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A cross-sectional study on the prevalence of illness in coastal bathers compared to non-bathers in England and Wales: findings from the Beach User Health Survey

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Highlights

- Bathing water quality in the UK has improved over the last few decades
- A cross-sectional study of self-reported illness in bathers and non-bathers was done
- Bathers reported a higher frequency of illness compared to non-bathers
- The reported risks of illness were similar to those measured in the 1990s

Abstract

The risks of illness associated with bathing in UK coastal waters have not been quantified since the early 1990s. Efforts have been made since then to improve the quality of bathing waters. The aim of this study was to quantify the prevalence of symptoms of illness associated with sea bathing in bathers in England and Wales. A cross-sectional study was conducted between June 2014 and April 2015. An online survey collected information from sea bathers and non-bathers on their visits to beaches in England and Wales along with the occurrence of symptoms of illness. 2631 people (1693 bathers, 938 non-bathers) responded to the survey. Compared to non-bathers, bathers were more likely to report skin ailments (adjusted prevalence odds ratio (AOR) = 2.64, 95% confidence interval (CI) 1.23 to 5.65, p=0.01), ear ailments (AOR = 3.77, 95% CI 1.84 to 7.73, p<0.001), and any symptoms of illness (AOR = 3.73, 95% CI 2.63 to 5.29, p<0.001). There was weak evidence of an increase in the odds of gastrointestinal illness (AOR = 1.59, 95% CI 0.96 to 2.65, p=0.07), respiratory ailments (AOR = 2.44, 95% CI 0.92 to 6.48, p=0.07) and eye ailments (AOR = 2.12, 95% CI 0.83 to 5.39, p=0.11). While the study design does not allow inference of causality, we do observe an association between

sea bathing in England and Wales and reported symptoms of ill health. This suggests that despite higher rates of compliance with water quality criteria among bathing waters nowadays, the odds of illness for bathers relative to non-bathers is similar in magnitude to estimates made in the 1990s.

1. Introduction

The introduction and survival of faecal microorganisms in seawater poses a health risk to people who use these environments for recreation. Many studies around the world, including in high-income countries, have reported an association between bathing in seawater affected by faecal pollution and an increased risk of a range of self-reported illnesses, such as gastrointestinal (GI), respiratory, skin, ear, and eye ailments (Leonard et al. 2018a, Wade et al. 2003). In 2003, Shuval *et al*. reported that every year over 120 million cases of GI illnesses are caused by swimming and bathing in polluted coastal waters worldwide (Shuval 2003). Since the introduction of the European Bathing Water Directive (76/160/EEC) in the 1970s, designated bathing waters have been monitored during the bathing season for levels of faecal indicator bacteria (FIB) in order to “preserve, protect and improve the quality of the environment and to protect human health” (European Parliament Council of the European Union 2006). The levels of faecal indicator bacteria present in bathing waters in England and Wales has decreased over the past 29 years (Supplementary Material Figure S1), and the proportion of designated bathing waters in the UK compliant with the European Bathing Water Directive has increased over the past 20 years from 77.1% in 1990 to 98.7% in 2014 (European Environment Agency 2008, 2014). In 2012 the UK started to transition to the revised Bathing Water Directive (2006/7/EC), which requires lower levels of the FIB, *Escherichia coli* and intestinal enterococci, to be reported at designated beaches in order for sites to be classified as compliant with the mandatory standard (European Parliament Council of the European Union 2006). In 2015, when the first classifications under the revised Bathing Water Directive were complete, 94.5% of bathing waters in the UK were compliant with these stricter standards

(European Environment Agency 2016). Improvements in water quality have been attributed to significant investment by the government and the water industry to upgrade facilities responsible for wastewater collection, treatment and disposal (Blackburn et al. 2017). However, waterways in the UK are still affected by treated and untreated faecal material introducing pathogenic microorganisms of human and animal origin, especially during wet weather (Arnold et al. 2017, Blackburn et al. 2017, Hall et al. 2012). Previous research has shown that wastewater treatment plant effluent is associated with increased prevalence of human pathogens and antibiotic resistant bacteria to river catchments which ultimately discharge to coastal waters (Amos et al. 2014). Bathers are therefore at risk of exposure to a variety of microorganisms, including those which are pathogenic or resistant to antimicrobials (Leonard et al. 2018b).

Academics, public health professionals, politicians and special interest groups debate the effectiveness of the current monitoring methods used to assess bathing water quality and safety (European Parliament Council of the European Union 2006). A concern being that FIB densities vary substantially throughout the course of the day and week, and vary along the length of a beach (Enns et al. 2012) and do not reflect risk of symptoms caused by other pathogenic microorganism, like viruses. Therefore, existing sampling efforts, which take place at a single site on each designated beach approximately once a week during the bathing season, may fail to capture spikes in FIB levels caused by sporadic pollution events, such as combined sewer overflows. Furthermore, people go in the sea outside the bathing season, and bathe at unmonitored beaches (Mills and Cummins 2013). Therefore, monitoring during the bathing season and at designated beaches for FIB may not reflect the public's true exposure to contaminants present in coastal waters.

Assessing the health risks to bathers of exposure to coastal waters can be achieved through conducting epidemiological surveys. However, there have been no large scale epidemiological studies of bathers in the UK since the 1990s when Kay and colleagues conducted a randomised controlled trial of 1216 adults which showed increased risk of illness among bathers compared to non-bathers (Fleisher et al. 1996, Kay et al. 1994). Therefore, the primary aim of the current study was to assess whether there is an association between water use and experiencing a variety of symptoms commonly associated with bathing. A secondary aim of this survey was to investigate whether there is an association between visiting beaches, as an indication of exposure to aerosolised seawater, and reporting symptoms of respiratory illness. To the best of our knowledge, the association between inhalation of aerosolised seawater by beach visitors and the risk of experiencing symptoms of respiratory infections has not been investigated using an online survey before.

2. Materials and methods

Between June 2014 and April 2015 a cross-sectional survey was conducted using a web-based questionnaire, called the Beach User Health Survey, hosted by Jisc Online Surveys (https://www.onlinesurveys.ac.uk, formerly Bristol Online Surveys). After giving informed consent, adults living in England and Wales completed the survey, which asked participants to retrospectively report their exposure to coastal waters in England and Wales in the previous two weeks, as well as the occurrence of symptoms of illness during the first and second week of recall. A copy of the survey is available in the supplementary materials.

2.1 Participant recruitment

It was calculated that 957 bathers and 957 non-bathers would need to be recruited to the study to detect a difference of five percentage points (15% versus 10%, respectively) in the percentage reporting illness with 90% power at the 5% (2-tailed) level of significance. The background rate of 10% of gastrointestinal (GI) illness among non-bathers was obtained from Kay and colleagues (1994) over a three-week period. These parameters were chosen in order to detect the same difference as reported by the last study to quantify bather illness in the UK.

Participant recruitment was facilitated by Surfers Against Sewage (SAS), a marine conservation charity based in the southwest of England, with members from across the UK. The Beach User Health Survey was advertised to SAS members (more than 40 000 individuals) via email as well as being shared on social media (Facebook and Twitter). The survey was made available on four separate occasions throughout a one-year period. It was available twice during the bathing season (between 2 June 2014 and 15 June 2014, and again between 19 August 2014 and 1 September 2014), and twice outside the bathing season (between 10 November 2014 and 23 November 2014, and again between 13 April 2015 and 26 April 2015). Each time the survey was available for two weeks for people to participate, and was available to all eligible people, whether or not they had taken part in previous waves of data collection.

People were eligible to take part in this study if they were adults (aged 18 and above) who lived in England and Wales. People were excluded from the survey if they reported going into the sea anywhere other than in England or Wales in the previous two weeks.

2.2 Exposure definitions

Responses to questions about recent visits to the beach were used to assign respondents to the following exposure categories:

Bathers: people who reported any contact with the sea in the past two weeks, regardless of whether or not they reported visiting a beach;

Non-bathers: *Beach-going non-bathers* (people who reported visiting the beach in the past two weeks but did not report going into the sea in this time) and *non-beachgoers* (people who reported not going to the beach nor going into the sea in the previous two weeks).

2.3 Health outcomes

Six health outcomes were investigated: cases of gastrointestinal illness, acute febrile respiratory infection (AFRI), skin ailments, ear ailments, eye ailments, and any illness. The case definitions for the first five of these were the same as those reported by Kay *et al*. (1994) and Fleisher *et al*. (1996) (Figure 1). In addition, a composite measure of illness, any illness, was included. This was defined as reporting one or more symptoms of illness.

Participants were asked to report symptoms of illness they experienced in the previous two weeks and symptom data were recorded separately for the first week of recall and the second week of recall. Cases were counted if responders reported a symptom in the second week which they had not reported during the first week of recall (i.e. new symptoms).

Gastrointestinal illness:

Vomiting, or
Diarrhoea, or
Indigestion with fever, or
Nausea with fever

Acute Febrile Respiratory Infection: At least one symptom from each of the columns below:

Fever	AND	Headache, or Body aches, or Unusual fatigue, or Loss of appetite	AND	Sore throat, or Runny nose, or Cough

Skin ailment:

Skin rash or ulcer, or
Sores, or
Skin irritation, or
Itching

Ear ailment: Ear pain (with or without concurrent discharge)

Eye ailment: Sore red eyes (with or without concurrent discharge)

Any illness: One or more of the following symptoms: vomiting, diarrhoea, indigestion, nausea, fever, headache, body ache, unusual fatigue, loss of appetite, sore throat, runny nose, cough, skin rash or ulcer, sores, skin irritation, itching, ear pain (with or without concurrent discharge), or sore red eyes (with or without concurrent discharge)

Figure 1. Case definitions for the health outcomes investigated

2.4 Statistical analyses

To assess whether there is an association between bathing in the sea and experiencing symptoms of illness, respondents who reported going into the sea in the previous two weeks (bathers) were compared to people who reported not going into the sea in the same period (non-bathers). For this primary comparison, beach-going non-bathers and non-beachgoers were combined into a single non-bathing group as we were specifically interested in the effect of bathing itself and not the effect of going to the beach. The extent to which the main relationship of interest (exposure to bathing water and illness) differed across the four waves of data collection was examined using logistic regression models with tests of interaction for the effect of bathing season. Since the season during which responses were submitted had a negligible effect on the association of interest (Supplementary Materials Table S1), data were pooled across the four waves of data collection, and logistic regression was used to estimate crude prevalence odds ratios which were adjusted for confounding factors where possible. A limit was set on the number of confounders included in each model: The maximum number of confounders that could be adjusted for was 10% of the total number of cases (or non-cases, depending on which number was the smaller of the two) of each health outcome. Confounders considered for inclusion were selected from the following: time of year, pre-existing condition, diet, age, sex, level of educational attainment, regular bathing, whether members of their household were unwell with similar symptoms, animal ownership, smoker, exposure to recreational waters other than seawater, immunosuppressed, recent international travel, and risk perception. These confounders were prioritised for inclusion in order of their suspected importance (Supplementary Table S2). Since it was possible for participants to submit data in all four waves of data collection, repeat responders were identified by the email address they provided upon completion of the survey and analyses allowed for the correlation between scores that were provided by the same respondent by calculating information sandwich ("robust") estimates of standard error for the odds ratios (Hanley et al. 2003). Adjusted odds ratios (AOR) are reported along with 95% confidence intervals (CI) and p-values.

To assess whether there was an association between visiting the beach and experiencing respiratory illness, symptom data were compared between respondents who reported going to the beach but did not go in the sea (beach-going non-bathers) and those who did not report going to the beach in the previous two weeks (non-beachgoers). Again, data from all four waves were pooled in a single analysis, and logistic regression with robust standard errors was used to estimate odds ratios for cases of acute febrile respiratory illness.

This study was approved by the University of Exeter Medical School Research Ethics Committee (reference number 14/02/039).

3. Results

3.1 Recruitment

Between June 2014 and April 2015, a total of 2,644 respondents completed the Beach User Health Survey: 769 in the first wave of data collection, 492 in the second, 546 in the third, and 837 in the final wave (Figure 2). Thirteen people were excluded because the beaches they had visited were not in England or Wales, leaving 2631 responses for analysis. The characteristics of participants in each exposure group are reported in Table 1.

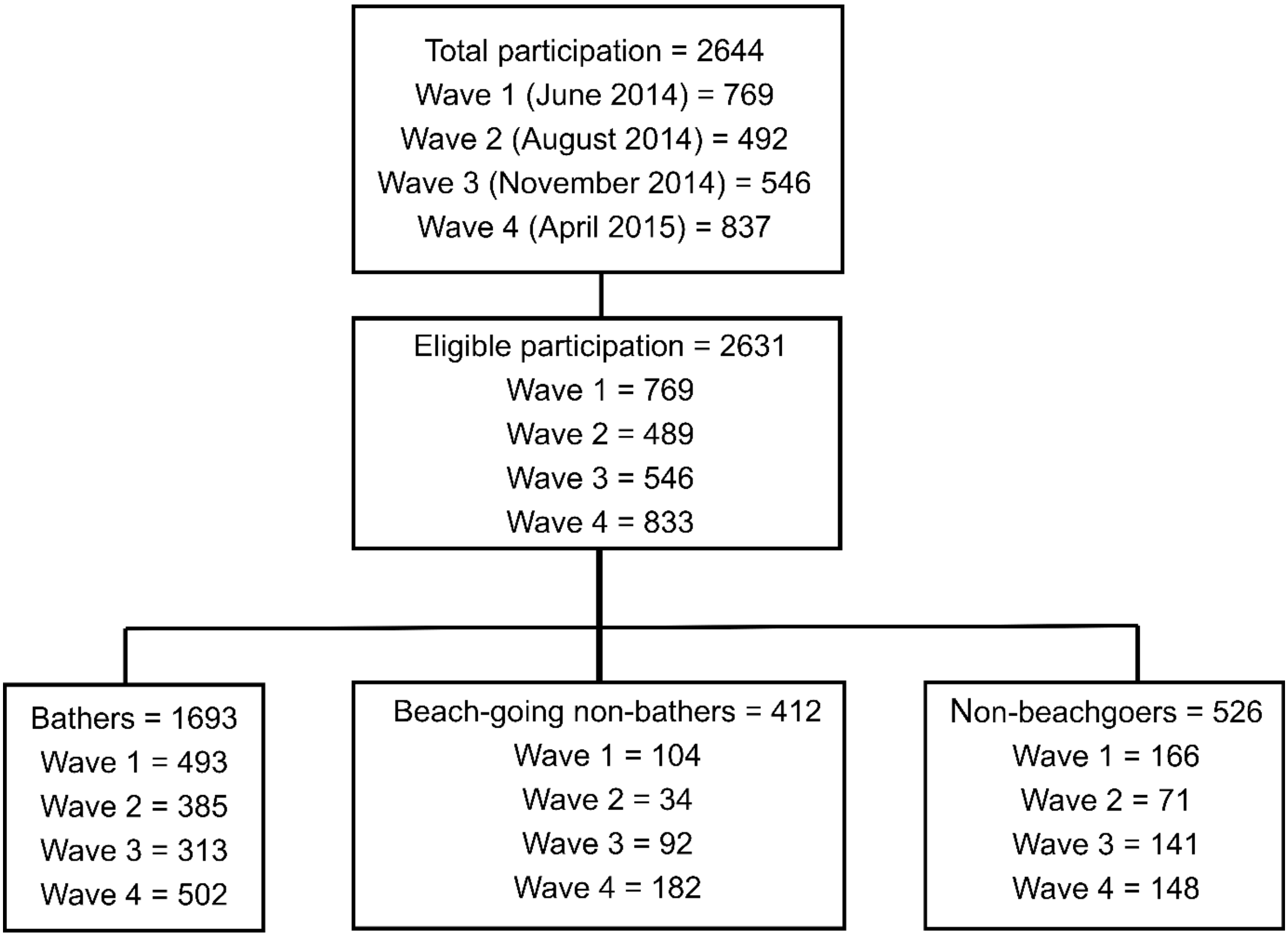

Figure 2. Participant recruitment flow diagram

Table 1. Characteristics of survey participants. * Level of educational attainment based on Office for National Statistics 2011 Census categories: Level 1: 1-4 General Certificate of Secondary Education (GCSEs) or equivalent; Level 2: 5+ GCSEs or equivalent; Level 3: 2+ A-levels or equivalent; Level 4: Bachelor’s degree or equivalent, higher qualifications. See Supplementary Materials Table S3 for how these educational attainment categories map onto the International Standard Classification of Education 2011. A repeat responder was an individual who responded to more than one wave of data collection, identified using email address submitted by participants.

Characteristics	**Bathers N=1,693**	**Beach-going non-bathers N=412**	**Non-beachgoers N=526**
Males, n (%)	979 (57.8%)	127 (30.8%)	220 (41.8%)
Age 18 – 24, n (%)	276 (16.3%)	51 (12.4%)	109 (20.7%)
25 – 34, n (%)	483 (28.5%)	123 (29.9%)	147 (27.9%)
34 – 44, n (%)	490 (28.9%)	102 (24.8%)	142 (27.0%)
45 – 54, n (%)	309 (18.3%)	72 (17.5%)	77 (14.6%)
55 – 64, n (%)	105 (6.2%)	50 (12.1%)	41 (7.8%)
65+, n (%)	30 (1.8%)	14 (3.4%)	10 (1.9%)
Level of educational attainment			
No formal qualifications, n (%)	13 (0.8%)	2 (0.5%)	4 (0.8%)
Level 1*, n (%)	34 (2.0%)	15 (3.6%)	17 (3.2%)
Level 2*, n (%)	97 (5.7%)	17 (4.1%)	23 (4.4%)
Apprenticeship, n (%)	34 (2.0%)	4 (1.0%)	7 (1.3%)
Level 3*, n (%)	343 (20.3%)	61 (14.8%)	85 (16.2%)
Level 4*, n (%)	1092 (64.5%)	284 (68.9%)	350 (66.5%)
Other, n (%)	80 (4.7%)	29 (7.0%)	40 (7.6%)
Household member ill in the past 2wks, n (%)	185 (10.9%)	30 (7.3%)	44 (8.4%)
Diet (eaten the following in the past 2wks)			
Shellfish, n (%)	553 (31.5%)	138 (33.5%)	165 (31.4%)
Mayonnaise, n (%)	975 (57.6%)	251 (61.7%)	307 (58.4%)
Takeaway food, n (%)	660 (39.0%)	155 (37.6%)	218 (41.4%)
Chicken, n (%)	1242 (75.8%)	296 (71.8%)	380 (72.2%)
Eggs, n (%)	1334 (78.8%)	336 (81.6%)	402 (76.4%)
Cold meat pies, n (%)	290 (17.1%)	59 (14.3%)	89 (16.9%)
Salad, n (%)	1405 (83.0%)	359 (87.1%)	417 (79.3%)
Barbequed food, n (%)	468 (27.6%)	85 (20.6%)	102 (19.4%)
Any of the above, n (%)	1627 (96.1%)	398 (96.6%)	489 (93.0%)
Pre-existing medical conditions			
Digestive, n (%)	196 (11.6%)	53 (12.9%)	65 (12.4%)
Respiratory, n (%)	189 (11.0%)	42 (10.2%)	58 (11.0%)
Skin, n (%)	221 (13.1%)	50 (12.1%)	76 (14.4%)
Allergies, n (%)	329 (19.4%)	88 (21.4%)	108 (20.5%)
Other, n (%)	138 (8.2%)	33 (8.0%)	49 (9.3%)
Any of the above, n (%)	711 (42.0%)	181 (43.9%)	240 (45.6%)
Immunosuppressed, n (%)	39 (2.3%)	15 (3.6%)	20 (3.8%)
Smoke, n (%)	210 (12.4%)	40 (9.7%)	68 (12.9%)
International travel in the past 2wks, n (%)	123 (7.3%)	21 (5.1%)	76 (14.4%)
Bathing other than in sea in past 2wks, n (%)	617 (36.4%)	142 (34.5%)	192 (36.5%)
Animal ownership, n (%)	934 (55.2%)	253 (61.4%)	250 (47.7%)
Risk perception, n (%)			
Oil spills, n (%)	634 (37.4%)	142 (34.5%)	192 (36.5%)
Objects floating in the water, n (%)	992 (58.6%)	248 (60.2%)	349 (66.3%)
Chemical pollution, n (%)	1025 (60.5%)	231 (56.1%)	325 (61.8%)
Sewage pollution, n (%)	1485 (87.7%)	354 (85.9%)	467 (88.8%)
Rip currents, n (%)	790 (46.7%)	241 (58.5%)	328 (62.4%)
Algal blooms, n (%)	334 (19.8%)	87 (21.1%)	129 (24.5%)
Weaver fish, n (%)	613 (36.2%)	180 (43.7%)	200 (38.0%)
Worried about any of these, n (%)	1605 (94.8%)	385 (93.4%)	250 (47.5%)

3.2 Illness in bathers compared to non-bathers

Compared to non-bathers, a greater proportion of bathers reported new symptoms of illness for all investigated health outcomes (Table 2). After adjusting for confounders, bathers were more likely to report skin ailments (AOR=2.64, 95% CI 1.23 to 5.65, p=0.01), ear ailments (AOR=3.77, 95% CI 1.84 to 7.73, $p<0.001$), and any symptoms of illness (AOR=3.73, 95% CI 2.63 to 5.29, $p<0.001$), compared to non-bathers. There was only weak evidence of an increase in gastrointestinal illnesses (AOR=1.59, 95% CI 0.96 to 2.65, p= 0.07), or of acute febrile respiratory infection (AFRI) (AOR=2.44, 95% CI 0.92 to 6.48, p= 0.07), and little evidence of an increase in eye complaints (AOR=2.12, 95% CI 0.83 to 5.39, p=0.11).

Health outcome	Bathers (N=1693)	Non-bathers (N=938)	Crude risk ratio	Crude prevalence odds ratio	Adjusted prevalence odds ratio (95% CI) p-value
Gastrointestinal illness [a] n (%)	80 (5.1%)	25 (2.8%)	1.84	1.89	1.59 (0.96, 2.65) p=0.07
Acute febrile respiratory infection [b] n (%)	21 (1.3%)	5 (0.5%)	2.32	2.34	2.44 (0.92, 6.48) p=0.07
Skin ailments [c] n (%)	36 (2.3%)	9 (1.0%)	2.30	2.33	2.64 (1.23, 5.65) p=0.01
Ear ailments [d] n (%)	58 (3.7%)	9 (1.0%)	3.80	3.91	3.77 (1.84, 7.73) p<0.001
Eye ailments [e] n (%)	32 (2.0%)	6 (0.6%)	3.08	3.12	2.12 (0.83, 5.39) p=0.11
Any symptoms of illness [f] n (%)	258 (24.0%)	54 (7.2%)	3.33	4.07	3.73 (2.63, 5.29) p<0.001

Table 2 Number (%) of cases of health outcomes reported among bathers during the last seven days of recall compared to participants who reported not going into the sea (non-bathers). Confounders adjusted for in final models: [a] time of year, diet, pre-existing conditions affecting digestive health, similar illness in household, regular bather, any contact with recreational waters in the past two weeks that were not the sea; [b] time of year, pre-existing conditions affecting respiratory health; [c] time of year, pre-existing conditions affecting skin, immunosuppressed, sex; [d] time of year, regular bather, sex, immunosuppressed, age, level of educational attainment; [e] time of year, pre-existing conditions affecting eye health, regular bather, age, level of educational attainment; [f] time of year, any pre-existing conditions, regular bather, diet, age, level of educational attainment, similar illness in household, sex, risk perception, immunosuppressed, any contact with recreational waters in the past two weeks that were not the sea, pet ownership, smoker, recent overseas travel

3.3 Respiratory illness in beach-going non-bathers compared to non-beachgoers

The reporting of acute febrile respiratory infection (AFRI) was rare for both beach-going non-bathers and non-beachgoers, and therefore the sample size was too small to adjust the odds ratio for confounders. Three out of 405 (0.7%) beach-going non-bathers reported symptoms that indicated a case of AFRI compared to two out of 521 (0.4%) of non-beachgoers. Therefore there is no evidence of an association between visiting a beach and reporting acute febrile respiratory infection: AOR = 1.94 (95% CI 0.32, 11.7), p=0.47.

4. Discussion

This is the first study conducted in England and Wales to quantify the prevalence of experiencing symptoms of ill health in bathers and non-bathers following the transition to the revised Bathing Water Directive (2006/7/EC) in 2012, and since the last study which was conducted in the 1990s. The primary objective of the Beach User Health Survey was to assess whether bathers are more likely to report symptoms of infection than non-bathers. The results suggested that among people who reported having been in the sea in the previous two weeks (bathers), a higher proportion reported symptoms of illness in the second week period, compared to people who reported not going into the sea (non-bathers). There was strong evidence of an association between sea bathing and reporting of skin ailments, ear ailments, and any symptoms of illness. While a higher proportion of bathers reported cases of gastrointestinal (GI) illness, acute febrile respiratory infection (AFRI) and eye ailments compared to non-bathers, there was only weak evidence of an association between sea bathing and these health outcomes.

The odds ratios reported here are higher than those reported in a recent meta-analysis on the risks of gastrointestinal illness, ear ailments and any illness following sea bathing in other high-income countries (Leonard et al. 2018a). While at the higher end of the systematic review estimates, these results are still within limits expected from data gathered from other high-income countries. The odds ratios reported in this study are similar in magnitude to those reported by Kay et al. (1994) and Fleisher et al. (1996) from the randomised controlled trial conducted between 1989 and 1992 (Figure 3), which collected incident cases of these health outcomes occurring over a three week period. Previous studies have reported an increase in the risk of GI illness associated with sea bathing (Kay et al. 1994, Leonard et al.

2018a), yet here there was only weak evidence of an association between bathing and GI illness. This was also the case for eye ailments.

The sample size calculation was based on data from Kay et al. 1994, which reported that 14.8% of bathers and 9.7% of non-bathers experienced incident cases of GI illness. However, the data collected in our 2014-2015 survey suggests that the rates of GI illness in bathing and non-bathing participants of the study population have decreased to 5.1% and 2.8% respectively. In addition, the risk differences in the present study are smaller compared to this earlier study. Therefore, if the relationship is causal in nature, the numbers needed to harm are greater than before, with 43 bathing water exposures resulting in 1 case of gastrointestinal illness in 2014 to 2015 compared to 20 exposures from 1989 to 1992 (Supplementary Materials Tables S4). These differences could be explained by differences in study design, participant recruitment, and length of follow-up.

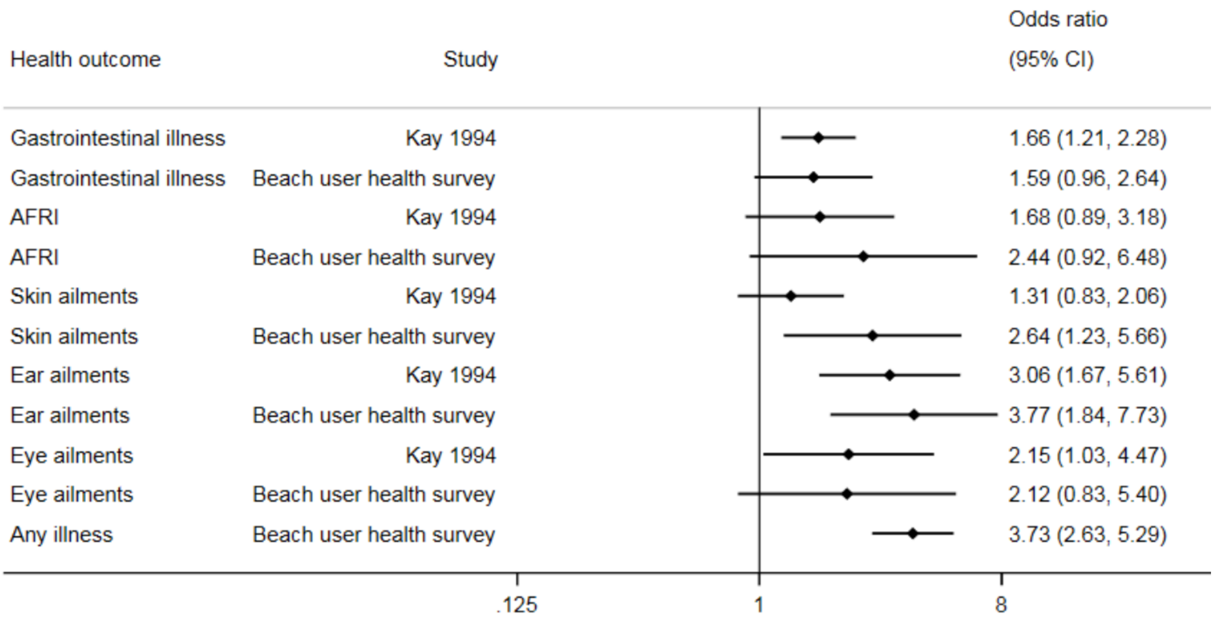

Figure 3. Forest plot displaying the odds of experiencing illness in bathers compared to non-bathers in the Beach User Health Survey (2014-2015) and the trial conducted between 1989 and 1992 (data extracted from Kay et al. 1994 and Fleisher et al. 1996). AFRI: acute febrile respiratory infection.

The web-based survey format allowed the efficient collection and analysis of data from a large number of adults in England and Wales between June 2014 and April 2015, and collected useful information on the bathing habits and symptoms experienced by members of the public visiting coastal waters in England and Wales. Despite more than 99% of coastal bathing waters in England and Wales meeting the minimum standard of the European Bathing Water Directive in 2014 and more than 80% meeting the guideline standard (Department for Environment Food & Rural Affairs 2014), bathers were still reporting greater numbers of new cases of several categories of illness compared to non-bathing participants. Other studies have reported similar increases in risk of illness among bathers exposed to bathing waters that have been classified as being of excellent quality (Papastergiou et al. 2012). One possible explanation for these observations could be that faecal indicator bacteria are not optimal indicators for the agents present in coastal bathing waters responsible for illnesses among bathers (Benjamin-Chung et al. 2017, Papastergiou et al. 2012). It has been suggested that the majority of bather illnesses are caused by viral pathogens, such as enterovirus and adenovirus (Fleisher et al. 1996, Maunula 2007). Other agents present in coastal waters that may be responsible for bather illness are non-faecal microorganisms, like *Staphylococcus aureus* (Charoenca and Fujioka 1995), *Pseudomonas aeruginosa* (Wade et al. 2013), and non-microbiological agents in the water introduced by pollution. Even seawater itself may play a role in the occurrence of ear ailments by increasing the pH and reducing the amount of wax in the ear canal, thus making the ear more prone to infection due to over growth of bacteria in the outer ear (Wade et al. 2013). The levels of some of these are not routinely monitored in bathing waters, are not targeted for reduction during wastewater treatment, and may not correlate well with faecal indicator bacteria densities (Benjamin-Chung et al. 2017, Wade et al. 2018, Wu et al. 2011). However, it is not possible to identify the agents responsible for the symptoms reported in the survey by collecting participants' self-reported symptoms alone. Further research needs to be done on bathing communities to elucidate the aetiology of these bathing-associated health complaints. Another explanation for higher prevalence of bather illness despite high compliance with water quality standards could be that nearly half of responses from bathers were submitted outside the bathing season, when water quality is not monitored at beaches. However, there were no differences in the odds of reporting symptoms of illness outside the bathing season compared to during the bathing season (Supplementary Material Table S5). Nearly a quarter (24.6%) of recruited bathers reported visiting undesignated beaches (sites that have not been selected for water quality monitoring) and these bathers might be exposed to higher levels of pollution compared to bathers visiting designated beaches (Blackburn et al. 2017, Department for Business Engergy & Industrial Strategy 2018).

A second objective of this study was to compare the prevalence of reporting acute febrile respiratory infection (AFRI) between beach-going non-bathers and non-beachgoers because inhalation of pathogens in aerosolised seawater during beach visits could cause symptoms of respiratory illness in beach goers. There was little evidence that the prevalence of AFRI was higher among beach-going non-bathers than people who did not go to the beach. There was also little evidence of difference in AFRI between bathers and non-bathers, which is consistent with results reported in several recent studies conducted in other high-income countries (Arnold et al. 2017, Arnold et al. 2013, Colford et al. 2012, Fleisher et al. 2010, Papastergiou et al. 2012). This may be due to the case definition for AFRI being very specific: at least three different symptoms must be reported simultaneously in order to be considered a case. One of these symptoms must be fever, which people are especially unreliable at self-diagnosing (Nguyen et al. 2010) and the sample size was insufficient to detect a small increase in a rare condition. It is also possible that participants visiting coastal areas that are not beaches were exposed to aerosolised seawater, but were classed as unexposed in the analysis (misclassification bias). The results suggest that visiting a beach carries with it no increase in the likelihood of experiencing symptoms of respiratory illness. Additionally, visiting a beach was not associated with increased prevalence of any of the other health outcomes investigated (Table S6).

Web-based surveys have been successfully utilised to collect information in a cost-effective way from sea bathers for epidemiological surveys (Arnold et al. 2017, Harding et al. 2015, O'Halloran et al. 2017), but the information provided by participants is self-reported and is therefore susceptible to self-selection, recall and self-report biases. The effects of these biases in the present study have been reduced by asking respondents about their exposures and health in the recent past, and by controlling for potential confounders (for example age, sex, and risk perception) in the analyses where the sample size permitted this (Fleisher and Kay 2006). However, all sources of bias cannot be eliminated. Due to the cross-sectional design of the study, it was not possible to determine whether exposure preceded the occurrence of new symptoms of illness, and therefore the causal nature of the association with bathing water cannot be determined. Recruitment was primarily through Surfers Against Sewage (SAS), which is an environmental charity whose remit is to improve the quality of marine environments. People self-selecting for this study were likely to be either more aware about the potential health risks of swimming in water polluted by sewage, or to be more motivated to participate and to over-report symptoms of ill health to provide evidence that pollution of seawater is still an issue. By analysing only symptoms of illness that occurred in the last seven days of recall and not in the first week of recall, respondents would have to over-report only in the second week of recall for this to have an impact on the results. Analysis of the prevalence of health outcomes reported over both weeks of recall is provided in the Supplementary Materials (Table S7). By using a web-based survey and recruiting participants via social media, the survey had the potential to be shared and circulated more widely outside the SAS membership base. Despite this, the sample here is not likely to be representative of the general population, limiting the generalisability of these findings. For example, data were only submitted by adults, since children were not eligible to take part in the study. Children tend to swallow more water compared to adults (Dufour et al. 2017) and have less developed immune systems, contributing to higher risk of illness in this population (Arnold et al. 2016). Therefore the results reported here may underestimate the size of the association between sea water exposure and the reporting of illness for a significant portion of the bathing community.

5. Conclusions

This is the first large-scale study conducted in England and Wales to investigate the prevalence of illness associated with sea bathing since the 1990s. While causality cannot be inferred, the results of this study indicate that bathers experience a variety of non-enteric symptoms of illness, particularly skin ailments, ear ailments, and any symptoms of illness at a greater level than non-bathers. An increased proportion of bathers reported symptoms of gastrointestinal illness but this was not statistically significant. Limited data exist on the current likelihood of bathers in England and Wales experiencing non-enteric symptoms of illness. This study provides useful, up-to-date information for public health practitioners and policy makers to bear in mind alongside other evidence, when considering bathing waters in England and Wales for recreational use.

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References

Amos, G.C., Hawkey, P.M., Gaze, W.H. and Wellington, E.M. (2014) Wastewater effluent contributes to the dissemination of CTX-M-15 in the natural environment. J Antimicrob Chemother 69(7), 1785-1791.

Arnold, B.F., Schiff, K.C., Ercumen, A., Benjamin-Chung, J., Steele, J.A., Griffith, J.F., Steinberg, S.J., Smith, P., McGee, C.D., Wilson, R., Nelsen, C., Weisberg, S.B. and Colford, J.M., Jr. (2017) Acute Illness Among Surfers After Exposure to Seawater in Dry- and Wet-Weather Conditions. Am J Epidemiol 186(7), 866-875.

Arnold, B.F., Schiff, K.C., Griffith, J.F., Gruber, J.S., Yau, V., Wright, C.C., Wade, T.J., Burns, S., Hayes, J.M., McGee, C., Gold, M., Cao, Y., Weisberg, S.B. and Colford, J.M., Jr. (2013) Swimmer illness associated with marine water exposure and water quality indicators: impact of widely used assumptions. Epidemiology 24(6), 845-853.

Arnold, B.F., Wade, T.J., Benjamin-Chung, J., Schiff, K.C., Griffith, J.F., Dufour, A.P., Weisberg, S.B. and Colford, J.M., Jr. (2016) Acute Gastroenteritis and Recreational Water: Highest Burden Among Young US Children. Am J Public Health 106(9), 1690-1697.

Benjamin-Chung, J., Arnold, B.F., Wade, T.J., Schiff, K., Griffith, J.F., Dufour, A.P., Weisberg, S.B. and Colford, J.M., Jr. (2017) Coliphages and Gastrointestinal Illness in Recreational Waters: Pooled Analysis of Six Coastal Beach Cohorts. Epidemiology 28(5), 644-652.

Blackburn, H., O'Neill, R., Rangeley-Wilson, C., Moncrieff, C. and Tompkins, J. (2017) Flushed away: How sewage is still polluting the rivers of England and Wales, World Wildlife Fund.

Charoenca, N. and Fujioka, R.S. (1995) Association of staphylococcal skin infections and swimming. Water Science and Technology 31(5-6), 11-17.

Colford, J.M., Schiff, K.C., Griffith, J.F., Yau, V., Arnold, B.F., Wright, C.C., Gruber, J.S., Wade, T.J., Burns, S., Hayes, J., McGee, C., Gold, M., Cao, Y., Noble, R.T., Haugland, R. and Weisberg, S.B. (2012) Using rapid indicators for Enterococcus to assess the risk of illness after exposure to urban runoff contaminated marine water. Water Research 46(7), 2176-2186.

Department for Business Engergy & Industrial Strategy (2018) Average monthly rainfall and deviations from the long term mean.

Department for Environment Food & Rural Affairs (2014) 2014 mandatory compliance results for bathing waters in the UK.

Dufour, A.P., Behymer, T.D., Cantu, R., Magnuson, M. and Wymer, L.J. (2017) Ingestion of swimming pool water by recreational swimmers. J Water Health 15(3), 429-437.

Enns, A.A., Vogel, L.J., Abdelzaher, A.M., Solo-Gabriele, H.M., Plano, L.R., Gidley, M.L., Phillips, M.C., Klaus, J.S., Piggot, A.M., Feng, Z., Reniers, A.J., Haus, B.K., Elmir, S.M., Zhang, Y., Jimenez, N.H., Abdel-Mottaleb, N., Schoor, M.E., Brown, A., Khan, S.Q., Dameron, A.S., Salazar, N.C. and Fleming, L.E. (2012) Spatial and temporal variation in indicator microbe sampling is influential in beach management decisions. Water Res 46(7), 2237-2246.

European Environment Agency (2008) Bathing water results 2008 - United Kingdom.

European Environment Agency (2014) BWD Report for the Bathing Season 2014: The United Kingdom.

European Environment Agency (2016) UK bathing water quality in 2015.

European Parliament Council of the European Union (2006) Directive 2006/7/EC of the European Parliament and of the Council of 15 February 2006 concerning the management of bathing water quality and repealing Directive 76/160/EEC. Union, E.P.a.t.C.o.t.E. (ed).

Fleisher, J.M., Fleming, L.E., Solo-Gabriele, H.M., Kish, J.K., Sinigalliano, C.D., Plano, L., Elmir, S.M., Wang, J.D., Withum, K., Shibata, T., Gidley, M.L., Abdelzaher, A., He, G., Ortega, C., Zhu, X., Wright, M., Hollenbeck, J. and Backer, L.C. (2010) The BEACHES study: Health effects and exposures from non-point source microbial contaminants in subtropical recreational marine waters. International Journal of Epidemiology 39(5), 1291-1298.

Fleisher, J.M. and Kay, D. (2006) Risk perception bias, self-reporting of illness, and the validity of reported results in an epidemiologic study of recreational water associated illnesses. Marine Pollution Bulletin 52(3), 264-268.

Fleisher, J.M., Kay, D., Salmon, R.L., Jones, F., Wyer, M.D. and Godfree, A.F. (1996) Marine waters contaminated with domestic sewage: Nonenteric illnesses associated with bather exposure in the United Kingdom. American Journal of Public Health 86(9), 1228-1234.

Hall, V., Taye, A., Crook, P., Maguire, H., Anderson, C., Wright, A., Dave, J. and Walsh, B. (2012) Epidemiological investigation of an outbreak of gastrointestinal illness following a mass-participation swim in the River Thames, Public Health England, London.

Hanley, J.A., Negassa, A., Edwardes, M.D. and Forrester, J.E. (2003) Statistical analysis of correlated data using generalized estimating equations: an orientation. Am J Epidemiol 157(4), 364-375.

Harding, A.K., Stone, D.L., Cardenas, A. and Lesser, V. (2015) Risk behaviors and self-reported illnesses among Pacific Northwest surfers. Journal of Water & Health 13(1).

Kay, D., Fleisher, J.M., Salmon, R.L., Jones, F., Wyer, M.D., Godfree, A.F., Zelenauch-Jacquotte, Z. and Shore, R. (1994) Predicting likelihood of gastroenteritis from sea bathing: Results from randomised exposure. Lancet (North American Edition) 344(8927), 905-909.

Leonard, A.F.C., Singer, A., Ukoumunne, O.C., Gaze, W.H. and Garside, R. (2018a) Is it safe to go back into the water? A systematic review and meta-analysis of the risk of acquiring infections from recreational exposure to seawater. Int J Epidemiol 47(2), 572-586.

Leonard, A.F.C., Zhang, L., Balfour, A.J., Garside, R., Hawkey, P.M., Murray, A.K., Ukoumunne, O.C. and Gaze, W.H. (2018b) Exposure to and colonisation by antibiotic-resistant E. coli in UK coastal water users: Environmental surveillance, exposure assessment, and epidemiological study (Beach Bum Survey). Environ Int 114, 326-333.

Maunula, L. (2007) Waterborne norovirus outbreaks. Future Virol 2(1), 101 - 112.

Mills, B. and Cummins, A. (2013) The economic impact of domestic surfing on the United Kingdom.

Nguyen, A.V., Cohen, N.J., Lipman, H., Brown, C.M., Molinari, N.A., Jackson, W.L., Kirking, H., Szymanowski, P., Wilson, T.W., Salhi, B.A., Roberts, R.R., Stryker, D.W. and Fishbein, D.B. (2010) Comparison of 3 infrared thermal detection systems and self-report for mass fever screening. Emerg Infect Dis 16(11), 1710-1717.

O'Brien, S.J. (2013) The "decline and fall" of nontyphoidal salmonella in the United kingdom. Clin Infect Dis 56(5), 705-710.

O'Halloran, C., Silver, M.W., Lahiff, M. and Colford, J., Jr. (2017) Respiratory Problems Associated with Surfing in Coastal Waters. EcoHealth 14(1), 40-47.

Papastergiou, P., Mouchtouri, V., Pinaka, O., Katsiaflaka, A., Rachiotis, G. and Hadjichristodoulou, C. (2012) Elevated bathing-associated disease risks despite certified water quality: A cohort study. International Journal of Environmental Research and Public Health 9(5), 1548-1565.

Shuval, H. (2003) Estimating the global burden of thalassogenic diseases: human infectious diseases caused by wastewater pollution of the marine environment. Journal of Water & Health 1(2), 53-64.

Tam, C.C., Rodrigues, L.C., Viviani, L., Dodds, J.P., Evans, M.R., Hunter, P.R., Gray, J.J., Letley, L.H., Rait, G., Tompkins, D.S., O'Brien, S.J. and Committee, I.I.D.S.E. (2012) Longitudinal study of infectious intestinal disease in the UK (IID2 study): incidence in the community and presenting to general practice. Gut 61(1), 69-77.

Wade, T.J., Augustine, S.A.J., Griffin, S.M., Sams, E.A., Oshima, K.H., Egorov, A.I., Simmons, K.J., Eason, T.N. and Dufour, A.P. (2018) Asymptomatic norovirus infection associated with swimming at a tropical beach: A prospective cohort study. PLoS ONE 13(3), e0195056.

Wade, T.J., Pai, N., Eisenberg, J.N.S. and Colford Jr, J.M. (2003) Do U.S. Environmental Protection Agency water quality guidelines for recreational waters prevent gastrointestinal illness? A systematic review and meta-analysis. Environmental Health Perspectives 111(8), 1102-1109.

Wade, T.J., Sams, E.A., Beach, M.J., Collier, S.A. and Dufour, A.P. (2013) The incidence and health burden of earaches attributable to recreational swimming in natural waters: a prospective cohort study. Environ Health 12, 67.

Wu, J., Long, S.C., Das, D. and Dorner, S.M. (2011) Are microbial indicators and pathogens correlated? A statistical analysis of 40 years of research. Journal of Water & Health 9(2), 265-278.

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