

Water Exposure is a Common Risk Behavior Among Soft and Gas-Permeable Contact Lens Wearers

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Purpose: To understand soft contact lens (SCL) and gas-permeable (GP) lens wearers' behaviors and knowledge regarding exposure of lenses to water.

Methods: The Contact Lens Risk Survey (CLRS) and health behavior questions were completed online by a convenience sample of 1056 SCL and 85 GP lens wearers aged 20 to 76 years. Participants were asked about exposing their lenses to water and their understanding of risks associated with these behaviors. Chi-square analyses examined relationships between patient behaviors and perceptions.

Results: GP lens wearers were more likely than SCL wearers to ever rinse or store lenses in water (rinsing: 91% GP, 31% SCL, $P < 0.001$; storing: 33% GP, 15% SCL $P < 0.001$). Among SCL wearers, men were more likely to store (24% vs. 13%, $P = 0.003$) or rinse (41% vs. 29%, $P = 0.012$) their lenses in water. Showering while wearing lenses was more common in SCL wearers (86%) than GP lens wearers (67%) ($P < 0.0001$). Swimming while wearing lenses was reported by 62% of SCL wearers and 48% of GP lens wearers ($P = 0.027$). Wearers who rinsed (SCL; $P < 0.0001$, GP;

$P = 0.11$) or stored lenses in water (SCL; $P < 0.0001$, GP $P = 0.007$) reported that this behavior had little or no effect on their infection risk, compared with those who did not. Both SCL ($P < 0.0001$) and GP lens wearers ($P < 0.0001$) perceived that distilled water was safer than tap water for storing or rinsing lenses.

Conclusions: Despite previously published evidence of *Acanthamoeba* keratitis' association with water exposure, most SCL, and nearly all GP lens wearers, regularly expose their lenses to water, with many unaware of the risk.

Key Words: soft contact lenses, gas-permeable lenses, *Acanthamoeba*, keratitis, swimming, showering

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There are approximately 40.9 million contact lens wearers in the United States, of whom >90% wear soft contact lenses (SCL).¹ Proper lens care, such as replacing care solution daily,² using a clean storage case,³ and avoiding overnight wear,⁴ is essential to minimize the risk of adverse events such as microbial keratitis (MK) and corneal inflammatory events (CIEs). One of the most visually devastating forms of MK is *Acanthamoeba* keratitis (AK). Nearly 85%⁵ of *Acanthamoeba* cases occur in contact lens wearers, and a primary risk factor for developing AK is exposing contact lenses to water.⁶

Acanthamoeba has been found in air, dust, soil, and water—including tap water.^{5,7} Contact lens wearers have contracted *Acanthamoeba* from exposure to pools,⁸ hot tubs,⁸ homemade saline,⁹ and from household tap water.¹⁰ Other commonly isolated pathogenic microbes associated with contact lens-related complications include strains of *Pseudomonas*, *Serratia*, *Stenotrophomonas*, and *Achromobacter*, all of which can be found in tap water or in plumbing system biofilms.^{11,12}

Avoiding tap water exposure when wearing contact lenses is important,¹⁰ yet, many gas-permeable (GP) lens product package inserts instruct the patient to use water during the lens cleaning process and most SCL package instructions do not mention risk of exposure of lenses to water. Such water exposure potentially contaminates the lens and storage case and places the patient at risk for serious infection. A recent case report draws attention to an AK case, in which a patient complied with manufacturer GP care solution guidelines, which included a tap water-rinsing step, and an infection developed.¹³ Those authors emphatically

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called for changes in industry labeling and in practice to eliminate the use of tap water for cleaning GP lenses or any storage cases. They also sought better warnings for patients on the danger of using tap or distilled water for lens care.¹³

Despite warnings from the United States Food and Drug Administration (FDA)¹⁴ and the Centers for Disease Control and Prevention (CDC)¹⁵ about the risks of contact lens exposure to water, products that instruct wearers to use tap water during cleaning and rinsing remain on the market and cases of AK have not declined since the 2007 US multistate *Acanthamoeba* keratitis outbreak investigation.¹⁶

The purpose of this study was to evaluate the attitudes and behaviors of a contemporary cohort of contact lens wearers regarding their lenses and water exposure through an online survey of behaviors and perceptions relating to contact lens wear.

METHODS

This study is a secondary analysis of data collected from an adult population to evaluate self-reported behaviors related to contact lens wear and water exposure. The study followed the Declaration of Helsinki and received approval from The Ohio State University Institutional Review Board. To be an eligible participant, one had to be a current (wore lenses in the week preceding the survey) GP or SCL wearer aged 18 years or above. Participants were recruited by a marketing research company (Schlesinger Associates, Iselin, NJ), which fielded the survey online. Participants were members of the research firm's market research panel and wore contact lenses. Panel members were recruited in-person, through internet advertising, e-mail campaigns, or telephone calls. Panel members were located in the United States and were not geographically restricted.

To describe the prevalence of the hygiene and demographic factors related to contact lens wear, the Contact Lens Risk Survey (CLRS)¹⁷ was administered to the sample of contact lens wearers described above.¹ The CLRS was developed for SCL wearers and was adapted to include GP lens wearers. The CLRS uses a standard methodology and validated set of questions,^{17,18} including questions pertaining to self-reported demographics, closed eye conditions, exposure of lenses to water, and case hygiene. Several questions were also added to assess perceptions and beliefs toward behaviors of contact lens wear and care.

Water-related behaviors surveyed included rinsing lenses with tap water, storing lenses in tap water, showering with

lenses, swimming while wearing lenses, and handling of the lens case after lens application to the eye. Response options for the frequency of practicing a behavior were "always," "fairly often," "sometimes," "infrequently," and "never." For swimming, the response options were "daily," "weekly," "monthly," "<monthly," and "never." Options for what was done with the lens case after lenses have been placed on the eye included "rinse with solution," "rinse with water," "dry with tissue," "put caps back on," "air dry without caps," and "other." For several behaviors, participants' perceptions were queried as to whether a particular behavior "prevents infection," "has little/no effect," or "is likely to cause infection."

Because of the inherent risk of exposing contact lenses to water, participants with a reported response of ever practicing a behavior (ie, always, fairly often, sometimes, infrequently) were grouped together during analysis and then compared with those who reported never performing that behavior. Using χ^2 analysis, statistical comparisons were made regarding specific behaviors and their corresponding perceptions. The Bowker test of symmetry was used to compare perceptions related to tap and distilled water for rinsing and storing lenses. Additional corrections for multiple comparisons were not incorporated. Sample sizes for each reported behavior or perception differ because of incomplete responses.

RESULTS

The survey was completed by 1141 adults consisting of 1056 SCL wearers and 85 GP lens wearers. The SCL wearers were younger (range: 20–76 yrs, mean 44.3 ± 11.9 yrs) than the GP lens wearers (range: 23–74 yrs, mean: 52.7 ± 12.4 yrs) ($P < 0.0001$). The majority of participants were women and white (Table 1).

Exposures to Water

Of the 85 GP lens wearers surveyed, 81 provided responses to the rinsing and storing questions. Of those 81, 91% reported that they ever rinsed their lenses with tap water, compared with 31% of the 1008 SCL wearers ($P < 0.001$) (Fig. 1). Of the 81 GP lens wearers, 33% reported storing lenses in tap water compared with 15% of 894 SCL wearers ($P < 0.001$) (Fig. 1). Of 184 male SCL wearers, 41% reported rinsing their lenses with tap water compared with 29% of 824 female SCL wearers ($P = 0.012$), but this difference was not found among 12 male GP lens wearers (100%) and 90% of 69

TABLE 1. Demographic Characteristics of CLRS Participants

Race	Men	Women	Age, Mean (SD), yrs	Age Range, yrs	Soft Lenses	GP Lens
African American	19	115	44.5 (11.4)	21–69	131	3
Asian	13	34	37.2 (9.1)	23–64	44	3
Hispanic	19	44	39.7 (10.5)	22–64	58	5
White	144	685	46.1 (12.1)	20–76	758	71
Mixed	7	47	40.3 (11.3)	23–69	53	1
Not reported	2	12	45.4 (14.7)	23–70	12	2
Total	204 (18%)	937 (82%)	44.9 (12.1)	20–76	1056 (93%)	85 (7%)

Reported Frequency of Tap Water Exposure Behaviors for Gas Permeable and Soft Lenses

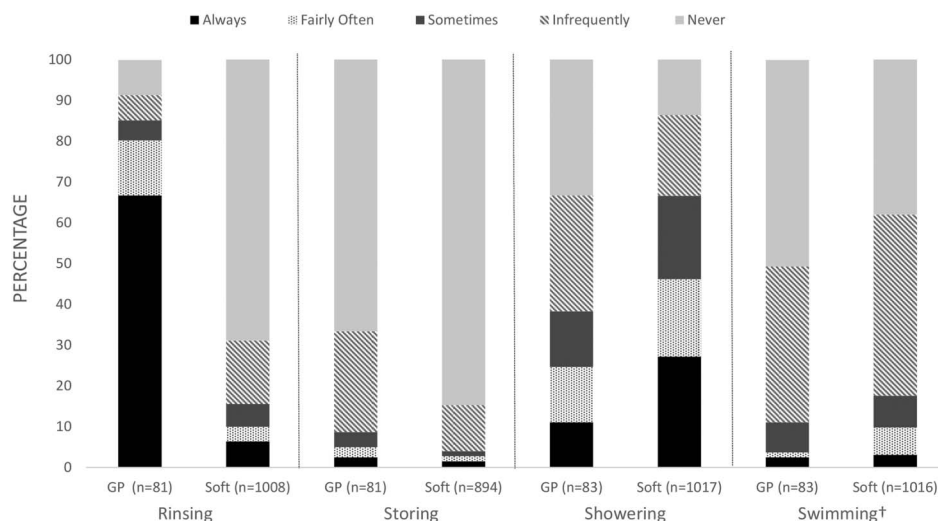


FIGURE 1. Reported frequency of soft lens and gas-permeable lens exposure to water through rinsing, storing, showering, or swimming. †Swimming frequency recorded as daily, weekly, monthly, <monthly, never. GP, gas-permeable lens; Soft, soft lens.

female GP lens wearers ($P = 0.22$). Of 163 male SCL wearers, 24% reported storing their lenses in water compared with 13% of 731 female SCL wearers ($P = 0.003$), but this difference was not found among 58% of 12 male and 33% of 69 female GP lens wearers ($P = 0.17$).

Of 278 SCL wearers who reported ever rinsing lenses with tap water, 115 (41%) stored lenses in tap water compared with 22 (4%) of the 615 who never rinsed lenses with tap water ($P < 0.0001$). Of 278 SCL wearers who reported ever rinsing lenses with tap water, 141 (51%) reported rinsing their storage case with tap water as compared with 231 (37%) of 619 who did not rinse lenses with tap water ($P < 0.0001$). Wearers of GP lenses who reported ever rinsing lenses with tap water ($n = 74$) were equally likely to store lenses in tap water (32%) compared with those who never rinsed lenses with tap water (43%) ($P = 0.31$). Of 74 GP lens wearers, 59% who reported rinsing lenses with water also rinsed their storage case with tap water compared with 28% of the nontap water-rinsing group ($P = 0.011$).

Showering while wearing lenses was the most common exposure to water for SCL wearers, reported by 878 (86%), and was reported by 54 (67%) of GP lens wearers (Fig. 1). There was no difference in exposure for showering while wearing contact lenses between male SCL wearers (90% of 186) and female SCL wearers (86% of 831) ($P = 0.66$) or male GP lens wearers (85% of 13) and female GP lens wearers (64% of 70) ($P = 0.27$). Swimming while wearing contact lenses was reported in 62% of 1016 SCL wearers and 51% of 83 GP lens wearers (Fig. 1). There was no difference in reported exposure for swimming while wearing contact lenses between 66% of 186 male SCL wearers and 61% of 830 female SCL wearers ($P = 0.63$) or 38% of 13 GP lens-wearing males and 53% of 70 GP-wearing females ($P = 0.07$).

For other known CIE or MK risk factors, SCL wearers who ever rinsed lenses with tap water were more

likely to wear lenses overnight (always or often; 27% of 313), compared with those who never rinsed lenses with tap water (15% of 694; $P < 0.0001$). Of 137 SCL wearers who ever stored lenses in tap water, 30% wore lenses overnight (always or often) compared with 16% of the 757 who never stored lenses in tap water ($P < 0.0001$). Wearers of SCL who rinsed lenses with tap water were also more likely to never, infrequently, or sometimes discard solution (22% of 278) compared with the non-rinsing group (9% of 622) ($P < 0.0001$). This was the same for SCL wearers who stored lenses in tap water (26% of 137) compared with the nonstoring group (10% of 757) ($P < 0.0001$).

Perception of Risk Related to Water Exposure of Lenses

Compared with GP lens wearers, SCL wearers perceived a greater risk of acquiring infection through rinsing lenses with tap or distilled water or storing lenses in tap or distilled water (all $P < 0.0001$) (Table 2).

Rinsing lenses with distilled water was perceived as having less risk than rinsing lenses with tap water. This was true for all SCL wearers regardless of whether they rinsed with tap water ($P < 0.0001$, all) and for GP lens wearers who reported rinsing lenses with tap water ($P < 0.0001$) (Table 3). Storing lenses in distilled water was perceived as having less risk than storing lenses in tap water for all wearers, regardless of whether they stored lenses in tap water ($P < 0.0001$, all groups).

Among SCL wearers, those who reported lens exposure to water (rinsing, storing, showering, or swimming) perceived a lower risk of infection for each water-related behavior compared with those who never engaged in that particular behavior (all $P < 0.0001$) (Table 3). For GP lens wearers, participants who ever rinsed lenses with tap water ($P = 0.011$)

TABLE 2. Perception of Risk Related to Contact Lens Water Exposure

	SCLs	Gas-Permeable Lenses	
	Frequency (%)	Frequency (%)	
Rinse lenses tap* water			
Is likely to cause infection	564 (59)	15 (19)	<0.0001
Has little/no effect	360 (38)	49 (62)	
Prevents infection	32 (3)	15 (19)	
Rinse lenses distilled* water			
Is likely to cause infection	209 (22)	2 (3)	
Has little/no effect	582 (61)	39 (49)	<0.0001
Prevents infection	162 (17)	38 (48)	
Rinse lenses solution			
Is likely to cause infection	12 (1)	0	
Has little/no effect	91 (10)	10 (13)	0.43
Prevents infection	849 (89)	70 (87)	
Store lenses tap† water			
Is likely to cause infection	723 (76)	34 (43)	
Has little/no effect	211 (22)	45 (57)	<0.0001
Prevents infection	22 (2)	0	
Store lenses distilled† water			
Is likely to cause infection	313 (33)	9 (11)	
Has little/no effect	527 (55)	50 (63)	<0.0001
Prevents infection	113 (12)	20 (25)	
Lens wear showering			
Is likely to cause infection	134 (14)	6 (8)	
Has little/no effect	799 (84)	73 (92)	0.095
Prevents infection	22 (2)	0	
Lens wear swimming			
Is likely to cause infection	604 (63)	46 (58)	
Has little/no effect	336 (35)	33 (42)	0.3
Prevents infection	15 (2)	0	
Lens wear hot tubs			
Is likely to cause infection	355 (37)	26 (33)	
Has little/no effect	586 (61)	52 (66)	0.74
Prevents infection	12 (1)	1 (1)	

*Rinsing with distilled water was perceived with less risk of infection than rinsing with tap water for SCL wearers ($P < 0.0001$) and GP lens wearers ($P < 0.0001$).

†Storing lenses in distilled water was perceived with less risk of infection than storing lenses in tap water for SCL wearers ($P < 0.0001$) and GP lens wearers ($P < 0.0001$).

or stored lenses in tap water ($P = 0.007$) perceived a lower risk of infection with those behaviors than those who did not have those behaviors.

Risk perception for rinsing lenses with tap water and storing lenses in tap water was compared by sex. For SCL wearers who ever rinsed lenses with tap water, men (11%) were more likely to perceive that this behavior prevents infection than did women who rinse lenses with tap water (6%) ($P < 0.0001$). Men who stored lenses in tap water were less likely than women to perceive that this behavior causes infection when they were SCL wearers (males 45%; females 57%) ($P < 0.0001$) or GP lens wearers (males 14%; females 25%) ($P = 0.01$).

DISCUSSION

This study showed a high level of lens exposure to water among contact lens wearers. It also found a significant number of contact lens wearers with incorrect perceptions about the risk of infection associated with these exposures. SCL wearers were more likely to expose their lenses to water indirectly by swimming and showering, whereas GP lens wearers were more likely to directly expose lenses to tap water through rinsing or storing of lenses. The latter is not surprising as GP lens wearers historically have received different lens care instructions than SCL wearers.

Most contact lens (CL) wearers reported showering while wearing lenses, and, among those who did, most perceived this practice as having little risk of developing an eye infection. In a separate study population that completed the CLRS, 75% of SCL wearers aged 12 to 33 reported showering with lenses more often than “some of the time,” and this behavior peaked at college age.¹⁷ Although exposure to water through showering is a plausible risk for infection, the increased risk for developing a contact lens-related adverse event due to showering while wearing lenses has not been established. Joslin et al¹⁹ postulated that because *Acanthamoeba* has been isolated from air, these microbes may aerosolize during showering, which openly exposes the contact lens and ocular surface. In the univariate analyses of 2 recent studies, showering was identified as a risk factor for CIEs²⁰ and MK.²¹

Swimming with contact lenses was reported by most of the SCL wearers and many GP lens wearers, although with lower frequency (times per month) than showering with contact lenses. The participants who swam while wearing lenses did not perceive this to be a risky behavior. It has been shown that swimming with lenses can increase the bacterial bioburden on lenses²² and can expose the ocular surface to *Acanthamoeba*. Swimming has been identified as a likely factor for AK in GP lens wearers,²³ orthokeratology wearers,²⁴ frequent replacement SCL wearers,²³ and daily disposable lens wearers.²⁵ Avoiding contact lens wear while swimming is the safest practice; however, if one chooses to swim while wearing reusable contact lenses, a pair of tight-fitting goggles should be worn, thorough disinfection should occur in the evening,²² and patients should be educated to be alert for signs and symptoms of infection after swimming.

More troubling than swimming or showering while wearing contact lenses is direct contact of tap water to the lens surface by rinsing or storing. It is not surprising that GP lens wearers report rinsing their lenses with tap water, as most GP care systems include a step in which tap water is recommended for removing the lens cleaner.¹³ Not one SCL care system recommends rinsing SCLs with tap water; however, 10% of respondents reported always or fairly often rinsing their SCL with water. Although rinsing with tap water is included in GP lens care guidelines, there are several orthokeratology case reports, including some with children, in which tap water was used for rinsing or storing lenses and an AK event ultimately developed.^{26,27} Although lenses were exposed to water in these case reports, the role of overnight wear in orthokeratology cannot be readily dismissed.²⁸ Although not statistically

TABLE 3. Perception of Risk Related to Contact Lens Water Exposure by Actual Reported Water Exposure

	SCLs			Gas-Permeable Lenses		
	No Water, %	Any Water, %	P	No Water, %	Any Water, %	P
Rinse lenses tap water	n = 657	n = 298		n = 7	n = 72	
Is likely to cause infection	69	37		57	15	
Has little/no effect	29	56	<0.0001	14	67	0.011
Prevents infection	2	7		29	18	
Rinse lenses distilled water	n = 654	n = 298		n = 7	n = 72	
Is likely to cause infection	27	12		14	1	
Has little/no effect	62	59	<0.0001	43	50	0.12
Prevents infection	11	29		43	49	
Rinse lenses solution*	n = 654	n = 297		n = 7	n = 73	
Is likely to cause infection	1	2		0	0	
Has little/no effect	8	14	0.004	43	10	0.011
Prevents infection	91	84		57	90	
Store lenses tap water	n = 728	n = 133		n = 52	n = 27	
Is likely to cause infection	78	53		54	22	
Has little/no effect	20	40	<0.0001	46	78	0.007
Prevents infection	2	7		0	0	
Store lenses distilled water	n = 725	n = 133		n = 52	n = 27	
Is likely to cause infection	36	16		15	4	
Has little/no effect	55	61	<0.0001	62	67	0.28
Prevents infection	9	23		23	30	
Lens wear showering†	n = 133	n = 822		n = 26	n = 53	
Is likely to cause infection	38	10		12	6	
Has little/no effect	60	88	<0.0001	88	94	0.36
Prevents infection	2	2		0	0	
Lens wear swimming‡	n = 361	n = 594		n = 41	n = 38	
Is likely to cause infection	78	54		63	53	
Has little/no effect	20	44	<0.0001	37	47	0.33
Prevents infection	2	2		0	0	

*Perceptions on the risk of infections with contact lens solution between those who ever rinse in tap water compared with those who never rinse in tap water.

†Those who reported never showering in lenses are compared with those who ever shower in lenses.

‡Those who reported never swimming with lenses are compared with those who ever swim in lenses.

Bold numbers indicate a statistical significance of $p < 0.05$.

significant, a recent CDC case-control study of AK in GP lens wearers reported slightly increased risk of development of AK associated with rinsing GPs with water.²⁹ Currently, there is no consensus among practitioners on the risk or benefit of the tap water rinse for GPs.³⁰

Although no GP or SCL care system or contact lens care guidelines recommend storing lenses in water, we speculate that the rinsing step recommended for some GP solutions could confuse patients into thinking water is safe for storage. In this study, GP lens care brands were not recorded. *Acanthamoeba* is capable of adhering to hydrogels, GP lenses, polymethyl methacrylate (PMMA), and silicone hydrogels.³¹ Trophozoite adherence can occur in as little as 10 seconds, and the raw number of adhered microbes increases over time.³² *Acanthamoeba* trophozoites and cysts can adhere to all surfaces, although the cysts bind to a lesser extent than the trophozoites.³³ *Acanthamoeba* adherence rates also differ among lens materials.³¹ If a water supply is contaminated with *Acanthamoeba* and the water is subsequently used for lens storage, then these microbes certainly are capable of adhering to a lens and case surface.

Exposure to any source of water while wearing contact lenses may increase the risk of an infectious¹⁰ or inflammatory event.^{18,20} Although treated recreational water (eg, pools) and most tap water are disinfected to prevent gastrointestinal illnesses, they are not sterile and contain bacteria,¹² protozoans,⁷ and even fungi.³⁴ Many of the organisms responsible for MK (eg, *Acanthamoeba*, *Pseudomonas*) grow in plumbing biofilms. These organisms can adhere to contact lenses and lens storage cases if the cases come into contact with contaminated tap water and are not properly cleaned and disinfected. The level of water contamination depends on the water source (untreated sources likely being more contaminated than treated sources), region,⁶ season,²³ or after a rainfall. Water sources may vary in microbial load depending on the regulations specifying allowable disinfectants in water supplies.³⁵

One method for decreasing the number of microbes in a supply of water is distillation. Distillation entails boiling the water, thereby killing microbes, including *Acanthamoeba* cysts.³⁶ The resulting steam is then condensed, helping also to remove particulates. Both SCL and GP lens wearers collectively perceived that the use of distilled water for rinsing

contact lenses or storing lenses is safer than using tap water. This perception can be misleading as there are other ways besides water for microbes to be introduced into the process; for example finger surfaces are contaminated with bacteria with or without hand washing,³⁷ and eyelids and conjunctiva have a baseline bioburden,³⁸ microbes of which can easily be transferred to a lens,³⁹ or a storage case.⁴⁰ If distilled water is used to rinse a lens, the only “disinfective” property of the water would be physical removal of microbes not tightly adhered to the lens surface. If distilled water is used for storage, then no disinfection of the lens or storage case occurs.

Regardless of reporting lens rinsing with tap water or not, over 40% of the SCL and GP lens wearers reported that they typically rinse their storage case with tap water. The contact lens storage case has been identified as a common fomite for developing MK.^{3,4} Exposing the storage case to tap water is a clear risk factor for developing AK,⁴¹ likely because water organisms that cause MK can adhere and grow in these cases. Seal et al asked participants who wear SCL daily to refrain from swimming with lenses, avoid using tap water for rinsing the lenses or storage cases, and to air dry their storage cases daily for a 1-month period. Although there was no mention of whether participants showered with lenses on or not, *Acanthamoeba* was not isolated from any storage case.⁴¹ Recently, Tilia et al found that rinsing storage cases with water also increased the likelihood of contamination with Gram-negative bacteria,⁴² specifically with *Stenotrophomonas maltophilia*, *Delftia acidovorans*, *Achromobacter* spp., *Serratia marcescens*, and *Pseudomonas* spp. These bacteria have been isolated from the lenses, storage cases, and ocular surfaces of patients with mild to severe corneal conditions.^{18,43} In addition, Wu et al⁴⁰ found that allowing the storage case to air dry is associated with lower contamination rates than nonair dried cases. This suggests that eliminating storage case or lens tap water exposure can significantly reduce the likelihood of contaminating a contact lens with microbes.

In this study, among SCL wearers, men were more likely than women to report contact lens exposure to water through rinsing or storage and also perceived these behaviors with less risk. In a survey by Morgan et al⁴⁴, women had better compliance with contact lens behaviors compared with men. In our study, it is difficult to draw definitive conclusions regarding differences between sexes as this sample was heavily weighted toward women.

This study may be limited by a sample that might not be representative of all CL wearers. As a convenience sample, it was mostly women, with no participants aged below 20 years, and included only a small sample of GP lens wearers. Future studies should also consider focus groups to further develop the most appropriate question/response options to understand patients’ perceptions of risk.

In summary, water exposures among CL wearers are common. Rinsing lenses with tap water is particularly prevalent with GP lens wearers, possibly because of current care system guidelines. Contact lens users should never rinse soft lenses with tap water or store any type of lens in tap or distilled water, but many wearers reported practicing these

behaviors. Practitioners need to better educate their patients to avoid exposing their lenses or storage case to any source of water. Likewise, manufacturers should continue to innovate lens care products that thoroughly disinfect and clean lenses while avoiding a tap water-rinsing step.

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