ORIGINAL ARTICLE

Cleaning Tasks and Products and Asthma Among Health Care Professionals

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Objective: Health care workers are at risk for work-related asthma, which may be affected by changes in cleaning practices. We examined associations of cleaning tasks and products with work-related asthma in health care workers in 2016, comparing them with prior results from 2003. **Methods:** We estimated asthma prevalence by professional group and explored associations of self-reported asthma with job-exposure matrix–based cleaning tasks/products in a representative Texas sample of 9914 physicians, nurses, respiratory/occupational therapists, and nurse aides. **Results:** Response rate was 34.8% (n = 2421). The weighted prevalence rates of physician-diagnosed (15.3%), work-exacerbated (4.1%), and new-onset asthma (6.7%) and bronchial hyperresponsiveness symptoms (31.1%) were similar to 2003. New-onset asthma was associated with building surface cleaning (odds ratio [OR], 1.91; 95% confidence interval [CI], 1.10–3.33), use of ortho-phthalaldehyde (OR, 1.77; 95% CI, 1.15–2.72), bleach/quaternary compounds (OR, 1.91; 95% CI, 1.10–3.33), and sprays (OR, 1.97; 95% CI, 1.12–3.47). **Conclusion:** Prevalence of asthma/bronchial hyperresponsiveness seems unchanged, whereas associations of new-onset asthma with exposures to surface cleaning remained, and decreased for instrument cleaning.

Keywords: asthma, cleaning products, health care, occupational risk factors

Approximately 8% of US adults have asthma.[1,2] Among these, approximately 15% to 25% of cases are considered work-related asthma (WRA), which includes asthma exacerbated or induced de novo by inhalation exposures in the workplace.[3] At least 2.25 million people in the United States aged 15 to 65 years are at risk for WRA,[4,5] and the annual economic

LEARNING OUTCOMES

- Evaluate changes in asthma prevalence among Texas health care workers (HCWs) from 2003 to 2016, focusing on physician-diagnosed, work-exacerbated, and new-onset asthma.
- Calculate and compare weighted asthma prevalence rates within a sample of 2421 HCWs, utilizing statistical analysis to assess temporal trends.
- Utilize self-reported data and statistical methods to discern shifts in asthma prevalence, contributing to an improved understanding of HCWs' respiratory health risks.

impact of WRA is estimated at $6 billion.[6,7] Not all occupations have the same risk of WRA, with health care workers (HCWs) known to be at high risk.[8,9] Among HCWs, nurses, nurse aides, and housekeeping personnel are high-risk occupations for WRA.[6,10–13]

Asthma triggers in HCWs include cleaning products, disinfectants, and medications.[14,15] A 2003 study of asthma in Texas HCWs found significant associations with exposures such as medical instrument cleaning, cleaning of surfaces, and use of powdered latex gloves in the 1992–2000 period.[8,16] Recent studies highlighted the importance of cleaning and disinfection as a risk factor for WRA.[10–12,15,17,18] Known factors include the

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type of tasks (eg, cleaning of general building surfaces or medical instrument cold sterilization),[8,18] product use (eg, decalcifying agents, toilet cleaners),[19,20] application method (eg, sprays, which can volatilize chemicals that are usually fairly nonvolatile),[21–23] and work setting (eg, operating rooms, where exposures are among the highest in health care settings),[24,25] along with the use of respiratory protection. High-level disinfectants, such as glutaraldehyde, peracetic acid, or ortho-phthalaldehyde (OPA), are used daily in health care environments, along with disinfectants such as alcohol and bleach, often used as sprays.[26,27] This literature called for more research on infection control and prevention practices in HCWs, particularly among nurses, who have the highest asthma risk.

Over the past two decades, and in light of the COVID-19 pandemic, there have been major changes in the nature and frequency of cleaning and disinfection products, with a greater emphasis on automation of practices and increased use of protective equipment.[8,28–35] A greater focus on controlling hospital-acquired infections has led to detailed cleaning and disinfection guidelines, with concurrent changes in environmental policies and regulations that may have unintended consequences on HCWs.[31,34] However, a recent report found no change in the percentage of WRA cases associated with cleaning agents, underscoring the need to increase the knowledge of potential cleaning hazards.[9] A literature review on cleaning agents in health care settings emphasized that larger, more contemporary population-based studies of HCWs exposed to cleaning agents are needed.[34,36–39]

To assess the current prevalence of WRA among HCWs and whether changes in cleaning products exposure and tasks affected the prevalence, we conducted a population-based study of Texas HCWs and compared the findings to the 2003 study among the same target population.

METHODS

Survey Population

Five health care occupations were identified from their respective state licensing boards or certification organizations[40–45] and targeted for a statewide cross-sectional confidential mail survey: physicians (n = 61,661), nurses (n = 361,719), respiratory therapists (respiratory therapists [RTs], n = 13,223), occupational therapists (occupational therapists [OTs], n = 12,556), and certified nurse aides (CNAs, n = 108,718). Inclusion criteria were (*a*) age 18 years or older and (*b*) having an active Texas license or certification in 2016. The sample size calculations for the first four groups were similar to the 2003 study, requiring a sample for each group of 1400 participants (total = 5600) to ensure $\alpha = 0.05$ and $\beta = 0.20$, an expected response rate of at least 50%, and an expected proportion of eligible respondents of 90%.[44] Nurses may practice in various settings and have consistently been identified as being at risk for asthma, and prior studies are limited on characterizing their work habits and environments, so we oversampled nurses, mailing 3200 surveys (registered nurses = 1600, licensed vocational nurses = 800, and advance practice registered nurses = 800). Given historically low response rates of physicians to mail surveys,[46] we also oversampled them to ensure a sufficient number of physicians in the analysis (n = 400 additional surveys for a total of 1800). Because CNAs were recruited in a stand-alone pilot study,[13] their sample size (n = 1057) calculations followed a method for a single-group cross-sectional study[45] based on $\alpha = 0.05$ and a 3% margin of error. With a 50% expected response rate, 2114 surveys were mailed to CNAs. The combined target population of HCWs included 9914 surveys mailed between October 2016 and February 2017, following Dillman and colleagues' five-wave approach to survey administration.[47] Like in 2003, a $1 incentive was provided with each survey. Informed consent was in the form of an introduction letter, and survey completion implied consent to participate. Participants could return the hard-copy questionnaire by mail or complete it online. The Committee for Protection of Human Subjects at UTHealth School of Public Health approved the study.

The overall response rate was 34.8% (n = 3444): 41.0% for OTs, 40.2% for nurses, 37.9% for RTs, 34.1% for physicians, and 21.1% for CNAs. For comparability across analyses, we created an analytical sample (n = 2421 respondents without missing data) (Table 1). Compared with this sample, the excluded respondents with missing data (n = 905) were slightly older (50.4 vs 48.8 years); had fewer non-Hispanic Whites (48.9% vs 59.6%), fewer physicians (9.2% vs 11.8%) and nurses (53.1% vs 69.7%), and more CNAs (34.0% vs 13.5%); and had a lower prevalence of new-onset asthma (NOA) (5.9% vs 6.7%), higher prevalence of bronchial hyperresponsiveness (BHR) (40.1% vs 31.1%), and fewer HCWs using powdered latex gloves in 1992–2000 (66.6% vs 71.6%).

Data Collection

Asthma Risk Factor Job Exposure Matrix

Occupational exposures were determined using an asthma risk factor job-exposure matrix (JEM) designed for HCWs. Originally developed and used in 2003, this JEM was updated for the 2016 study by a multidisciplinary team of physicians, industrial hygienists, and epidemiologists who conducted walk-throughs and focus groups at three tertiary hospitals, two nursing homes, and two outpatient clinics in Houston. The updated JEM included (*a*) the 2003 exposure categories; (*b*) new exposure categories reflecting specific tasks (eg, endoscopy) and environments (eg, intensive care units); (*c*) broader nursing professions (eg, nurse aides); and (*d*) broader practice settings to include areas within and outside hospitals (eg, outpatient clinics).

The JEM-derived exposures were classified into two categories: (*a*) tasks or practices: patient care cleaning and disinfection, medical instrument cleaning, and building surface cleaning (including sprays); and (*b*) products or compounds classified into cleaning agents, including glutaraldehyde, OPA, enzymatic cleaners, bleach, quaternary ammonium compounds, sprays, and powdered latex glove use.

This updated JEM was then coded by a group of experienced industrial hygienists, occupational physicians, toxicologists, and occupational health professionals working in health care settings, both hospitals and outpatient clinics. "Exposed" was defined as the probability that an HCW in a given cell was exposed to the task or product at least once per week: a code of 0 indicated a high probability of no exposure, a 1 indicated a low probability of exposure, and a 2 indicated a high probability of exposure. Each coder independently assigned codes to the entire JEM, followed by a team review to identify disagreements, resolved by consensus. Based on their job title and practice setting, the coded JEM was applied to respondents' current and longest-held job as HCW.

Survey Instrument

As in 2003, in 2016, we asked about demographics, occupational history, and health. In 2016, we added new questions on exposures and occupational history to characterize better exacerbated or occupational asthma. The questionnaire was pilot tested in a small group of Houston HCWs for timing, ease of use, and comprehensibility. The final questionnaire was available in two formats, an online version and a paper-based version compatible with direct data entry with the HP Teleform (version 11; Sunnyvale, CA) software, which recognizes and digitizes handwriting on a scanned paper-based survey.

Study Variables

Four self-reported asthma outcomes were defined: (*a*) physician-diagnosed asthma (PDA), (*b*) new-onset PDA (NOA), (*c*) work-exacerbated asthma (WEA), and (*d*) BHR symptoms. Physician-diagnosed asthma was defined as a yes to: "Have you ever had asthma?" and "If yes, has it been confirmed by a doctor?" New-onset asthma was defined as PDA after entry into the health profession by comparing the age at which the asthma diagnosis was made to the number of years as HCW. Work-exacerbated asthma was defined among respondents with a history of PDA as a yes to: "Have

TABLE 1. Descriptive Characteristics* of the Analytical Sample and the Excluded Sample of Texas Health Care Workers, 2016 (N = 3,326)

Characteristics	Analytical Sample (n = 2,421)	Excluded Sample (n = 905)	$P^{\dagger}$
Age, mean ± SE, y	48.8 ± 0.36	50.4 ± 0.60	<0.001
Sex, n (%)			<0.01
Women	1,852 (83.2)	657 (88.0)	
Men	569 (16.8)	147 (12.0)	
Race, n (%)			<0.001
Non-Hispanic White	1,450 (59.6)	362 (48.9)	
Hispanic	434 (17.5)	133 (22.6)	
Non-Hispanic Black	265 (12.9)	100 (17.7)	
Others	272 (10.0)	74 (10.8)	
Atopy, n (%)	388 (15.4)	146 (18.2)	0.13
Obesity, n (%)			0.01
(Body mass index ≥30 kg/m^2)	630 (27.9)	233 (34.1)	
Smoking, n (%)			0.04
Never smokers	1,830 (74.7)	613 (74.7)	
Current smokers	111 (5.4)	54 (8.2)	
Former smokers	480 (19.8)	148 (17.1)	
Job seniority, n (%)			0.02
0–10 y	634 (26.6)	207 (24.5)	
11–20 y	655 (26.0)	222 (24.9)	
21–30 y	543 (21.0)	171 (17.7)	
≥31 y	589 (26.4)	300 (32.9)	
Profession, n (%)			<0.001
Physicians	430 (11.8)	139 (9.2)	
Nurses	947 (69.7)	298 (53.1)	
Respiratory therapists	399 (2.5)	133 (2.0)	
Occupational therapists	442 (2.5)	119 (1.6)	
Certified nurse aides	203 (13.5)	211 (34.0)	
Asthma-related conditions, n (%)			
Physician-diagnosed asthma (PDA)	389 (15.3)	140 (17.8)	0.17
New-onset asthma (among PDA)	157 (6.7)	49 (5.9)	0.53
Work-exacerbated asthma (among PDA)	16 (4.1)	8 (0.9)	0.33
Bronchial hyperresponsiveness‡ symptoms	775 (31.1)	279 (40.1)	<0.001
Cleaning-related tasks and products (post-2003), n (%)			
Patient cleaning and disinfection	2,121 (90.0)	625 (86.6)	0.04
Instrument cleaning			
Endoscopy	716 (28.9)	182 (28.3)	0.79
Glutaraldehyde	700 (27.8)	185 (29.3)	0.53
Ortho-phthalaldehyde	950 (45.8)	232 (41.4)	0.11
Enzymatic cleaners	475 (10.2)	118 (11.5)	0.44
Building surface cleaning			
Bleach	1,763 (75.6)	461 (77.4)	0.40
Quaternary ammonium compounds	1,763 (75.6)	461 (77.4)	0.40
Sprays	1,781 (77.0)	461 (77.6)	0.76
Stripping/waxing/buffing	0	0	—
Powdered latex gloves, n (%)			
Pre-1992	1,762 (84.2)	463 (84.9)	0.69
1992–2000	1,502 (71.6)	374 (66.6)	0.04
2001–2006	215 (5.9)	53 (5.3)	0.43
2007 onward	214 (5.9)	53 (5.3)	0.48
Aerosolized medications (post-2003), n (%)	1,131 (58.3)	260 (48.9)	<0.001
Spill at work	93 (4.3)	21 (3.3)	0.37

*From weighted sample.

$^{\dagger}P$ values of χ^2 test for differences in proportions and of t test for mean differences.

‡Bronchial hyperresponsiveness.

you had an attack/episode while you were at work in the last 12 months?" and "If yes, do you know what triggered that last attack/episode?".

The presence or absence of BHR symptoms was determined based on a previously validated eight-item predictor of PC_{20} (provocative concentration of methacholine causing a 20% fall in FEV_1 [forced expiratory volume in the first second])[48] assessing these symptoms: occurrence of trouble breathing; wheezing or whistling in the chest; attacks of shortness of breath; nocturnal cough attacks; chest tightness attacks; itchy/watery eyes or a feeling of chest tightness when near animals, feathers, or dust; and itchy or watery eyes when near trees, grass, flowers, or pollen. Respondents who left the eight items blank

were set to missing (n = 4). A continuous score (from 0 to 1) was created and dichotomized based on the published cutoff, where >0.5 indicates the presence of BHR. Next, two scenarios were created for respondents with at least one nonmissing item: (1) a best scenario coding all missing symptoms as absent and (2) a worst scenario coding those symptoms as present. We set to missing respondents who obtained a different score in both scenarios (n = 26) and kept the scores for those respondents whose score (either ≤0.5 or >0.5) under both scenarios was the same.

The main independent variables were occupational exposures as defined by the JEM. In the coded JEM, the number of occupation–practice setting combinations coded 1 (low probability) for exposure

was very small for almost all exposures and considered too small for meaningful analyses. Thus, occupational exposure variables were dichotomized by collapsing codes 1 and 2 into a single "exposed" category, with 0 reflecting the nonexposed groups. Job-exposure matrix codes for the longest held job were used because the majority (55.6%) of respondents indicated that their current job was their longest-held job. If the longest-held job was outside health care, the JEM codes from the current job were used. Also, the questionnaire asked a yes/no question on having ever been involved in a chemical spill or gas release at work.

Covariates included age, sex, race/ethnicity, professional group, years as an HCW (10-year groups), smoking status (never, current, or former), and obesity (body mass index ≥30 kg/m^2). Atopy was determined based on a history of allergies to animals, dust, or dust mites.[8] Of the 220 respondents missing age, we imputed it for 139 of them based on their nonmissing number of years as HCW and the average number of years at which the profession typically starts (eg, 26 years for physicians; 22 years for nurses, RTs, and OTs; and 16 years for CNAs).

Statistical Analysis

Being a complex survey data set, we applied survey weights with proportions based on census data on health care professionals. Poststratification weights were calculated to obtain prevalence estimates that were representative of the population size for each professional group. We calculated unweighted counts and weighted prevalence of PDA, NOA, WEA, and BHR. Multivariate regression models were built following Hosmer and Lemeshow covariate selection strategy.[49] Separate regression models were built for each class of exposure tasks and products because initial strong collinearity ($r \geq 0.70$) was found among occupational exposures, mainly within instrument cleaning (glutaraldehyde, endoscopy, OPA), building surface cleaning (sprays with quaternary compounds and bleach), and latex glove use (among all time axes).

We used logistic regression models to estimate the associations (odds ratio [OR] and corresponding 95% confidence interval [95% CI]) between each independent variable and the outcomes. Variables with a $P < 0.25$ in the univariate analyses (ie, age, sex, race, atopy, obesity, smoking, and job seniority) were entered into the multiple regression models. We assessed interactions of patient care cleaners with smoking, race, obesity, and seniority, but none were statistically significant. Hosmer-Lemeshow goodness-of-fit tests for survey data[50] indicated good model fit ($P > 0.05$). Stata's *svy* package for weighted data was used for the analyses.[51,52]

Finally, we adhered to STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines in the completion of this study (Supplemental Digital Content, http://links.lww.com/JOM/B423).

RESULTS

Table 1 shows descriptive statistics for the analytic (n = 2421) and excluded (n = 905) samples. The majority of the analytical sample was middle age (48.8 years old), female (83.2%), non-Hispanic White (59.6%), and never-smokers (74.7%). The prevalence of obesity was 27.9%, and the prevalence of atopy was 15.4%. The sample was evenly distributed by job seniority (20%–25% in each group). Most participants were nurses (69.7%), followed by CNAs (13.5%), physicians (11.8%), and RTs or OTs (both with 2.5%).

The overall weighted prevalence rates for PDA, NOA, WEA, and BHR symptoms were 15.3%, 6.7%, 4.1%, and 31.1%, respectively. There were differences by profession ($P < 0.01$) in the prevalence of NOA: 8.0% in OTs, 7.6% in nurses, 6.3% in RTs, 4.9% in physicians, and 3.4% in CNAs. Bronchial hyperresponsiveness symptoms also varied by profession ($P = 0.02$): 38.3% in OTs, 36.3% in RTs, 34.7% in nurses, 30.5% in CNAs, and 27.6% in physicians. There were no statistically significant differences for PDA, and the sample for WEA was too small to stratify by profession.

In the unadjusted models (Table 2), NOA was associated with age (OR, 1.03; 95% CI, 1.02–1.04) and inversely associated with race,

particularly among non-Hispanic blacks (OR, 0.35; 95% CI, 0.15–0.82) as compared with non-Hispanic Whites, atopy (OR, 2.47; 95% CI, 1.57–3.88), and job seniority, with the odds of NOA increasing with advancing age (ORs ranging from 5.48 to 11.39). Bronchial hyperresponsiveness symptoms were associated with sex (OR, 1.68; 95% CI, 1.28–2.20; female vs male) and atopy (OR, 6.75; 95% CI, 5.00–9.11).

Regarding cleaning tasks and products (Table 3), the use of OPA (OR, 2.07; 95% CI, 1.38–3.10), bleach and quaternary compounds (OR, 1.89; 95% CI, 1.16–3.09, for each), sprays (OR, 1.92; 95% CI, 1.17–3.15), and powdered latex glove after 2000 (OR, 0.25; 95% CI, 0.09–0.69) was associated with NOA. After adjusting for age, sex, race, atopy, obesity, smoking status, and years on the job, statistically significant associations remained for NOA with the use of OPA for instrument cleaning (OR, 1.77; 95% CI, 1.15–2.72), bleach and quaternary ammonium compounds used to clean building surfaces (OR, 1.91; 95% CI, 1.10–3.33 for both), sprays in building surface cleaning (OR, 1.97; 95% CI, 1.12–3.47), and latex gloves from 2001 to 2006 (OR, 0.25; 95% CI, 0.09–0.73) and 2007 onward (OR, 0.26; 95% CI, 0.09–0.76). For BHR, only an inverse association with patient care cleaners was found (OR, 0.64; 95% CI, 0.44–0.92).

Compared with 2003 (Table 4), the overall prevalence of NOA remained high (6.6% in 2003, 6.7% in 2016), and the BHR prevalence increased from 27.4% to 31.1%. Disregarding statistical significance, the associations between NOA and patient care cleaners, surface cleaners, use of powdered latex gloves, and spill at the workplace were essentially unchanged, except for a weakening of the association with patient care cleaners and instrument cleaning (1.60 to 0.66 for patient care cleaners, 2.22 to 1.36 for instrument cleaners).

DISCUSSION

The overall prevalence rates of NOA (6.7%) and BHR symptoms (31.1%) among HCWs remained high, or were slightly higher,

TABLE 2. Unadjusted[a] Associations (ORs and 95% CIs) of Sample Demographic and Job-Related Characteristics With Asthma-Related Conditions Among Texas Health Care Workers, 2016 (n = 2,421)

Characteristics[b]	New-Onset Asthma OR (95% CI)	BHR Symptoms OR (95% CI)
Age (continuous)	**1.03 (1.02–1.04)**	1.00 (0.99–1.01)
Sex		
Men	Ref	Ref
Women	1.72 (0.98–3.03)*	**1.68 (1.28–2.20)**
Race (non-Hispanic White)	Ref	Ref
Hispanic	0.58 (0.32–1.05)*	0.79 (0.59–1.07)*
Non-Hispanic Black	**0.35 (0.15–0.82)**	0.66 (0.46–0.94)*
Others	0.59 (0.28–1.27)*	1.03 (0.73–1.46)
Atopy	**2.47 (1.57–3.88)**	**6.75 (5.00–9.11)**
Obesity	1.37 (0.90–2.11)*	
Smoking (nonsmokers)	Ref	Ref
Current smokers	0.83 (0.30–2.30)	1.22 (0.76–1.98)
Former smokers	1.14 (0.69–1.89)	1.33 (1.02–1.74)*
Job seniority (0–9 y)	Ref	Ref
10–16 y	**5.48 (2.07–14.48)**	1.15 (0.85–1.55)
17–26 y	**8.60 (3.30–22.39)**	1.27 (0.93–1.74)
≥27 y	**11.39 (4.50–28.87)**	1.10 (0.81–1.49)

BHR, bronchial hyperresponsiveness; CI, confidence interval; OR, odds ratio.

Values in bold font, *P* < 0.05.

*$P \leq 0.25$.

[a] From weighted logistic regression models.

[b] All from the self-reported questionnaire, except cleaning agents and latex use, which were assessed with the job-exposure matrix.

[c] Quaternary ammonium compounds.

TABLE 3. Crude and Adjusted* Associations (ORs and 95% CIs) of Cleaning Tasks and Products With Asthma-Related Conditions Among Texas Health Care Workers (n = 2,421)

	New-Onset Asthma		BHR Symptoms	
	Unadjusted	Adjusted	Unadjusted	Adjusted
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Cleaning-related tasks				
Patient care cleaning and disinfection	**0.56 (0.32–0.98)**	0.66 (0.37–1.17)	**0.63 (0.44–0.88)**	**0.64 (0.44–0.92)**
Instrument cleaning				
Endoscopy	1.34 (0.87–2.06)	1.36 (0.86–2.15)	0.92 (0.72–1.17)	0.98 (0.76–1.28)
Building surface cleaning				
Sprays	**1.92 (1.16–3.15)**	**1.97 (1.12–3.47)**	0.86 (0.68–1.09)	0.86 (0.62–1.20)
Cleaning-related products				
Instrument cleaning				
Glutaraldehyde	1.29 (0.83–1.99)	1.24 (0.78–1.95)	1.04 (0.81–1.32)	1.03 (0.79–1.34)
Ortho-phthalaldehyde	**2.07 (1.38–3.10)**	**1.77 (1.15–2.72)**	0.93 (0.75–1.16)	0.90 (0.71–1.14)
Enzymatic cleaners	1.51 (0.86–2.67)	1.42 (0.79–2.54)	1.23 (0.89–1.71)	1.21 (0.84–1.75)
Building surface cleaning				
Bleach	**1.89 (1.16–3.09)**	**1.91 (1.10–3.33)**	0.87 (0.69–1.10)	0.78 (0.60–1.02)
Quaternary ammonium compounds	**1.89 (1.16–3.09)**	**1.91 (1.10–3.33)**	0.87 (0.69–1.10)	0.78 (0.60–1.02)
Sprays	**1.92 (1.17–3.15)**	**1.97 (1.12–3.47)**	0.86 (0.68–1.09)	0.79 (0.61–1.04)
Powdered latex glove use				
Pre-1992	1.55 (0.86–2.80)	1.41 (0.77–2.58)	0.84 (0.64–1.11)	0.90 (0.65–1.23)
1992–2000	1.42 (0.90–2.23)	1.20 (0.75–1.91)	1.03 (0.81–1.29)	1.00 (0.78–1.29)
2001–2006	**0.25 (0.09–0.69)**	**0.25 (0.09–0.73)**	**0.69 (0.49–0.96)**	0.88 (0.61–1.28)
2007 onward	**0.25 (0.09–0.70)**	**0.26 (0.09–0.76)**	0.70 (0.50–0.97)	0.90 (0.62–1.31)
Spill at work	1.40 (0.60–3.31)	0.94 (0.37–2.37)	**1.91 (1.17–3.13)**	1.72 (0.99–3.00)

BHR, bronchial hyperresponsiveness; CI, confidence interval; OR, odds ratio.

Values in bold font, $P < 0.05$. The similar odds ratios for bleach and quaternary ammonium compounds are because of similar codes that were entered in the job-exposure matrix.

*From weighted logistic regression models adjusted for age, sex, race, atopy, obesity, smoking, and job seniority.

in 2016 as compared with 2003 (6.6% and 27.4%, respectively). Some associations with cleaning tasks and products changed, whereas others remained the same.[8] The association of NOA with patient care cleaners and with instrument cleaning and disinfection of medical instruments decreased substantially (40% to 60%), and exposure to powdered latex appeared even more controlled (OR < 1), but exposure to cleaning of building surfaces remained unchanged (ORs approximately 2). Importantly, BHR symptoms, which, in 2003, were associated with cleaning of building surfaces and acute exposures to chemical spills, had no elevated odds for any cleaning-related exposures in 2016.

The decrease in what was previously a greater than twofold risk for NOA associated with medical instrument cleaning is encouraging. This likely reflects the widespread use of enclosed, automated disinfection procedures for endoscopes in recent years (ie, automated endoscope reprocessors [AERs]).[53,54] Automated endoscope reprocessors have evolved over the past 15 years, incorporating several functions, including leak testing, cleaning, and postcleaning rinse, followed by high-level disinfection, a second rinse, and drying, all previously done manually. Over this period, glutaraldehyde, the main cold sterilant used to disinfect medical instruments and which had been repeatedly identified as a sensitizer capable of inducing asthma,[55–58] was steadily replaced by OPA. Being less volatile than glutaraldehyde, OPA was expected to affect the respiratory system less.[59] However, although glutaraldehyde was not a significant risk factor in our study, we did observe a twofold increase in the odds of NOA associated with OPA. This is consistent with recent reports of OPA-associated acute respiratory symptoms and skin sensitization.[27,60] Although used primarily for AER-based medical instrument disinfection, OPA is also used in other situations, some of

TABLE 4. Comparison Between 2003 and 2016 of Prevalence and Adjusted* Associations (ORs and CIs) Between Cleaning-Related Tasks and Products With Asthma-Related Conditions Among Texas Health Care Workers

	New-Onset Asthma		BHR Symptoms	
	2003 Study (n = 2,738)	2016 Study (n = 2,421)	2003 Study (n = 2,738)	2016 Study (n = 2,421)
	Prev. = 6.6%	Prev. = 6.7%	Prev. = 27.4%	Prev. = 31.1%
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Cleaning-related products				
Patient care cleaners	1.60 (0.18–14.16)	0.66 (0.37–1.17)	0.79 (0.35–1.78)	**0.64 (0.44–0.92)**
Instrument cleaning	**2.22 (1.34–3.67)**	1.36 (0.86–2.15)	1.26 (0.95–1.67)	0.98 (0.76–1.28)
Surface cleaners	**2.02 (1.20–3.40)**	**1.97 (1.12–3.47)**	**1.63 (1.21–2.19)**	0.78 (0.60–1.02)
Latex 2000–2006	0.42 (0.13–1.29)	**0.25 (0.09–0.73)**	0.61 (0.34–1.11)	0.88 (0.61–1.28)
Latex 2007 and later	NA	**0.26 (0.09–0.76)**	NA	0.90 (0.62–1.31)
Spill at work	1.23 (0.53–2.87)	0.94 (0.37–2.37)	**2.02 (1.28–3.21)**	1.72 (0.99–3.00)

BHR, bronchial hyperresponsiveness; CI, confidence interval; OR, odds ratio; Prev., Prevalence.

Values in bold font, $P < 0.05$.

*Adjusted for age, sex, race, atopy, obesity, smoking, and number of years as health care professional.

which may entail a greater risk of direct exposure, such as electrocardiographic probes or cryosurgical equipment.[59] Ortho-phthalaldehyde is also used in cleaning the container systems, removing and rinsing soaked instruments, their disposal, and other maintenance procedures for AERs.[59] Hence, more research on OPA seems warranted.

The persistent association of NOA with cleaning general building surfaces, at a magnitude similar to 2003, is concerning. We also examined the associations between common tasks and cleaning products, which was not done in 2003. The increased association with bleach may be due to resurgence in the use of bleach in the United States as part of intensified attempts to control hospital-acquired infections, particularly those associated with *Clostridium difficile*.[61–64] Reports of asthma associated with exposure to quaternary ammonium compounds surfaced 18 years ago[65] but have continued to appear.[66–69] Previous studies have described the frequent use of cleaning sprays as an asthma risk factor.[23,70] The disappearance of the negative association of NOA with powdered latex glove use observed in 2003 continues, likely reflecting the widespread substitution of latex by nonlatex products, as well as improvements in the manufacturing use of less allergenic, lightly powdered or nonpowdered latex gloves.[71–75] Although latex glove use has dramatically decreased in clinical settings, there are still some settings where hypoallergenic nonpowdered (or lightly powdered) latex gloves may still be in use. In our 2003 study, we found that many latex control programs had been implemented in the mid-1990s to late 1990s, such that we found a marked decrease in the risk of allergy associated with latex glove use after 2000. When we again examined this association, the magnitude of the association was similar to that in 2003, probably indicating that controls for latex allergy have remained effective in the subsequent period.

Finally, that BHR symptoms do not seem related to occupational exposures to cleaning products and chemicals is also encouraging. This may be due to increased awareness; more standardized procedures for prompt prevention, detection, and control of chemical spills; better training of personnel; and the use of appropriate personal protective equipment per newer Occupational Safety and Health Administration guidelines.[76]

Health care settings are committed to regularly cleaning and disinfecting their facilities to prevent spreading disease and infection. But during the COVID-19 pandemic, particularly in its early phases when the risk of getting the SARS-CoV-2 (severe acute respiratory syndrome coronavirus 2) virus from a contaminated surface was thought to be high, the frequency of cleaning and disinfection of surfaces intensified to reduce virus exposure from surface contact. This overall increase in the extent, frequency, and intensity of use of disinfectants, particularly bleach-based ones, not only in health care facilities but also in households may have exacerbated the effect of cleaning on asthma. Later, it was determined that COVID-19 spread mainly through the air, but it is unclear if cleaning practices and use of products have returned to prepandemic levels. At the same time, that effect may have been buffered by the widespread use of tight-fitting respirators such as the N95 masks to reduce exposure to virus aerosols. However, N95 masks do not protect from chemical odors, gases, or vapors. Although there is likely a bidirectional association of cleaning products and practices with asthma, more research is needed to establish which direction predominates.

Our study strengths are the sampling and weighting strategy, which produced a statewide representative sample of five HCW groups. This makes results generalizable to similar workers in the United States and other countries. Comparisons should be made cautiously because cleaning and disinfection products may vary by country or even in health care environments within a country. Likewise, the job duties ascribed to specific HCW groups, for example, nurses or therapists, may be different those than in the United States. Adding CNAs, a previously unstudied group, is a strength and allows comparison to other nursing professionals in the current study. Finally, preserving the same study design, sampling strategy, and execution as in the 2003 study allows meaningful time comparisons.

Our study also had limitations. The overall lower response rate (approximately 39% for the four occupational groups included in

2003, ie, all but CNAs) than in 2003 (66%) may reflect a well-described general trend toward declining response rates in epidemiological surveys.[77–79] However, the final number of responses in the analytical sample (n = 2347) was comparable to the 2003 study (n = 2738), and we used statistical weights to increase sample representativeness. Also, the excluded sample differed somewhat from the analytical sample in a few demographic characteristics (ie, a bit older, fewer Whites, and more nurses) and asthma-related measures (less NOA, more BHR). Still, a potential selection effect is unlikely because most of these differences were small; we oversampled nurses; and, as discussed previously, our results on asthma are coherent and consistent with other research.

In summary, the prevalence of NOA and BHR symptoms in 2016 was similar to 2003. The association of NOA with exposures to building surface cleaning remained, decreased for instrument cleaning, and improved for powdered latex glove use. In part, these changes may be attributable to technological changes in disinfection procedures and the decline in the use of some disinfectants. However, the increased association with exposure to OPA and the continued association with cleaning building surfaces should be monitored, along with using alternative products and practices (eg, less use of bleach and aerosols). Overall, improving exposure controls and clinical asthma management could help decrease the asthma burden among HCWs.

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