A Section 508–conformant HTML version of this article is available at https://doi.org/10.1289/EHP14945.

Occupational Exposure to Disinfectants and Risk of Incident Cardiovascular Disease among US Nurses: The Nurses' Health Study II

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Background: Exposure to certain chemicals in disinfectants has been associated with vascular dysfunction in toxicological studies, but the association between disinfectant exposure and clinical cardiovascular disease (CVD) remains unclear.

Objective: The aim of this study was to evaluate the association between occupational exposure to disinfectants and subsequent risk of CVD among US nurses.

Methods: We included 75,675 participants from The Nurses' Health Study II who maintained a nursing job and reported data on occupational disinfectant exposure. We estimated hazard ratios (HR) and 95% confidence intervals (CIs) of incident CVD, including coronary heart disease (CHD) and stroke, using Cox proportional hazard models comparing job types and general disinfection tasks between participants. We also used a job–task–exposure matrix to evaluate the risk of CVD by frequency of cleaning/disinfection tasks and exposure levels of seven specific disinfectants (formaldehyde, glutaraldehyde, hypochlorite bleach, hydrogen peroxide, alcohol, quaternary ammonium compounds, and enzymatic cleaners).

Results: During 10 y of follow-up (2009–2019), we documented 726 incident cases of CVD. In fully adjusted models, the hazard ratio of CVD among nurses who worked in operating rooms was 1.72 [95% confidence interval (CI): 1.25, 2.36], in comparison with those working as educators or administrators. A similar pattern of associations was found when we separately assessed the risk for CHD and stroke [HR = 1.69 (95% CI: 1.11, 2.58) and HR = 1.69 (95% CI: 1.05, 2.74), respectively] among operating room nurses, in comparison with those working as educators or administrators. Those who used disinfectants weekly had modest elevations in CVD risk (HR = 1.21; 95% CI: 1.04, 1.40), in comparison with women who never used disinfectants. The highest CVD risk was observed among nurses using disinfectants or spray or aerosol products 4–7 d/wk and those exposed to the highest levels of the seven specific disinfectants listed above.

Conclusion: Exposure to disinfectants in real-world health care settings was associated with a higher risk of CVD, including CHD and stroke, among US nurses. https://doi.org/10.1289/EHP14945

Introduction

Cardiovascular disease (CVD) is the leading cause of death in women, contributing to more than 8.9 million deaths globally in 2019, representing 34.6% of the total global mortality.[1,2] Although a dramatic decline in cardiovascular deaths for both men and women has been observed in the past 3 decades, global data suggest a stagnation in the improvement of CVD incidence and mortality among women.[2,3] In the United States, a sharp slowing in the decline of coronary heart disease (CHD) mortality rate has also been reported among younger women 35–54 y of age.[4] To address the plateauing reduction of CVD burden, it is critical to identify new CVD risk factors, including potentially modifiable ones such as occupational exposure, that are unique to or more common among younger women.[2,5]

Health care is one of the largest employment sectors in the US economy. In 2021, the estimated number of US health care workers was over 18 million, of whom a staggering 80.0% were women.[6] Given the high prevalence of cardiovascular risk factors (e.g., occupational exposure, night shift work, and job strain), health care professionals are particularly vulnerable to CVD.[7,8] Disinfectants and cleaning products are commonly used by health care workers, particularly nurses, to disinfect reusable medical devices and operating rooms.[9] Unfortunately, these products used in health care settings often contain various harmful chemicals, such as formaldehyde, hypochlorite, hydrogen peroxide, and glutaraldehyde, which have demonstrated adverse effects on vascular or endothelial function (e.g., cardiomyocyte apoptosis and changes in endothelial cell function, blood pressure, and heart rate) in animal studies.[10–14] Several

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Supplemental Material is available online (https://doi.org/10.1289/EHP14945).

The authors declare they have no conflicts of interest related to this work to disclose.

Received 7 March 2024; Revised 11 March 2025; Accepted 24 March 2025; Published 9 May 2025.

population studies also reported that exposure to disinfectants through inhalation or dermal contact was associated with changes in cardiac function parameters (e.g., heart rate variability, carotid distensibility, and intima-media thickness) and increased risk of CVD mortality among adults.[15–17] To our knowledge, no study has explored the association of occupational exposure to disinfectants in real-world health care settings with long-term risk of CVD. In addition, disinfectant exposure levels vary by job types in health care settings,[18,19] but whether the association of occupational exposure to disinfectants with CVD is influenced by job types is unclear. In the present study, we explored the association between job types, disinfection tasks, and exposure to specific chemicals and the long-term risk of incident CVD among 75,675 nurses from the Nurses' Health Study II (NHSII), a large, ongoing, prospective study with biennial follow-ups spanning over 3 decades.

Methods

Study Population

The NHSII is an ongoing cohort established in 1989 by recruiting 116,429 US female, registered nurses 25–42 y of age from California, Connecticut, Indiana, Iowa, Kentucky, Massachusetts, Michigan, Missouri, Texas, New York, North Carolina, Ohio, Pennsylvania, and South Carolina.[20] Biennial questionnaires with follow-up response rates >90% were self-reported to collect participant information on occupational exposure, lifestyle factors, and health-related characteristics. Eligible participants for the current study were those who were alive without a history of CVD before the baseline analysis in 2009, maintained a nursing job in the period 2009–2013, and did not have missing data on occupational disinfectant exposure (Figure 1). Study procedures have been approved by the institutional review boards of the Brigham and Women's Hospital and the Harvard T.H. Chan School of Public Health. According to the approved procedures, the completion of biennial questionnaires implied consent.

Ascertainment of Disinfectant Exposure

Job types and disinfectant use were collected in 2009, 2011, and 2013 using an occupational questionnaire adapted for the US context from European studies.[19,21] Job types were reported as emergency room, operating room, intensive care units, outpatient or community, nursing education or administration, nursing outside hospitals, other inpatient nurses, other hospital nursing, nonnursing employment, homemaker, and retired. Participants also separately reported their weekly use of any disinfectants (e.g., formaldehyde, glutaraldehyde, bleach, hydrogen peroxide, ethylene oxide, and ortho-phthalaldehyde) for cleaning surfaces and medical instruments as never, <1 d/wk, 1–3 d/wk, and 4–7 d/wk. In 2011 and 2013, they additionally reported information on their frequency of weekly use of spray or aerosol products for disinfection tasks (surface cleaning/disinfection, instrument cleaning/disinfection, patient care, or air freshening) using the same frequency categories. For each question, participants reporting "1–3 d/week" or "4–7 d/week" were classified as "weekly users" and those reporting "never" or "<1 day/week" were classified as "less than weekly users." To define disinfection tasks performed weekly, responses on the use of disinfectants for cleaning medical instruments and surfaces were combined into a three-level variable: no weekly disinfection tasks, weekly use for surface cleaning only, and weekly use for cleaning at least medical instruments (regardless of surface disinfection).[22,23] The category of "clean instruments only" was not analyzed separately because of the small number of participants in this category (2.9%).[23]

We used a nurse-specific job–task–exposure matrix (JTEM) derived from NHSII participants to assess exposure to the seven most commonly reported disinfectants or cleaning products (formaldehyde, glutaraldehyde, hypochlorite bleach, hydrogen peroxide, alcohol, quaternary ammonium compounds, and enzymatic

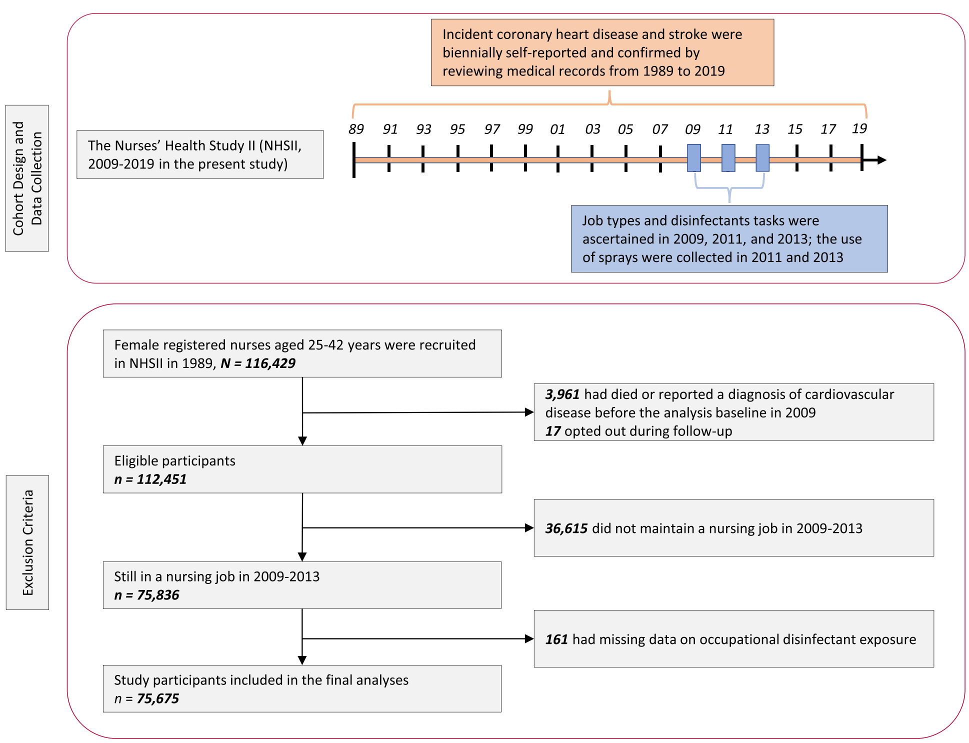


Figure 1. Cohort design and exclusion criteria.

cleaners). The JTEM was developed based on data collected in a subsample of 9,073 NHSII participants, as described in detail elsewhere,[23] and then applied to the entire study population.[22,24] In brief, the JTEM was constructed using responses from NHSII nurses without asthma (2014–2015) to the occupational exposure questions described above. It quantified exposure levels by calculating the percentage of participants reporting the use of each disinfectant in specific nursing jobs and task categories. The JTEM job–task axis consisted of 24 possible combinations of 8 nursing job types and 3 cleaning task categories (surface cleaning only, at least instrument cleaning, or none). For each disinfectant, exposure was classified into low, medium, or high levels based on predefined cutoffs within each job or job–task combination. Given the structure of the JTEM, a "high" exposure level represents a higher probability of frequent (weekly) exposure rather than absolute intensity, frequency, or concentration. Because cutoffs were specific to each disinfectant and relative to the average use within job or task categories, a "high" level of one disinfectant (e.g., glutaraldehyde) is not directly comparable to a "high" level of another (e.g., alcohol) in terms of exposure magnitude. The JTEM ultimately assigned exposure levels for each of the seven specific disinfectants into low, medium, and high levels based on nurses' job types and general disinfection tasks.

Ascertainment of CVD

Incident CVD events of interest included fatal and nonfatal CHD (myocardial infarction or coronary revascularization, including percutaneous coronary intervention or coronary artery bypass graft surgery) and stroke.[25,26] When participants reported an incident event on biennial questionnaires, research investigators, who were previously blinded to the participants' health information, reviewed their medical records with the participants' permission. Nonfatal myocardial infarction was confirmed using medical record evidence of symptoms, along with either diagnostic electrocardiographic results or elevated cardiac-specific enzymes.[26] Nonfatal stroke was confirmed by medical record evidence of a neurological deficit with a sudden or rapid onset that lasted more than 24 h or until the time of death.[26] Deaths due to CVD were identified by next of kin, postal authorities, or a search of the National Death Index. Over 98% of deaths from the original Nurses' Health Study have been successfully ascertained.[27] CHD or stroke listed as the primary cause of death on the death certificate was ascertained as fatal CHD or stroke.[26,28]

Covariates

Height and age at menarche were self-reported in 1989. Major ancestry (categorized as Southern European, Hispanic, Scandinavian, Other Caucasian, African American, Asian, and other Mediterranean) and race (categorized as Asian, White, Hispanic, American Indian/Alaska Native, Native Hawaiian or Other Pacific Islander, Black or African American, and other) were self-reported in 1989 and 2005, respectively. Household income was self-reported in 2001. Parity, age at first child's birth (if applicable), oral contraceptive use, parental history of CVD before age 60 y, working night shifts, menopausal status, hormone treatment, smoking status, and current body weight were updated every 2–4 years since 1989. We calculated body mass index (BMI) for each follow-up cycle. Job strain, defined as high job demands combined with low job control, was assessed using Karasek's Job Content Questionnaire from 1993 to 1997.[29] Participants who had below-median job control scores and above-median job demands scores were identified as having high job strain.[29] Physical activity was reported every 4–6 y since 1991. Dietary quality was assessed based on validated semiquantitative food frequency questionnaires assessed every 4 y since 1991.[30] The Alternative Healthy Eating Index (AHEI) 2010 was developed to incorporate data from food frequency questionnaires, which consists of 11 components, including alcohol consumption, vegetables, fruit, whole grains, nuts and legumes, long chain omega-3 fats, polyunsaturated fatty acids, sugar-sweetened drinks and fruit juice, red and processed meat, trans fat, and sodium.[31]

Data Analysis

Descriptive analyses were conducted for continuous variables [means ± standard deviation (SD)] and categorical variables [n (%)], which were standardized to the age distribution of the study population due to the importance of age as a CVD risk factor and its influence on behaviors, medical history, and other life course factors.[32] Nurses were followed from the return date of 2009–2013 questionnaires when occupational exposure was collected until the date of CVD, death, or the end of follow-up (30 June 2019), whichever occurred first. Occupational exposure was handled as a time-varying variable, with the highest reported exposure level carried forward (Text S2).[24] Cox proportional hazard models were fit to estimate the hazard ratios (HRs) and 95% confidence intervals (CIs) for the associations between job types, general disinfection tasks, and exposure to specific chemicals (evaluated by JTEM) and risk of incident CVD.

The basic model structure was as follows:

$$I(t, x, U, i) = I_{oi}(t) \times \exp\left[1 \times x(t) + 2 \times U(t)\right],$$

where 1 is the log_e of the incidence rate ratio describing the increase or decrease in the baseline incidence rate at time t due to a one-unit increase in exposure $x(t)$ at time t, $U(t)$ is a vector of other risk determinants at age t, 2 is the vector of log_e incidence rate ratios describing the increase or decrease in the baseline incidence rate due to a one-unit increase in these other *a priori* determinants of CVD risk, t is the age at which the outcome of interest is diagnosed, and $I_{oi}(t)$ is the baseline incidence rate of CVD at age t in stratum I.[33] Cox proportional hazards regression models were implemented using SAS PROC PHREG and the Anderson–Gill data structure was used to efficiently handle time-varying covariates. In this structure, a new data record was created for every questionnaire cycle during which a participant was at risk, with covariates updated based on responses at the time of questionnaire return. To minimize confounding by age, calendar time, and potential two-way interactions between these time scales, we jointly stratified the analysis by age in months at the start of the follow-up and calendar year of the current questionnaire cycle.[34] The time scale for the analysis was measured as months since the start of the current questionnaire cycle, which was equivalent to age in months due to our data structure and modeling approach. Departures from the proportional hazards assumption were tested by likelihood ratio tests comparing models with and without the interaction terms for age or calendar time by exposure.[35]

We identified potential confounders related to disinfectant exposure (work in an operating room) and CVD by systematic literature reviews, following the guidance from "Evidence Synthesis for Constructing Directed Acyclic Graphs (DAG)."[32,36] First, a pool of covariates related to disinfectant exposure (work in operating rooms) and CVD was determined by a series of systematic literature reviews. Second, we constructed a saturated DAG by drawing directed or undirected edges between all variables, including exposure, outcomes, and identified covariates, using DAGitty (version 3.1; https://dagitty.net/dags.html). Third, we assessed each of the assumed causal relationships in the saturated DAG by sequential causal criteria, including temporality, validity, and theoretical support. Finally, we identified the following confounding factors existing in the NHSII: age (in months, continuous),[37,38] parity [1 (reference), 2, or ≥3],[39–42] age at first birth [≤25 (reference) vs. >25 y of age],[39,41,42] job strain [high vs. low (reference)],[40,43,44] parental history of CVD before age 60 y [yes vs. no (reference)],[45] and household income [<USD $50,000 (reference), $50,000–$99,999, or ≥$100,000 per year)],[46,47] which are included in the primary multivariable models (Figure S1). In addition, race/ethnicity [non-Hispanic White vs. other (reference)] is a social construct and has been associated with occupational exposure and CVD.[48,49] Therefore, we also included race/ethnicity as a proxy metric in the primary multivariable model to adjust for multigenerational and sociohistorical effects of racism and discrimination.[50] In a secondary multivariable model, we further adjusted for lifestyles and the risk factors of CVD that might also act as mediators, including oral contraceptive use [never (reference), past, or current],[42,51] menopausal status [premenopausal (reference), postmenopausal, or unsure or biologically uncertain],[42,51] hormone treatment [never (reference), past, or current],[42,51] smoking status [never smoker (reference), former smoker, current smoker: 1–14, 15–24, or 25 cigarettes/d],[52–54] physical activity [0 (reference), 0.1–1.0, 1.1–2.4, 2.5–5.9, or ≥6 h/wk],[52–54] AHEI-2010 dietary score [quintiles, with the lowest quintile (reference) representing the least healthy diet],[52–54] and BMI [<18.5 (reference), 18.5–24.9, 25–29.9, or ≥30 kg/m^2].[52,53,55] Covariates with missing values during follow-up were carried forward from the previous questionnaire; if missing from all questionnaires, a missing indicator was created.[56,57]

Stratified and interaction analyses were performed to assess the potential effect modification by BMI (≥25 vs. <25 kg/m^2), physical activity (moderate-to-vigorous intensity of <150 vs. ≥150 min/wk), smoking status (past and current vs. never), AHEI-2010 dietary score (in the top 2 quintiles vs. the bottom 3 quintiles), night shift work (yes vs. no), and high job strain (yes vs. no). The multiplicative interaction between disinfectant exposure and these variables was assessed using the Wald test.[57,58] The additive interaction was assessed by calculating the relative excess risk due to interaction (RERI).[31,58] Several sensitivity analyses were conducted to test the robustness of the findings. First, we excluded nurses who never returned follow-up questionnaires in 2011–2017 period to assess the influence of loss during follow-up. Second, we excluded women who had a diagnosis of type 2 diabetes, chronic obstructive pulmonary disease, or asthma before 2009 to assess whether associations were influenced by potential job changes due to health concerns. Third, we excluded cases of percutaneous coronary intervention or coronary artery bypass graft surgery from end points, because these procedures were self-reported. Fourth, we additionally adjusted for alcohol intake [0 (reference), 1–14, or ≥15 g/d] to assess the influence of alcohol consumption. Finally, we assessed the influence of job-related factors (e.g., night shift work, job strain, and job types) by *a*) excluding women who engaged in night shift work, *b*) restricting the analysis to women employed in operating rooms, and *c*) conducting stratified analyses for the associations of job types with CVD risk according to job strain levels. All data were analyzed using SAS (versions 9.3) for UNIX (SAS Institute Inc.).

Results

Population Characteristics

Among 75,675 nurses included in the current analyses, the mean ± SD of age and BMI at baseline in 2009 were 54.5 ± 4.5 y and 27.8 ± 6.4 kg/m^2, respectively. A total of 21,311 (28.2%) nurses used disinfectants weekly to clean surfaces only, and 21,762 (28.7%) used disinfectants weekly to clean surfaces or medical instruments. Most characteristics of the study participants were similar between those who did vs. did not use disinfectants weekly. However, nurses who used disinfectants to clean surfaces and/or instruments had a higher prevalence of nighttime shift work and were more likely to experience high job strain and to work in emergency rooms, operating rooms, or inpatient units (Table 1).

Job Types, Cleaning/Disinfection Tasks, and CVD

During 10 y (666,152 person-years) of follow-up, we documented 726 incident cases of CVD, including 413 CHD and 318 stroke cases. The crude cumulative incidence of CVD was higher among women who worked in operating rooms than among those working as educators or administrators (1.51 vs. 1.00 per 1,000 person-years; Figure 2). In comparison with women working as educators or administrators, age-adjusted multivariable Cox models showed a higher risk of CVD among women working in operating rooms (crude HR = 1.71; 95% CI: 1.25, 2.35). The HR of CVD was similar after additionally adjusting for other potential confounders (i.e., parity, age at first birth, job strain, parental history of CVD, and household income) (HR = 1.68; 95% CI: 1.22, 2.31) and adulthood lifestyle and CVD risk factors (HR = 1.72; 95% CI: 1.25, 2.36). In addition, we found a higher risk of CVD among nurses using disinfectants every week (adjusted HR = 1.21; 95% CI: 1.04, 1.40), in comparison with nurses who never used disinfectants. The risk of CVD was slightly higher among nurses using disinfectants to clean surfaces or medical instruments than among nurses cleaning surfaces only [adjusted HR = 1.24 (95% CI: 1.03, 1.48) and HR = 1.18 (95% CI: 0.98, 1.41), respectively], in comparison with nurses who never used disinfectants). A similar pattern of associations was found when we separately assessed the risk for CHD and stroke [adjusted HR = 1.69 (95% CI: 1.11, 2.58) and HR = 1.69 (95% CI: 1.05, 2.74, respectively], among operating room nurses, in comparison with those working as educators or administrators; Figure 3). Weekly use of spray or aerosol products was not associated with CVD or stroke (Figures 2 and 3). However, we observed a positive association between weekly use of spray or aerosol products and CHD (adjusted HR = 1.29; 95% CI: 1.02, 1.62; Figure 3). When we jointly classified nurses according to the use of spray or aerosol products and disinfectants (Table S1), nurses who used both spray or aerosol products and other disinfectants had the highest risk of CVD and CHD (Table S1). However, only nurses reporting weekly use of spray or aerosol products (but not other disinfectants) had a higher risk of stroke.

Frequency of Cleaning/Disinfection Tasks, Chemical-Specific Products, and CVD

When the risk of CVD was stratified by the frequency of cleaning/disinfection tasks (Table 2), the strongest associations were found among nurses with the most frequent exposure (4–7 d/wk). In comparison with nurses reporting no cleaning/disinfection tasks, nurses who conducted surface, instrument, and spray cleaning/disinfection 4–7 d/wk had higher HRs for CVD of 1.30 (95% CI: 1.06, 1.60), 1.28 (95% CI: 1.01, 1.62), and 1.26 (95% CI: 0.99, 1.61), respectively. The risk of CVD was also higher for nurses with high exposure levels of the most common disinfectants or cleaning products evaluated by JTEM (formaldehyde, glutaraldehyde, hypochlorite bleach, hydrogen peroxide, alcohol, quaternary ammonium compounds, and enzymatic cleaners), in comparison with nurses with low levels (Table 3).

Interaction and Sensitivity Analyses

There were no multiplicative and additive interactions between disinfectant exposure and BMI, physical activity, smoking status, night shift work, or job strain (Table S2). However, the association

Table 1. Age-standardized baseline (2009) characteristics according to weekly use of disinfectants to clean surfaces and/or instruments among nurses from the Nurses' Health Study II ($n = 75{,}675$).[a,b]

Characteristic	Total	Weekly use of disinfectants to clean surfaces and/or instruments		
		None	Surfaces only	Surfaces and/or instruments
Number of participants (n)	75,675	32,602	21,311	21,762
Baseline age [mean ± SD (y)][c]	54.5 ± 4.5	54.9 ± 4.5	54.4 ± 4.5	53.8 ± 4.5
Baseline BMI [mean ± SD (kg/m^2)]	27.8 ± 6.4	27.8 ± 6.5	27.8 ± 6.3	27.7 ± 6.2
<25	30,061 (39.7)	13,010 (40.1)	8,438 (39.6)	8,613 (39.3)
25–29.9	23,241 (30.8)	9,892 (30.2)	6,509 (30.6)	6,840 (31.6)
≥30	22,370 (29.5)	9,700 (29.6)	6,363 (29.9)	6,307 (29.1)
Total physical activity [mean ± SD (h/wk)]	2.7 ± 3.6	2.7 ± 3.5	2.7 ± 3.5	2.8 ± 3.7
AHEI-2010 dietary score (mean ± SD)	64.8 ± 13.5	65.6 ± 13.6	64.5 ± 13.4	64.0 ± 13.3
Parity	1.9 (1.2)	1.9 (1.2)	1.9 (1.2)	2.0 (1.2)
Oral contraceptive use [n (%)]				
Current	1,756 (2.3)	756 (2.6)	454 (2.1)	546 (2.2)
Former	61,159 (80.8)	26,446 (80.6)	17,217 (80.8)	17,496 (81.1)
Never	9,008 (11.9)	3,848 (11.7)	2,499 (11.7)	2,661 (12.3)
Race/ethnicity [n (%)]				
Non-Hispanic White	70,008 (92.4)	30,299 (92.9)	19,715 (92.5)	19,994 (91.8)
Other	5,667 (7.6)	2,303 (7.1)	1,596 (7.5)	1,768 (8.2)
Income [n (%); USD per year]				
<50,000	8,517 (11.6)	3,166 (9.7)	2,467 (11.6)	2,884 (13.4)
50,000–99,999	27,672 (36.7)	11,658 (35.7)	7,730 (36.3)	8,284 (38.2)
≥100,000	17,454 (22.3)	8,900 (27.1)	4,619 (21.7)	3,935 (18.2)
Smoking status [n (%)]				
Never	49,493 (65.5)	21,096 (65.1)	14,068 (66.0)	14,329 (65.4)
Former	21,203 (27.9)	9,522 (28.8)	5,864 (27.6)	5,817 (27.2)
Current 1–34 cigarettes/day	4,461 (6.0)	1,753 (5.4)	1,231 (5.8)	1,477 (6.8)
Current ≥35 cigarettes/day	147 (0.2)	70 (0.2)	38 (0.2)	39 (0.2)
Parental history of CVD before age 60 y [n (%)]				
Yes	20,288 (26.9)	8,681 (26.3)	5,720 (26.9)	5,887 (27.4)
No	55,387 (73.1)	23,921 (73.7)	15,591 (73.1)	15,875 (72.6)
Night shiftwork [n (%)]				
Yes	54,709 (72.7)	22,703 (69.8)	15,607 (73.2)	16,399 (75.2)
No	20,966 (27.3)	9,899 (30.2)	5,704 (26.8)	5,363 (24.8)
High job strain [n (%)]				
Yes	20,825 (28.4)	7,409 (22.9)	6,428 (30.2)	6,988 (32.0)
No	54,850 (71.6)	25,193 (77.1)	14,883 (69.8)	14,774 (68.0)
Job type [n (%)]				
Education or administration	8,984 (10.3)	6,923 (21.2)	1,593 (7.5)	468 (2.2)
Outpatient, other nurses	40,439 (52.3)	19,872 (60.9)	11,253 (52.8)	9,314 (43.2)
ED or inpatient unit	20,732 (29.4)	4,893 (15.1)	6,499 (30.5)	9,340 (42.5)
Operating room	5,520 (8.0)	914 (2.8)	1,966 (9.2)	2,640 (12.1)

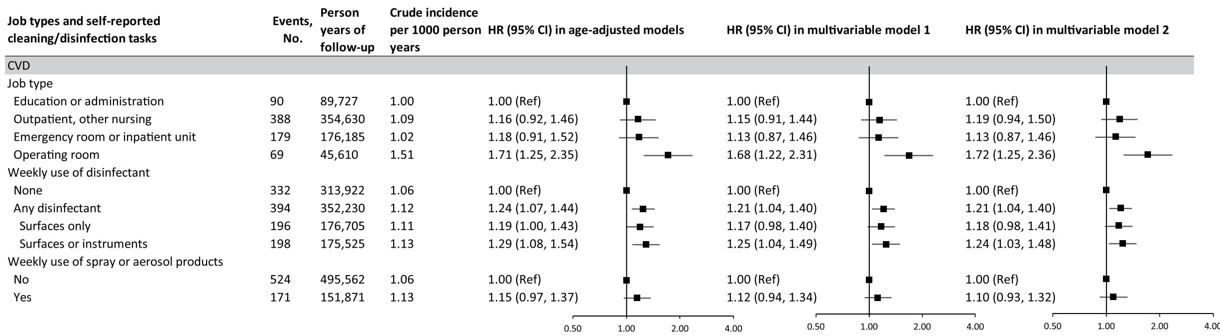
Note: AHEI, Alternative Healthy Eating Index; BMI, body mass index (calculated as weight in kilograms divided by height in square meters); CVD, cardiovascular disease; ED, emergency department; SD, standard deviation.
[a]Means (SD) for continuous variables and number (%) for categorical variables are standardized to the age distribution of the study population (except for age), because of the importance of age as a risk factor for CVD and in modifying behaviors, medical history, and other life course factors.
[b]A total of 22,073 (29.1%), 2,037 (2.7%), and 6,934 (9.2%) nurses had missing data on income, diet (including alcohol intake), and night shift work, respectively.
[c]Values are not age-adjusted.

was slightly stronger among nurses with a lower AHEI dietary score (p for additive interaction = 0.068; RERI = 0.29; 95% CI: −0.02, 0.61). Sensitivity analyses showed similar associations of job types and cleaning/disinfection tasks with CVD risk when we excluded nurses who never returned follow-up questionnaires in the 2011–2017 period; when we excluded nurses with type 2 diabetes, chronic obstructive pulmonary disease, or asthma before 2009; when we excluded self-reported cases of percutaneous coronary intervention or coronary artery bypass graft surgery from end points; and when we additionally adjusted for alcohol intake (Table S3). Most positive associations between general disinfection tasks and chemical-specific exposure and CVD risk exhibited similar or greater HRs even after excluding women who worked night shifts (Tables S4 and S5) and when restricting the analysis to women employed in operating rooms (Tables S6 and S7). When job types were assessed separately according to low and high job strain (Table S8), nurses working in operating rooms, regardless of job strain, consistently had the highest risk of CVD, CHD, and stroke.

Discussion

In this large prospective cohort consisting of 75,675 nurses, we found an increased risk of CVD over 10 y of follow-up (666,152 person-years) among nurses who worked in operating rooms and those using disinfectants and spray or aerosol products. Moreover, we found positive dose–response relationships between the frequency of cleaning/disinfection tasks and exposure levels of chemical-specific disinfectants and the risk of CVD.

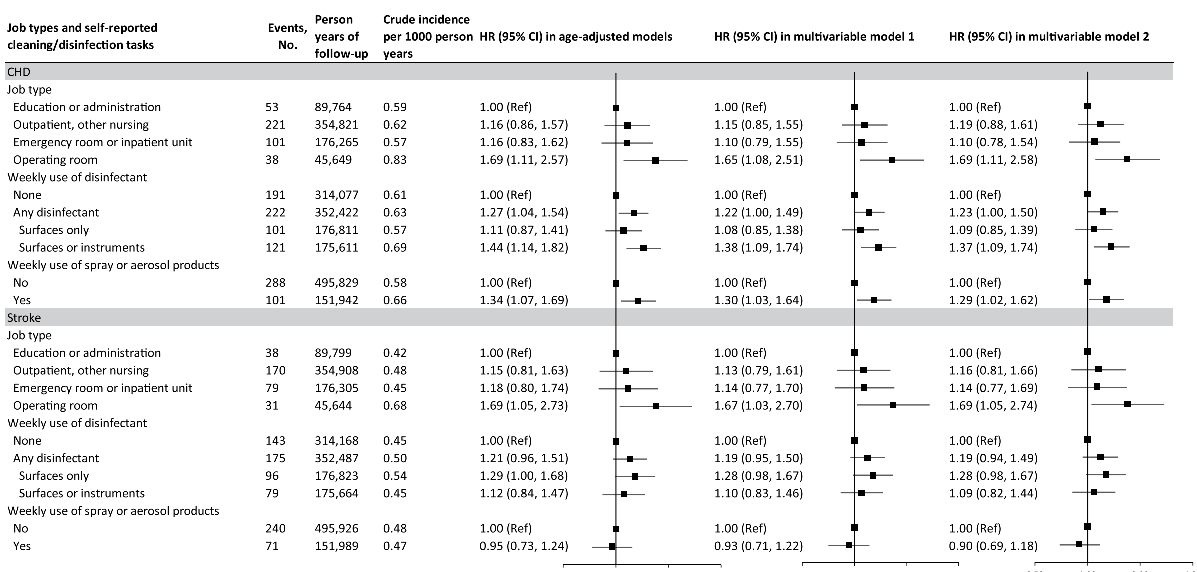
Existing evidence from *in vivo*, *in vitro*, and population studies has consistently revealed that exposure to disinfectant chemicals, such as formaldehyde, hydrogen peroxide, ethanol, and quaternary ammonium compounds, can induce oxidative stress and inflammation,[59–63] both of which play an important role in the pathogenesis of CVD.[64] Disinfectant exposure may also affect gut, oral, and upper airway microbiomes,[65,66] which, in turn, have been associated with chronic respiratory and cardiovascular diseases in population studies.[67–70] In support of our findings, exposure to certain chemicals commonly used in disinfectants, including formaldehyde, hypochlorite, hydrogen peroxide, and isopropyl alcohol, has



Job types and self-reported cleaning/disinfection tasks	Events, No.	Person years of follow-up	Crude incidence per 1000 person years	HR (95% CI) in age-adjusted models	HR (95% CI) in multivariable model 1	HR (95% CI) in multivariable model 2
CVD						
Job type						
Education or administration	90	89,727	1.00	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
Outpatient, other nursing	388	354,630	1.09	1.16 (0.92, 1.46)	1.15 (0.91, 1.44)	1.19 (0.94, 1.50)
Emergency room or inpatient unit	179	176,185	1.02	1.18 (0.91, 1.52)	1.13 (0.87, 1.46)	1.13 (0.87, 1.46)
Operating room	69	45,610	1.51	1.71 (1.25, 2.35)	1.68 (1.22, 2.31)	1.72 (1.25, 2.36)
Weekly use of disinfectant						
None	332	313,922	1.06	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
Any disinfectant	394	352,230	1.12	1.24 (1.07, 1.44)	1.21 (1.04, 1.40)	1.21 (1.04, 1.40)
Surfaces only	196	176,705	1.11	1.19 (1.00, 1.43)	1.17 (0.98, 1.40)	1.18 (0.98, 1.41)
Surfaces or instruments	198	175,525	1.13	1.29 (1.08, 1.54)	1.25 (1.04, 1.49)	1.24 (1.03, 1.48)
Weekly use of spray or aerosol products						
No	524	495,562	1.06	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
Yes	171	151,871	1.13	1.15 (0.97, 1.37)	1.12 (0.94, 1.34)	1.10 (0.93, 1.32)

Figure 2. Adjusted HRs and 95% CIs from Cox proportional hazard models for the risk of CVD by job types and self-reported cleaning/disinfection tasks among 75,675 nurses from the Nurses' Health Study II (2009–2019). A total of 1,271 nurses did not have data on the use of spray or aerosol products. In the age-adjusted model, age in months at the start of follow-up and calendar year of the current questionnaire cycle were included as stratified variables. Multivariable model 1 was additionally adjusted for race/ethnicity [non-Hispanic White vs. other (reference); parity: 1 (reference), 2, or ≥3]; age at first birth [≤25 (reference) vs. >25 y of age]; high job strain [yes vs. no (reference)]; parental history of CVD before age 60 y [yes vs. no (reference)]; and household income [<USD $50,000 (reference), USD $50,000–$99,999, or ≥USD $100,000 per year]. Multivariable model 2 was additionally adjusted for oral contraceptive use [never (reference), past, or current], menopausal status [premenopausal (reference), postmenopausal, or unsure or biologically uncertain], hormone treatment [never (reference), past, or current], smoking status [never smoker (reference), former smoker, current smoker: 1–14, 15–24, or 25 cigarettes/d], physical activity [0 (reference), 0.1–1.0, 1.1–2.4, 2.5–5.9, or ≥6 h/wk], AHEI-2010 dietary score [quintiles, with the lowest quintile (reference) representing the least healthy diet], and BMI [<18.5 (reference), 18.5–24.9, 25–29.9, or ≥30 kg/m^2]. Forest plots show the estimated HRs (boxes) and CIs (horizontal lines through the boxes). Note: BMI, body mass index; CI, confidence interval; CVD, cardiovascular disease; HR hazard ratio.

been associated with vascular or endothelial dysfunctions in *in vivo* or *in vitro* studies.[10,11,71] In population studies, Mehta et al. reported that long-term frequent use of household spray and scented products, particularly air freshening sprays, was associated with reduced heart rate variability, a key clinical marker for CVD, among 581 Swiss adults.[15] Similarly, intervention studies demonstrated a reduced brachial artery flow–mediated dilation and changes in carotid distensibility and intima-media thickness immediately after a 90-min formaldehyde exposure (197 ± 79 ppb) in 10 healthy adult females.[17,72] In a nationwide registry-based study consisting of 64,689 females with type 2 diabetes, the subsequent risk of CVD mortality was highest among manufacturing workers, housekeepers, and cleaners across the 30 most common occupations.[16] Respiratory diseases, particularly chronic obstructive pulmonary disease and asthma, have been associated with adverse cardiovascular consequences and thus may serve as



Job types and self-reported cleaning/disinfection tasks	Events, No.	Person years of follow-up	Crude incidence per 1000 person years	HR (95% CI) in age-adjusted models	HR (95% CI) in multivariable model 1	HR (95% CI) in multivariable model 2
CHD						
Job type						
Education or administration	53	89,764	0.59	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
Outpatient, other nursing	221	354,821	0.62	1.16 (0.86, 1.57)	1.15 (0.85, 1.55)	1.19 (0.88, 1.61)
Emergency room or inpatient unit	101	176,265	0.57	1.16 (0.83, 1.62)	1.10 (0.79, 1.55)	1.10 (0.78, 1.54)
Operating room	38	45,649	0.83	1.69 (1.11, 2.57)	1.65 (1.08, 2.51)	1.69 (1.11, 2.58)
Weekly use of disinfectant						
None	191	314,077	0.61	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
Any disinfectant	222	352,422	0.63	1.27 (1.04, 1.54)	1.22 (1.00, 1.49)	1.23 (1.00, 1.50)
Surfaces only	101	176,811	0.57	1.11 (0.87, 1.41)	1.08 (0.85, 1.38)	1.09 (0.85, 1.39)
Surfaces or instruments	121	175,611	0.69	1.44 (1.14, 1.82)	1.38 (1.09, 1.74)	1.37 (1.09, 1.74)
Weekly use of spray or aerosol products						
No	288	495,829	0.58	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
Yes	101	151,942	0.66	1.34 (1.07, 1.69)	1.30 (1.03, 1.64)	1.29 (1.02, 1.62)
Stroke						
Job type						
Education or administration	38	89,799	0.42	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
Outpatient, other nursing	170	354,908	0.48	1.15 (0.81, 1.63)	1.13 (0.79, 1.61)	1.16 (0.81, 1.66)
Emergency room or inpatient unit	79	176,305	0.45	1.18 (0.80, 1.74)	1.14 (0.77, 1.70)	1.14 (0.77, 1.69)
Operating room	31	45,644	0.68	1.69 (1.05, 2.73)	1.67 (1.03, 2.70)	1.69 (1.05, 2.74)
Weekly use of disinfectant						
None	143	314,168	0.45	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
Any disinfectant	175	352,487	0.50	1.21 (0.96, 1.51)	1.19 (0.95, 1.50)	1.19 (0.94, 1.49)
Surfaces only	96	176,823	0.54	1.29 (1.00, 1.68)	1.28 (0.98, 1.67)	1.28 (0.98, 1.67)
Surfaces or instruments	79	175,664	0.45	1.12 (0.84, 1.47)	1.10 (0.83, 1.46)	1.09 (0.82, 1.44)
Weekly use of spray or aerosol products						
No	240	495,926	0.48	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
Yes	71	151,989	0.47	0.95 (0.73, 1.24)	0.93 (0.71, 1.22)	0.90 (0.69, 1.18)

Figure 3. Adjusted HRs and 95% CIs from Cox proportional hazard models for the risk of CHD and stroke by job types and self-reported cleaning/disinfection tasks among 75,675 nurses from the Nurses' Health Study II (2009–2019). A total of 1,271 nurses did not have data on the use of spray or aerosol products. In the age-adjusted model, age in months at the start of follow-up and calendar year of the current questionnaire cycle were included as stratified variables. Multivariable model 1 was additionally adjusted for race/ethnicity [non-Hispanic White vs. other (reference); parity: 1 (reference), 2, or ≥3]; age at first birth [≤25 (reference) vs. >25 y of age]; high job strain [yes vs. no (reference)]; parental history of CVD before age 60 y [yes vs. no (reference)]; and household income [<USD $50,000 (reference), USD $50,000–$99,999, or ≥USD $100,000 per year]. Multivariable model 2 was additionally adjusted for oral contraceptive use [never (reference), past, or current], menopausal status [premenopausal (reference), postmenopausal, or unsure or biologically uncertain], hormone treatment [never (reference), past, or current], smoking status [never smoker (reference), former smoker, current smoker: 1–14, 15–24, or 25 cigarettes/d], physical activity [0 (reference), 0.1–1.0, 1.1–2.4, 2.5–5.9, or ≥6 h/wk], AHEI-2010 dietary score [quintiles, with the lowest quintile (reference), representing the least healthy diet], and BMI [<18.5 (reference), 18.5–24.9, 25–29.9, or ≥30 kg/m^2]. Forest plots show the estimated HRs (the box in the middle of each horizontal line) and CIs (horizontal lines through the boxes). Note: BMI, body mass index; CI, confidence interval; CHD, coronary heart disease; CVD, cardiovascular disease; HR hazard ratio.

Table 2. Adjusted HRs and 95% CIs from Cox proportional hazard models for the risk of CVD by self-reported frequency of cleaning/disinfection tasks among 75,675 nurses from the Nurses' Health Study II (2009–2019).

Self-reported frequency of cleaning/disinfection tasks	Events (n)	Person-years of follow-up	Crude incidence per 1,000 person-years	HR (95% CI)		
				Age-adjusted model[c]	Multivariable model 1[d]	Multivariable model 2[e]
Clean surface						
Never	209	190,729	1.10	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
<1	148	142,820	1.04	1.06 (0.86, 1.31)	1.05 (0.85, 1.30)	1.05 (0.85, 1.30)
1–3	185	180,303	1.03	1.13 (0.93, 1.38)	1.11 (0.91, 1.36)	1.12 (0.91, 1.37)
4–7	184	152,910	1.20	1.37 (1.12, 1.68)	1.32 (1.08, 1.62)	1.30 (1.06, 1.60)
p For trend[a]	—	—	—	0.003	0.009	0.012
Clean instruments						
Never	407	375,211	1.08	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
<1	121	115,928	1.04	1.05 (0.86, 1.28)	1.03 (0.84, 1.26)	1.03 (0.84, 1.27)
1–3	112	106,126	1.06	1.12 (0.91, 1.39)	1.10 (0.89, 1.35)	1.10 (0.89, 1.36)
4–7	86	69,497	1.24	1.38 (1.09, 1.74)	1.32 (1.04, 1.67)	1.28 (1.01, 1.62)
p For trend[a]	—	—	—	0.011	0.035	0.050
Spray or aerosol products[b]						
Never	381	357,311	1.07	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
<1	143	138,251	1.03	1.04 (0.85, 1.26)	1.02 (0.84, 1.23)	1.00 (0.83, 1.22)
1–3	90	89,443	1.01	1.03 (0.82, 1.30)	1.00 (0.80, 1.27)	1.00 (0.79, 1.26)
4–7	81	62,427	1.30	1.35 (1.06, 1.73)	1.31 (1.03, 1.67)	1.26 (0.99, 1.61)
p For trend[a]	—	—	—	0.047	0.10	0.17
Any disinfectant						
Never	195	175,294	1.11	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
<1	137	138,913	0.99	0.99 (0.79, 1.23)	0.97 (0.78, 1.21)	0.97 (0.78, 1.21)
1–3	194	188,176	1.03	1.12 (0.91, 1.37)	1.09 (0.89, 1.34)	1.10 (0.90, 1.35)
4–7	200	164,379	1.22	1.37 (1.12, 1.67)	1.32 (1.07, 1.61)	1.30 (1.06, 1.59)
p For trend[a]	—	—	—	0.002	0.006	0.008

Note: —, no data; CI, confidence interval; CVD, cardiovascular disease; HR, hazard ratio; Ref, reference.
[a]p-Values for trend were estimated by including the exposure term (coded as 1–4) as a continuous variable in models.
[b]A total of 1,271 nurses did not have data on the use of spray or aerosol products.
[c]In the age-adjusted model, age in months at the start of follow-up and calendar year of the current questionnaire cycle were included as stratified variables.
[d]Multivariable model 1 was additionally adjusted for race/ethnicity [non-Hispanic White vs. other (reference); parity: 1 (reference), 2, or ≥3]; age at first birth [≤25 (reference), vs. >25 y of age); high job strain (yes vs. no (reference)]; parental history of CVD before age 60 y [yes vs. no (reference)]; and household income [<USD $50,000 (reference), $50,000–$99,999, or ≥$100,000 per year).
[e]Multivariable model 2 was additionally adjusted for oral contraceptive use [never (reference), past, or current], menopausal status [premenopausal (reference), postmenopausal, or unsure or biologically uncertain], hormone treatment [never (reference), past, or current], smoking status [never smoker (reference), former smoker, current smoker: 1–14, 15–24, or 25 cigarettes/d], physical activity [0 (reference), 0.1–1.0, 1.1–2.4, 2.5–5.9, or ≥6 h/wk], AHEI-2010 dietary score [quintiles, with the lowest quintile (reference) representing the least healthy diet], and BMI [<18.5 (reference), 18.5–24.9, 25–29.9, or ≥30 kg/m^2].

intermediate pathways in the association between disinfectant exposure and CVD.[73–75] Many population studies have reported that exposure to disinfectants is associated with an increased incidence or prevalence of asthma and respiratory symptoms among workers with different occupations.[76–83] In addition to these previous findings, our recent work showed that occupational disinfectant exposure was associated with an increased risk of asthma and chronic obstructive pulmonary disease among nurses from the NHS, NHSII, and NHS3.[9,18,24,84,85]

Our study augments the evidence by examining job types, disinfection tasks, and exposure to specific chemicals in relation to incident CVD among health care workers. We found that the highest risk of CVD was found among nurses who used disinfectants or spray or aerosol products with a frequency of 4–7 d/wk. When we jointly classified nurses according to the use of spray or aerosol products and disinfectants, the highest risk of CVD and CHD was seen among nurses who used both spray or aerosol products and other disinfectants. However, a higher risk of stroke was found only among nurses reporting weekly use of spray or aerosol products without additional use of disinfectants. Furthermore, nurses with higher exposure levels to the most commonly used disinfectants or cleaning products, as assessed by the JTEM, had a higher risk of CVD in comparison with those with lower exposure levels. We did not find any interaction between job types and disinfectant exposure and BMI, physical activity, smoking status, night shift work, or job strain. In addition, the associations of general disinfection tasks and chemical-specific exposure with CVD risk largely persisted (HRs of similar or greater magnitude) even after excluding women who worked night shifts and when restricting the analysis to women employed in operating rooms. When job types were assessed separately according to low and high job strain, the highest risk of CVD, CHD, and stroke was consistently found among nurses working in operating rooms, regardless of job strain. Together, these results suggest that the positive association between disinfectant exposure and CVD risk is independent of these lifestyles and job-related factors. However, we found evidence of a positive relative excess risk of CVD due to the interaction between disinfectant exposure and low-quality diet, suggesting that these two factors may interact synergistically to further accelerate the development of CVD.

The present study has several strengths, including its large population size, prospective design, high biennial follow-up response rates, and rigorous ascertainment of occupational exposure, key covariates, and CVD cases. However, there are also limitations. First, participants self-reported their job types and disinfection tasks, which may have led to exposure misclassification. However, the prospective design and consistent positive dose–response relationships between the frequency of cleaning or disinfection tasks and exposure levels of chemical-specific disinfectants and CVD indicate that our findings are less likely to be materially biased by exposure misclassification. Second, coronary revascularization procedures, body weight, and lifestyle factors (e.g., diet, physical activity, smoking) were self-reported. However, in a subgroup of participants from the Health Professionals Follow-up Study, 96% of self-reported coronary revascularization cases have been demonstrated to be reliable in comparison with medical records.[86] Similarly, self-reported lifestyle factors have been demonstrated to be highly

Table 3. Adjusted HRs and 95% CIs from cox proportional hazard models for the risk of CVD by specific disinfectants/cleaning products evaluated by job–task–exposure matrix among 75,675 nurses from the Nurses' Health Study II (2009–2019).

Occupational exposure	Events (*n*)	Person-years of follow-up	Crude incidence per 1,000 person-years	HR (95% CI)		
				Age-adjusted model[b]	Multivariable model 1[c]	Multivariable model 2[d]
Formaldehyde						
Low	589	555,579	1.06	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
Middle	45	36,943	1.22	1.31 (0.97, 1.78)	1.28 (0.95, 1.74)	1.30 (0.96, 1.77)
High	92	73,630	1.25	1.32 (1.05, 1.64)	1.30 (1.04, 1.62)	1.31 (1.05, 1.64)
p For trend[a]	—	—	—	0.006	0.009	0.007
Glutaraldehyde						
Low	350	337,648	1.04	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
Middle	101	88,674	1.14	1.23 (0.99, 1.54)	1.21 (0.97, 1.51)	1.20 (0.96, 1.50)
High	275	239,830	1.15	1.30 (1.11, 1.53)	1.27 (1.08, 1.49)	1.28 (1.09, 1.51)
p For trend[a]	—	—	—	0.001	0.004	0.003
Hypochlorite bleach						
Low	294	275,855	1.07	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
Middle	166	144,998	1.14	1.17 (0.97, 1.42)	1.15 (0.95, 1.40)	1.15 (0.95, 1.39)
High	266	245,298	1.08	1.22 (1.03, 1.44)	1.18 (0.99, 1.40)	1.17 (0.98, 1.38)
p For trend[a]	—	—	—	0.020	0.056	0.078
Hydrogen peroxide						
Low	331	313,135	1.06	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
Middle	88	81,601	1.08	1.13 (0.89, 1.43)	1.12 (0.88, 1.42)	1.13 (0.89, 1.43)
High	307	271,416	1.13	1.27 (1.09, 1.49)	1.23 (1.05, 1.45)	1.23 (1.05, 1.44)
p For trend[a]	—	—	—	0.003	0.010	0.012
Alcohol						
Low	294	275,855	1.07	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
Middle	118	103,697	1.14	1.17 (0.94, 1.44)	1.14 (0.92, 1.41)	1.11 (0.90, 1.38)
High	314	286,599	1.10	1.21 (1.03, 1.42)	1.18 (1.00, 1.39)	1.18 (1.00, 1.39)
p For trend[a]	—	—	—	0.019	0.048	0.053
Quaternary ammonium compounds						
Low	294	275,855	1.07	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
Middle	125	117,310	1.07	1.08 (0.87, 1.33)	1.06 (0.86, 1.31)	1.03 (0.84, 1.28)
High	307	272,987	1.12	1.26 (1.07, 1.48)	1.22 (1.04, 1.44)	1.22 (1.03, 1.44)
p For trend[a]	—	—	—	0.005	0.018	0.018
Enzymatic cleaners						
Low	514	490,190	1.05	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
Middle	40	42,014	0.95	1.00 (0.73, 1.38)	0.98 (0.71, 1.36)	0.96 (0.69, 1.32)
High	172	133,949	1.28	1.39 (1.17, 1.65)	1.36 (1.14, 1.62)	1.36 (1.14, 1.62)
p For trend[a]	—	—	—	<0.001	0.001	0.001

Note: —, no data; CI, confidence interval; CVD, cardiovascular disease; HR, hazard ratios; Ref, reference.
[a]*p*-Values for trend were estimated by including the exposure term (coded as 1–3) as a continuous variable in models.
[b]In the age-adjusted model, age in months at the start of follow-up and calendar year of the current questionnaire cycle were included as stratified variables.
[c]Multivariable model 1 was additionally adjusted for race/ethnicity [non-Hispanic White versus other (reference), parity 1 (reference), 2, or ≥3], age at first birth [≤25 (reference) vs. >25 y of age)], high job strain [yes vs. no (reference)], parental history of CVD before age 60 y [yes vs. no (reference)], and household income [<USD $50,000 (reference), $50,000–$99,999, or ≥$100,000 per year)].
[d]Multivariable model 2 was additionally adjusted for oral contraceptive use [never (reference), past, or current], menopausal status [premenopausal (reference), postmenopausal, or unsure or biologically uncertain], hormone treatment [never (reference), past, or current], smoking status [never smoker (reference), former smoker, current smoker: 1–14, 15–24, or 25 cigarettes/d], physical activity [0 (reference), 0.1–1.0, 1.1–2.4, 2.5–5.9, or ≥6 h/wk], AHEI-2010 dietary score [quintiles, with the lowest quintile (reference) representing the least healthy diet], and BMI [<18.5 (reference), 18.5–24.9, 25–29.9, or ≥30 kg/m^2].

reliable in NHSII or the original NHS.[31,87–89] Third, we did not collect data on protective equipment during cleaning or disinfection tasks. However, in a subgroup of 4,102 nurses from NHSII, only 5% of participants wore any masks or respiratory protection devices when they used disinfectants or cleaning products.[22] Fourth, we collected occupational exposure in 2009–2013 and did not consider the influence of changes in disinfectant exposure due to health concerns. In our previous study, we found that NHSII nurses who had respiratory conditions tended to move to jobs with lower disinfectant exposure across a 22-y follow-up (1989–2011).[18] However, our sensitivity analyses showed similar associations when we excluded nurses reporting type 2 diabetes, chronic hypertension, or asthma before the analysis baseline in 2009. Fifth, as an observational study, our findings are limited in their causal interpretation. However, because it would be unethical to randomize participants to disinfectant exposure, high-quality observational studies provide the best available evidence on the long-term relationship between occupational disinfectant exposure and CVD risk. Sixth, although we considered various confounders and risk factors for CVD, confounding from unmeasured covariates (e.g., changes in disinfectant formulations, socioeconomic factors, and other occupational exposures) cannot be fully ruled out. Finally, our study population was mainly non-Hispanic White female nurses, which may limit the generalizability of our findings. Additional studies should be conducted to validate our findings among male professionals and individuals from diverse racial and ethnic backgrounds.

Conclusion

In this large prospective cohort, the use of disinfectants and spray or aerosol products was associated with an increased subsequent risk of CVD. When we jointly classified nurses according to the use of spray or aerosol products and disinfectants, the highest risk of CVD and CHD was found among nurses who used both. However, a higher risk of stroke was seen only among nurses exclusively reporting weekly use of spray or aerosol products. These findings suggest that occupational disinfectant exposure may contribute to the burden of CVD among health care workers. Furthermore, our results highlight the need to develop policies and technologies aimed at reducing disinfectant exposure in health care settings, such as eliminating or substituting harmful chemicals, developing nonchemical technologies for disinfection (e.g., steam and ultraviolet light), avoiding aerosols with tiny droplets by using alternative methods or nozzle heads that produce larger droplets, and ensuring the use of personal protective equipment.

Acknowledgments

The authors thank the participants and staff of the NHSII for their invaluable contributions and thank staff from the cancer registries in the following states for their help: Alabama, Arizona, Arkansas, California, Colorado, Connecticut, Delaware, Florida, Georgia, Idaho, Illinois, Indiana, Iowa, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Minnesota, Nebraska, New Hampshire, New Jersey, New York, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, Rhode Island, South Carolina, Tennessee, Texas, Virginia, Washington, and Wyoming. The authors assume full responsibility for analyses and interpretation of these data.

Y-X.W. and O.D. had full access to all of the data in the study and took responsibility for the integrity of the data and the accuracy of the data analysis. Y-X.W. analyzed data and drafted the manuscript. Y-X.W., C.A.C., and C.M. conceived, developed, and designed the study. O.D. checked the accuracy of the data analysis. All authors participated in the interpretation of the results, preparation of the manuscript, and critical revisions.

This study was supported by the National Natural Science Foundation of China (82473581) and the National Institutes of Health grants U01-HL145386, U01-CA176726, R01-HL034594, R01-HL088521, UM-CA186107, P01-CA87969, R01-CA49449, R01-CA67262, U01-HL145386, U01-CA167552, R01-HL35464, R24-ES028521-01, and R01-ES031657. The funders had no role in considering the study design or in the collection, analysis, interpretation of data, writing of the report, or decision to submit.

The data used in the present study will not be made publicly available, but they can be requested by sending email to nhsaccess@channing.harvard.edu.

The procedures for accessing data from the NHSII are also described at https://www.nurseshealthstudy.org/researchers.

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