Preventing and controlling *Cryptosporidium* spp. in aquatic facilities: environmental health practitioners' experiences in Victoria, Australia

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Abstract

Objective: To identify barriers and enablers to preventing and controlling *Cryptosporidium* spp. in aquatic facilities as perceived by environmental health practitioners (EHPs).

Methods: A qualitative, constructivist study with a purposive sample of seven EHPs from Victoria, Australia, was conducted. A focus group discussion was guided by a semi-structured interview schedule using open-ended questions. The audio-recorded focus group was transcribed verbatim and analysed using thematic analysis.

Results: Five themes represented the perceived barriers and enablers: i) pool water testing methods; ii) resources and training for EHPs; iii) knowledge and behaviour of aquatic facility operators and swimming pool users; iv) regulation; and v) aquatic facility and swimming pool design. Two key barriers within these themes included aquatic facility regulation and unhealthy swimming behaviours.

Conclusions: Several barriers and enablers to preventing and controlling *Cryptosporidium* spp. in aquatic facilities were perceived by EHPs. Suggestions to overcome perceived barriers were also identified. Further research is required to determine the impact of these findings on the incidence of cryptosporidiosis associated with aquatic facilities.

Implications for public health: The findings contribute to a greater understanding of the barriers and enablers to *Cryptosporidium* spp. prevention and control in aquatic facilities, which may improve the effectiveness of current prevention and control strategies.

Key words: cryptosporidiosis, swimming pool, prevention and control, barriers and enablers, environmental health practitioner

Cryptosporidiosis is a gastrointestinal disease caused by the protozoan parasite *Cryptosporidium* spp., with the disease presenting as gastroenteritis.[1] In addition to contributing to morbidity and mortality, gastroenteritis is estimated to cost the Australian economy more than $342 million annually through medical costs and lost productivity.[2] Cryptosporidiosis significantly contributes to this burden as the third most commonly notified gastrointestinal disease in Australia.[3] *Cryptosporidium* spp. is transmitted via the faecal-oral route with humans, cattle and other domesticated and wild animals acting as reservoirs for the parasite.[4] Transmission can occur directly by contact with an infected host or indirectly through contaminated food[4] and – often – contaminated water.[5,6]

Between 2011 and 2016, a total of 381 outbreaks of waterborne disease caused by parasitic protozoa were reported worldwide, with *Cryptosporidium* spp. the aetiological agent in 63% of outbreaks.[6] Outbreaks of cryptosporidiosis have been associated with aquatic facilities including swimming pools[7-23] and splash parks[24-27] worldwide. In Australia between 2001 and 2007, *Cryptosporidium* spp. contamination of swimming pools was associated with 41 of the 42 reported outbreaks of waterborne gastroenteritis associated with recreational water.[28] Between 2013 and 2017 in Victoria, Australia, 70 outbreaks of cryptosporidiosis were associated with aquatic facilities, with 421 confirmed cases (Joy Gregory, Department of Health and Human Services, May 2018, personal written communication). For the current study, aquatic facilities are inclusive of public recreational swimming pools and splash parks, and hotel and motel pools.

To effectively prevent and control the disease, combined efforts from public health authorities, swimming pool users and aquatic facility operators are critical.[7,21,24] Multiple strategies to prevent and control *Cryptosporidium* spp. in aquatic facilities exist; however, these are not always effective. For example, pool water treatment is ineffective as *Cryptosporidium* spp. is highly resistant to chlorine[29] and common filtration systems used in aquatic facilities have limited effectiveness in physically removing the pathogen from water.[30] Numerous studies investigating cryptosporidiosis outbreaks associated with aquatic facilities have highlighted several important factors for the prevention and control of the disease. These include the need for public education on cryptosporidiosis and healthy swimming practices,[21,24,25] alterations to swimming pool design,[24,25] and good maintenance of the aquatic facility.[9,14,23] Regulation has also

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been identified as an important element of *Cryptosporidium* spp. prevention and control.[31]

In Victoria, aquatic facilities are regulated under the *Public Health and Wellbeing Act* 2008[32] and the *Public Health and Wellbeing Regulations* 2009, which outline requirements for aquatic facility operators regarding facility maintenance, parameters for water quality and record-keeping.[33] Local government environmental health practitioners (EHPs) have a key role in the enforcement of these regulations. For the purposes of this study, EHPs are inclusive of practitioners who hold a professional qualification to practise as an Environmental Health Officer, or are employed as an Environmental Health Technician, with authorisation to perform duties under this legislation.[34] Enforcement of legislative requirements by EHPs among aquatic facilities may involve auditing of aquatic facilities, collecting pool water samples to assess compliance with legislative parameters, providing education regarding these requirements, and investigating sporadic cases or outbreaks of cryptosporidiosis.[34,35] While carrying out these duties, EHPs may liaise with a wide range of stakeholders including aquatic facility operators, swimming pool users, analysts and other affected parties inside and outside their own organisational setting, including other relevant local and state government agencies. Given this range of duties and liaison with various stakeholders, the researchers considered the experiences of EHPs would provide a unique insight and valuable source of knowledge to potentially enhance the effectiveness of current strategies used to prevent and control *Cryptosporidium* spp. in aquatic facilities. Therefore, we aimed to identify barriers and enablers to preventing and controlling *Cryptosporidium* spp. in aquatic facilities by investigating the experiences of EHPs involved in the implementation of legislative measures in this area. To our knowledge, this is the first time that an empirical investigation into EHPs experiences with respect to *Cryptosporidium* spp. prevention and control in Australia had been undertaken. This informed the research design and methods adopted for this study.

Methods

Research design

This study used an exploratory, qualitative research design positioned within the constructivist paradigm.[36] A focus group was used to explore EHPs' experiences of investigating cryptosporidiosis and inspecting aquatic facilities. Thematic analysis was used to identify perceived barriers and enablers to preventing and controlling *Cryptosporidium* spp. in aquatic facilities across various themes. Ethical approval was received from the Swinburne University Human Research Ethics Committee (SHR Project 2018/222).

Participants and recruitment

A purposive sampling strategy was used to recruit EHPs who were currently employed in Victoria and had a role in the implementation of the regulative requirements described previously. We were particularly interested in recruiting practitioners who had experience in investigating cryptosporidiosis and had inspected aquatic facilities. Invitational emails and promotional flyers were disseminated online via professional associations and networks. Interested participants contacted LC, who confirmed their eligibility to participate. Details of the focus group including the date, time and location were provided via email.

Data collection

A focus group was conducted in 2018 in Victoria, Australia, and guided by a semi-structured interview schedule using open-ended questions. The interview schedule was developed by all members of the research team and focused on asking the EHPs about their experiences of investigating cryptosporidiosis and inspecting aquatic facilities as part of their role. LC facilitated the focus group with support from SM and LD. The focus group lasted approximately one hour and forty-five minutes and was audio-recorded with participant consent. Written informed consent was obtained from all participants prior to the focus group. A demographic questionnaire was also administered to participants asking them about their personal and employment characteristics.

Data analysis

The audio-recorded focus group was transcribed verbatim by LC. Participants were provided with pseudonyms known only to the research team and any other potentially identifying information was removed. The transcript was analysed using thematic analysis. This took place through initial familiarisation with the data, involving the reading and re-reading of the transcript by LC and the development of open codes to assign labels to sections of the data. An iterative process of categorising codes and developing themes took place until all researchers were satisfied with the themes.[36] During each stage of the analysis, discussions were had with SM and LD to increase the validity of the themes constructed from the data. Quotes from participants were used to support the credibility of research findings. The demographic questionnaire was analysed using simple descriptive statistics.

Results

Participants

Seven EHPs participated in the focus group. All EHPs were born in Australia and spoke English at home. The majority (57%) of participants were aged 36–50 years while two (29%) were aged 18–25 years and one (14%) was aged 51–65 years. Of the seven EHPs, six were male and one female. The highest level of education held by the majority (57%) of EHPs was a bachelor's degree. Three EHPs had either a postgraduate diploma, diploma or certificate as their highest level of education. Four (57%) EHPs were employed as environmental health officers and three (43%) as environmental health technicians. All EHPs were employed by a local council as opposed to a private contractor, with 71% in full-time employment and 29% in part-time employment. The majority (86%) of EHPs worked in a city council within the north-west (43%), southern (14%) and eastern (29%) metropolitan regions of Victoria, Australia. One participant was from a rural city council in the north-west metropolitan region. Four (57%) EHPs had less than two years of experience in their current role while three EHPs had experience levels of between two years but less than five years, between five years but less than ten years, or more than ten years. Some participants were previously employed as environmental health technicians or student environmental health officers at their current or previous council.

Themes

Five themes representing the perceived barriers and enablers to *Cryptosporidium* spp. prevention and control in aquatic facilities were constructed: i) pool water

testing methods; ii) resources and training for EHPs; iii) knowledge and behaviour of aquatic facility operators and swimming pool users; iv) regulation; and v) aquatic facility and swimming pool design. A barrier was considered to be a factor that made it difficult for EHPs to investigate cryptosporidiosis and inspect aquatic facilities, whereas an enabler was considered to be a factor that facilitated EHPs to adequately undertake these tasks. Although the aim of the study was to identify barriers and enablers, the analysis also revealed several suggestions provided by some EHPs to address perceived barriers. A suggestion to address a perceived barrier was identified as a factor that could potentially aid in preventing and controlling cryptosporidiosis. Barriers, enablers and suggestions to overcome perceived barriers are represented below within the themes and supported by quotes from the EHPs.

Theme 1: Pool water testing methods

The EHPs' role in testing pool water at aquatic facilities was often focused on taking water samples to assess compliance with the chemical parameters set out in the *Public Health and Wellbeing Regulations* 2009. A focus on chemical compliance, as opposed to the microbial safety of the water, was perceived to be ineffective in preventing and controlling *Cryptosporidium* spp., as chemically compliant water may still contain *Cryptosporidium* spp.

> *You could test a pool and if it's compliant with the chemical parameters then you're on your way, but there might be a crypto outbreak the next day.* (Jordan)

Often, EHPs only took water samples to assess microbial compliance if the water was found to be chemically unsatisfactory. One EHP noted that even when water samples were collected and sent to the laboratory for microbiological testing, *Cryptosporidium* spp. was not a pathogen routinely tested for.

> *Crypto's one you have to look for, it's not a parameter, they [the laboratory] just do coliforms and pseudomonas, so unless you're really looking for it they're not testing for it anyway – it's not like a base test.* (Lee)

Theme 2: Resources and training for EHPs

The Victorian Department of Health and Human Services has published guidelines to assist EHPs in enforcing the regulations. The majority of participants considered the guidelines helpful, in particular, some EHPs reported using the guidelines to improve their knowledge of cryptosporidiosis and aquatic facilities and to enable more effective communication with aquatic facility operators.

> *The Department puts out good resources to give you a bit of knowledge to be able to go to the operators with.* (Lee)

Despite acknowledging the usefulness of these guidelines, the majority of the EHPs expressed the need for more practical training to supplement the written resources. One EHP suggested that practical training conducted by an expert could help to answer questions that the EHPs may still have after consulting the available guidelines and resources.

> *Someone who's a bit of an expert in it … some sort of crash course, half a day, a day, sort of hands-on training would be really good to then equip you to go out.* (Alex)

Theme 3: Knowledge and behaviour of aquatic facility operators and swimming pool users

Many of the EHPs had observed unhealthy swimming behaviours by swimming pool users during their inspections at aquatic facilities. These unhealthy behaviours included observing a pool user vomiting in the pool, patrons spitting out mouthfuls of water and patrons entering the pool without having first showered. In addition to direct observations, one EHP had also received a complaint from the public regarding an elderly lady swimming in soiled swimwear.

> *I just watch people walk, they pay their money and just go straight in the pool and they've come from the gym.* (Chris)

These observed behaviours were perceived to be due to a lack of knowledge and awareness about healthy swimming practices and cryptosporidiosis among pool users. In addition to the general perception that swimmers were unaware of cryptosporidiosis, EHPs reported that when conducting cryptosporidiosis case interviews, many interviewees revealed that they continued to swim with symptoms of gastrointestinal illness.

> *You could ask anyone that goes to a pool, "Have you thought about crypto and trying to minimise your chance of spreading it to someone else?" or "Do you know what it is?" I'd almost guarantee you that almost nobody would know.* (Jordan)

Some EHPs considered that the unhealthy swimming behaviour of not showering before swimming was influenced by what is considered socially acceptable. Comparisons were made between Australia, where showering before swimming was not considered normal practice, and European countries, where showering before swimming is common practice. One EHP proposed that unhealthy swimming behaviours may also be influenced by generational differences among swimmers, suggesting that it may be more common for older generations to shower before swimming compared to younger generations.

> *I agree with the social norms being a huge point of difference [when] comparing Australia to other countries where, growing up, you'd always jump in the pool completely dry.* (Jordan)

Some EHPs also perceived unhealthy swimming behaviours and a lack of knowledge to be related to a potential lack of translated material for people from non-English-speaking backgrounds. Signage displayed in aquatic facilities relating to healthy swimming practices was predominantly in English and, with a diverse group of people attending these facilities, EHPs considered this signage to be inadequate for communicating with swimmers from non-English-speaking backgrounds. One EHP reported that even with this signage displayed in aquatic facilities within their municipality, providing education to swimmers with limited English was an ongoing issue.

> *Especially one of the barriers would be language because a lot of new migrants are moving in. We've got posters up telling people about crypto but it's still an ongoing thing, educating people, and people with probably limited English.* (Francis)

The majority of EHPs agreed that providing education to the public regarding healthy swimming practices was an important strategy to change the behaviour of swimming pool users. Media and marketing campaigns were common suggestions for methods to educate the public. Comparisons were made to the perceived success of other public health education campaigns such as those aimed to reduce smoking or to stop people spitting in public.

> *Media campaigns or something along those lines is the best and most effective way of getting that across.* (Jordan)

However, one participant strongly believed that education as a means to prevent and control aquatic facility associated cryptosporidiosis would not be effective

and that efforts should instead be focused on identifying more effective disinfection methods.

> *It's admirable but in the society that we live in today in Australia it won't happen to an appreciable extent, I don't reckon. Therefore, I reckon regularly we need to get the pool water operators to give it a whack, the pool, chlorine dioxide or superchlorination, which is expensive, weekly and [during] busy times – something like that.* (Taylor)

The impact of unhealthy swimming behaviours on *Cryptosporidium* spp. in aquatic facilities was perceived to be compounded by the ability of aquatic facility operators and staff to respond to and control these contamination situations. During a compliance inspection, one EHP had observed a child vomit in the swimming pool, to which the lifeguards did not respond.

> *… speaking to some of the lifeguards about what they do if they see a kid vomit or something in the kid's pool and it actually happened when we were there, there was a little girl that was sick in the pool and they basically let it go.* (Lee)

Many EHPs reported visiting aquatic facilities where they perceived the operator to lack the appropriate knowledge and skills to adequately maintain an aquatic facility. This was perceived to be the case if the operator was unable to explain to the EHP how they operate the facility. Many EHPs reported that when they conducted pool water testing at these facilities, chlorine levels would often be unsatisfactory. Poor operators were often associated with smaller pools in hotels and motels.

> *A brand new operator … we got a complaint about the pool water and it was really quite cloudy and I remember standing there and she knew nothing about aquatic facilities really … I remember standing there saying, "So, is this quite acceptable?" and she looked back at me and said, "Oh yeah, it's alright".* (Taylor)

A lack of knowledge and skills among some aquatic facility operators was potentially thought to be influenced by language barriers. Some EHPs found it difficult to communicate with operators from non-English-speaking backgrounds when trying to discuss the operation of the aquatic facility.

> *Maybe English and language was a barrier to explaining and to get them to explain to you just so that you can confirm that they have knowledge and skills.* (Alex)

Despite negative experiences with some pool operators, many EHPs had also visited aquatic facilities where they considered the operators to be knowledgeable and skilful. Operators were perceived to be knowledgeable if they were able to adequately answer questions asked by the EHP about operating the facility. Some operators would explain how they monitored water quality or how they managed *Cryptosporidium* spp. risk. EHPs agreed that most operators had adequate knowledge, however, good operators were more often associated with council-owned facilities.

> *If they were council-run they were always very proactive on what they needed to do and what their operators or whoever was running the facility had to know.* (Lee)

Theme 4: Regulation

The EHPs raised several issues relating to current regulations concerning aquatic facilities. For example, some EHPs considered the non-prescriptive nature of legislation as a perceived challenge, particularly in the event of a suspected outbreak where the action of a pool operator to undertake a superchlorination was discretionary rather than mandated. This was perceived to be compounded by a lack of definitive evidence (i.e. no microbial sampling to confirm if *Cryptosporidium* spp. was present in the water) to link the aquatic facility to the outbreak.

> *Sometimes it can be upwards of two to three weeks down the track from when they've [person ill with cryptosporidiosis] been swimming and they [pool operators] are still required to do the superchlorination, so it's really hard to get them on board, particularly when we don't really have any hard cut evidence. We won't have done the micro-testing to say that, yes, there is crypto in there.* (Jordan)

EHPs also highlighted that undertaking routine pool water testing was not mandated within the legislation in the same way that other tasks such as compliance inspections of food premises were legislated. Without this obligation, several EHPs identified that pool water testing was a discretionary task rather than a priority within their council.

> *It's not a priority … swimming pools have always been that last thing because it's not mandatory for us to inspect. Pools … they get done but it's never been a priority.* (Francis)

EHPs raised the issue of having no legislative power enabling them to advise on the design of individual swimming pools or layout of aquatic facilities that would assist in *Cryptosporidium* spp. prevention and control. One EHP experienced issues with water quality in a facility where the design prevented adequate circulation. It was believed that this issue could have been identified and prevented had the EHP been involved in the planning stage. However, with no legislative power, some EHPs suggested it would be difficult to influence the planning of new facilities.

> *Even if they did send you a referral, if you then said you wanted to change the plans of the toilets and showers [that] are here … yeah, good luck.* (Taylor)

Furthermore, the EHPs highlighted that there is currently no legislative requirement for aquatic facilities to be registered with their local council in Victoria. As a result, many EHPs experienced difficulties in identifying if new facilities were operating in their municipality. Some EHPs indicated that they had located new facilities while driving past while others reported that they had been informed about new facilities by the operators of other aquatic facilities.

> *In the last three-and-a-half years, I've found four swimming pools just by accident.* (Francis)

In addition, with no registration requirement, some EHPs experienced difficulties in identifying the appropriate contact person at each aquatic facility. To allow new facilities to be easily identified and to improve the accountability of both local council and aquatic facility operators, EHPs suggested that aquatic facilities could be regulated in a similar way as required by other public and environmental health legislation. This would require all aquatic facilities to be registered with their local council and require each facility to nominate a contact person who may be required to undertake certified training.

> *If they are registered with Council, I guess there would be an associated fee and then you get some kick-back by that as well, but I guess it's that accountability too, and you could almost go down the same path as the Food Act.* (Shannon)

Theme 5: Design – aquatic facility and swimming pool design

The layout of some aquatic facilities, particularly the location of showering amenities, was perceived by more than half of the EHPs to be inadequate as the design does not encourage good bather hygiene.

EHPs had visited several facilities where the swimming pool was closer to the entry of the facility than the showering amenities were. This meant that swimmers must go out of their way to shower, which the EHPs perceived was unlikely to occur. Water parks and splash parks were perceived to be high-risk facilities, due to the design and outdoor nature of these parks. One EHP reported a lack of showering amenities at these parks and a lack of fencing, which was thought to increase the risk of contamination from animals. Additional splash features often unique to these parks including sprinklers were perceived to increase swimmers' exposure to disease spread via the faecal-oral route.

> *About the water park … it's how exposed they would be to the faecal-oral route as well.* (Shannon)

Many EHPs commented that issues with *Cryptosporidium* spp. contamination and poor water quality were attributed to individual pool design. Issues with pool water quality were often associated with toddler pools, which typically have a lower volume of water. One EHP had experienced issues with the design of these pools where different shapes had created dead spots and inhibited water circulation. Another EHP had experienced receiving two different water quality results after testing pool water in two separate areas of the pool.

> *In the toddler pools, there's usually these fantastic shapes and you see that there's dead spots in the corners and no circulation that's happening.* (Shannon)

Issues within the pool were also thought to be associated with having multiple pools on the same filtration system. It was noted that the nature of a connected filtration system means that if a contamination incident occurs in one pool all pools must be closed and disinfected to prevent the contamination spreading between pools. Conversely, a separate filtration system allows the contaminated pool to be isolated and disinfected to prevent the spread of contamination. One EHP reported issues at an aquatic facility with a shared filtration system.

> *I've found issues with pools where they're using the same filtration system for numerous pools and there are a few … that would probably be my biggest thing … if you've got the filtration system with three pools going on it, you have to close down the three pools.* (Francis)

Discussion

Overall, this study identified more barriers to *Cryptosporidium* spp. prevention and control in aquatic facilities compared to enablers. Only two enablers were identified by EHPs: the usefulness of written guidelines produced by the Victorian Department of Health and Human Services; and aquatic facility operators who possessed the appropriate knowledge and skills related to water quality and *Cryptosporidium* spp. management being required to adequately maintain the facility. Unhealthy swimming behaviours by swimming pool users, issues with pool water testing focusing on chemical compliance, a lack of knowledge and skills among some aquatic facility operators, and deficiencies in aquatic facility and swimming pool design were perceived to be barriers to *Cryptosporidium* spp. prevention and control in aquatic facilities.

Several of these barriers have previously been reported. Many studies have already identified the unhealthy swimming behaviours exhibited by many pool users, such as not showering before swimming and swimming while experiencing symptoms, including vomiting and diarrhoea, of gastrointestinal illness.[37,38] This is an important barrier as human faeces, which may be excreted when exhibiting these unhealthy swimming behaviours, are often implicated or suspected as the source of many swimming pool associated outbreaks of cryptosporidiosis.[13-16] Similarly, it has also been identified that some aquatic facility operators lack the skills and knowledge to adequately maintain an aquatic facility. Poor maintenance including unsatisfactory chlorine levels,[11] inadequate policies to ensure safe pool water,[23] not maintaining facility equipment[14] and inadequate record keeping[24] have been associated with cryptosporidiosis outbreaks.

Barriers associated with the design of swimming pools have also been reported. Shared filtration systems contributed to two swimming pool-associated outbreaks of cryptosporidiosis affecting more than 250 people.[24,25] Toddler pools have also previously been implicated in outbreaks of cryptosporidiosis.[25] Toddler pools are more likely to contain *Cryptosporidium* spp. oocysts and the low volume of water may inhibit effective disinfection of these pools leading to problems with water quality.[39] These findings are important as the users of these pools, who are likely to be children under five years of age, are at a higher risk of becoming infected with *Cryptosporidium* spp. and have the highest rates of cryptosporidiosis compared to other age groups.[40] Splash parks and water parks were perceived by EHPs in the current study to place swimmers at a higher risk of contracting disease. This finding is supported by numerous reports of cryptosporidiosis outbreaks linked to water parks worldwide.[24-27] Investigations of some of these outbreaks have determined that exposure to water through splash features such as water play fountains and water slides was associated with illness.[24]

This study also extends the knowledge of previously reported barriers by identifying factors that may be influencing these identified barriers. For example, unhealthy swimming behaviours are a known barrier;[37,38] however, this study identified that these behaviours may be influenced by a lack of translated educational material or generational differences among pool users, both of which have not been reported and would benefit from further investigation. To our knowledge, the finding that the location of showering amenities within the facility does not encourage good bather hygiene has not previously been reported. Showering before swimming is considered important as a means of reducing the likelihood of water contamination, as any potential contaminants on the body, particularly external faecal matter, can be reduced.[41] This is an important finding that requires further consideration, as poor bather hygiene has been implicated or suspected as the source of cryptosporidiosis outbreaks associated with aquatic facilities.[13-16]

Barriers associated with current pool water testing conducted by EHPs including the focus on chemical testing and lack of focus on microbial water quality have also not previously been reported. These barriers are important to consider as EHPs have many responsibilities in aiding in the prevention and control of *Cryptosporidium* spp. in aquatic facilities including the responsibility of communicating with pool operators regarding the pathogen and disease.[7]

In addition to the perceived barriers and enablers identified in this study, a number of suggestions were provided by some EHPs to overcome perceived barriers. These included providing education to swimming pool users to promote healthy swimming practices and increasing the practical training

for EHPs in dealing with *Cryptosporidium* spp. in aquatic facilities. This is supported by previous research that has highlighted education on cryptosporidiosis and healthy swimming practices as an important aspect of preventing and controlling the disease.[21,24,25,42] For example, following an outbreak of cryptosporidiosis in Utah in the US in 2007, education regarding healthy swimming practices was provided to the public and a follow-up survey found an improved understanding of healthy swimming practices in Utah residents compared to other states. The authors noted that the correlation between increased knowledge and exhibiting healthy swimming practices is unknown; however, there were no cryptosporidiosis outbreaks associated with aquatic facilities in Utah for the four years following the education campaign.[42]

It is important to acknowledge the perceived usefulness of the guidelines produced by the Victorian Department of Health and Human Services in educating the EHPs. However, it is also important to consider the suggestion made by EHPs to have practical training. Further investigation is needed to determine the current level of training of EHPs and what could be implemented to further enhance the knowledge and skills of EHPs.

The key finding of this study relates to the theme of regulation where EHPs identified several barriers. These included a lack of legislative requirements relating to the monitoring and compliance of aquatic facilities, particularly the absence of a requirement for all aquatic facilities to be registered with their local council. EHPs suggested implementing legislation requiring all aquatic facilities to be registered with council. While regulation, in general, has been recognised as an important component of *Cryptosporidium* spp. prevention and control,[31] the scope and detail of this type of regulation has not been previously reported. The benefit of having a registration requirement for all aquatic facilities in Victoria warrants further investigation. While a similar registration requirement to the one suggested in the current study exists in Iowa in the US,[43] to our knowledge, there has been no peer-reviewed literature on registration systems for aquatic facilities and no studies evaluating the impact of these systems on cryptosporidiosis incidence associated with aquatic facilities. One aspect of this requirement was the suggestion to have aquatic facility operators undertake certified training. This may be beneficial as several studies have identified that adequate pool water maintenance and compliance with required parameters is more likely at facilities with trained operators.[44-46] One study conducted in Croatia reported a 23.5% decrease in non-compliant water samples after providing training to aquatic facility operators.[46]

This study provides new insight into *Cryptosporidium* spp. prevention and control in aquatic facilities from the perspective of EHPs, who have a key role in investigating cryptosporidiosis and inspecting aquatic facilities. To our knowledge, no similar studies have been conducted.

Limitations

As this was an exploratory study, one focus group was conducted to understand the experiences of EHPs and identify their perceived barriers and enablers to preventing and controlling *Cryptosporidium* spp. in aquatic facilities. Given only one focus group was conducted, a limitation of the study is that findings may not be applicable to broader contexts. EHPs were mainly employed at councils within metropolitan Melbourne and so it is likely that the findings may resonate with other metropolitan councils; however, there may be different barriers and enablers to preventing and controlling cryptosporidiosis in rural and regional councils. Despite this limitation, some findings are in line with other literature in this area.

Conclusion and implications for public health

Evidently, cryptosporidiosis associated with aquatic facilities is a complex issue. Several barriers and enablers to preventing and controlling this issue were perceived by EHPs. EHPs also identified some suggestions to perceived barriers. To aid in addressing this complex issue, these findings may have the potential to enhance the effectiveness of current prevention and control strategies. As this was an exploratory study, further research is needed to determine the nature of the impact of these barriers and enablers and suggestions to address perceived barriers on cryptosporidiosis incidence associated with aquatic facilities. Findings such as the suggestion for all aquatic facilities to be registered with local councils and the perceived impact of language barriers on poor knowledge and behaviour of swimming pool users and aquatic facility operators have not previously been reported and require further investigation.

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