

A workforce-based study of occupational exposures and asthma symptoms in cleaning workers

David Vizcaya,^{1,2,3,4} Maria C Mirabelli,⁵ Josep-Maria Antó,^{1,2,3,4} Ramon Oriols,^{6,7} Felip Burgos,^{7,8} Lourdes Arjona,^{1,2,4} Jan-Paul Zock^{1,2,4}

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¹Centre for Research in Environmental Epidemiology (CREAL), Barcelona, Spain

²Hospital del Mar Research Institute (IMIM), Barcelona, Spain

³Universitat Pompeu Fabra (UPF), Barcelona, Spain

⁴CIBER Epidemiología y Salud Pública (CIBERESP), Barcelona, Spain

⁵Department of Epidemiology and Prevention, Division of Public Health Sciences, Wake Forest University School of Medicine, Winston-Salem, North Carolina, USA

⁶Servei de Pneumologia, Hospital Universitari Vall d'Hebron, Barcelona, Spain

⁷CIBER Enfermedades Respiratorias (CIBERES), Barcelona, Spain

⁸Servei de Pneumologia, Hospital Clínic, IDIBAPS, Barcelona, Spain

Correspondence to

David Vizcaya Fernández, CREAL-Centre for Research in Environmental Epidemiology, Barcelona Biomedical Research Park, Dr Aiguader, 88 08003 Barcelona, Spain; dvizcaya@creal.cat

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ABSTRACT

Objectives To study associations between use of cleaning products and asthma symptoms in cleaning workers.

Methods Information on respiratory symptoms, history of asthma, workplaces, use of cleaning products and acute inhalation incidents were obtained through a self-administered questionnaire. 917 employees of 37 cleaning companies in Barcelona were studied. 761 (83%) were current cleaners, 86 (9%) former cleaners and 70 (8%) had never worked as cleaners. Multivariable logistic regression analyses were used to evaluate the associations between specific exposures among current cleaners and wheeze without having a cold, chronic cough and current asthma. Associations with an asthma symptom score were also studied using negative binomial regression analyses to report mean ratios.

Results After adjusting for sex, age, nationality and smoking status, the prevalence of current asthma was non-significantly higher among current (OR 1.9; 95% CI 0.5 to 7.8) and former cleaners (OR 1.9; CI 0.6 to 5.5) than in never cleaners. Cleaners working in hospitals during the last year had a significantly increased prevalence of wheeze, current asthma and a 1.8 (95% CI 1.2 to 2.8) times higher mean asthma score. Use of hydrochloric acid was strongly associated with asthma score (mean ratio 1.7; 95% CI 1.1 to 2.6). Use of ammonia, degreasers, multiple purpose products and waxes was also associated with asthma score.

Conclusions Cleaning work in places with high demand for disinfection, high cleaning standards and use of cleaning products containing respiratory irritants is associated with higher risk of asthma symptoms. This suggests irritants have an important role in cleaning-related asthma.

INTRODUCTION

There is extensive evidence that cleaning workers and other professionals who use cleaning products at work are at increased risk of asthma.^{1–5} However, to date few studies have systematically evaluated specific cleaning-related risk factors for asthma and asthma symptoms. It has been suggested that products containing inhalant irritants such as ammonia and other alkaline compounds, acids and chlorine-releasing agents are likely to play an important role in both new-onset asthma and work-exacerbated asthma.^{6–8} Unravelling the responsible occupational exposures for asthma among cleaners is challenging because cleaning work covers a broad range of activities, there is a large turnover of workers between tasks

What this paper adds

- Cleaning workers are at increased risk of asthma but the underlying exposures responsible are unknown.
- Cleaning workers are widely exposed to different irritant cleaning products.
- The use of irritant cleaning products is associated with respiratory symptoms.
- Control measures to reduce or avoid exposure to irritant cleaning products may help reduce the burden of respiratory disorders in cleaning workers.

and most cleaning workers typically use many different products, some of which are irritants.

Recent studies have begun to disentangle the causes of asthma in cleaning workers and have identified exposure to irritant cleaning agents as a possible factor causing increased risk of asthma.⁹ Surveillance programs in different countries have shown that cleaning workers account for a considerable proportion of all work-related asthma cases, including both new-onset and work-aggravated asthma. Although cleaning products in general terms were considered the cause of asthma in many reported cases, only in very few instances was a specific cleaning product identified as causing asthma onset.^{10–11} Cleaning jobs may involve exposures related to the type of location where the cleaning is performed,¹² but chemical cleaning products typically comprise the main exposure among cleaners. The most frequently used products include hypochlorite salts, ammonia, hydrochloric acid and other respiratory irritants.⁶ In addition, many cleaning products are complex mixtures that are used in many different ways, thus resulting in a wide heterogeneity of exposure.⁶

Workforce-based studies are generally considered helpful to assess the variety of exposures involved in jobs which include many different tasks and products. They are also useful for the development of measures to control occupational hazards. Several workforce-based studies have been conducted to evaluate asthma risk among cleaners. Chlorine bleach was the most common agent related to respiratory symptoms in cleaning workers from Sao Paulo, although numbers were too small to evaluate the association between cleaning products and respiratory outcomes.¹³ In Ontario, the main risk factors for work-related

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symptoms were waxing, spot cleaning of carpets, oiling furniture, cleaning tiles and cleaning grout, but no evaluation of exposure to cleaning products was performed.¹⁴

However, there is little evidence of specific exposures to cleaning products or specific cleaning tasks being associated with asthma. Identifying specific products, work activities and workplaces related to health outcomes is important to develop new measures for prevention. The present study was conducted to evaluate the association of a wide range of specific cleaning exposures at work with asthma and respiratory symptoms in employees of cleaning companies, with special reference to exposure to irritant cleaning products.

METHODS

Study population

This study focuses on employees of cleaning companies. Between February 2007 and January 2008, we contacted all 1018 companies specialising in cleaning services in the province of Barcelona, in order to establish a convenient sample of cleaning companies with varying characteristics representing the entire sector. Of these, 286 (28%) had ceased their cleaning activities and thus were not eligible. Companies were asked to return a short questionnaire on the number of workers they employed and the main activities offered. We received completed questionnaires from 37 companies who were willing to participate in the study. The size of the participating companies varied from six to more than 1000 employees. The cleaning activities offered were heterogeneous, ranging from specialised cleaning activities to a wide range of services (see online supplementary table 1). Because we were unable to contact employees directly for legal reasons,¹⁵ questionnaires with informed consent forms were distributed to employees and collected later by representatives appointed by the companies (members of the human resources or occupational health and safety departments). In total, 4993 questionnaires were distributed between February and December 2008, and 950 (19%) completed questionnaires were returned.

The research project was approved by the Ethics Committee of the Municipal Institute of Medical Research (IMIM) of Barcelona and all participants provided written informed consent.

Questionnaire

Data were collected using a self-administered questionnaire that solicited information about respiratory symptoms, work activities, cleaning-related exposures, smoking habits and demographic characteristics. Respiratory symptom questions were taken from the Spanish version of the European Community Respiratory Health Survey questionnaire.¹⁶ For cleaning-related exposures we used a list of the most common products and workplaces in our population according to the activities reported by the companies as well as an exhaustive list of irritant cleaning products related to our *a priori* hypothesis. Other questions were based on previous studies and, where necessary, were adapted to our study population.^{1 2 17}

Definitions

Exposures

Cleaner status

Workers were classified as current, former and never cleaners according to answers to the following questions: (a) Have you ever worked as a cleaner? (b) What position do you currently hold in your company? and (c) What cleaning activities have

you performed during the last year (use of cleaning products, cleaning tasks and workplaces)?

Acute inhalation

Acute inhalation was defined as a positive answer to the question: Have you ever been involved in an accident at home, work or elsewhere that exposed you to high levels of vapours, gas, dust or fumes?

Outcomes

Current asthma

Current asthma was determined by an affirmative answer to at least one of the following three questions: (a) Have you been woken by an attack of shortness of breath at any time in the last 12 months? (b) Have you had an attack of asthma in the last 12 months? and (c) Are you currently taking any medicines including inhalers, aerosols or tablets for asthma?¹

Adult-onset asthma

Adult-onset asthma was defined as ever having had asthma AND having had the first asthma attack at the age of 16 years or later.

Asthma score

An asthma symptom score was calculated as the sum of the answers (0=no, 1=yes) to five questions on asthma symptoms in the last 12 months (wheeze with breathlessness, woken up with chest tightness, attack of shortness of breath at rest, attack of shortness of breath after exercise, woken by attack of shortness of breath). Determinants of this score have been described elsewhere.¹⁸

Chronic cough

Chronic cough was determined as usual cough during the day or at night in winter, on most days for up to 3 months each year.

Statistical analysis

The associations between cleaning worker status, cleaning exposures and respiratory health outcomes were evaluated using multivariable logistic regression analyses adjusted for age, country of birth (Spanish vs non-Spanish), sex and smoking habits (lifetime non-smoker, former smoker, smoker). Associations between cleaning-related exposures and asthma score were evaluated using negative binomial regression models to account for overdispersion in the data adjusted for the same variables as above; associations are reported as mean ratios with 95% CIs.

Three different reference categories were used to evaluate the associations between cleaning products and workplaces and respiratory outcomes among current cleaners. Reference categories were (a) never cleaners, (b) current cleaners who were exposed to none of the cleaning products or workplaces under study during the last year, and (c) a combined group composed of both of the above.

All analyses were conducted using SAS v 9.1.

RESULTS

After quality assessment, 33 (3%) of the 950 participants who returned questionnaires were excluded from the study population due to missing information on key variables, resulting in a final study population of 917. The large majority (761; 83%) were working as professional cleaners at the time they completed the questionnaire. The remaining participants had worked as cleaners in the past (ie, they were former cleaners, *n*=86, 9%) or had never worked as a cleaner (*n*=70, 8%). Current and former cleaners were on average 7 and 10 years, respectively, older than never cleaners (table 1). Never cleaners were more

Table 1 Demographic and respiratory health characteristics of the study population (N=917)

	Never cleaners (n = 70)	Former cleaners (n = 86)	Current cleaners (n = 761)
Age, mean (SD)	37.8 (8.7)	47.7 (10.0)	44.9 (9.8)
Former smoker, n (%)	11 (16)	8 (13)	77 (10)
Current smoker, n (%)	26 (38)	17 (28)	235 (32)
Female, n (%)	51 (73)	49 (75)	630 (83)
Non-Spanish, n (%)	4 (6)	13 (22)	199 (29)
Wheeze without having a cold, n (%)	7 (10)	11 (17)	83 (11)
Chronic cough, n (%)	6 (9)	10 (15)	95 (13)
Ever asthma confirmed by a doctor, n (%)	4 (6)	8 (12)	66 (9)
Current asthma, n (%)	4 (6)	6 (9)	81 (11)
Asthma score, mean (SD)	0.44 (0.87)	0.56 (1.23)	0.59 (1.12)
Adult-onset asthma, n (%)	3 (4)	5 (6)	37 (5)

likely to be current smokers. Women formed the majority of our study population (around 70%), in particular among current cleaners (83%). The proportion of immigrants among former and current cleaners (22 and 28%, respectively) was higher than among never cleaners (6%).

The prevalence of respiratory symptoms and physician-diagnosed asthma was highest in former cleaners and lowest in never cleaners (table 1), although the prevalence of current asthma symptoms was highest in current cleaners. We evaluated the association between cleaner status and the outcomes adjusting for potential confounders and found that the associations did not reach conventional levels of statistical significance (table 2). The ORs for wheeze without having a cold, chronic cough, current asthma and adult-onset asthma were around 2 for former cleaners and around 1.5 for current cleaners. A similar pattern for former cleaners and current cleaners was observed after evaluating the mean ratios for asthma score. Results for other respiratory outcomes were essentially similar (see online supplementary table 2).

The prevalence of asthma symptoms was higher in cleaners who had worked at nearly all the types of workplaces under study as compared to the reference group (table 3). Using reference group C, we found a generalised increased OR for all workplaces for wheeze without having a cold and these associations were consistent when the asthma score was analysed (table 3). Current asthma was significantly increased among cleaners who had worked in hospitals during the last year. Table 3 also shows that the prevalence of wheeze without having a cold and the mean asthma score increased with the number of different workplaces where cleaning was performed. Current asthma prevalence also shows higher ORs among

Table 2 Associations between asthma symptoms and cleaning worker status

	Former cleaners (n = 86) OR (95% CI)	Current cleaners (n = 761) OR (95% CI)
Wheeze without having a cold	2.0 (0.6 to 6.5)	1.3 (0.5 to 3.3)
Chronic cough	2.4 (0.7 to 8.2)	1.8 (0.7 to 4.7)
Current asthma	1.9 (0.5 to 7.8)	1.9 (0.6 to 5.5)
Adult-onset asthma	2.5 (0.5 to 12)	1.4 (0.4 to 4.9)
Asthma score*	1.4 (0.6 to 3.2)	1.4 (0.8 to 2.6)

ORs and 95% CIs from logistic regression models adjusted for age, nationality, sex and smoking status. Reference category: never cleaners (n=70).

*Mean ratios and 95% CIs from negative binomial regression models adjusted for age, nationality, sex and smoking status.

cleaners working in a greater number of different places, although this association was not statistically significant. There was no excess risk of chronic cough in any of the workplaces under study, and there was no association between chronic cough and the number of different workplaces. Comparisons of associations obtained using the three reference groups (A, B and C) showed that findings were essentially similar when using reference group B, although the CIs became wider. Associations did not reach statistical significance except for the analysis of asthma score when using reference group A, which consisted only of never cleaners (see online supplementary table 3).

Cleaning workers reported using many different irritant cleaning products in the last year (table 4). We used reference group C as the reference category to evaluate the associations between specific cleaning products and asthma outcomes. All irritant cleaning products were associated with a higher risk of asthma, although not all the associations were statistically significant. We found a statistically significant increased risk of wheeze without having a cold among current cleaners who reported the use of hydrochloric acid during the last year. In addition, the asthma score analysis showed a significantly elevated mean ratio among current cleaners who used many of the listed products during the last year, especially for hydrochloric acid. Chronic cough was significantly increased in current cleaners who used carpet cleaning products ever during the last year. Since many of the products were used by the same cleaning workers, we assessed the degree of exposure to cleaning products by means of the number of different cleaning products used during the last year. The prevalence of symptoms increased with the number of different products used, and p values for linear trend were statistically significant at the 95% level for wheeze without having a cold in the last year and at the 90% level for asthma score. Further analysis using other reference categories was conducted but results did not change substantially (see online supplementary table 4).

Overall, 147 current cleaners had experienced at least one accidental inhalation (table 5). These individuals had a higher risk of respiratory symptoms including wheeze, chest tightness and breathlessness at rest (see online supplementary table 5), although no significant associations with current asthma, asthma diagnosis or asthma score were seen. Some of these reported accidents were related to the mixing of incompatible cleaning products, which was associated mainly with an increased risk of wheeze. Fifteen of the current cleaners who ever suffered an acute inhalation reported that this was caused by a spill of cleaning products (see online supplementary table 5). However, numbers were too small to evaluate the associations with health outcomes in detail.

DISCUSSION

Our study showed that the use of irritant cleaning products by professional cleaners was associated with asthma and respiratory symptoms. This finding is consistent with previous studies in other populations,^{4 6 7} and suggests a key role for irritant-induced asthma mechanisms among these workers. In addition, a presumed role of irritants in the development of asthma in cleaners is further supported by the associations between acute inhalation accidents when mixing cleaning products and respiratory symptoms suggestive of asthma.

We also found an increased risk of asthma and asthma symptoms among cleaners who worked in a variety of settings, including private homes. This confirms previous findings of population-based studies carried out in Spain,^{2 19} which, however, did not find an increased risk of asthma or respiratory

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Table 3 Associations between workplaces and asthma and respiratory symptoms among current cleaners (N=761)

	n (%)	Current asthma		Wheeze without having a cold		Asthma score*		Chronic cough	
		Pr (%)	OR (95% CI)	Pr (%)	OR (95% CI)	Mean	MR (95% CI)	Pr (%)	OR (95% CI)
Unexposed group A†	70 (8)	6		10		0.42		12	
Unexposed group B‡	147 (18)	9		4		0.44		9	
Unexposed group C (reference)§	217 (26)	8	1	6	1	0.42	1	10	1
Workplace									
Private homes	233 (28)	12	1.5 (0.7 to 3.0)	11	2.2 (1.0 to 4.8)	0.69	1.7 (1.1 to 2.5)	13	1.2 (0.6 to 2.3)
Common areas in apartment buildings	212 (25)	12	1.4 (0.7 to 2.8)	13	2.4 (1.1 to 5.2)	0.59	1.4 (0.9 to 2.3)	11	0.9 (0.5 to 1.9)
Hospitals	204 (24)	16	2.1 (1.1 to 4.2)	15	2.9 (1.3 to 6.3)	0.79	1.8 (1.2 to 2.8)	13	1.2 (0.6 to 2.3)
Industry	198 (24)	9	1.1 (0.5 to 2.3)	14	2.4 (1.1 to 5.1)	0.66	1.5 (0.9 to 2.3)	9	0.8 (0.4 to 1.6)
Outdoors	186 (22)	11	1.5 (0.7 to 3.1)	14	2.6 (1.2 to 5.7)	0.68	1.7 (1.1 to 2.6)	9	0.8 (0.4 to 1.7)
Kitchens	178 (21)	12	1.5 (0.7 to 3.0)	13	2.5 (1.1 to 5.7)	0.72	1.6 (1.1 to 2.5)	11	1.1 (0.5 to 2.3)
Schools	177 (21)	6	0.7 (0.3 to 1.7)	13	2.0 (0.9 to 4.6)	0.51	1.2 (0.7 to 1.9)	13	1.3 (0.6 to 2.5)
Laboratories	136 (16)	12	1.4 (0.7 to 3.2)	9	1.8 (0.7 to 4.5)	0.58	1.4 (0.8 to 2.3)	9	0.8 (0.3 to 1.8)
Other healthcare settings	88 (10)	13	1.6 (0.7 to 3.8)	11	2.3 (0.9 to 6.0)	0.77	1.8 (1.0 to 3.2)	15	1.4 (0.6 to 3.1)
Number of different workplaces									
1–3 Different workplaces	437 (53)	10	1.2 (0.6 to 2.2)	12	2.2 (1.1 to 4.4)	0.59	1.4 (0.9 to 2.0)	13	1.2 (0.7 to 2.2)
4–9 Different workplaces	151 (18)	13	1.7 (0.8 to 3.7)	15	2.6 (1.2 to 5.9)	0.73	1.8 (1.1 to 2.8)	10	0.9 (0.4 to 1.9)
p Value for linear trend		0.16		0.02		0.02		0.87	

OR and 95% CI from logistic regression models for each workplace adjusted for age, nationality, sex and smoking status. Each individual may be represented in more than one category. Group C was used as the reference category for all comparisons.

*Mean ratio (MR) and 95% CI from negative binomial regression models for each workplace adjusted for age, nationality, sex and smoking status.

†Group A: never cleaners.

‡Group B: current cleaners who have not worked in any of the listed workplaces during the last year.

§Group C: never cleaners AND current cleaners who have not worked in any of the listed workplaces during the last year (group A+group B).

Pr (%), prevalence.

symptoms among non-domestic cleaning workers.^{2 19} In contrast, we found a statistically significant increased risk of asthma symptoms among non-domestic cleaners, including a large group of hospital cleaning workers. This association between occupational exposures of cleaning workers in hospitals

and asthma is consistent with previous findings in other healthcare-related populations. The European Community Respiratory Health Survey showed that nurses who frequently used cleaning sprays, bleach and/or ammonia had an excess risk of new-onset asthma.⁷ A workforce-based study among

Table 4 Associations between the use of cleaning products and asthma and respiratory symptoms among current cleaners (N=761)

	n (%)	Current asthma		Wheeze without having a cold		Asthma score*		Chronic cough	
		Pr (%)	OR (95% CI)	Pr (%)	OR (95% CI)	Mean	MR (95% CI)	Pr (%)	OR (95% CI)
Unexposed group A†	70 (8)	6		10		0.42		9	
Unexposed group B‡	91 (11)	8		5		0.41		10	
Unexposed group C (reference)§	161 (19)	7	1	6	1	0.42	1	9	1
Products									
Bleach	588 (78)	11	1.7 (0.8 to 3.5)	11	2.0 (0.9 to 4.2)	0.58	1.4 (0.9 to 2.2)	13	1.4 (0.7 to 2.8)
Degreasers	498 (76)	12	1.7 (0.8 to 3.6)	12	2.0 (0.9 to 4.2)	0.63	1.6 (1.0 to 2.4)	13	1.4 (0.7 to 2.8)
Multiple purposes	475 (75)	11	1.7 (0.8 to 3.5)	12	1.9 (0.9 to 4.2)	0.63	1.6 (1.0 to 2.5)	13	1.4 (0.7 to 2.7)
Glass cleaners	463 (74)	10	1.6 (0.8 to 3.4)	11	1.9 (0.9 to 4.1)	0.57	1.4 (0.9 to 2.2)	13	1.6 (0.8 to 3.1)
Perfumed products	420 (72)	11	1.7 (0.8 to 3.5)	11	2.0 (0.9 to 4.4)	0.59	1.5 (1.0 to 2.4)	14	1.6 (0.8 to 3.2)
Air fresheners	375 (70)	12	1.7 (0.8 to 3.7)	11	2.0 (0.9 to 4.6)	0.58	1.5 (1.0 to 2.4)	12	1.4 (0.7 to 2.7)
Mop products	340 (61)	10	1.1 (0.5 to 2.1)	11	1.8 (0.9 to 3.8)	0.58	1.3 (0.9 to 1.9)	13	1.1 (0.6 to 2.1)
Hydrochloric acid	333 (67)	12	1.8 (0.8 to 3.8)	14	2.6 (1.2 to 5.8)	0.71	1.7 (1.1 to 2.6)	14	1.6 (0.8 to 3.2)
Ammonia	319 (66)	10	1.4 (0.6 to 3.2)	12	2.1 (0.9 to 4.7)	0.60	1.6 (1.0 to 2.5)	14	1.6 (0.8 to 3.3)
Polishes/waxes	210 (57)	9	1.3 (0.5 to 3.0)	14	2.0 (0.9 to 4.7)	0.63	1.6 (1.0 to 2.6)	14	1.6 (0.8 to 3.5)
Solvents	153 (49)	5	0.7 (0.3 to 2.1)	12	1.5 (0.6 to 3.7)	0.40	1.0 (0.6 to 1.7)	10	1.2 (0.5 to 2.9)
Carpet cleaners	132 (45)	9	1.1 (0.4 to 3.0)	12	1.7 (0.7 to 4.5)	0.54	1.2 (0.7 to 2.2)	15	2.2 (1.0 to 5.1)
Number of different products									
1–6 Different products	354 (43)	10	1.5 (0.7 to 3.3)	10	1.7 (0.8 to 3.8)	0.58	1.5 (0.9 to 2.3)	12	1.3 (0.7 to 2.6)
7–12 Different products	316 (38)	12	1.8 (0.8 to 3.8)	13	2.3 (1.0 to 5.0)	0.63	1.6 (1.0 to 2.5)	13	1.5 (0.7 to 2.9)
p Value for linear trend		0.13		0.03		0.09		0.30	

OR and 95% CI from logistic regression models for each cleaning product adjusted for age, nationality, sex and smoking status. Each individual may be represented in more than one category. Group C was used as the reference category for all comparisons.

*Mean ratio (MR) and 95% CI from negative binomial regression models for each cleaning product adjusted for age, nationality, sex and smoking status.

†Group A: never cleaners.

‡Group B: current cleaners who had not used any of the listed cleaning products at work during the last year.

§Group C: never cleaners AND current cleaners who had not used any of the listed cleaning products at work during the last year (group A+group B).

Pr (%), prevalence.

Table 5 Associations between a history of acute inhalations and respiratory symptoms and asthma among current cleaners

	No history of acute inhalation (n=614)		Acute inhalation ever (n=147)		Cleaning products mixture (n=41)	
	Pr (%)		Pr (%)	OR (95% CI)	Pr (%)	OR (95% CI)
Wheeze without having a cold	10		16	1.4 (0.8 to 2.5)	24	2.3 (1.0 to 5.5)
Current asthma	10		11	1.2 (0.6 to 2.3)	9	1.0 (0.3 to 3.6)
Asthma score*	0.52		0.79	1.4 (0.9 to 2.2)	0.97	1.6 (0.8 to 3.4)
Chronic cough	12		15	1.1 (0.6 to 2.0)	20	1.4 (0.6 to 3.5)

OR and 95% CI from logistic regression models adjusted for age, nationality, sex and smoking habit.

*Mean ratio (MR) and 95% CI from negative binomial regression models adjusted for age, nationality, sex and smoking habit.

Reference category: no history of acute inhalation.

Pr (%), prevalence.

healthcare workers in Texas also showed that the use of cleaning agents was associated with a higher risk of asthma with onset after starting a healthcare career.^{20 21} Moreover, cleaners in our study working in kitchens and common areas in apartment buildings (eg, entrances, lifts, stairways, etc) had more asthma symptoms. These results suggest a role of irritant exposures in specific workplaces such as industrial kitchens and hospitals since they demand a high level of cleanliness and disinfection.

Regarding the use of specific products, we found an increased risk of asthma symptoms among cleaning workers who had used hydrochloric acid, degreasers, air fresheners or ammonia in the last year. This is consistent with previous findings^{6 7} and supports the hypothesis that respiratory irritants play a key role in asthma among cleaners. We also found that the use of perfumed cleaning products was associated with a higher asthma score. These products are commonly used in spray form, which facilitates inhalation,²² and usually contain limonene and pinene, which have been previously associated with respiratory adverse effects.²³ Limonene and pinene may act as respiratory irritants and may also have sensitising properties. Thus, sensitiser-induced asthma may also play a role. The number of different cleaning products used and the number of different workplaces are variables indicative of the degree of exposure including the variety of cleaning products used, heterogeneity of tasks and hours of work. Both were associated with respiratory symptoms. These apparent dose–response relationships strengthen the observation that respiratory symptoms are associated with exposure to irritant cleaning products. In our study, symptom-based asthma definitions were more strongly associated with specific cleaning exposures than ‘current asthma’, a definition that includes self-reporting of asthma. This might be indicative of a certain level of under-recognition of asthma among cleaning workers. It is possible that the disease characteristics of the predominant asthma phenotype in cleaners are less disabling, and thus lead to medical recognition in fewer cases. Alternatively, the association between respiratory disorders and specific cleaning exposures may be indicative of irritative symptoms or a different disorder rather than asthma. Due to the small number of reported diagnosed asthma cases in our study, it was not feasible to analyse the under-recognition of asthma in more detail.

This study confirmed the existence of a higher risk of asthma and respiratory symptoms among cleaning workers when compared to other workers in the same companies who had never worked as cleaners. This variation was not attributable to differences in age, sex, nationality or smoking status. These differences in respiratory symptoms were not statistically

significant, perhaps due to the small sample size of the reference category. Nevertheless, the highest risks were seen among former cleaning workers, suggesting the presence of a healthy worker effect in this population, which has been previously seen in other studies.² In addition, previous publications reported similar estimations of the ORs of having asthma among current and former cleaners compared to never cleaners.^{1 2 4}

Several limitations were inherent to the study population, mainly the response rate. The response rate among companies was low, although many of the companies first identified changed or ceased their activities or changed their name and/or address and therefore appeared twice in the initial database. Our study’s objective was to identify specific exposures related to respiratory symptoms among cleaning workers. Evaluating differences between companies was not within the scope of the study, and thus, the low response rate did not affect its internal validity, and the final sample of cleaning companies carried out a wide variety of activities and employed different numbers of employees. It was not possible to carry out a follow-up study of the non-responder population due to the Spanish legislation on personal data protection.¹⁵ For this reason, these results and conclusions must be treated with caution and possible participation bias must be considered, although the prevalence of the studied outcomes and the estimated ORs were similar to those found in other studies in cleaning workers.⁹ To evaluate a possible responder bias, we asked the companies to register responders and non-responders and collect information on four basic characteristics: sex, age, nationality and job position. Two companies completed the register and we found no major differences between responders and non-responders in any of the studied variables (see online supplementary table 6). No information regarding the respiratory health of non-participants could be obtained and a responder bias may have affected our results. Nevertheless, if the response were dependent on respiratory health status in a similar way for all workers irrespective of their tasks and their use of products, there would be no bias away from the null.

Exposures and symptoms were restricted to the last 12 months, probably reducing problems with recall. However, reporting of the use of certain cleaning products, in particular those with strong odours, could have been differential for those with asthma and those without respiratory problems and hence have introduced a bias away from the null. We believe that the consistent observation of increased asthma risk for an increasing number of different workplaces (a proxy for degree of exposure that is less likely to be related to respiratory symptoms by the participants) argues against this type of bias. In addition, the lack of association with solvents, which typically have strong odours, also does not favour a strong reporting or recall bias.

The observed risk estimates reflect a combination of new-onset (occupational) asthma and work-exacerbated asthma. We were not able to disentangle whether the exposures at work preceded the onset of asthma symptoms, or exposures worsened symptoms in individuals who had asthma before exposure started. Our definitions of asthma were consistent with previous studies,^{1 2} and partly avoided diagnostic differences between cultures, age groups and gender. On the other hand, the symptoms included in our definitions may be indicative of other chronic or acute respiratory disorders or non-specific irritation.

Since several non-exposed groups could be considered as the reference categories for different analyses, we performed exhaustive sensitivity analyses by using three different reference categories. The prevalence rates of respiratory symptoms were similar in the non-exposed groups considered and the

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associations between workplaces, the use of cleaning products and asthma were consistent for all definitions of reference category. Thus, this supported the decision to combine the group of never cleaners with current cleaners who were unexposed to the workplaces or products under study.

Despite these limitations, the present study is, to our knowledge, the first large workforce-based study on risk factors for asthma in cleaning workers employed in cleaning companies. This type of design allowed us to better characterise the use of cleaning products and activities among these workers. We have shown that workers employed in cleaning companies are exposed to a large variety of workplaces and products. Most of the products associated with an increased risk of asthma were irritants. Furthermore, we confirmed the findings of previous studies on cleaners. These results should help promote new prevention strategies for the protection of the health of cleaning workers. Reducing or avoiding the use of irritant cleaning products at work may help to reduce the burden of adverse respiratory effects in cleaning workers. In addition, there is a need for further research to understand the mechanisms underlying the asthma-related respiratory symptoms associated with irritant exposures among cleaning workers.

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David Vizcaya, Maria C Mirabelli, Josep-Maria Antó, et al.

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