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Swimming Pool Environment and Respiratory Health Issues Experienced by Masters Swimmers: Results from a Literature Review and Survey of United States Masters Swimming Clubs

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Cover Page Footnote

The authors of this report gratefully acknowledge the concern, collaboration, and guidance from the committee of Masters swimmers involved in this investigation, Tom Denes, Polly Phipps, Sangeeta Bhargava, and Dorothy Buchhagen, and United States Masters Swimming administrators and Sports Medicine Committee, Dawson Hughes, Daniel Paulling, Scot Raab, and Meg Carlson. This report is written in memory of the Masters swimmers who died of lung cancer, honoring their devotion to the sport and contributions to the USMS swimming community.

Abstract

After three members of a Masters adult swim club died of lung cancer, both a literature review and survey were conducted with representatives from 746 United States Masters Swimming clubs to explore a possible relationship between swimming and cancers of the respiratory tract. Six other clubs reported known cancers of the respiratory tract among club members, but none of the other 740 clubs reported a similar cluster of lung cancer. More clubs reported cases of chronic respiratory infections and widespread complaints about air quality. While no studies exploring a relationship between swimming and lung cancer could be found in the literature, there were studies that demonstrated damage to the lungs and mutated bladder cells post-swim from the presence of Disinfectant By-Products (DBPs). Few guidelines exist for safe levels of DBPs in the indoor pool environment. Authors urge more guidance regarding the enforcement of pool policies that protect respiratory health.

Keywords: Adult swimmers, health, swimming facilities, Masters swimming, respiratory illnesses

Introduction

Masters swimming has emerged as a popular recreational activity. United States Masters Swimming (USMS) is the governing body of Masters swimming in the U.S., sponsoring both competitions and workouts for adult swimmers who train primarily for the many health benefits that swimming offers. Over a three-year period, three members of a 250-member USMS club located in the suburbs of Washington, DC died of adenocarcinoma, the most common subtype of lung cancer to be diagnosed in people who have never smoked (Myers et al, 2019). The three swimmers were all 72 years-old at the time of death, non-smokers, and strong athletes who had spent a considerable portion of their adult years training primarily in an indoor pool environment. For 2016, incidence data compiled from cancer registries meeting U.S. Cancer Statistics data quality criteria show the rate of new cancers of the lung and bronchus (all types) for the 70-74 age group to be 330 per 100,000 or .33% (U.S. Cancer Statistics Working Group, 2019). Clusters of disease appearing within a community can be cause for concern. These three deaths spurred a preliminary investigation by a science committee of the Masters club comprised of scientists from the National Institutes of Health, an engineer, and an American University public health professor and undergraduate student to inquire whether there was anything in the scientific literature supporting a possible relationship between intensive swimming and lung cancer, and whether other Masters clubs had experienced similar clusters of lung cancer.

Method

The Center for Disease Control and Prevention (CDC, 1990) warned about the difficulty in investigating disease clusters and, even when "an excess" of a worrisome condition was confirmed, the likelihood of establishing a definite cause-and-effect relationship between the health event and an exposure was slight. Keeping this caveat in mind, the committee's first step was to review the literature investigating environmental exposures associated with swimming and respiratory health issues experienced by adult swimmers. The committee then created a 25-question Qualtrics survey, approved by American University's Institutional Review Board, to be sent by email to certified coaches/club representatives from each of the registered USMS clubs to learn of other clubs' experience with cancers of respiratory tract, including lung cancer, as well as respiratory health issues and concerns. The survey also collected descriptive data about the size of the clubs, age-range of members, number of practices offered, and more about the swimming pool environments where clubs held practices.

Results

Literature Review

Very few articles were found concerning environmental exposures among adult swimmers and the relationship of such exposures to health problems like cancer. Ten peer-reviewed articles examining the pool environment's effect on respiratory health from environmental health and medical journals were studied. Several articles focused upon the presence of Disinfectant-By-Products (DBPs) which form from the interaction of common pool chemicals like chlorine and bromine with swimmers' bodily fluids (e.g. sweat and urine) and skin-care products (e.g. sunscreen and deodorant). As background, the use of chlorine for water disinfection was hailed as a major public achievement of the 20th century; it was first used in 1850 by Dr. John Snow in an attempt to disinfect London's water supply during the infamous cholera epidemic. The first attempt to sterilize a swimming pool in the United States using chlorine was at Brown University in 1910, and this became more standard over the next 50 years. In 1961, the U.S. Public Health Service published a model ordinance governing the construction, sterilization, and use of public pools (Olsen, 2007). Today, chlorine remains the most widely used chemical for both drinking and swimming pool water disinfection in the U.S. (CDC, 2017). Bromine acts similarly to chlorine in the way that it kills bacteria and harmful contaminants but is more commonly used to sanitize pools heated at higher temperatures and hot tubs. A smaller but growing proportion of swimming pools are disinfected with saltwater electrolysis or ultra-violet light systems (Olsen, 2007).

In the indoor pool environment, the interaction between DBPs and the respiratory tract was found to be potentially harmful to swimmers (Carter & Joll, 2017, Richardson et al, 2010). A class of DBPs called chloramines which includes trichloramine (a gas that gives indoor pools their typical smell) has been found to be unstable in water and able to easily penetrate the lower airways of swimmers (Schmalz et al, 2011). Trihalomethanes (THMs), another class of DBPs which has been found to be carcinogenic in rodents (Kogevinas et al, 2010), have been detected in pool water and found to be seven times higher in the blood and exhaled breaths of swimmers after swimming in indoor pools (Lee & Zoh, 2009). More time spent swimming in chlorinated swimming pools was associated with increased THM concentrations (Kogevinas et al, 2010). Lee & Zoh also measured the lifetime cancer risks associated with exposure to THMs. They reported that individuals can be at increased risk for cancer through oral ingestion, dermal absorption, and inhalation of THMs with inhalation estimated to have the highest associated cancer risk. Studies exploring the effects of exposure to THMs specifically on lung cancer and other cancers of the respiratory tract were not found. Schmalz et al (2011) reported that the combination of trichloramine and other DBPs in the indoor swimming pool air produced inflammatory/adverse effects on lung cells. Kogevinas et al (2010) found that urine mutagenicity (i.e., causing a change in DNA) increased significantly after swimming. Richardson et al (2010), however, did not find a direct connection between DBPs in the water with mutagenicity of bladder or lung cells.

Recent studies confirm that chlorinated pools affect the lungs and are more likely to irritate the airways and lead to respiratory conditions like asthma (Carter & Joll, 2017; Fitch et al 2008). An earlier study of over 300 school children attending the same public pool in Brussels demonstrated a correlation between trichloramine and childhood asthma with cumulative pool attendance emerging as a strong risk factor for asthma among children (Bernard et al, 2006). Schmalz et al 2011 and Font-Ribera et al 2010 found that after swimming in a chlorinated pool, adult swimmers had increased lung permeability. When lung permeability was coupled with the increased lung capacity that was observed among athletes (Fitch et al, 2008), exposure increases which could make the lungs of athletes more susceptible to the harmful effects of DBPs and other chemicals.

Survey Results

The survey was sent to 3,314 email addresses of certified coaches or club representatives from each of the 746 registered United States Masters Swimming (USMS) clubs on April 12, 2019. An accompanying email explained that the purpose of the survey was to learn about respiratory health issues affecting Masters

swimmers and included questions about club size, age demographics, number of weekly practices, pool environment, and respiratory health issues and concerns reported by club swimmers.

Table 1
Descriptive Statistics

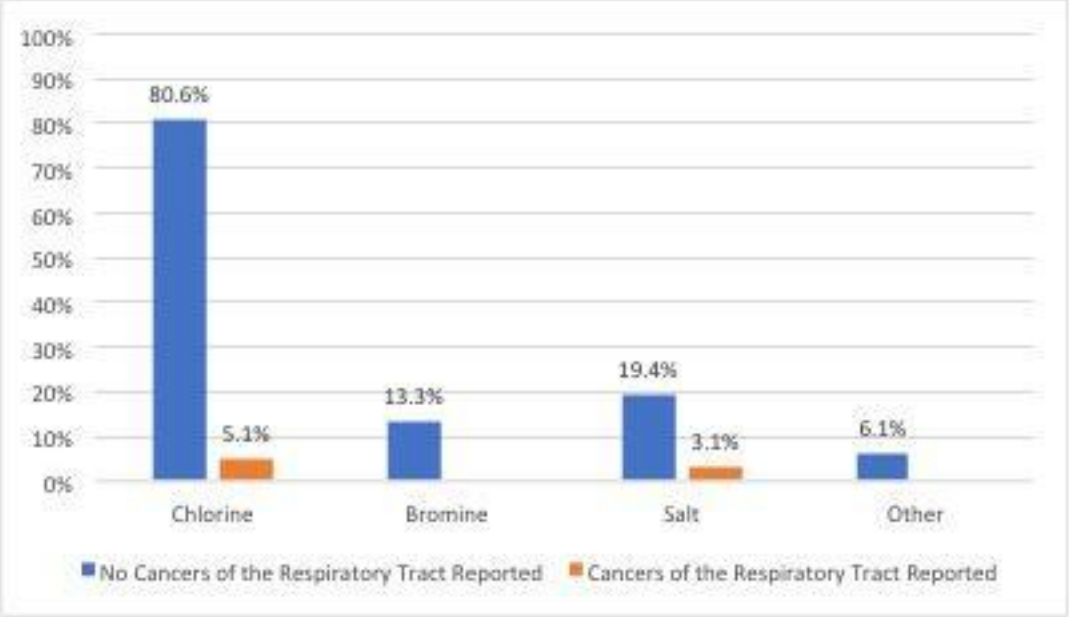
Variable	Min	Max	Mean	SD
Respondent's Years at Club	1	36	10.4	9.2
Club Size	2	600	75.1	106.4
% of Practices at Indoor Pool	0	100	67.83	41.8
% Member Ages				
18-29	0	60	5.2	8
30-39	0	60	10.5	11.2
40-49	0	70	16.6	15.5
50-59	0	100	18.2	16.89
60-69	0	80	11.9	13.7
70-79	0	40	4.6	7.2
80-89	0	20	1.2	3.2
90-99	0	21	0.4	2.4
Number of Weekly Practices	N	%		
<3	39	28.5		
4-6	46	33.6		
7-9	16	11.7		
10-12	17	12.4		
>13	19	13.9		
Role at Club	N	%		
Coach	102	72.9		
President	11	7.9		
Other	27	19.3		

The email had 1,529 opens, and there were 222 clicks on the Qualtrics survey link, yielding a total of 205 responses and a 27.5% response rate. 72.9% of the respondents were coaches and their mean number of years associated with the club was 10.4 (ranging from 1-36 years). Club size ranged from 2-600, with an average club size of 75.1; most of the clubs reported the highest percentage of their

swimmers falling in the 50+ age group. Most clubs offered more than 4-6 practices per week and 44% of the clubs held all of their practices at indoor pools. See Table 1 for a summary of statistics.

Chlorine was the most common disinfectant of indoor pools, used in some combination by 85.7% of the respondents (see Figure 1). Respondents were also asked about the chemical composition of the deck cleaners used at the pool; however, the majority of respondents were unable to provide any information about the type of deck cleaner used.

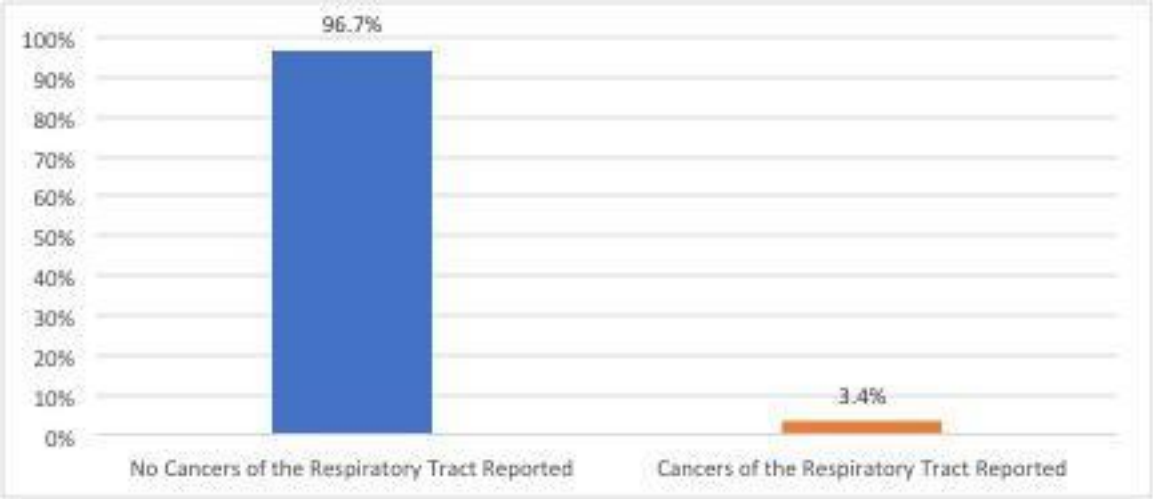
Figure 1
Disinfectants used in indoor pools



Lung Cancer and Other Cancers of the Respiratory Tract

Few other clubs reported a cluster of lung cancers similar to the cluster of three experienced by the club initiating the investigation. 96.7% of club respondents did not report any cancers of the respiratory tract (lung, bronchus, or larynx) among club members. A total of seven club respondents reported the known presence of respiratory tract cancers among club members (see Figure 2) with five respondents reporting the known presence of lung cancer (in the range of 1-4 cases). None of the club respondents reported a known history of smoking which was the only additional exposure inquired about, but which did not include asking about exposure to second-hand smoke among the swimmers afflicted with lung cancer.

Figure 2
Clubs reporting cancers of the respiratory tract among members



Chronic Respiratory Infections and Ventilation/Air Quality

Three of the seven clubs reporting cancers of the respiratory tract also indicated the presence of chronic respiratory infections among club members. For the entire sample, 38.7% of club respondents reported knowing of club members with chronic respiratory infections, with 34.8% of these respondents reporting more than five members known to have chronic respiratory infections. Thirty percent of club respondents who held practices—at least some of the time—at an indoor pool reported that their club members 'frequently' expressed concern about the ventilation/air quality in the club's primary indoor pool (see Figure 3).

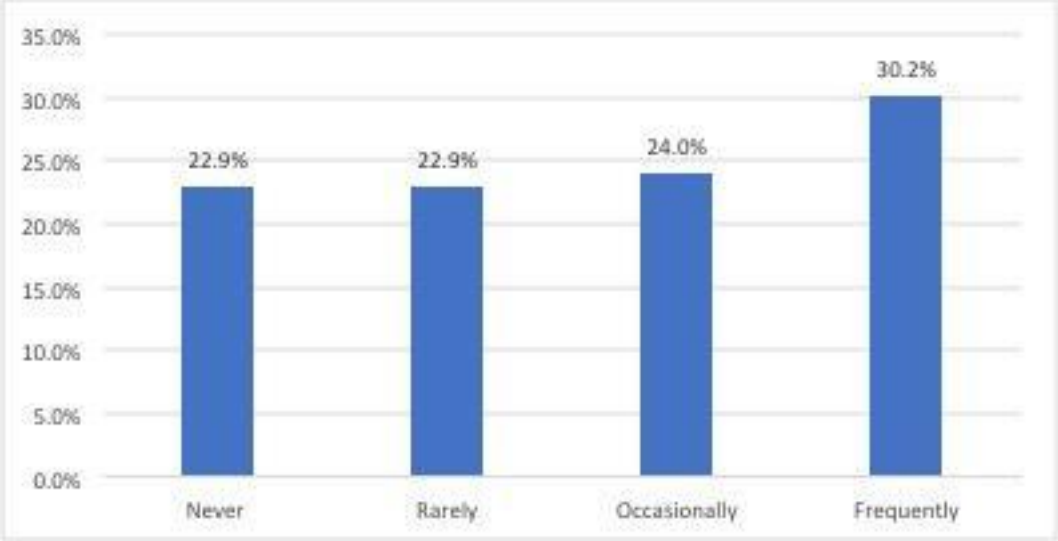
Club respondents frequently mentioned asthma, bronchitis, and sinus infections as the type of respiratory health issues experienced within the club. Club respondents reported very few known histories of smoking among swimmers experiencing other respiratory health issues. The survey data did reflect that USMS swimmers at clubs throughout the country complained about ventilation/air quality and chlorine management. Long time coaches noted far fewer instances of these types of complaints in the outdoor pool environment.

> One club reported 30 of its 50 members impacted by chronic respiratory infections and none with cancers of the respiratory tract. 75% of members are 50+, and the club offers 13 indoor practices/ week in a pool disinfected with chlorine only; members frequently express concern about ventilation at the main indoor pool where practices are held.

Another club reported 20 of its 92 members impacted by chronic respiratory infections and one case of cancer of the larynx. 60% of members are 50+ and the club offers 7-9 practices/week. 90% of the practices are held indoors; chlorine and salt are used to disinfect; members frequently express concerns about ventilation.

Figure 3

Frequency of air quality/ventilation concerns at indoor pools



Differences in Pool Environment, Number of Weekly Practices, and Showering Before Swimming Policies for Clubs Reporting Cancers of the Respiratory Tract

The small number of clubs reporting cancers of the respiratory tract (n=7) made it difficult to meaningfully compare differences in the pool environment and exposures between clubs with respiratory tract cancers and those without. For example, no meaningful differences existed in the percentage of practices held indoors between the small sample (n=7) of clubs reporting cancers of the respiratory tract (71%) and those not reporting any of these cancers (67.7%) (see Figure 4*)*. No obvious connection appeared between the reporting of cancers of the respiratory tract and the number of practices held a week, with at least one reported case in each range, and two cases in the 7-9 weekly practices range (see Figure 5).

Figure 4

Cancers of the respiratory tract reporting by percentage of indoor practices

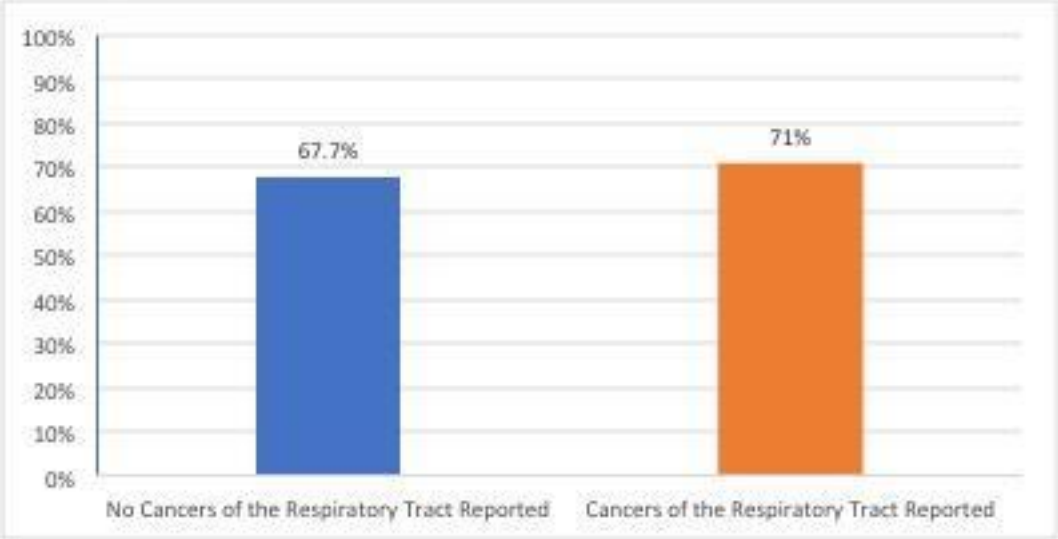
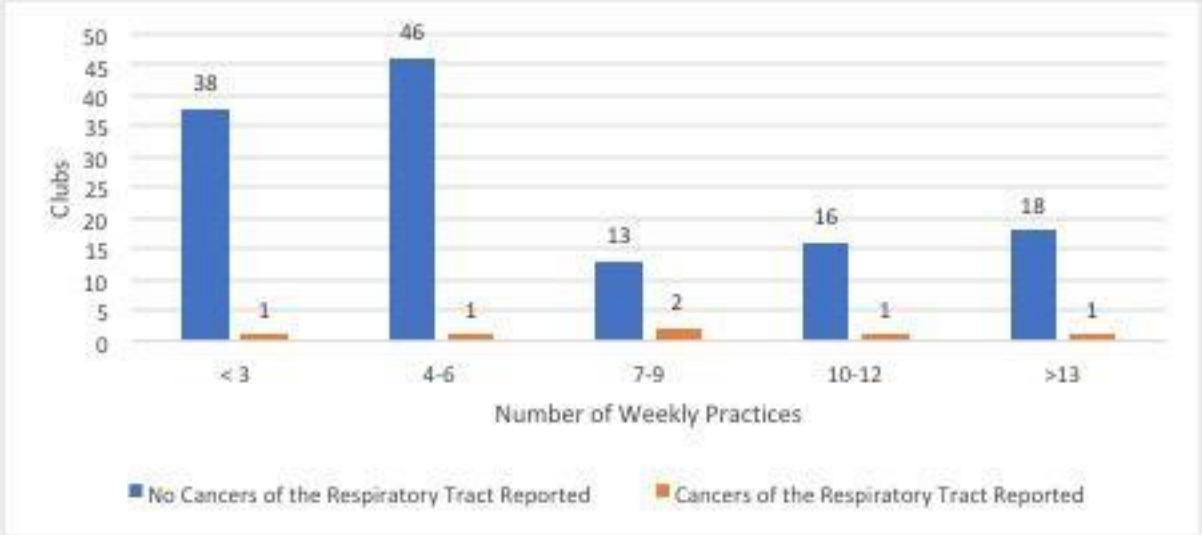


Figure 5

Cancers of the respiratory tract reporting by the number of weekly practices

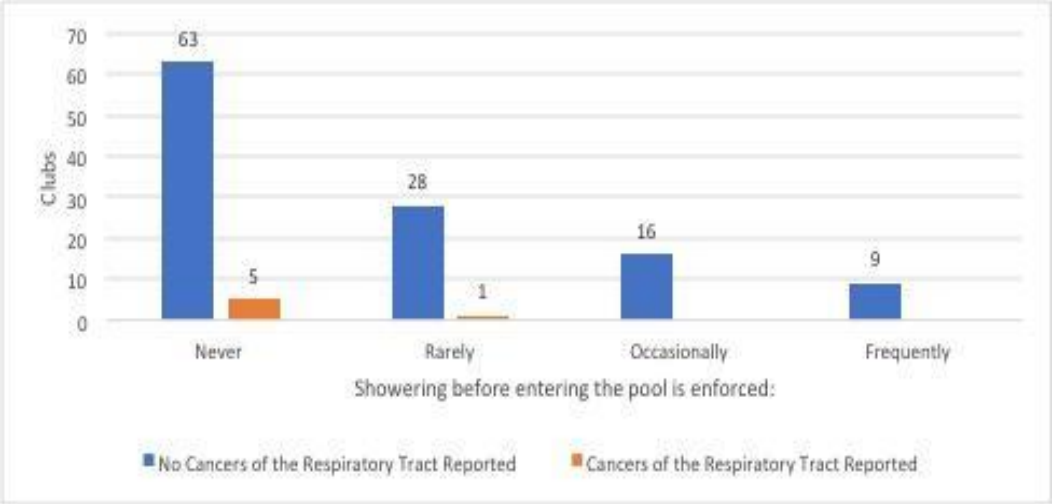


Additionally, complaints about ventilation/air quality and chlorine management were not found to be higher among the small group of clubs reporting swimmers with cancers of the respiratory tract. Showering before entering the pool is a practice that could reduce risk from the damaging effects of DBPs. All of the club respondents (100%) reporting the presence of cancers of the respiratory tract

indicated that showering before entering the pool was *never* or *rarely enforced*, while 21.6% of clubs reporting no cancers indicated that showering was *occasionally* or *frequently* enforced (see Figure 6). Because of the small number of clubs reporting cancers of the respiratory tract, it is not possible to attribute meaningful differences in the pool environments, practice schedules, and enforcement of showering policies between clubs with known cases of these types of cancers and the clubs without known cases of these types of cancers.

Figure 6

Cancers of the respiratory tract reporting by showering enforcement



Discussion

Masters swimmers are dedicated to improving or maintaining their fitness through swimming. They often spend high percentages of their leisure time in the pool. The positive health gains from swimming might be increased by reducing the potential health risks of the pool water (Kogevinas et al, 2010) caused by DBPs and other chemicals that lead to respiratory discomfort and could also be potentially mutagenic. Research findings recommended increasing air circulation in indoor pool settings to reduce the concentrations of DBPs as well as choosing a suitable disinfection method (Lee & Zoh, 2009); however, it is difficult to define "suitable" as studies are lacking directly comparing the DBPs generated by the wide variety of disinfectants currently used alone and in combination, including salt water electrolysis, chlorine, bromine, and ozone. Currently, apart from Germany and Denmark, few specific guidelines appear to exist worldwide or in the U.S. for the concentrations of DBPs in the swimming pool environment (Carter & Joll, 2017). The latest recommendation by the CDC in the United States, via section 4.6.2.7.81

of the Model Aquatic Health Code (MAHC), states that "sufficient return air intakes shall be placed near aquatic venue surfaces such that they remove the highest concentration of airborne DBP contaminated air" and that "the air handling system shall be designed considering airflow across the water surface to promote removal of DBPs" (CDC, 2018). While these two sections of the MAHC exist, our survey findings indicate that these guidelines are either too broad or not properly enforced, as 77% of club respondents have noted concerns about the air quality/ventilation at their indoor swimming pool facilities. Given that the production of DBPs increases when disinfectants like chlorine and bromine interact with bodily fluids and skin products, it is possible that policies around showering before entering the pool, which were found to be rarely enforced at the pools where USMS clubs hold their practices, could protect from some of the health problems associated with DBPs. Additionally, more studies are needed to investigate the health benefits/reduction of risk of using disinfectants other than chlorine.

Limitations

In analyzing the data collected, the authors note that we were unable to determine from this small study if the total number of known cases of lung and bronchus cancer within the USMS clubs exceeded the 56/100,000 rate of new cases found in the general population (U.S. Cancer Statistics Working Group, 2019). Additionally, as stated earlier, because of the small number of cancers of the respiratory tract reported, it is difficult to make meaningful comparisons between the swimming pool environments of clubs experiencing cancers of the respiratory tract and those without. And, because of the long latency associated with cancer, it is important to consider that exposures contributing to cancer development, whether within the swimming pool environment, home, or workplace, were likely to have begun many years or decades prior to both diagnosis and association with the Masters club.

The authors had hoped to be able to conduct a follow up study with other clubs reporting Masters swimmers with cancers of the respiratory tract to specifically learn more about types of lung cancer diagnosed and of both swimming-related and other exposures, but unfortunately, only one other of the seven club respondents reporting cancer provided contact information for follow up. Just six of these seven club respondents answered questions completely limiting what can be learned about conditions in the pool environment and these types of cancers. It should also be noted most club respondents were unable to provide comprehensive information about swimmers in the club afflicted with non-cancer respiratory health issues, as well. It is understandable that most Masters club coaches and leaders would not be aware of information like the smoking history of

club members or average hours per week spent swimming. The relationships and familiarity between coaches and participants can vary greatly within clubs, and it is reasonable to assume that respondents associated with the club for many years (e.g., one for 36 years) would be likely to report more details about the respiratory health of club members than those respondents with a shorter history with the club.

Since few club coaches are likely to know about environmental exposures experienced earlier in life by the club members with cancer of the respiratory tracts, (including the total number of years/hours per week spent swimming) it would be most helpful to obtain this information from family members and close associates, or, when possible, the afflicted swimmers themselves. Even with these limitations, we hope that our attempt to learn more about the swimming pool environment and respiratory health issues experienced by Masters swimmers may serve as a helpful first step to investigating these relationships. Another useful contribution from the analysis of this survey were the descriptive data generated from the 205 Masters swim clubs responding to the survey, including age range frequencies, number of practices offered, indoor vs. outdoor swimming pool environments, and disinfectants used. Perhaps further collaboration with USMS for a future study might generate more meaningful data demonstrating the importance of a safe swimming pool environment for protecting the health of Masters swimmers.

Conclusions

The survey with USMS club respondents/coaches and literature review were conducted in response to concern within a large USMS club about the possibility of an elevated risk for lung cancer for Masters swimmers. The literature review did not indicate cause for immediate alarm, but did support the possibility among swimmer athletes for the development of lung cancer from excessive inhalation of DBPs and other chemicals. The USMS survey results found just seven Masters clubs (of the 205 completing the survey) reporting known cases of cancers of respiratory tract and no other teams reported a cluster similar to the club that initiated the investigation. More conclusive data generated from the survey were that a greater number of clubs reported known cases of chronic respiratory infections and widespread complaints about ventilation/air quality.

Guidance from the CDC (1990) presented earlier in this report reminded us that looking more closely at cancer clusters may be useful for generating hypotheses (e.g., the combined carcinogenic effects on the lungs of the disinfectants and poor ventilation more often reported in the indoor pool environment) that can then be more rigorously investigated. With that in mind, the authors of this report recommend that the CDC, perhaps in conjunction with other researchers in the U.S.

who are studying water and air chemistry in the pool environment, conduct a robust epidemiologic investigation of adult swimmers who have been afflicted with lung cancer. In addition, we urge closer analysis and monitoring of indoor pool environments and consideration of alternatives to chlorine as a primary disinfectant. A team approach is needed to address these next steps to learn more about and ensure the safety of a popular, health-promoting past time.

- Generate more specific guidelines for Disinfectant-By-Products in the indoor pool environment and how they are measured and monitored.
- Encourage conversations with pool managers about the potentially harmful interaction of Disinfectant-By-Products with the respiratory tract, and the importance of establishing sufficient ventilation and rules enforcing showering before swimming.
- Interview family members/close associates of the Masters swimmers who have died from lung cancer to learn more about the number of years, hours/week spent in the indoor pool environment as well as exposure to known carcinogens including tobacco smoke, asbestos, and radon.
- Collaborate with the CDC's Healthy Swimming Program, CDC cancer epidemiologists, and researchers investigating swimming pool water disinfection methods and the effects on water and air chemistry in the indoor pool environment.
- Research protective health benefits from using less chlorine and newer disinfection processes such as UV light, salt, ozone, and direct hydroxyl injection.

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