (FIB) levels during the storm season in winter months (Turbow et al., 2003; Given et al., 2006). There is a growing body of research highlighting the role of urban runoff following rainfall events as a basis for elevated FIB levels in coastal areas (e.g. Noble et al., 2003; Dwight et al., 2002).

A higher proportion of illness complaints were received from Southern California than from Northern California, supporting previous research that surfers in urbanized regions are more likely than surfers in rural areas to become ill after contact with seawater (Dwight et al., 2004). GIS mapping of illness survey data provided a clear visual identification of many illness hot spots, which allows environmental managers and health care agencies to develop strategies to identify problem areas where contamination sources should be investigated. Application of this method helps to identify sites at which follow-up epidemiologic studies should be conducted on marine bathers.

Results of our investigation suggest that respondents most commonly suffered from sinus-related ailments and gastrointestinal symptoms, such as diarrhea, vomiting, upset stomach, and nausea. The illness symptoms are consistent with previously reported health outcomes for bathers exposed to contaminated recreational waters (DeWailly et al., 1986; Cabelli et al., 1982; Kay et al., 1994; Haile et al., 1999; Dwight et al., 2004). The percentage of respondents who sought medical treatment was also consistent with previous findings concerning the typical severity of RWI’s (Fleisher et al., 1998). There was a high percentage of skin rashes for this study as compared to previous studies on the frequency of skin rash in marine bathers, suggesting that some respondents may have experienced symptoms related to sun exposure rather than RWI (Fleisher et al., 1996). On the other hand, skin and wound infections resulting from contact with contaminated water are possible (Efratiou, 2001). The observed age distribution of respondents in our study indicated most respondents were young adults. Previous research concerning health risks of bathing suggests that young children exposed to sewage contaminated seawater were at increased risk for certain health ailments, such as GI, compared to adults (Alexander et al., 1992). Follow-up research should be focused on acquiring adverse health outcome data for young children since parents can fill out complaint forms on behalf of children and submit them through the internet.

Precise interpretation of illness complaints for this study was confined by the open-ended nature of survey items pertaining to health outcomes. Respondents were asked to describe ailments in writing and often did so in layman’s terms. Because the survey design process is both iterative and dynamic, revisions can be made to the instrument to incorporate a higher proportion of close-ended, binary

![Symptoms](image-url)
response items concerning the nature of illness symptoms, and the survey can be re-administered.

Internet-based survey methodologies provide distinct advantages over traditional survey methods. The type of analysis presented here can lead to a better overall understanding of the burden of illness for marine recreational exposures especially through increased potential for follow-up with health care providers. Health officials can use the method employed here to investigate whether adverse water quality events coincide with times and locations of illness complaints so as to identify time-space clusters of RWI. Such efforts have taken place in the County of San Diego, California, albeit using a slower, mail/facsimile-based survey method of RWI reporting (County of San Diego, 2000). Similar studies can be designed to target illnesses in beach users other than surfers and swimmers.

Although we were able to examine trends in coastal water impairment per county on a yearly basis, we could not match historical water quality data to the precise dates, times, and locations at which complaints were received. The correlation between coastal water impairment and illness complaints by county may be mediated by factors such as population size, population density, and total number of surfers per region. Another limitation to the current study is that the true response rate for the survey is unknown. Web “hits” and unique site visitation could not be used to assess the total number of people who viewed the ocean illness survey over the study period. Temporal trends in annual responses to the survey may also be reflective heightened awareness and visitation to the website, and/or heightened awareness of coastal water quality impairment and RWI.

We did not attempt to estimate the total number of exposed individuals in the water at any particular location on any particular day during the study period. Also, we did not collect illness outcome data for non-swimmers. Further, we did not attempt to account for non-water related risk factors for illness. Therefore, a fundamental limitation to our approach is that the survey responses we received do not provide a true risk estimate in terms of attack rates of particular symptoms, relative risk of contamination to non-swimmers, or attributable risk from exposure to coastal water contamination.

The potential for selection bias in our study exists by virtue of the self-selection process via website visitation (See Eysenbach and Wyatt, 2002). Our subject pool may be disproportionately comprised of individuals who are concerned about water pollution. In the event that we have inadvertently oversampled individuals who hold such views (Eysenbach and Wyatt, 2002), then the possibility of overestimation of the total number of and severity of illnesses exists. We assert a priori that any directional bias in reporting by frequent web visitors and/or organization members is almost certainly offset by the true number of RWI’s in marine waters that go undocumented and unreported. For example, those who suffer from milder cases of illness are particularly less likely to be detected through routine surveillance practices (Mead et al., 2000). Also, beachgoers in Southern California may not be concerned with the real swimming-related health risks attributable to coastal water contamination (Turbow et al., 2004). Many members of the beach-going public may also simply be unaware that they can log onto a website to document their ailments. Further assessment of the level of public awareness of RWI complaint hotlines and websites is needed.

Our survey instrument used to measure exposure among marine bathers did not separate surfing from swimming activities. Surfers may have heightened levels of exposure compared to swimmers by virtue of greater frequency and duration of water contact. Further examination is needed to discriminate the risk of RWI associated with single-exposure and repeated exposure events. Frequent water use may increase the level of exposure on a per-event basis but also confer resistance (Schijven and de Roda Husman, 2006). We did not attempt to assess whether or not the illness complaints for this study were single-exposure events. As a group of participants in marine water contact recreation, surfers tend to be young healthy adults without suppressed immune systems (Gammie et al., 2002). In the event that our sample was comprised of a disproportionately large fraction of surfers who had high levels of exposure compared to swimmers, then the possibility exists that we may have oversampled a less vulnerable subgroup for our study.

Illness data gathered for this investigation should be considered “complaints”, and not “cases” (see Wethington and Bartlett, 2006). We report here on the voluntary efforts of a non-profit organization to monitor illness. Health agencies are responsible for protecting the public from harmful contamination. An area for future research is to examine the extent to which information about the frequency and severity of symptoms revealed through web-based survey methods is coincident with data collected through site-specific, epidemiologic methods with third party illness verification.

These findings confirm a growing body of research to suggest citizens will volunteer health information over the internet. Web-based surveys can provide an alternative or a supplement to epidemiologic investigations of surfers. In spite of the limitations discussed above, we clearly demonstrated the positive value for an improved illness surveillance system.

The results of this investigation support existing evidence on the link between coastal water impairment and adverse health outcomes in marine bathers. Our findings are also consistent with previous studies on the estimated temporal and spatial distribution of illnesses. There is a fundamental need for systematic, disease surveillance of marine bathers. Health officials can save time and resources by shifting from mail, facsimile, and telephone-based systems of disease reporting towards web-based technologies for
gathering health data. The illness-reporting process should be facilitated and streamlined as a matter of public policy.

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Disclaimer

For this research, we analyzed an existing data set provided by Surfrider Foundation without identifiers. We certify that we were not engaged in any direct contact with human subjects. University of California Irvine’s IRB board classified this study as non-human subjects research. Data was accessed with written permission of Rick Wilson, P.E. of Surfrider Foundation.

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