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An Assessment of Disinfection-Related Water Chemistry at Public Pools and Spas in Louisville, Kentucky

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An Assessment of Disinfection-Related Water Chemistry at Public Pools and Spas in Louisville, Kentucky

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Abstract **The growth in the number of pools to more than 7.4 million in the U.S. has been accompanied by a rise in recreational water illnesses (RWIs). Effective pool management, though, can mitigate RWI risks. Inadequate management presumably occurs more frequently where training is less formalized and/or pool operation is a minor aspect of the job of the responsible pool manager(s). During summer 2018, weekly evaluations were performed at public venues in Louisville, Kentucky. Disinfectant levels and other items were monitored and compared with venue-specific (pool or spa) criteria. Among 1,312 venue surveys, 1,173 (89.4%) met criteria and 139 (10.6%) did not meet criteria. Overall, multivariable logistic regression showed a significant association between the likelihood of a venue meeting criteria and setting type. Specifically, hotels had 120% increased odds of not meeting criteria (adjusted odds ratio = 2.2; 95% confidence interval [1.3, 3.8]) compared with other settings. Despite spas having an 80% elevated odds of not meeting criteria compared with pools in a univariate analysis, upon adjusting for setting, spas were not associated with an increased risk of not meeting criteria. Research identifying reasons for these differences in meeting criteria between settings would be beneficial for informing public health interventions for aquatic environments.**

Introduction

With more than 7.4 million swimming pools in the U.S. as of the mid-2000s (Otto, 2006) there are typically between 300 million and 350 million swimming instances occurring annually in the U.S., making swimming one of the top four recreational activities in the U.S. (Otto, 2006; U.S. Census Bureau, 2009). With a substantial proportion of the U.S. population using pools, an accompanying substantial number of recreational water illnesses (RWIs) have been documented, including 27,219 illnesses and 8 deaths attributable to 493 reported outbreaks of RWIs from treated recreational water environments from 2000–2014 (Hlavsa, Kunz, & Beach, 2017). The frequency of RWIs is underestimated by outbreak reporting alone, as many RWIs are one of the following: not reportable conditions, not severe enough in affected patients to seek clinical evaluation, not able to be associated with recreational water exposure, and/or not part of a reported recreational water-related outbreak.

Effective pool management decreases the risk of users contracting RWIs. In studies examining 22,131 and 84,187 pool inspections in the U.S. from 2002 and 2013, respectively, 8.3% and 12.3% of the inspections warranted immediate closure of the pool being inspected (Centers for Disease Control and Prevention [CDC], 2003; Hlavsa et al., 2016). The most frequent violations observed in both studies were related to disinfection inadequacies specifically pertaining to disinfectant concentrations, pH, and chemical feeders. Inadequacies pertaining to pool disinfection can present harmful chemical exposure opportunities or enhance the survivability and/or growth of pathogens including but not limited to *Pseudomonas aeruginosa, Cryptosporidium, Giardia,* norovirus, and toxigenic *E. coli* (Black, Keirn, Smith, Dykes, & Harlan, 1970; Hlavsa et al., 2015; Seyfried & Fraser, 1980; Shields, Gleim, & Beach, 2008). Therefore, inadequate adherence to sound disinfection protocols enhances risks for respiratory, ocular, and cutaneous ailments among pool visitors and workers (Fantuzzi et al., 2010; Nickmilder & Bernard, 2007). Furthermore, swimmer shedding of microbial flora (including potential pathogens) occurs in aquatic environments (Gerba, 2000; Smith & Dufour, 1993) and when coupled with insufficient disinfection, this situation presents an increased infectious disease risk to recreators. Studies on untreated recreational waters have demonstrated a positive association between densitites of fecal indicator organisms in water and the risk of experiencing a swimming-associated gastrointestinal illness (Prüss, 1998; Wade, Pai, Eisenberg, & Colford, 2003), and this risk is greater when the contamination is of human origin (Soller, Schoen, Bartrand, Ravenscroft, & Ashbolt, 2010).

An analysis of treated recreational water-associated outbreaks by Hlavsa and coauthors (2017) indicates that the leading setting associated with 32% of the outbreaks from 2000–2014 were within hotel environments. Data on the population size recreating in hotel environments could be unknown, which limits recreational water-associated illness risk comparisons with other settings. Furthermore, among outbreaks with unidentified etiologies, hotel settings were linked to 56% of these 108 outbreaks between 2000 and 2014 (Hlavsa et al., 2017). In 2016, it was noted that studies on inspection failures could hold some utility for understanding setting-specific intervention opportunities that might reduce setting-specific RWIs including outbreaks; however, these types of data analyses were not possible due to their inspection forms and subsequent data being limited to pool category and not including setting (Hlavsa et al., 2016). Upon using data with pool setting documented, as done in a Georgia statewide analysis (N = 4,441), hotels and motels (n = 1,133) led the state in noncompliance related to disinfection residual concentrations and pH levels with 287 and 205 violations, respectively. In comparison, subdivision pools were the most numerous setting type in the 2014 Georgia database (n = 1,179) and had 113 and 64 events related to noncompliance in the disinfection residual concentrations and pH levels, respectively (Shack, Redmond, & Rustin, 2016).

While there has been much evidence published on the relationship between improperly managed swimming facilities, bacterial growth, and its association to outbreaks of RWIs, little research exists demonstrating the role of pool setting and how local health departments (LHDs) can tailor educational interventions with their business sectors and various pool operators so together they can be partners in protecting and promoting public health while preventing disease. Prior to developing sector-specific interventions related to pool health, data can help inform need. In this study, based upon prior observations reported in the literature, it was hypothesized that hotel swimming pools would be at greater risk for inspection failure than other settings and thus could be an area or sector whereby future in-depth study or tailored interventions might be warranted.

Methods

During summer 2018, data were collected from approximately one third of the public pools present in the Louisville metropolitan area of Jefferson County, Kentucky. Overall, 143 locations, many with more than one body of water (venue), were visited once per week from the end of May 2018 until the middle of August 2018. Each location was visited on the same day of the week, excluding days with inclement weather. During each visit, the pH, free chlorine, and alkalinity were screened using a LaMotte Insta-Test test strip. If free chlorine levels were out of range after the screening, either <1.00 ppm or >3.00 ppm (or <2.00 ppm or >6.00 ppm if the pool used bromine instead of chlorine), the water was then measured using a DPD (anhydrous N,N-diethyl-p-phenylenediamine) method, thereby providing a more accurate result.

For spas, the Louisville Metro Department of Public Health and Wellness states that standard spa chlorination should range from 2.0–3.0 ppm and the temperature should not exceed 104 °F (40.0 °C) (Louisville–Jefferson County Metro Government, 2020). Beyond pool chemistry, additional observations regarding pool environment safety were made during these visits. For any issues warranting further investigation in the interest of public health and safety, the health inspector in-charge was immediately notified for follow-up and intervention as needed.

The data collected throughout the day were logged daily into Microsoft Excel denoting the following:

1. survey location;
2. date of visit;
3. survey route used;
4. presence or absence of chlorine/bromine;
5. if the disinfectant was within, above, or below range;
6. general comments;
7. indoor or outdoor facility;
8. the facility setting (e.g., apartment, gym, swim school, hotel, etc.);
9. the inspection venue (i.e., pool or hot tub/spa);
10. number of water bodies present (e.g., pools, spas, etc.);
11. the pool pump manufacturer; and
12. pool filter manufacturer.

Data were unavailable for a majority of the pump and filter manufacturers and were therefore not included in the data analysis. Stata 15 was used for performing the statistical analysis. Descriptive statistics including means and frequencies were first examined to explore the value in later hypothesis testing. Crude and multivariable logistic regression analyses were then performed. For multivariable analyses, data were treated as clustered by primary sampling unit (PSU) with the svyset command in Stata. PSUs were the sample location identifiers previously established by the health department.

Upon developing the most parsimonious multivariable model, a saturated model was developed using all the significant (p < .05) and marginally associated (p < .15) terms from the individual crude analyses and then variables were removed sequentially by backward elimination. The independent variable of interest was the categorical variable pertaining to setting type (e.g., hotel, apartment/condominium, other) and the dependent variable was compliance (coded dichotomously for did or did not meet criteria). Continuous terms such as the number of venues (sum of the pools and hot tub/spas) at a setting and water body size were also examined in the models as categorical and/or on a $\log_{10}$ scale. Final models were examined for model fit using the Hosmer–Lemeshow goodness of fit test and model discrimination using the area under the receiver operator characteristic (ROC) curve.

Results

Overall, a total of 1,312 surveys were performed across 142 different settings. Complete data were gathered and entered for 1,284 (98%) of these surveys. Most surveys involved pools or hot tubs/spas in apartment complexes and condominium communities (n = 544), followed by other settings (n = 402), and hotels/motels (n = 366). Within the classification of "other," fitness centers, clubs, and community/neighborhood pools represented 318 of the 402. Results from t-testing and Mann–Whitney testing demonstrated that hotel pools were on average and by rank (smallest to largest) significantly smaller in size (by volume) than both apartment/condominium pools and the other pools ($p < .0001$). In gallons, the median size hotel venue (pools and spas) was 12,600 gallons versus 31,600 gallons for apartments/condominiums and 79,400 gallons for other pools (Table 1).

Overall, among the 1,312 venue surveys, 1,173 (89%) were observed to meet disinfection criteria. Among the 139 (11%) observed not meeting criteria, 66 (47%) were from observations occurring at hotel/motel settings (Table 2). The hotel setting ($n = 366$) represented 28% of all surveys. Univariate logistic regression provides the crude odds ratio (c*OR*) not adjusting for other factors and suggests that the odds of not meeting criteria were 160% (c*OR* = 2.6) higher in the hotel/motel setting compared with all nonhotel/motel settings and 250% higher (c*OR* = 3.5) than the "other" setting, which includes all settings except apartment/condominium pools. Crude analysis also suggested that indoor locations, spas, and survey routes E and L were linked to significant ($p < .05$) increased odds (c*OR* > 1.0) of not meeting criteria (Table 2). Chlorine treatment, more pools/spas, and larger venues were associated with a significantly lower likelihood of not meeting criteria (c*OR* < 1.0) and therefore were more likely to meet disinfection criteria (Table 2).

For evaluating the relationship between hotel/motel settings and meeting disinfection criteria more thoroughly, the most parsimonious multivariable model was created, which accounted for the clustering effect of sampling by the 142 PSUs and adjusting for significant covariates. Table 3 demonstrates that venue size in $\log_{10}$ gallons, survey route, and number of venues at a location were significant ($p < .05$) covariates. The other covariates that were significant in Table 2 but not present in the model in Table 3 were removed sequentially using the backward elimination approach as they were no longer significant, possibly being explained better by the terms that remained. Ultimately, the final multivariable model provides adjusted odds ratios (a*OR*), demonstrating that the adjusted odds of not meeting criteria were 120% higher (a*OR* = 2.2; 95%, confidence interval (*CI*) [1.3, 3.8]) among hotels/motels than nonhotel/motel settings. Larger water volumes and more venues at the survey locations were associated with an increased likelihood of meeting criteria. The overall model discrimination using the area under the ROC curve was 69% and the model achieved adequate fit whereby there was no difference ($p > .05$) between the fitted modeled results and the actual observations.

TABLE **1**

Descriptive Statistics of Continuous Variables by Setting Type

Setting Type	Setting Attribute	#	Mean	Median	Range
Hotel/motel	Venues per location	366	1.6	2.0	1.0–2.0
Hotel/motel	Venue size ($\log_{10}$ gallon)	366	3.9	4.1	0–5.9
Hotel/motel	Venue size ($\log_{10}$ L)	366	4.5	4.7	0–6.5
Apartment/condominium	Venues per location	544	1.2	1.0	1.0–3.0
Apartment/condominium	Venue size ($\log_{10}$ gallon)	544	4.3	4.5	0–5.6
Apartment/condominium	Venue size ($\log_{10}$ L)	544	4.9	5.0	0–6.2
Other setting	Venues per location	402	2.8	2.0	1.0–6.0
Other setting	Venue size ($\log_{10}$ gallon)	402	4.6	4.9	0–5.8
Other setting	Venue size ($\log_{10}$ L)	402	5.2	5.5	0–6.4

Spas and indoor pool settings did not appear to significantly influence the final model in Table 3. When in the adjusted model, neither spas ($p = .652$) or indoor pools ($p = .720$) were significant and were dropped. In the crude univariate analysis (Table 2), both terms were associated with a significant increase in the odds of not meeting criteria (*OR* > 1.0; $p < .05$). Furthermore, hotel settings are significantly more likely to have hot tubs/spas and indoor pools than other settings (chi-square $p < .05$). Specifically, among 946 surveys in nonhotel environments, only 23 (2.4%) occurred at spas versus 110 (30%) of 366 in hotel environments. Overall, 82% of hotel pool surveys occurred at indoor venues versus 17% of surveys in nonhotel/motel environments. To further explore this issue, additional stratified analyses occurred.

In the case of both pools and spas, the frequency of not meeting criteria was higher in all hotel venues compared to nonhotel setting venues; whereby the frequency of not meeting criteria, regardless of venue, was >18% across hotel strata (Tables 4 and 5). Among hotels, of greatest risk were the outdoor pools with a 23% failure frequency and a 200% greater likelihood of not meeting criteria than nonhotel outdoor pools (a*OR* = 3.0; 95% *CI* [1.3, 7.0]; Table 5). Spas in nonhotel settings were not significantly different than pools in nonhotel settings in univariate (c*OR*) or multivariable analyses as demonstrated by the 95% *CI* including numbers both below and above 1.0 (Table 4). Similar findings were demonstrated in Table 5 whereby in nonhotel settings, there was no difference in the frequency of meeting criteria among indoor and outdoor pools.

Discussion

This study was specifically limited to approximately one third of the public swimming pools and hot tubs/spas located in the Louisville metropolitan area, as these venues were assigned to the lead study investigator before the summer season as part of a defined geographic region. Overall, 10.6% of the total surveys yielded results that indicated disinfection criteria were not being met. While 18% of hotel pool surveys did not appear to meet criteria related to disinfection, the frequency was lower: 9% among apartment/condominium pools and 6% among other setting types. The descriptive results demonstrate that across all sectors there are opportunities for improvement in meeting public health standards. Beyond the apparent challenges observed among hotel/motel settings with respect to meeting disinfection criteria, our study demonstrates that locations with more venues and larger volumes of water are more likely to meet criteria (Tables 2 and 3). It is plausible that large facilities with larger pools, such as waterparks or recreation centers, view ensuring compliance with greater emphasis because the larger pools are likely to be more essential to their visitors' experi-

TABLE **2**

Univariate Analyses (Crude Odds Ratio) Pertaining to Relationships Between Categorical Items Surveyed and Compliance With Disinfection Criteria Set by the Local Health Authority

Covariate	Category	# of Surveys	Not Meeting Criteria # (%)	c*OR* (95% *CI*)	*p*-Value
Disinfectant	Bromine	274	43 (15.7)	Referent	
	Chlorine	1,029	95 (9.2)	0.55 (0.37, 0.81)	.002
Number of pools/spas	1	734	81 (11.0)	Referent	
	2	376	50 (13.3)	1.24 (0.85, 1.80)	.269
	≥3	202	8 (4.0)	0.33 (0.16, 0.70)	.004
Location setting	Other	402	24 (6.0)	Referent	
	Apartment/condominium	544	49 (9.0)	1.56 (0.94, 2.59)	.086
	Hotel	366	66 (18.0)	3.47 (2.12, 5.66)	<.001
Hotel setting	Other	946	73 (7.7)	Referent	
	Hotel	366	66 (18.0)	2.63 (1.84, 3.76)	<.001
Size (gallon x 1,000)	<15[a]	330	48 (14.6)	Referent	
	≥15–26[b]	323	41 (12.6)	0.85 (0.54, 1.32)	.462
	≥26–53[c]	336	32 (9.5)	0.62 (0.38, 0.99)	.048
	≥53–780[d]	320	18 (5.6)	0.35 (0.20, 0.62)	<.001
Aquatic venue	Pool	1,179	117 (9.9)	Referent	
	Spa	133	22 (16.5)	1.80 (1.10, 2.96)	.020
Indoor/outdoor	Outdoor	843	76 (9.0)	Referent	
	Indoor	460	62 (13.5)	1.57 (1.10, 2.25)	.013
Inspection route	F	449	30 (6.7)	Referent	
	E	410	62 (15.1)	2.49 (1.57, 3.93)	<.001
	G	231	18 (7.8)	1.18 (0.64, 2.17)	.593
	L	203	26 (12.8)	2.05 (1.18, 3.57)	.011

c*OR* = crude odds ratio; *CI* = confidence interval.
[a]<56,000 L.
[b]≥56,000–98,000 L.
[c]≥98,000–201,000 L.
[d]≥201,000–295,000 L.

ence and therefore to the venue's business model than a hotel with a five-person-capacity pool. Additionally, smaller venues might be more likely to experience challenges in terms of both quantity and water volume due to more rapid changes in water quality for a variety of reasons.

The results here are among a few studies that have assessed disinfection-related data with consideration of aquatic setting (Shack et al., 2016). Our results demonstrate a need to assist small pool operators and hotel operators with meeting disinfection criteria. Furthermore, our results appear congruent with reporting related to the Centers for Disease Control and Prevention's Network for Aquatic Facility Inspection Surveillance, whereby 11.9% of the 64,580 routine inspections performed in 2013 resulted in noncompliance in meeting disinfection standards (Hlavsa et al., 2016). In this study, looking at the 2018 Louisville Metro data, we observed 10.6% of the surveys performed to have not met disinfection criteria.

Beyond inspecting facilities on a regular basis, strategies that put greater emphasis on encouraging the certification of pool operators likely would enhance pool water chemistry simply due to increased education and awareness. This approach has been demonstrated previously in a study where pH levels and combined chlorine levels of inspected pools were significantly more likely to be in compliance in facilities that employed certified pool operators versus noncertified operators (Johnston & Kinziger, 2007). Enhanced communication and stronger encouragement of pool operator certification and/or education with managers of hotels and other public swimming venues go beyond regulatory enforcement, but likely are tantamount for promoting and protecting public health.

For instance, free chlorine and pH violations during routine pool inspections in Nebraska were twice as likely to occur at locations not requiring pool operators to be certified (Buss et al., 2009). Similar benefits of training were again observed outside the U.S. in Croatia (Bilajac, Vukić Lušić, Doko Jelinić, & Rukavina, 2012).

Operator certification and training are described in the Model Aquatic Health Code (MAHC), which comprises voluntary guidelines for authorities updating or establishing codes related to aquatic facilities (CDC, 2018). The MAHC includes provisions for facilities to have qualified operators. Operators are credentialed by the authority having jurisdiction through participation in training recognized by the authority. The MAHC identifies water disinfection and water chemistry as two of the four minimum teaching elements for training (CDC, 2018). Also included in the MAHC are provisions aimed at reducing pool chemical injuries. Mini-MAHCs have been developed, including one on pool chemical injuries because there are more than 13,000 estimated annual emergency room visits associated with pool chemical exposures in public and residential environments (Laco, Hubbard, & McClenahan, 2020; Vanden Esschert et al., 2019).

Continued surveillance on public swimming pools is essential for public health, as swimming and water recreation have become more popular in recent decades. Given that more than 1,000 illnesses from RWI outbreaks occur annually, with many more occurring outside of outbreaks, it is clear that monitoring swimming facilities remains necessary (Otto, 2006). CDC and the National Environmental Health Association offer pool inspection training and an Aquatic Inspector app for iPads as a way to support monitoring efforts (Laco et al., 2020).

Based on research by Rose and Ludwig (2009), increasing regular communication between LHDs and public entities has the potential to reinforce compliance with health standards. Working together, businesses, LHDs, and nongovernmental organizations can potentially usher in a sharing of useful resources and data. This approach ultimately can improve aquatic facility staff's understanding that environmental health professionals are willing to be partners in public health, answer questions, and share advice related to best management practices (Beatty, Harris, & Barnes, 2010).

TABLE **3**

Multivariable Logistic Regression Model and Associated Adjusted Odds Ratios Demonstrating the Relationship Between a Finding of Not Meeting Criteria And Various Covariates

Covariate	β	Wald's *t*	*p*-Value	a*OR* (95% *CI*)[a]
Hotel pool/spa	0.802	3.00	.003	2.23 (1.32, 3.78)
Pool size ($\log_{10}$ L)[b]	-0.254	-2.38	.018	0.78 (0.63, 0.96)
Route F	Referent			Referent
Route E	0.604	1.77	.078	1.83 (0.93, 3.59)
Route G	0.263	0.78	.435	1.30 (0.67, 2.52)
Route L	0.720	1.97	.051	2.05 (1.0, 4.22)
Number of pools/spas	-0.305	-2.27	.025	0.74 (0.56, 0.96)
Constant	-1.136			

a*OR* = adjusted odds ratio; *CI* = confidence interval.

[a]a*OR* values with a 95% *CI* range >1.0 are associated with a greater likelihood of not meeting criteria. a*OR* values with a 95% *CI* range <1.0 are associated with a greater likelihood of meeting criteria.

[b]When expressed in $\log_{10}$ gallon: $\beta = 0.758$; $t = -2.35$; a*OR* (95% *CI*) = 0.76 (0.60, 0.96); and $p = .020$.

TABLE **4**

Univariate and Multivariable Analysis for Frequency of Meeting Disinfection Criteria by Hotel Pools and Spas Versus Nonhotel Pools and Spas

Covariate	# of Surveys	Does Not Meet Criteria # (%)	c*OR* (95% *CI*)	a*OR* (95% *CI*)[a]
Nonhotel pool	923	72 (7.8)	Referent	Referent
Nonhotel spa	23	1 (4.4)	0.54 (0.07, 4.0)	0.51 (0.21, 1.26)
Hotel pool	256	45 (17.6)	***2.52 (1.69, 3.77)***	***2.21 (1.25, 3.93)***
Hotel spa	110	21 (19.1)	***2.79 (1.63, 4.75)***	*2.02 (0.88, 4.67)*

c*OR* = crude odds ratio; a*OR* = adjusted odds ratio; *CI* = confidence interval.

[a]The adjusted model expressed includes covariates included in the final model from Table 3.

Note. Italicized numbers indicate $p < .10$. Italicized and bolded numbers indicate $p < .05$.

Limitations

The schedule might have biased the results because each location was planned to be surveyed on the same day each week based on the specific routes; therefore, the survey times could have been predicted by operators. Additionally, a higher rate of patronage would be expected on the weekend than on the weekday sample dates. Despite awareness of an impending arrival of a surveyor, not meeting pool disinfection standards remained common and more problematic pool chemistry might have existed in higher frequencies on dates where inspections were not expected or on the weekends.

Our study might not be applicable to all of Louisville, Jefferson County, Kentucky, or larger geographic areas. The pools studied were all assigned to the same surveyor covering the east side of the metropolitan area. Almost no pools or spas near the city

TABLE **5**

Univariate and Multivariable Analysis for Frequency of Meeting Disinfection Criteria Frequency Among Indoor and Outdoor Aquatic Venues in Hotel and Nonhotel Settings

Covariate	# of Surveys	Does Not Meet Criteria # (%)	c*OR*	a*OR* (95% *CI*)[a]
Nonhotel outdoor	778	61 (7.8)	Referent	Referent
Nonhotel indoor	159	11 (6.9)	0.87 (0.44, 1.7)	1.16 (0.57, 2.34)
Hotel outdoor	65	15 (23.1)	**3.52 (1.87, 6.64)**	**3.03 (1.33, 6.96)**
Hotel indoor	301	51 (16.9)	**2.40 (1.61, 3.57)**	**2.16 (1.16, 4.01)**

c*OR* = crude odds ratio; a*OR* = adjusted odds ratio; *CI* = confidence interval.
[a]The adjusted model expressed includes covariates included in the final model from Table 3.
Note. Bolded numbers indicate $p < .05$.

center were included. The results given in the study might show a greater frequency of meeting disinfection criteria than other communities due to the active nature of the health department with respect to aquatics compared with other departments. Lastly, the statistical model in Table 3 achieved nearly 70% discrimination in detecting surveys whereby the disinfection criteria were not met. More variables, such as knowledge of pumps, filter models, and other factors also could have influenced results. Due to limited operator recordkeeping of pump and filter models, some variables could not be studied. Also, when stratifying, some of the strata reflected a low number of pools. This finding suggests that larger studies, possibly even national studies, are warranted to confirm these results for informing interventions to enhance pool chemistry compliance.

Conclusion

The results from our study demonstrate the location or setting of aquatic venues (pools and spas) are linked to compliance. Statistically significant differences ($p < .05$) were observed between hotel and nonhotel settings with respect to the frequency of their venues meeting disinfection criteria. These results suggest a need for further research into why this difference exists between facility setting types, because this information could inform intervention opportunities. Additionally, our study validated the idea that as more aquatic venues are present at one location, the location is more likely to meet criteria overall. Larger facilities with aquatics being central to their operations can invest greater resources toward responsible pool maintenance and compliance for preventing pool closures; however, more research is needed to validate this claim. Larger studies with a regional or national focus could further validate the observations in our study, which could enable better interventions for protecting the health of people in the U.S. who engage in aquatic recreation.

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continued on page 24

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