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Journal of Water & Health

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Journal of Water and Health Vol 00 No 0, 1 doi: 10.2166/wh.2022.232

A cross-sectional study on infectious health risks regarding freshwater sports practice in Brittany, France

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ABSTRACT

Freshwater sports expose practitioners to pathogens in the water environment and may result in infection. In French Brittany, these infections are particularly worrying, especially since 2016 with an increase in the incidence of leptospirosis reaching 1 case per 100,000 inhabitants, which represents the highest incidence observed since 1920. We aimed to estimate the prevalence of infectious diseases related to freshwater sports practice and to identify the factors associated with these infections among freshwater sports licensees in Brittany, France. From March 18, 2019, to May 8, 2019, we interviewed freshwater sports licensees (online study) and club presidents and instructors (phone study) in Brittany. Licensee participants were 18 years old or more and practiced at least one freshwater sport in one of the 79 Brittany clubs. We used logistic regression models to study the association between our variables of interest and potential risk factors. In total, 551 licensees (20.3% of the total number of licensees) and 38 clubs (48.1%) were surveyed. Among the licensees, 29 (5.3%) reported being diagnosed with leptospirosis, of which 12 (41.3%) occurred in the last 5 years. The most reported symptoms were skin irritation/itchy skin (24.3%) and 39 individuals (7.1%) reported at least one hospitalization in their lifetime for a disease related to freshwater sports. The occurrence of leptospirosis was negatively associated with boarding from a pontoon (odds ratio (OR)=0.20, 95% confidence interval (95% CI) 0.06–0.56), practicing for less than 4 years (OR=0.17, 95% CI 0.04–0.56) compared to more than 10 years, and the occurrence of leptospirosis was positively associated with taking a soapy shower after practice (OR=4.38, 95% CI 1.90–10.51). Eskimo roll was positively associated with the occurrence of otitis and conjunctivitis (OR=3.22, 95% CI 1.82–6.03), and skin irritation/itchy skin (OR=1.66, 95% CI 0.99–2.84). Otitis, conjunctivitis, and skin irritation/itchy skin are the most common reported freshwater sport-related diseases in French Brittany. Despite a good level of knowledge of prevention measures, their implementation by licensees and clubs remains low. Further studies are needed to identify practices associated with infectious risk in freshwater sports.

Key words: epidemiology, freshwater sports, leptospirosis, water-related infections

HIGHLIGHTS

- This study contributes to a better understanding of the burden of infectious diseases linked to the practice of freshwater sports.
- One of the main results is that despite a good knowledge of prevention measures, their implementation by licensees and clubs practicing

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freshwater sports remains weak.

- These observations could help to better define prevention measures to improve the health of practitioners.

LIST OF ABBREVIATIONS

AIC	Akaike information criterion
ARS	Agence Régionale de Santé
CI	Confidence interval
CK	Canoe-kayak
CNIL	Commission Nationale Informatique et Libertés
CPP	Comité de Protection des Personnes
EHESP	Ecole des Hautes Etudes en Santé Publique
FFCK	French Federation of Canoe-Kayak
IDEA	International Course in Applied Epidemiology
OR	Odds ratio
SW	Still waters
WW	White waters

INTRODUCTION

Freshwater activities, mostly represented by canoe-kayak (CK), but also dragon boat, rafting, open-water swimming, and paddle (Allag-Dhuisme *et al.* 2016), are popular in many countries in the world. Brittany, in the North-West of France, is a region where these activities are particularly developed, with 79 clubs gathering 5,359 members in 2017.

Besides traumatic injuries, the main health risks related to freshwater activities are infectious. They arise from the presence of pathogenic bacteria, viruses, yeasts, or parasites in water, mainly due to pollution (Sinclair *et al.* 2009). Most infections lead to mild manifestations (e.g., digestive disorders or skin irritations) but they may be more severe causing ear or eye infections, respiratory symptoms, acute gastroenteritis, and skin and soft tissues infections. The risk of infection depends on the level of contact between the body and water, especially when practicing freshwater sports such as kayaking, canoeing, rafting, or swimming in open water (Nardone *et al.* 2004; Estavoyer *et al.* 2013; DeFlorio-Barker *et al.* 2018; Hintaran *et al.* 2018).

The poor microbiological quality of water has been linked to waterborne diseases outbreaks (Schets *et al.* 2011). Fecal pollution, due to the proximity of bathers, water treatment plants, and livestock farming, was shown to cause acute febrile respiratory illnesses, and acute gastrointestinal and dermatologic illnesses among exposed individuals (WHO 2006; Hlavsa *et al.* 2011; Sanborn & Takaro 2013). In addition, recreational water users can be exposed to free-living microorganisms that are naturally present in water, such as cyanobacteria (WHO 2006; Fewtrell & Kay 2015), held responsible for outbreaks encompassing gastroenteritis, abdominal pain, flu-like symptoms, ear and eye irritations, and rashes (Buratti *et al.* 2017; Ullah *et al.* 2018).

Another major concern is leptospirosis, the most important zoonotic disease worldwide with one million cases and 60,000 deaths each year (Centers for Disease Control and Prevention 1997; Costa *et al.* 2015). It is caused by nine distinct species of spirochetes from the genus *Leptospira* and is mainly transmitted by urine from terrestrial mammals (Wynwood *et al.* 2014). Human infections are often asymptomatic or paucisymptomatic (Guillois *et al.* 2018), but they can lead to severe diseases with hemorrhagic and hepatic complications, especially with the icterohemorrhagic serogroup (Tubiana *et al.* 2013; Haake & Levett 2015). Identified risk factors of this infection are occupational exposure to rodents or fecal pollution (e.g., sewage workers or water treatment plant workers), but also leisure practices such as CK, for 10–24% of cases according to a study carried out in France (Estavoyer *et al.* 2013). In recent years, the number of leptospirosis cases in France has increased (Baranton & Postic 2006), with a total of 600 cases over the 2013–2016 period (Centre National de Référence de la Leptopirose 2015; Centre National de Référence de la Leptopirose 2017). Furthermore, in September 2016, a cluster of 14 leptospirosis cases was reported in Brittany among kayakers practicing in the Vilaine river (Guillois *et al.* 2018). Another important point to consider is that leptospirosis is not a notifiable disease, which means that most cases are reported voluntarily to the National Reference Center for leptospirosis inducing under-detection (Centre National de Référence de la Leptopirose 2015; Centre National de Référence de la Leptopirose 2017). Furthermore, the fact that diagnostic tests for leptospirosis have drawbacks or insufficiencies considerably limits the effectiveness of detecting this disease.

The prevention of infections related to freshwater sports practice relies on water quality control and individual preventive behaviors. In France, water testing is not systematically mandatory for areas dedicated to freshwater sports and depends on

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regional recommendations. For example, in Brittany, the Regional Health Agency (ARS – 'Agence Régionale de Santé') recommends a water testing twice a month. On the other hand, behavioral determinants such as wearing individual protective equipment (long dry suit, shoes, gloves, etc.), adopting preventive practices (e.g., protecting wounds before practicing, rinsing equipment with clean water), or even vaccination in the case of leptospirosis, were shown to be effective in preventing infections. All these measures were compiled by the ARS of Brittany in a booklet available on its website that is distributed to the clubs (Agence Régionale de Santé 2016). However, the knowledge and implementation of these measures by practitioners and clubs remain unclear.

The assessment of illnesses related to freshwater sports practice can help to put into context public health protections and improve monitoring and notification programs. Nevertheless, literature describing illnesses related to freshwater sports practice in France is still scarce. Here, we assessed the prevalence of infectious diseases related to freshwater sports practice and identified their associated factors among licensees participating to our survey in Brittany, France. Additionally, we evaluated the extent of prevention knowledge and practices among freshwater sports licensees, as well as the role of the clubs in preventive measures advertisement and implementation.

METHODS

Study population

We conducted a cross-sectional study from March 18, 2019, to May 8, 2019, in Brittany. Two separate surveys were conducted. One dedicated to freshwater sports licensees and one to club presidents and instructors. Interviews were carried out by 29 trainees of the field epidemiology course IDEA ('International Course in Applied Epidemiology'), under the supervision of epidemiologists from the French School of Public Health ('Ecole des Hautes Etudes en Santé Publique' – EHESP), and Santé Publique France (the French national public health agency).

Licensees

The source population for the 'licensees survey' (Supplementary Additional File 1) were licensees from the French Federation of Canoe-Kayak (FFCK), aged over 18 years old, who practice at least one freshwater sport in one of the 79 Brittany clubs. To collect information on their type of sports practice, their practice and prevention habits, medical history they would attribute to their sports practice, and their knowledge level regarding infectious risks, they were surveyed using an online questionnaire created on Wepi© (Epiconcept 2018). All voluntary members practicing at least one freshwater sport and who agreed to answer the online survey were included. We sent the survey by email on March 28, 2019, and two reminders were sent on March 29, 2019, and March 31, 2019. Out of the 2,838 provided email addresses, only 2,714 were valid and enabled to reach a recipient. A total of 676 recipients responded to our survey (response rate 24.9%), out of which we included 551 members that met our inclusion criteria.

Clubs

Club presidents and instructors were contacted by phone and surveyed using a second questionnaire addressing the prevention measures implemented in their club (Supplementary Additional File 2). In the case of unsuccessful contact attempts, recipients were not reached more than four times. We contacted 72 clubs, of which 38 responded to the survey (a response rate of 52.8%).

Data collection

Licensees

We asked the licensees whether they were ever diagnosed with leptospirosis by a physician and when it occurred. We also collected the frequency over the last 2 years of conjunctivitis, otitis, skin irritation/itchy skin, and gastroenteritis following freshwater sports practice. Literacy of freshwater sports-related diseases, health prevention measures, and their compliance level were also collected.

As there is no official recommendation, to assess the level of knowledge of the licensees, we created our own scores (Supplementary Additional File 3). The first evaluated their knowledge of the health risks linked to freshwater sports practice and the second quantified their knowledge of the prevention measures. The levels of knowledge were considered as good when the scores were over 3 out of 6 and over 5 out of 10, respectively.

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The second score assessed licensees' compliance with recommendations by a third score ranging from 0 to 8 (Supplementary Additional File 3). We considered that recommendations were followed by the participants when the score was over 3 out of 8.

Depending on the time and degree of exposure to water, some freshwater sports were considered riskier than others regarding waterborne diseases. CK in white waters (WW CK, i.e., slalom, descent, CK in rivers), kayak polo, rafting, open-water swimming, and stand-up paddle are associated with direct skin or mucosal contact with water. Moreover, they are associated with a higher risk to drink water, especially when practicing an Eskimo roll (method to right a capsized kayak, either by body moving, or by using a paddle), and were thus classified as exposing activities in our study. On the other hand, paracanoe, sprint canoe, handikayak, still water CK (SW CK), and dragon boat are associated with a lower risk of water exposure and were thus classified as non-exposing.

Clubs

We asked the clubs' presidents and instructors about health risk elements close to the practice site: the presence of rodents, a sewage treatment plant, a rainwater discharge plant, and/or livestock that have access to the water body. We also asked them about the closing periods of the club, the organization of excursions outside the nautical base, and the organization of competitions. Regarding their control of health risks, we asked the clubs about water testing (frequency, tested microorganisms, person in charge of sampling), but also whether health records and reports of leptospirosis cases in their club are available.

In addition, two club-specific scores were created in this study for descriptive purposes (no threshold defined). The first one evaluated the level of infrastructures of the clubs aiming at limiting health risks (see Supplementary Additional File 1). The second one assessed the level of information that clubs provide to their licensees about the health risks associated with their practice, referred to as the awareness score (see Supplementary Additional File 1).

Statistical analysis

We used logistic regression models to evaluate associations between variables of interest and practice of freshwater sports or sociodemographic factors. All variables significant in univariate analysis ($p<0.2$) were included in the multivariate models. In the multivariate model explaining the occurrence of leptospirosis, the following variables were included: sex, practicing eskimo roll, practicing slalom, practicing kayak polo, practicing canoe sprint, practice duration, boarding from a pontoon, taking a soapy shower after practicing, pratice frequency, health risk awareness, and vaccination. In the multivariate model explaining the occurrence of skin irritations/itchy skin, the following variables were included: sex, age, practicing slalom, practicing kayak polo, taking a soapy shower after practicing, practicing eskimo roll, main practice site in a natural river, main practice site in a canal, main practice site in an artificial lake, practice frequency, practice duration, health risk awareness, and wearing protective equipment over summer. Finally, in the multivariate model explaining the occurrence of conjunctivitis/otitis, the following variables were included: sex, age, practicing eskimo roll, practicing an exposing freshwater sport, practice duration, practice frequency, and checking for water quality before practice.

We used the stepwise method to select our final variables, considering the Akaike Information Criterion (AIC) (Akaike 1974). A *p*-value lower than 5% was considered statistically significant, and odds ratios (ORs) were displayed with their 95% confidence intervals (95% CIs). Participants with missing data were excluded from the analysis. All analyses were performed with R (version 3.6.1) (Akaike 1974).

Ethics and consent to participate

This study aims at analyzing the behavior of the studied population and its association with a risk of infection. This type of non-interventional research, exclusively based on anonymous questionnaires, is covered under French Public Health law by paragraph II.1.D of the article R1121-1 which states that it is not considered as clinical research on humans and does not require the approval of an ethical committee (CPP). No name or identifier of participants was collected; therefore, no declaration to the National Commission on Informatics and Liberty (CNIL) was required.

RESULTS

Licensees

Table 1 gathers the characteristics of the 551 surveyed licensees. Most licensees were males (70.4%), had been practicing for less than 10 years (55.5%), and competitively (50.6%). SW CK was the main practice activity (57.5%), and the natural river

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was the main practice site (71.1%). Most participants (56.6%) reported having an exposing activity. These exposing activities were mostly practiced by men (78.2%) and younger members (34.3% among 18–29 years old, and 11.2% among 62–77 years old). Eskimo roll was practiced by 61.7% of the licensees. Most of the participants (68.4%) practiced freshwater sport less than once a week.

In total, 240 (43.6%) licensees had a good level of knowledge regarding health risks (score greater than 3 out of 6, Supplementary Additional File 3). The risk of leptospirosis was known by 72.2% of the licensees. Members were less aware about otitis, gastroenteritis, and conjunctivitis risks, with 30.7, 28.7, and 18.1%, respectively, who knew about these risks. Despite these scores, almost 80% said someone had raised their awareness about these risks. Clubs were the main source of information (48.5%), followed by relatives (21.2%).

Concerning the preventive measures, 76.2% of the licensees had a good knowledge (score greater than 5 out of 10, Supplementary Additional File 3). Participants identified risk factors as: practicing amongrodents (84.6%), drinking water (82.0%), and swimming (65.7%). They identified protective factors as: washing, disinfecting, and covering wounds (89.8%), taking a shower immediately after the activity (86.9%), rinsing the equipment with drinkable water (74.8%), and being vaccinated against leptospirosis (67.3%).

Only 116 (21.1%) participants had a good compliance score (score greater than 3 out of 8, Supplementary Additional File 3). We noted that 46.5% of the participants systematically rinsed their equipment with potable water, 37.2% systematically used a pontoon, 34.3% systematically took a soapy shower after practice, and 3.3% systematically checked for water quality before practice. Only 8.2% reported wearing a long drysuit all year round, and 3.5% were vaccinated against leptospirosis. Average scores were better for licensees with less than 10 years of practice.

A total of 29 (5.3%) licensees had at least one episode of leptospirosis between 1990 and 2019, of which 12 occurred after 2013 (Table 2). Over the last 2 years, the most reported medical events were skin irritation/itchy skin (24.0%), otitis (12.3%), and conjunctivitis (5.8%). Abdominal pain, diarrhea, and vomiting were less notified (2.2, 1.8, and 0.5%, respectively). We observed that 69 (12.5%) licensees had consulted a physician over the last 2 years due to symptoms related to their practice. A hospitalization for a freshwater sport-related disease during their lifetime was reported by 39 participants (7.1%).

In the multivariable model presented in Figure 1, boarding from a pontoon seemed to protect participants from developing leptospirosis (OR=0.2, 95% CI 0.1–0.6) as well as practicing for less than 4 years (OR=0.2, 95% CI 0.1–0.6). There was a positive association between being vaccinated against leptospirosis and having declared leptospirosis in the past (OR=8.8, 95% CI 2.2–32.0), as well as taking soapy showers after practicing freshwater sports and having a history of leptospirosis (OR=4.4, 95% CI 1.9–10.5).

Practicing Eskimo roll was positively associated with otitis or conjunctivitis (OR=3.2, 95% CI 1.8–6.0) (Figure 2). Practicing on a canal was positively associated with skin irritation/itchy skin (OR=1.6, 95% CI 1.0–2.5) (Figure 3). On the contrary, 62–77 years old participants seemed protected against skin irritation/itchy skin compared to 18–29 years old licensees (OR=0.3, 95% CI 0.1–0.6).

Clubs

Out of the 38 responding clubs, we could reach the presidents of only 24 clubs (63.2%). The information on the other clubs were obtained through the interview of instructors. Table 3 gathers the characteristics of the surveyed clubs. The main practice site for clubs was rivers (44.7%) followed by artificial lakes (18.4%). Two-thirds of the clubs had no seasonal closing period; the others reported closing seasonally, at least once a year (34.3%). Most of the clubs (78.9%) organized excursions outside the club more than 10 times a year and 76.3% of the clubs organized at least one competition per year. Among the various health risk elements exposed during the interview, all the clubs were concerned by at least one. Most of them reported having rodents near the club (86.8%), followed by a rainwater discharge plant (65.8%). Regarding the infrastructure score, 29 clubs (76.3%) scored 4 or more out of 5 (5 being the best level a club could have in terms of health risks prevention, Supplementary Additional File 3).

The maximum awareness score of 12 out of 12 was reached by two clubs (5.3%), and 18 clubs (47.4%) scored over 7 out of 12 (12 being the best level of information that a club can provide to their licensees about the health risks associated with freshwater sports practice, Supplementary Additional File 3).

The ARS guide that lists the individual and collective preventive measures was known to 25% of the clubs. Most of the clubs had their sites eutrophicated (n=23, 60.5%), yet only 13 clubs tested their water for cyanobacteria (34.2%), 8 clubs

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Table 1 | Characteristics of the surveyed licensees (N=551) stratified by sex

Variable	Total (N=551)	Female (n=163)	Male (n=388)
Age (years)			
18–29	126 (22.9%)	37 (22.7%)	89 (22.9%)
30–45	130 (23.6%)	28 (17.2%)	102 (26.3%)
46–61	199 (36.1%)	72 (44.2%)	127 (32.7%)
62–77	96 (17.4%)	26 (16.0%)	70 (18.0%)
Missing	0 (0.0%)	0 (0.0%)	0 (0.0%)
Practiced activity[a]			
WW CK[b]	246 (44.6%)	54 (33.1%)	192 (49.5%)
SW CK[c]	317 (57.5%)	98 (60.1%)	219 (56.4%)
Dragon Boat	33 (6.0%)	25 (15.3%)	8 (2.1%)
Handi-kayak or Para-canoe	7 (1.3%)	1 (0.6%)	6 (1.5%)
Canoe Sprint	77 (14.0%)	24 (14.7%)	53 (13.7%)
Open-Water Swimming	13 (2.4%)	5 (3.1%)	8 (2.1%)
Stand-up Paddle	23 (4.2%)	4 (2.5%)	19 (4.9%)
Slalom	137 (24.9%)	30 (18.4%)	107 (27.6%)
Kayak polo	95 (17.2%)	16 (9.8%)	79 (20.4%)
Rafting	2 (0.4%)	0 (0.0%)	2 (0.5%)
Missing	0 (0.0%)	0 (0.0%)	0 (0.0%)
Main practice site on a canal			
Yes	178 (32.3%)	50 (30.7%)	128 (33.0%)
No	373 (67.7%)	113 (69.3%)	260 (67.0%)
Missing	0 (0.0%)	0 (0.0%)	0 (0.0%)
Activity type			
Exposing[d]	312 (56.6%)	68 (41.7%)	244 (62.9%)
Non-exposing[e]	239 (43.4%)	95 (58.3%)	144 (37.1%)
Missing	0 (0.0%)	0 (0.0%)	0 (0.0%)
Practice of the Eskimo roll			
Yes	340 (61.7%)	67 (41.1%)	273 (70.4%)
No	205 (37.2%)	94 (57.7%)	111 (28.6%)
Missing	6 (1.1%)	2 (1.2%)	4 (1.0%)
Practice duration			
0–4 years	172 (31.2%)	68 (41.7%)	104 (26.8%)
5–9 years	134 (24.3%)	42 (25.8%)	92 (23.7%)
>10 years	241 (43.7%)	52 (31.9%)	189 (48.7%)
Missing	4 (0.7%)	1 (0.6%)	3 (0.8%)
Practice frequency			
More than once a week	174 (31.6%)	44 (27.0%)	130 (33.5%)
Less than once a week	377 (68.4%)	119 (73.0%)	258 (66.5%)
Missing	0 (0.0%)	0 (0.0%)	0 (0.0%)
Competition practice			
Yes	279 (50.6%)	69 (42.3%)	210 (54.1%)
No	178 (32.3%)	73 (44.8%)	105 (27.1%)
Missing	94 (17.1%)	21 (12.9%)	73 (18.8%)

(*Continued.*)

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Table 1 | Continued

Variable	Total (*N*=551)	Female (*n*=163)	Male (*n*=388)
Systematic soapy shower after practice			
Yes	189 (34.3%)	64 (39.3%)	125 (32.2%)
No	362 (65.7%)	99 (60.7%)	263 (67.8%)
Missing	0 (0.0%)	0 (0.0%)	0 (0.0%)
Systematic use of a pontoon			
Yes	205 (37.2%)	85 (47.9%)	261 (32.7%)
No	346 (62.8%)	78 (52.1%)	127 (67.3%)
Missing	0 (0.0%)	0 (0.0%)	0 (0.0%)

[a]Several answers are possible per licensee.
[b]White water Canoe-Kayak.
[c]Still water Canoe-Kayak.
[d]WW CK, kayak polo, rafting, open-water swimming, and stand-up paddle.
[e]Para-canoe, sprint canoe, handi-kayak, SW CK, and dragon boat.

for bacteria (21.1%), and 4 for other microorganisms (10.5%). Among them, the incentive to sample was given by local authorities (44.7%) or by clubs themselves (10.5%).

Only six clubs (15.8%) reported having a health record to collect licensees' symptoms and illnesses related to their sports practice. Moreover, 11 clubs (28.9%) informed licensees of the need to report their potential symptoms and/or practice-related illnesses to the club; 15 clubs (39.5%) reported that at least one leptospirosis case occurred in their club. Among them, nine reported it happened during the last 5 years, including one club with a cluster of cases.

DISCUSSION

Summary of findings and implications in terms of public health recommendations

This study aims at improving our understanding of the knowledge level of freshwater sports practitioners regarding health risks, preventive measures, and their compliance with recommendations in Brittany, France.

The knowledge level of preventive measures among licensees was good, but these measures were not well followed in daily practice and were even followed less with more years of experience. Despite being aware of preventive measures related to freshwater sports practices – through their respective club or relatives' recommendations – only a quarter of licensees reported implementing most of the recommendations. However, compliance with recommendations was better when licensees knew about freshwater sports-related diseases, especially for licensees with less than 10 years of practice. Furthermore, the level of information provided by instructors and presidents of all FFCK clubs in Brittany, defined as club's awareness scores, was found to be high, but best practices recommendations published by the ARS were unknown to most of them. These findings underline gaps in the communication of preventive advice. A possible explanation could be that clubs are directly informed by their local federation, but that communication channels between local health authorities and clubs are inefficient. Further studies are required to better understand these existing gaps between knowledge and practices. Indeed, the perception of the risk could influence the behaviors of the licensees, instructors, and presidents of clubs. Using a more integrated perspective through mixed approaches (quantitative and quantitative methods) could help to address this public health issue.

A high proportion of otitis, conjunctivitis, and skin irritation/itchy skin was reported, which is consistent with findings from other studies (Centre National de Référence de la Leptopirose 2017). Moreover, we found that ear, nose, and throat symptoms were positively associated with Eskimo roll, which is coherent with the regular and repeated contacts with water due to this technique. Only few gastrointestinal symptoms were reported, which are anyhow not specific, and could hardly be linked with freshwater sports practice. We also got a high number of leptospirosis cases among freshwater sports licensees which could be partly explained by the cluster of 14 kayakers reported along the Vilaine river in 2016 (Guillois *et al.* 2018). This event, along with the increase in the number of cases between 2013 and 2016, should lead

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Table 2 | Health characteristics related to freshwater sports practice (*N*=551)

Characteristics	*n* (%)
Medical consultation for symptoms related to freshwater sports practice over the last 2 years	
Yes	69 (12.5)
No	474 (86.0)
Missing	8 (1.5)
Symptoms experienced as a result of practicing freshwater sports over the last 2 years	
Gastrointestinal symptoms[a]	
Yes	18 (3.3)
No	533 (96.7)
Missing	0 (0.0)
Otitis[a]	
Yes	483 (87.7)
No	68 (12.3)
Missing	0 (0.0)
Conjunctivitis[a]	
Yes	519 (94.2)
No	32 (5.8)
Missing	0 (0.0)
Skin irritation/itchy skin[a]	
Yes	419 (76.0)
No	132 (24.0)
Missing	0 (0.0)
Leptospirosis diagnosis[b]	
Yes	29 (5.3)
No	512 (92.9)
Missing	10 (1.8)
Hospitalization for a freshwater sport-related illness (excluding trauma)[b]	
Yes	39 (7.1)
No	507 (92.0)
Missing	5 (0.9)
Vaccination against leptospirosis	
Yes	19 (3.4)
No	532 (96.6)
Missing	0 (0.0)

[a]Abdominal pain, diarrhea, or vomiting at least once.
[b]Over lifetime.

public health authorities to question themselves on their cause and on the relevance of the 2005 national recommendation for vaccination against leptospirosis based on a case-by-case prescription after individualized risk assessment by the physician (Direction Générale de la Santé). Real-world evidence studies and cost-effectiveness analysis could contribute to a better understanding of the vaccine effectiveness and help guide prevention strategies.

The high observed proportion of infectious diseases and the lack of compliance with recommendations emphasize the need for strengthening information about prevention measures. Regular communication campaigns could be organized with dedicated training courses for licensees and supervisors, and official materials should be shared with every club. Clubs should be encouraged to provide equipment such as showers with soap, freshwater sports outfits, places to rinse water equipment, or

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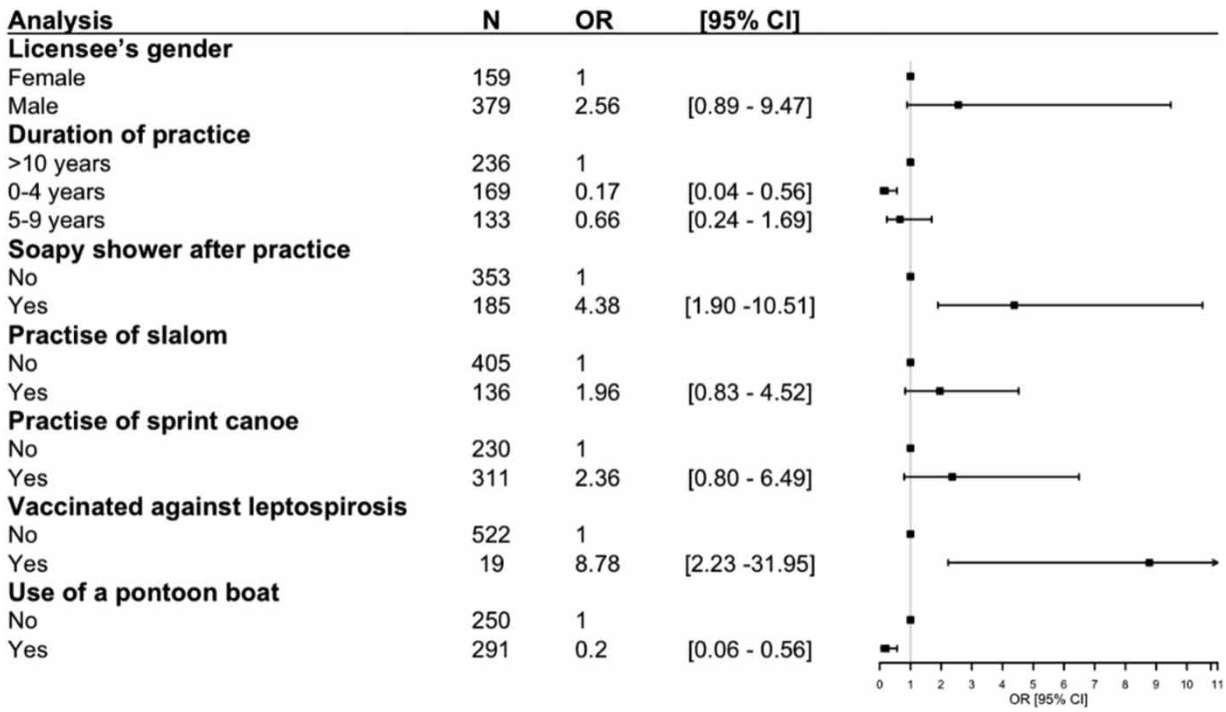

Figure 1 | Factors associated with the occurrence of leptospirosis among freshwater sports licensees. In this multivariate logistic regression, 538 licensees were included, and 13 were excluded due to missing data.

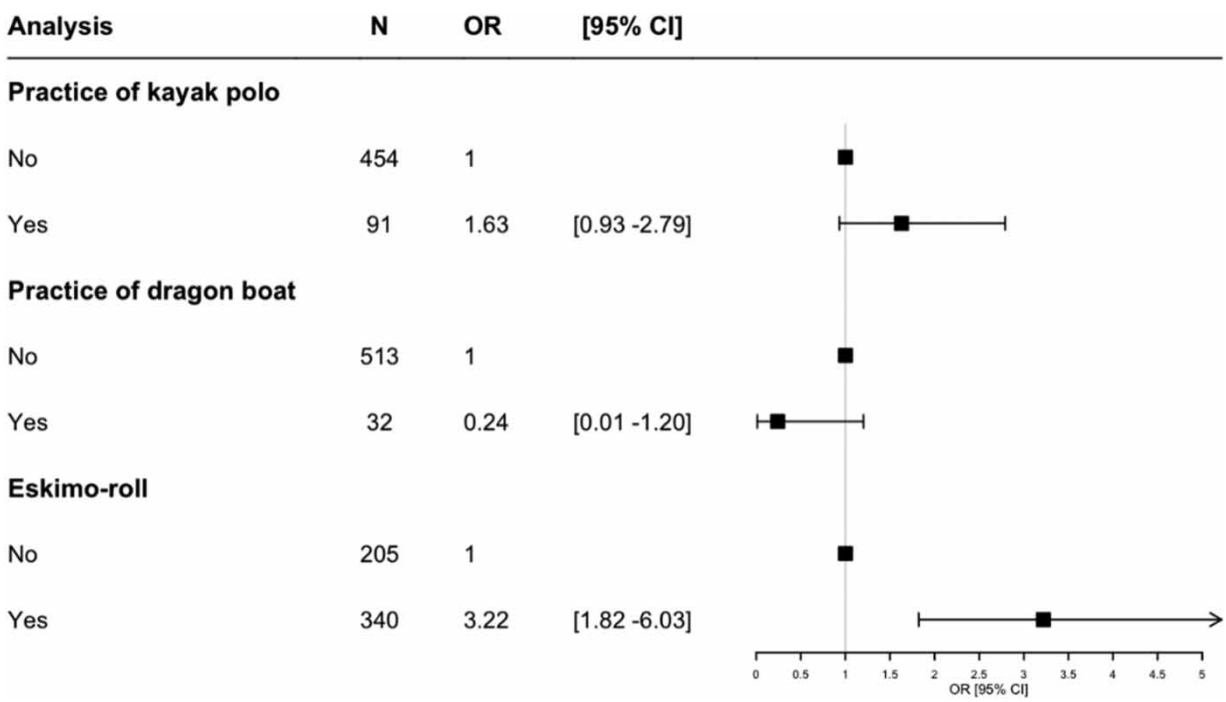

Figure 2 | Factors associated with the occurrence of otitis and/or conjunctivitis among freshwater sports licensees. In this multivariate logistic regression, 545 licensees were included, and 6 were excluded due to missing data.

pontoons. Water testing could be organized twice a month by the ARS or city halls, with an alert system in case of abnormality. Clubs should, therefore, report their places of practice to public administration to target sampling sites. This indexing work is already implemented by the FFCK but has not yet been completed (FFCK). In case of abnormality in water testing

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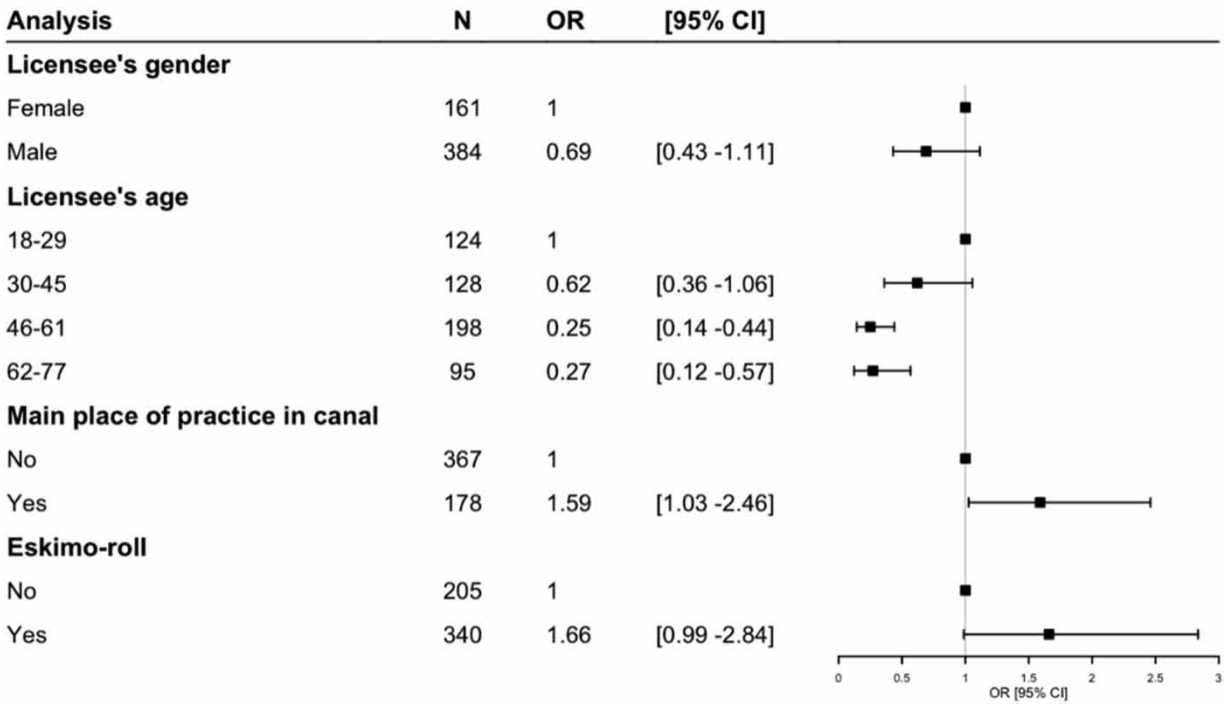

Figure 3 | Factors associated with the occurrence of skin irritation/itchy skin among freshwater sports licensees. In this multivariate logistic regression, 545 licensees were included, and 6 were excluded due to missing data.

results, clubs should inform licensees, close the concerned sites, and forbid practice until a healthy level is reached. Licensees practicing Eskimo roll should be informed of the risk of otitis and conjunctivitis, and the ways to prevent that risk. The risk of leptospirosis was not known by 27.8% of practitioners. It is important to inform practitioners about the disease so that they consult a doctor at the first sign of symptoms.

Limitations

This study is cross-sectional; thus, we had inherent troubles interpreting temporality between explanatory variables and dependent variables. We identified a positive association between a history of leptospirosis and taking a soapy shower or being vaccinated against leptospirosis, whereas a negative association was expected. Here, we cannot rule out that preventive measures were applied after leptospirosis infection inversing temporality between exposition and disease and leading to a positive association. For example, the participants who declared having had leptospirosis could have been considered at risk of re-infection by the practitioners and thus had a post-infection vaccination, the positive association between leptospirosis and being vaccinated. In addition, we could not assess the incidence of freshwater sport-related diseases, which could help prioritize prevention measures. Due to the online survey, we can doubt the representativeness of our sample despite the satisfactory response rate. Indeed, this type of survey has potentially favored the participation of licensees who are interested in their health status or have already had one of the outcomes of interest. Moreover, the survey being declarative, it is possible that the disease frequencies were either overestimated, due to the selection bias, or underestimated since asymptomatic and paucisymptomatic forms may have not been reported. Finally, clubs were surveyed by different interviewers by phone, leading to a potential measurement bias. However, this bias may be limited as the interviewers were trained and had guidelines for asking questions.

Perspectives

Freshwater sports associated health risks must be considered in the light of the One Health concept. This approach recognizes that human health, animal health, plants health, and our environment are closely connected. It underlines the importance of multidisciplinary work (stakeholders, scientists from various fields, etc.) to improve public health.

In this context, further studies investigating leptospirosis risks regarding freshwater sports practice in France should consider additional elements. First, the exposure should be characterized more precisely. For example, the identification of all

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Table 3 | Characteristics of the surveyed clubs (N=38)

Variable	*n* (%)
Main practice site	
Natural river	17 (44.7)
Canal	6 (15.8)
Artificial lake	7 (18.4)
White-water stadium	5 (13.2)
Missing	3 (7.9)
Proximity of practice site to risk factors[a]	
Rodents	33 (86.8)
Livestock	20 (52.6)
Water treatment plant	24 (63.2)
Rainwater collection	25 (65.8)
Missing	0 (0.0)
Trip frequency outside from the practice site (by year)	
Never	1 (2.6)
From 1 to 5 times	1 (2.6)
From 6 to 10 times	6 (15.8)
More than 10 times	30 (78.9)
Missing	0 (0.0)
Eutrophication of the practice site	
Yes	23 (60.5)
No	15 (39.5)
Missing	0 (0.0)
Frequency of water testing	
More than twice a month	9 (23.7)
Less than twice a month	13 (34.2)
Does not know	16 (42.1)
Missing	0 (0.0)
Health record to notify events	
Yes	6 (15.8)
No	30 (78.9)
Does not know	2 (5.3)
Missing	0 (0.0)
Closing periods	
Never	24 (63.2)
In winter	3 (7.9)
In summer	8 (21.1)
In summer and winter	2 (5.3)
Missing	1 (3.0)

[a]Several answers are possible per club.

Leptospira sp. hosts as well as their respective contribution to the circulation of the different *Leptospira* serogroups could be a real asset. The exposure quantification, the characterization of the exposure type (ingestion, wonds, etc.), and the identification of the presence of *Leptospira* sp. in the water, soils, fauna, and flora could be explored. A detailed characterization of the environment could help to identify which environmental factors may lead to an increase in leptospirosis exposure

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(e.g., meteorological factors, type of practice sites, and biophysical factors). Second, the dose-response assessment using animal models could help to better understand the physiopathological pathways that lead to the disease (infectious dose, etc.). In this sense, we can imagine the establishment of a quantitative health risk assessment (QHRA), a quantitative microbiological risk assessment (QMRA), and/or a serological study on the surrounding fauna to be able to quantify the number of seropositive individuals in the environment. Finally, as mentioned previously, the identification and characterization of risky and protective behaviors using mixed methods should not be neglected in these studies in order to implement efficient measures.

Therefore, using a multidisciplinary approach on this subject will help to better understand exposure, physiological susceptibility, and individual adaptation capacity related to leptospirosis that are key elements to address this public health issue.

Our study highlights that surveillance and prevention of infectious diseases related to freshwater sports should be considered by stakeholders, and that multidisciplinary approaches should be implemented for future studies. This is all the more important in a context of adaptation to climate change as a rise of eutrophication, and consequently of cyanobacteria, in freshwater sports in France has already been observed (Ullah *et al.* 2018) and that temperatures are increasing rapidly (Pachauri & Meyer 2014).

CONCLUSIONS

This study highlights the potential burden of infectious diseases related to the practice of freshwater sports in French Brittany. It also shows that the knowledge of health risks among licensees remains insufficient and the recommendations of good practices are not perfectly followed. This suggests a need to strengthen prevention methods and good practices in clubs to prevent infectious diseases. Further analytical studies are required to better understand the causes of freshwater sport-related diseases.

ACKNOWLEDGEMENTS

We would like to thank the Regional Committee of Canoe Kayak of French Brittany for providing us the licensees' email address and the club staff's phone number. The authors would like to acknowledge the work performed by the 34th IDEA Field Epidemiology training group: Lucie Adélaïde, Fatouma Ali, Stéphanie Antoniol Postic François Benezit, Manon Benjdir, Delphine Berthod, Hanifa Bouziri, Sacha Camail, Alexandre Descamps, Camille Estevenin, Virginie Gigonzac, Pauline Kooh II, Nicolas Lafosse, Maylis Layan, Claire Leblanc, Paul Lemarquis, Mihiau Mapotoeke, Clément Massonnaud, Athinna Nisavanh, Emma Oliosi, Alan R. Patlán-Hernández, Julie Prudhomme, Dimbintsoa Rakotomalala Robinson, Maheninasy Rakotondrainipiana, Claire Sauvage, Modou Sow, Tatiana Ticona, Fanny Velardo, Monika Wolska, Yvonnick Guillois, Delphine Antoine, and Pascal Crépey.

AVAILABILITY OF DATA AND MATERIALS

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request. All codes are available from the corresponding author upon reasonable request.

AUTHORS' CONTRIBUTION

F.V., H.B., L.A., E.O., M.L., and A.D. were major contributors in writing the manuscript. F.V., H.B., M.L., J.R., and P.C. analyzed the data. All authors read, reviewed, and approved the final manuscript.

COMPETING INTERESTS

The authors declare that they have no competing interests.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

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First received 3 September 2021; accepted in revised form 11 January 2022. Available online 25 January 2022

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