

Respiratory health in professional cleaners: symptoms, lung function, and risk factors

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Abstract

Aims: To assess and characterise respiratory symptoms and lung function in professional cleaners, and determine potential risk factors for adverse respiratory outcomes.

Methods: Symptoms, pre/post-bronchodilator lung function, atopy, and cleaning exposures were assessed in 425 cleaners and 281 reference workers.

Results: Cleaners had an increased risk of asthma (past 12 months), defined as: woken by shortness of breath, asthma attack, or asthma medication (OR=1.83, 95%CI=1.18-2.85). Despite this, they had similar rates of current wheezing (OR=0.92, 95%CI=0.65-1.32) and were less likely to have a doctor diagnosis of asthma (OR=0.62, 95%CI=0.42-0.92). Cleaners overall had lower lung function (FEV₁, FVC; p<0.05). Asthma in cleaners was associated with less atopy (OR=0.35, 95%CI=0.13-0.90), fewer wheezing attacks (OR=0.40, 95%CI=0.17-0.97; >3 vs ≤3 times/year) and reduced bronchodilator response (6% vs 9% mean FEV₁-%-predicted change, p<0.05) compared to asthma in reference workers. Cleaning of cafes/restaurants/kitchens and using upholstery sprays or liquid multi-use cleaner was associated with symptoms, whilst several exposures were also associated with lung function deficits (p<0.05).

Conclusions: Cleaners are at risk of some asthma-associated symptoms and reduced lung function. However, as it was not strongly associated with wheeze and atopy, and airway obstruction was less reversible, asthma in some cleaners may represent a distinct phenotype.

Keywords: asthma, lung function, atopy, cleaners, risk factors

Introduction

Cleaning is a multibillion-dollar industry globally, employing a large fraction of the workforce.¹⁻³ Several cross-sectional studies conducted between 1975 and 2006 found an association between cleaning and/or cleaning products and asthma symptoms with risk estimates ranging between 1.5 and 2.5,⁴ and a large population-based study found that cleaners had an excess risk of asthma in 11 of 12 industrialised countries.⁵ Cleaners are frequently exposed to a range of agents including chlorine/bleach, ammonia, ethanolamines, chloramine-T, aldehydes, and quaternary ammonium compounds (QACs),⁶ which may contribute to both new-onset asthma through sensitisation (in a minority) or irritation, and exacerbation of pre-existing asthma.⁷ Importantly, as many people worldwide, other than cleaners, are exposed to cleaning products, asthma due to, or exacerbated by cleaning products is a considerable public health concern.

To date, most studies in cleaners have identified asthma based on symptoms, with limited functional data (lung function, airway hyperresponsiveness, and atopy) available to allow a more complete characterisation of airway disease. In particular, assessment of reversible airway obstruction (considered a primary asthma characteristic)⁸ has rarely been conducted. It therefore remains unclear how asthma in cleaners compares with asthma in other (occupational) settings. Finally, relatively few studies have examined specific risk factors, such as exposures to particular tasks, workplaces and cleaning agents.

The aims of this study were to assess: 1) the prevalence, risk and determinants of respiratory symptoms in professional cleaners; 2) how asthma in cleaners compares with asthma in other settings; and 3) the effects of cleaning and cleaning-related exposures on lung function and bronchodilator response in cleaners.

Methods

Study population

Cleaners (n=425) were employed at hospitals, schools, commercial buildings, and hospitality and industrial settings (mostly meat works; Table 1). They were recruited through the Service and Food Workers Union (SFWU) or organisations employing/contracting cleaners. The comparison group (n=281) comprised 201 retail/service workers and 80 bus drivers recruited from similar geographical areas. Response rates for cleaners and reference population were 74% and 34% respectively. The study was approved by the Massey University Ethics Committee: Southern A (07/29).

Interviews

Questionnaires based on the European Community Respiratory Health Survey (ECRHS)⁹ were administered face-to-face. Asthma was identified using a well-characterised ECRHS definition based on: 1) woken by shortness of breath in the last 12 months; 2) asthma attack in the last 12 months; or 3) current asthma medication.¹⁰ We also asked if asthma had been confirmed by a doctor, the nature of participants' respiratory symptoms (particularly about presence and/or frequency of symptoms associated with wheezing/whistling in the chest, breathlessness, and cough,), and about relevant exposures including specific cleaning activities, use of particular cleaning products, personal protective equipment (PPE; specifically respiratory protection) use, and potential confounders such as ethnicity, age, medication, and smoking. Asthma severity was defined as mild, moderate or severe based on frequency of wheezing attacks (mild, 0-3; moderate, 4-12; severe, ≥ 12) or baseline FEV₁ % (mild, $\geq 80\%$ predicted; moderate, ≥ 60 and $< 80\%$; severe, $< 60\%$) (modified from ¹¹). Ethnicity was defined as Māori (indigenous people of New Zealand), Pacific peoples (Samoan, Tongan), NZ European and other (eg. Asian).

Lung function testing

Lung function testing was conducted at the start of the work shift using EasyOne portable ultrasonic spirometers (ndd Medizintechnik AG, Zurich, Switzerland) according to American Thoracic Society (ATS) guidelines.¹² Both pre and post-bronchodilator lung function were measured, with post-

bronchodilator measurements conducted 20 minutes after salbutamol (200 µg) administration via pressurised metered dose inhaler and volumatic spacer. Forced Vital Capacity (FVC) and Forced Expiratory Volume in one second (FEV₁) were used in the analyses. Predicted lung function values were determined using National Health and Nutrition Examination Survey III equations.¹³

Reversibility of airway obstruction was expressed as absolute volume change and percentage increase from pre-bronchodilator measurements.¹⁴

Atopy

Atopy was assessed using skin prick tests as previously described¹¹ using the following aeroallergen solutions: positive control (histamine), negative control (diluent), cat, dog, grass mix, *Alternaria*, *Cladosporium*, *Penicillium*, and house dust mite (Hollister-Stier Laboratories, Spokane, WA, USA). All tests were read at 15 minutes. Atopy was defined as having at least one positive skin prick test (with a wheal diameter of greater than 3mm) to any allergen.

Data analyses

Initial analyses examined the risk of respiratory symptoms, atopy, and asthma in all cleaners (n=425) using the entire comparison group (n=281) as reference. Pre and post-bronchodilator lung function parameters were compared between cleaners (n=408) and comparison group (n=280). Case-case analyses were subsequently performed in the cleaners (n=115) and comparison group (n=38) identified as having asthma to evaluate differences in symptoms and lung function between these groups. The effect of specific exposures (such as duration of work, work location or use of a particular agent) on risk of asthma and lung function parameters was assessed by comparison with an appropriate internal reference group (e.g. cleaners working in other types of premises, cleaners not exposed to that agent) and with the entire comparison group (n=281). For analyses involving dichotomous outcomes, prevalence odds ratios were calculated using multiple logistic regression adjusting for potential confounders (smoking, age, sex, ethnicity). For continuous outcome variables, multiple linear regression analyses were conducted adjusting for the same confounders. All analyses were conducted using SAS v9.3 (SAS Institute Inc, Cary, NC).

Results

Cleaners had a higher proportion of women, Māori and Pacific people, smoked more, and were older than the reference group (Table 1). Analyses were therefore controlled for age, sex, ethnicity and smoking, or stratified as appropriate. The most common cleaning activities included: dusting, sweeping, vacuuming, mopping, wet cleaning, damp wiping, cleaning toilets, and window or mirror cleaning. In total, 74% (n=315) of cleaners were employed cleaning only one type of business, the most common of which was hospitals/pharmacies (n=103); bedrooms/accommodation (n=64); factories (n=54); offices (n=40); schools (n=29); shops (n=11); homes (n=7); and cafes/restaurants (n=5). The remainder (n=110) cleaned multiple types of premises; 2 types (n=63); 3-5 types (n=37); >5 (n=6) (incomplete data n=4; Supplementary Table 1). Almost 50% of the reference workers also undertook cleaning activities, but at considerably lower frequency than those reported by cleaners (data not shown).

Cleaners had an increased risk of current asthma (27% versus 14%; adjusted odds ratio (aOR)=1.83, 95%CI (95% confidence interval) 1.18-2.85), and were more likely to be taking medication for asthma (14.8% versus 9.3%; aOR=1.32, 95%CI 0.78-2.25; Table 2), although the latter finding did not reach statistical significance. They were also more likely to have several other respiratory symptoms including waking due to shortness of breath (17.4% versus 5.3%; aOR=2.52, 95%CI 1.26-5.05) and weekly dry cough (22.1% versus 14.2%; aOR=1.66, 95%CI 1.05-2.61), but not wheezing/whistling in the chest (39.8% versus 36.7%; aOR=0.92, 95%CI 0.65-1.32; Table 2) in the last 12 months. Other cough-related symptoms, such as coughing attacks in the past 12 months and daily cough with phlegm were also more prevalent amongst cleaners, although these did not reach statistical significance (data not shown). Despite the increased respiratory symptoms observed, cleaners were less likely to have self-reported asthma ever (24.9% versus 30.6%; aOR=0.66, 95%CI 0.46-0.97), or been diagnosed with asthma by a doctor (22.4% versus 28.5%; aOR=0.62, 95%CI 0.42-0.92); Table 2).

Cleaners had lower (absolute and predicted) baseline lung function (FEV₁ and FVC, $p < 0.05$; Table 2) than the reference population, even after adjustment for age, gender, ethnicity, and smoking status. These differences remained after bronchodilator administration. No significant differences in bronchodilator response were observed, with the exception of a small increase in absolute FVC in cleaners compared with the reference group (0.01 L versus 0.04 L; $p < 0.05$; Table 2).

When compared with asthma in the reference group, asthma amongst cleaners was associated with less atopy (58.6% versus 76.3%; aOR=0.35, 95%CI 0.13-0.90; Table 3) and fewer wheezing attacks in the last 12 months (aOR=0.40, 95%CI 0.17-0.97; for having >3 attacks compared with ≤ 3 attacks). No other significant differences in respiratory symptoms were observed, and the frequency of mild, moderate, or severe asthma was similar between the two groups (Table 3). However, cleaners with asthma (as defined above) were significantly less likely to self-report asthma (aOR=0.14, 95%CI 0.03-0.66) or have a doctor's diagnosis of asthma (aOR=0.32, 95%CI 0.11-0.93). Age of onset of asthma was higher amongst cleaners than the reference group (mean 24.1 years versus 20.5 years; data not shown), although this did not reach statistical significance.

There were no significant differences in baseline lung function between asthmatics in the cleaners and reference groups, although asthmatics in the reference group had a small but significantly reduced FEV₁/FVC ratio (0.7 versus 0.8; $p < 0.05$). Also, despite similar baseline measurements, asthma among cleaners was associated with more irreversible airway obstruction. In particular, bronchodilator administration resulted in 8ml lower increase in absolute FEV₁ among cleaners ($p < 0.05$), which translated to a 5.7% increase in FEV₁ compared with 8.9% in the reference group ($p < 0.05$; Table 3). Nonetheless, the percentage of individuals identified as having a bronchodilator response $>10\%$ in the two groups was similar (23% and 26%, $p = 0.41$; data not shown).

The presence of current asthma was not associated with duration of employment as a cleaner, or with any specific cleaning activities (Table 4). However, cleaners who reported working in cafes/restaurants/kitchens had a significantly increased asthma risk compared with those who worked

in domestic, commercial or office settings (aOR=2.75, 95%CI 1.23-6.17; Table 4). Different settings were associated with some variations in agents used (Supplementary Table 2), but when comparing cleaners with high and low exposure to specific agents, the majority of products were not significantly associated with increased risk of asthma. However, frequent use of liquid multi-use cleaner (aOR=1.66, 95%CI 1.04-2.64) or sprays for cleaning carpets, rugs or upholstery (aOR=3.25, 95%CI 1.16-9.10) did show a significant association with asthma. When comparing cleaners with high exposures with reference workers (with low exposures), the majority of the exposures and agents studied were associated with increased asthma risk (Table 4).

Within the cleaners, duration of employment was not associated with any lung function deficits, although cleaning cafes/restaurants/kitchens or hospitals was associated with reduced pre and post-bronchodilator lung function (Table 5). Of the agents to which cleaners were regularly exposed, ammonia (reduced pre-bronchodilator PEF; Table 5), glass cleaning sprays (reduced pre-bronchodilator FVC: Table 5), and oven cleaning sprays (reduced post-bronchodilator FVC reversibility; Supplementary Table 3) were associated with statistically significant deficits in lung function. ** Compared with the external reference group, cleaners were more likely to have reduced lung function parameters for the majority of exposures (data not shown OR supplementary tables (IN PREPARATION)).

Discussion

This study found that professional cleaners have an increased risk of asthma and reduced lung function. Cleaners identified as having asthma were more likely to be non-atopic, less likely to have a doctor diagnosis of asthma, and had airway obstruction that was less responsive to bronchodilator administration. Working in cafes/restaurants/kitchens and/or use of multiuse cleaner and upholstery sprays was associated with a significantly increased asthma risk, whilst exposure to ammonia, glass cleaning and oven sprays was associated with reduced (pre-bronchodilator) lung function.

Our findings are consistent with previous international reports on asthma risk in cleaners.⁴ However, despite the increased risk of asthma based on the ECRHS definition, cleaners were less likely to report that they actually had asthma or had ever received a diagnosis of asthma. There are several possible reasons for this. Firstly, cleaners are more likely to be of a low socioeconomic background, which alongside being Māori or Pacific ethnicity, is associated with poor access to healthcare resources.¹⁵ Secondly, there was a significant difference in smoking between cleaners and reference workers. As smokers are more likely to report respiratory symptoms,¹⁶ this may have been identified as asthma using the ECRHS definition. However, smoking was controlled for, and is therefore unlikely to explain the difference in asthma risk. Thirdly, it could be that ECRHS asthma definition, despite its extensive use and characterisation, may misclassify other respiratory symptoms or conditions as asthma.^{17,18} If true, this suggests that cleaning exposures may lead to asthma-like respiratory symptoms, rather than asthma *per se* (see below).

The reason for the significantly lower baseline FEV₁ and FVC (as well as PEF and FEF₂₅₋₇₅; data not shown) among cleaners is not clear, as this has not been previously reported. However, a recent longitudinal ECRHS report suggested an association between long-term exposure to cleaning products and accelerated lung function decline in women doing cleaning work.¹⁹ Our data appear to support this. There is also a possibility that despite adjustment, ethnic differences in lung function between the cleaning and reference population may have contributed. However restricting the analyses to non-

Māori and non-Pacific (for whom specific and current normative lung function values are not available) did not alter the results (data not shown).

To our knowledge, bronchial hyperresponsiveness (BHR) or reversibility tests were conducted in only four previous epidemiological studies on asthma in cleaners.⁴ One study (in which BHR was assessed by methacholine challenge) showed that only 18% of cleaners with asthma had BHR; similar to that observed in the general population.²⁰ Similar findings were reported in an unpublished study of 39 cleaners with asthma symptoms, of which only 25% had evidence of BHR,²¹ and by our data, which suggest that only one fifth of cleaners with asthma had >10% bronchodilator reversibility (clinical studies suggest a cut-off of >12% may be used to identify asthma).²² It has been hypothesised that respiratory symptoms in this population may therefore be indicative of sensory reactivity due to irritant exposure (as many cleaning agents have an irritant effect on both skin and mucous membranes) rather than asthma, which has been described as airway sensory hyperreactivity.²¹ This would also be consistent with respiratory symptoms in cleaners not being associated with atopy (discussed below). Alternatively, respiratory symptoms in some cleaners may represent a distinct (atypical) asthma phenotype not associated with wheeze and atopy, and associated with less post-bronchodilator reversibility, as shown in our study.

A point of novelty in this study was the assessment of bronchodilator reversibility. In one previous study of 42 cleaners, Vizcaya *et al*²³ found that asthma was associated with an 8% lower post-bronchodilator response compared to cleaners without asthma, but this study did not have a non-cleaning comparison group with asthma. As stated above, we found only limited evidence of bronchodilator response in cleaners with asthma symptoms. In fact, we observed that overall, cleaners with asthma had a reduced response to bronchodilator administration, suggesting that airflow obstruction among this population was less reversible. Irreversible airflow obstruction is generally considered an indicator of chronic obstructive pulmonary disease (COPD). As COPD is another major obstructive respiratory disease with some similar symptoms to asthma, we sought to identify individuals with COPD using the ratio of FEV₁/FVC of <0.7 as an indicator of airflow limitation.²⁴

We observed no significantly increased prevalence of individuals conforming to this definition of COPD in either cleaners (11.8%) or reference (11.1%), or amongst cleaners or reference workers with asthma symptoms (21.2% and 36.8% respectively (aOR 0.43 (95%CI 0.16-1.15)). A low prevalence of COPD amongst cleaners with asthma symptoms has previously been reported,²³ and alongside our data (although limited in power), suggest that COPD is not a major cause of respiratory symptoms among cleaners.

Similar to bronchodilator response, only a few studies assessing respiratory symptoms in cleaners have objectively assessed atopy, with most studies relying on self-reported allergy.²⁵ We found that atopy prevalence did not differ significantly between cleaners and reference workers. However, asthma in cleaners was associated with reduced atopy prevalence, suggesting that atopic mechanisms are not likely to be a major contributor to respiratory symptoms in this group. Instead, respiratory disease in cleaners is more likely to involve non-allergic mechanisms as described above, and suggested in other studies.^{27,28} Further data suggesting that atopic TH₂-mediated inflammation may not be important has been provided by the aforementioned small study of 42 cleaners with asthma, in which asthma was not associated with eosinophilic (TH₂)-mediated inflammation.²³

Relatively little is known about specific causal exposures. Cleaning agents that have been suggested to be involved include chlorine/bleach, ammonia, and ethanolamines.^{6,7} Also, some studies have suggested a role for the use of cleaning sprays, kitchen cleaning, washing dishes using bleach, furniture polishing, and the use of oven sprays and polishes.²⁸ For example, in a study of 3503 ECRHS II participants,²⁹ use of cleaning sprays at least weekly was associated with increased asthma symptoms (RR 1.49; 95%CI 1.12-1.99), with glass-cleaning, furniture and air freshener sprays showing the strongest associations. From this, it was estimated that one in seven asthma cases in all adults is associated with the use of cleaning sprays. In support of several of these findings, we observed an increased risk of symptoms and/or lung function deficits with use of ammonia, glass cleaning sprays, oven-cleaning sprays and upholstery sprays (Table 4 and 5).

Duration of employment as a cleaner was not associated with either increased asthma risk or lung function. No association between asthma symptoms and duration of employment was observed in an earlier study³⁰ but there are conflicting reports.³¹ It is possible that duration of employment is only important if the working environment being cleaned is considered (which we were not able to do as we did not have a complete and detailed work history). We observed that working in kitchens, cafes and restaurants, as well as industrial settings, was associated with an increased risk of respiratory symptoms when compared with domestic, office and other commercial cleaning, whilst all of the associated exposures, in addition to working in hospitals, were also associated with decrements in lung function. This contrasts with at least two previous studies, in which domestic cleaners had either a higher risk of asthma than non-domestic cleaners³² or had more respiratory symptoms than industrial cleaners.³³

In conclusion, this study has shown that cleaners in New Zealand have an increased risk of work-related respiratory symptoms, which was not clearly associated with atopy. Cleaners had reduced baseline lung function but no increase in bronchodilator response, suggesting that this lung function deficit was predominantly irreversible. Whilst cleaners with respiratory symptoms were identified as asthmatics using the ECRHS definition, we suggest that, at least in some cases, cleaning-related respiratory symptoms may more appropriately be described as an asthma-like disorder.

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Table 1. Demographic and work characteristics for cleaners and reference workers.

	Cleaners (n=425)		Reference (n=281)	
	n	%	n	%
Sex				
Males	97	22.8	142	50.5
Females	328	77.2	139	49.5
Ethnicity				
New Zealand European	141	33.2	189	67.3
Māori	114	26.8	38	13.5
Pacific	119	28.0	29	10.3
Other	51	12.0	24	8.5
Smoking status				
Current smoker	178	41.9	81	28.8
Ex-smoker	59	13.9	75	26.7
Non-smoker	188	44.2	124	44.1
Type of cleaning work ¹				
Homes/schools/offices/shops/hotels	329	77.4	-	-
Hospitals/pharmacies	138	32.5	-	-
Industrial/other	75	17.6	-	-
Café/Restaurant/Kitchens	63	14.8	-	-
Outside	21	4.9	-	-
	mean	SD	mean	SD
Age	45	12.9	40	15.1
BMI	29.5	7.0	28.8	6.6
Years worked in current job (yrs)	8.5	8.61	6.2	7.13
Number of hrs/wk working as a cleaner	33.8	12.08	-	-

¹ Cleaners were often involved in multiple types of cleaning work hence the combined number of cleaners listed for each type of cleaning exceeded 425.

Table 2. Respiratory symptoms, atopy status and lung function in cleaners (n=425) and reference workers (n=281)

Symptoms	Cleaners (n=425)		Reference (n=281)		crude OR (95%CI)	adjusted OR (95%CI) ^a
	n	%	n	%		
Asthma (defined by ECRHS)	116	27	38	14	2.44 (1.63-3.65)**	1.83 (1.18-2.85)**
Asthma ever	106	24.9	86	30.6	0.75 (0.54-1.05)	0.66 (0.46-0.97)*
Diagnosis confirmed by doctor	95	22.4	80	28.5	0.72 (0.51-1.02)	0.62 (0.42-0.92)*
Currently taking medication	63	14.8	26	9.3	1.71 (1.05-2.77)*	1.32 (0.78-2.25)
Wheezing/whistling (past 12 months)	169	39.8	103	36.7	1.14 (0.84-1.56)	0.92 (0.65-1.32)
Wheezing in the chest (at least once a week)	47	11.1	17	6	1.93 (1.09-3.44)*	1.65 (0.87-3.13)
Woken by shortness of breath in past 12 months	74	17.4	15	5.3	2.99 (1.58-5.63)**	2.52 (1.26-5.05)**
Dry cough (at least once a week)	94	22.1	40	14.2	1.72 (1.14-2.58)**	1.66 (1.05-2.61)*
Atopy (positive SPT)	212	49.9	153	54.4	0.84 (0.62-1.14)	0.78 (0.56-1.09)
Lung function	Mean	SD	Mean	SD	Mean	
Baseline (Prebronchodilator)	(n=408)		(n=280)		Difference (95%CI)	
FEV ₁ (L)	2.52	0.75	3.17	0.91	-0.20 (-0.29, -0.10)**	
(% predicted)	81.72	15.62	88.06	15.81	-3.12 (-5.68, -0.57)*	
FVC (L)	3.22	0.87	3.99	1.03	-0.25 (-0.36, -0.14)**	
(% predicted)	84.05	14.67	89.78	13.86	-3.25 (-5.55, -0.96)**	
FEV ₁ /FVC	0.78	0.08	0.79	0.08	0.00 (-0.01, 0.02)	
Bronchodilator response	(n=395)		(n=277)			
Increase in FEV ₁ (L)	0.07	0.15	0.10	0.17	-0.03 (-0.05, 0.00)	
Increase in FEV ₁ (% change)	3.58	6.96	3.81	6.24	-0.67 (-1.80, 0.47)	
Increase in FVC (L)	0.01	0.28	0.04	0.26	-0.05 (-0.09, -0.00)*	
Increase in FVC (% change)	0.94	9.24	1.43	7.28	-1.15 (-2.59, 0.28)	

^aAdjusted for age, gender, ethnicity, smoking; *p<0.05; **p<0.01

Table 3. Respiratory symptoms, atopy status and lung function in cleaners and reference workers with asthma

Symptoms	Cleaners (n=116)		Reference (n=38)		crude OR (95%CI)	adjusted OR (95%CI) ^a
	n	%	n	%		
Asthma ever	79	68.1	36	94.7	0.12 (0.03-0.52)**	0.14 (0.03-0.66)*
Diagnosis confirmed by doctor	73	62.9	32	84.2	0.32 (0.12-0.82)*	0.32 (0.11-0.93)*
Currently taking medication	63	54.3	26	68.4	0.55 (0.25-1.19)	0.56 (0.23-1.36)
Wheezing/whistling in past 12 months	94	81.0	35	92.1	0.37 (0.10-1.30)	0.28 (0.07-1.10)
Number of attacks of wheezing/whistling in the past 12 months					0.53 (0.25-1.11)	0.40 (0.17-0.97)*
Wheezing in the chest (at least once a week)	29	25.0	9	23.7	1.07 (0.46-2.53) at least once a week vs. at most twice a month	0.90 (0.34-2.39) at least once a week vs. at most twice a month
Woken by shortness of breath attack in past 12 months	74	63.8	15	39.5	2.05 (0.94-4.51) For subjects ever wheezing or whistling in the past 12 months	1.91 (0.74-4.92) For subjects ever wheezing or whistling in the past 12 months
Dry cough (at least once a week) in past 12 months	39	33.6	10	26.3	1.42 (0.63-3.22) at least once a week vs. at most twice a month	0.98 (0.38-2.52) at least once a week vs. at most twice a month
Severity (mild/moderate/severe) ¹²	33/49/31	29.2/43.4/27.4	13/13/12	34.2/34.2/31.6		
Atopy (positive SPT)	68	58.6	29	76.3	0.46 (0.20-1.06)	0.35 (0.13-0.90)*
Lung function	Mean	SD	Mean	SD	Mean	
Baseline (Prebronchodilator)	(n=113)		(n=38)		Difference (95%CI)	
FEV ₁ (L)	2.3	0.8	2.7	1.0	0.1 (-0.14, 0.34)	
(% predicted)	76.8	17.4	77.3	20.3	3.6 (-3.52, 10.72)	
FVC (L)	3.1	0.9	3.7	1.2	-0.04 (-0.32, 0.24)	
(% predicted)	82	16.1	86.9	19	-0.92 (-7.39, 5.56)	
FEV ₁ /FVC	0.8	0.1	0.7	0.1	0.04 (0.01, 0.08)*	
Bronchodilator response	(n=109)		(n=38)			
Increase in FEV ₁ (L)	0.1	0.1	0.2	0.2	-0.08 (-0.15, -0.01)*	
Increase in FEV ₁ (% change)	5.7	8.0	8.9	10.0	-3.63 (-7.22, -0.03)*	

Increase in FVC (L)	0.1	0.3	0.1	0.3	-0.04 (-0.15, 0.08)
Increase in FVC (% change)	3.1	9.9	3.8	9.6	-1.32 (-5.39, 2.76)

^a Adjusted for age, gender, ethnicity, smoking; *p<0.05; ** p<0.01; For whom data is available

Table 4. Associations between exposures, cleaning activities and current asthma in exposed cleaners versus unexposed cleaners and external comparison group

Exposure/cleaning activity	Current asthma	
	Internal comparison OR (95% CI) ^{1S}	External comparison OR (95% CI) ^{2S}
Years worked as a cleaner		
0 years (retail/service/bus drivers; n=281)		REF
<3 years (n=134)	REF	1.62 (0.93-2.82)#
3-10 years (n=141)	1.38 (0.78-2.44)	2.08 (1.24-3.48)**
>10 years (n=150)	1.16 (0.62-2.19)	1.79 (0.99-3.23)*
Type of cleaning		
Retail/service/bus drivers (n=281)		REF
Homes/schools/offices/shops/hotels (n=175)	REF	1.39 (0.82-2.36)
Hospital (n=126)	1.07 (0.62-1.86)	1.52 (0.86-2.71)
Café/restaurant/kitchen (n=32)	2.75 (1.23-6.17)*	3.77 (1.7-8.38)**
Industrial (n=67)	1.90 (0.95-3.79)#	2.63 (1.36-5.08)**
Outside (n=21)	2.13 (0.76-6.00)	2.96 (1.07-8.20)*
Cleaning activities		
Dusting, sweeping, vacuuming (n=366)	0.65 (0.34-1.26)	1.72 (1.09-2.71)*
Mopping, wet cleaning, damp wiping (n=395)	1.33 (0.51-3.43)	1.86 (1.19-2.91)**
Cleaning the toilet bowl (n=323)	1.16 (0.66-2.05)	1.89 (1.19-2.99)**
Polishing, waxing, shampooing (n=95)	0.85 (0.49-1.45)	1.60 (0.86-2.95)
Cleaning windows or mirrors (n=320)	1.02 (0.60-1.73)	1.84 (1.16-2.92)**
Cleaning the kitchen (n=243)	0.92 (0.58-1.45)	1.77 (1.08-2.89)*
Washing or soaking clothes/linen by hand (n=27)	0.43 (0.14-1.29)	0.83 (0.27-2.62)
Washing clothes by machine (n=58)	1.44 (0.76-2.75)	2.36 (1.20-4.66)*
Cleaning machinery in an industrial setting (n=57)	0.99 (0.49-1.99)	1.84 (0.89-3.80)#
Use of cleaning products		
Detergents/ washing powders (n=169)	1.14 (0.73-1.78)	1.97 (1.18-3.28)**
Polishes/waxes (n=65)	1.12 (0.62-2.05)	2.01 (1.03-3.93)*
Liquid multiuse cleaner (n=138)	1.66 (1.04-2.64)*	2.49 (1.48-4.18)**
Bleach (n=158)	1.04 (0.67-1.64)	1.87 (1.12-3.14)*
Ammonia (n=53)	1.11 (0.58-2.14)	1.97 (0.97-4.01)#
Decalcifiers/acids (n=25)	1.54 (0.65-3.68)	2.77 (1.11-6.92)*
Solvents/stain removers (n=24)	1.19 (0.47-3.02)	2.11 (0.80-5.55)
Other cleaning products not further specified (n=357)	1.79 (0.91-3.53)#	2.00 (1.27-3.14)**
Furniture sprays (n=60)	1.41 (0.78-2.55)	2.50 (1.27-4.91)**
Glass cleaning sprays (windows, mirrors) (n=262)	1.07 (0.68-1.69)	1.88 (1.17-3.02)**
Sprays for carpets, rugs or curtains (n=16)	3.25 (1.16-9.10)*	5.57 (1.94-16.03)**
Sprays for mopping the floor (n=90)	1.20 (0.71-2.04)	2.13 (1.18-3.87)*
Oven sprays (n=6)	0.66 (0.08-5.85)	1.24 (0.14-11.03)
Ironing sprays (n=2)	NA	NA
Air refreshing sprays (n=111)	0.97 (0.59-1.60)	1.81 (1.02-3.23)*
Multi-purpose antibacterial cleaning sprays (n=128)	1.28 (0.80-2.04)	2.15 (1.25-3.68)**
Other sprays (n=37)	1.16 (0.54-2.49)	2.14 (0.96-4.76)#

REF = reference

Adjusted for age, sex, ethnicity, smoking; # p<0.10; *p<0.05; **p<0.01

¹ OR for cleaners exposed to each cleaning agent or spray at least once a week vs. cleaners being exposed to the cleaning agent or spray less than once a week.

² OR for cleaners exposed to each cleaning agent or spray at least once a week vs. all comparison group (retail/service workers & bus drivers; n=281)

Table 5. Associations between exposures, cleaning activities and lung function in cleaners (n=425).

Exposure/cleaning activity	Prebronchodilator						Post bronchodilator ^b
	FEV ₁ (L)	FEV ₁ (% predicted)	FVC (L)	FVC (% predicted)	PEF (% predicted)	FEV ₁ /FVC	Increase in FEV ₁ (% change)
Years worked as a cleaner							
<3 years (n=134)	REF	REF	REF	REF	REF	REF	REF
3-10 years (n=141)	0.01(-0.12,0.14)	-0.88(-4.71,2.94)	0.04(-0.12,0.19)	-0.60(-4.10,2.91)	0.29(-4.60,5.19)	-0.01(-0.03,0.01)	0.03(-1.78-1.83)
>10 years (n=150)	0.02(-0.13,0.16)	-0.74(-4.96,3.48)	0.01(-0.16,0.19)	-0.87(-4.74,3.01)	-0.08(-5.48,5.32)	0.00(-0.02,0.02)	-0.22(-2.22-1.77)
Type of cleaning							
Homes/schools/offices/shops/hotels (n=175)							
Hospital (n=126)	-0.10(-0.21,0.00)#	-3.11(-6.29,0.07)#	-0.13(-0.26,-0.00)*	-2.98(-5.90,-0.05)*	-2.92(-6.99,1.16)	0.00(-0.02,0.01)	-0.46(-1.97,1.05)
Café/restaurant/kitchen (n=32)	-0.17(-0.33,-0.00)*	-6.33(-11.19,-1.46)*	-0.14(-0.34,0.06)	-4.43(-8.91,0.05)#	-7.99(-14.23,-1.76)	-0.03(-0.05,-0.01)*	2.44(0.18,4.71)*
Industrial (n=67)	0.08(-0.06,0.21)	1.37(-2.61,5.36)	0.07(-0.09,0.24)	0.42(-3.25,4.09)	4.12(-0.99,9.23)	0.00(-0.02,0.02)	0.36 (-1.51,2.24)
Outside (n=21)	-0.03(-0.22,0.16)	-1.05(-6.64,4.53)	-0.01(-0.24,0.23)	-0.25(-5.39,4.90)	-0.47(-7.63,6.69)	-0.01(-0.04,0.02)	-0.51(-3.12,2.10)
Use of cleaning products (often vs sometimes/never)							
Washing powder (n=386)	0.03(-0.08,0.13)	0.96(-2.07,3.98)	0.05(-0.07,0.18)	1.5(-1.27,4.28)	-0.08(-0.37,0.21)	0(-0.02,0.01)	0.55(-0.86,1.97)
Polishes/waxes (n=81)	0.15(0.01,0.28)*	4.56(0.46,8.67)*	0.12(-0.04,0.29)	3.23(-0.54,7.07)#	0.27(-0.13,0.67)	0.01(-0.01,0.03)	-0.36(-2.28,1.56)
Liquid multiuse cleaner (n=280)	0.04(-0.06,0.15)	1.42(-1.75,4.58)	0.09(-0.04,0.22)	2.2(-0.7,5.1)	0.22(-0.09,0.52)	-0.01(-0.02,0.01)	0.8(-0.68,2.28)
Bleach (n=195)	-0.02(-0.12,0.09)	-0.22(-3.27,2.83)	-0.02(-0.15,0.1)	-0.31(-3.11,2.49)	0.09(-0.21,0.38)	0(-0.02,0.01)	-0.65(-2.08,0.78)
Ammonia (n=101)	0.1(-0.05,0.25)	1.23(-3.21,5.68)	0.14(-0.04,0.32)	1.3(-2.78,5.38)	0.01(-0.42,0.44)	0(-0.02,0.02)	0.63(-1.44,2.7)
Decalcifiers/acids (n=34)	0.11(-0.11,0.33)	2.55(-3.97,9.06)	0.19(-0.08,0.46)	2.95(-3.02,8.92)	0.36(-0.27,0.99)	0(-0.04,0.03)	-0.18(-3.19,2.83)
Solvents/stain removers (n=44)	0.03(-0.19,0.25)	1.86(-4.68,8.39)	0.02(-0.25,0.29)	0.92(-5.08,6.91)	0.33(-0.3,0.97)	0.01(-0.02,0.04)	2.49(-0.52,5.5)
Other unspecified cleaning products (n=41)	0.01(-0.12,0.15)	0.07(-4.01,4.14)	0.09(-0.07,0.26)	1.52(-2.22,5.25)	-0.22(-0.62,0.17)	-0.02(-0.03,0)	-0.22(-2.11,1.68)
Furniture sprays (n=60)	0.09(-0.06,0.23)	2.48(-1.7,6.65)	0.05(-0.12,0.22)	0.67(-3.15,4.49)	2.53(-2.85,7.9)	0.02(0,0.04)#	-0.17(-2.12,1.78)
Glass cleaning sprays (n=262)	-0.07(-0.17,0.03)	-1.16(-4.21,1.89)	-0.13(-0.26,-0.01)*	-2.38(-5.17,0.41)#	-0.49(-4.39,3.41)	0.01(0,0.03)#	-0.17(-1.60,1.26)
Sprays for carpets, rugs or curtains (n=16)	0.15(-0.11,0.4)	6(-1.57,13.56)	0.12(-0.19,0.43)	4.22(-2.7,11.13)	9.24(-0.45,18.93)#	0.02(-0.02,0.05)	-2.10(-5.61,1.42)
Sprays for mopping the floor (n=90)	-0.1(-0.23,0.02)#	-2.96(-6.57,0.64)	-0.1(-0.25,0.05)	-2.11(-5.4,1.19)	-1.16(-5.79,3.47)	-0.01(-0.02,0.01)	1.90(0.21,3.58)*
Oven sprays (n=6)	-0.14(-0.55,0.28)	4.13(-8.1,16.36)	-0.22(-0.72,0.28)	2.8(-8.38,13.97)	-3.54(-19.23,12.16)	0.02(-0.04,0.08)	-3.92(-9.58,1.75)
Ironing sprays (n=2)	-0.02(-0.73,0.69)	4.42(-16.61,25.45)	-0.24(-1.1,0.62)	-2.13(-21.35,17.1)	2.44(-24.56,29.44)	0.06(-0.04,0.16)	-2.69(-12.45,7.08)
Air refreshing sprays (n=111)	0.03(-0.08,0.15)	1.27(-2.14,4.68)	0.02(-0.12,0.16)	0.9(-2.23,4.02)	2(-2.38,6.38)	0.01(-0.01,0.02)	-0.81(-2.41,0.79)
Multi-purpose cleaning sprays (n=128)	-0.01(-0.12,0.1)	-0.08(-3.27,3.1)	0(-0.13,0.13)	0.23(-2.68,3.15)	-0.84(-4.93,3.25)	-0.00(-0.02,0.01)	1.13(-0.36,2.61)
Other sprays (n=37)	0.02(-0.16,0.2)	1.5(-3.85,6.85)	-0.06(-0.28,0.16)	-0.45(-5.33,4.44)	0.95(-5.94,7.84)	0.01(-0.01,0.04)	2.04(-0.52,4.60)

^a Adjusted for age, sex, ethnicity, smoking. Values represent general linear regression coefficients (95%CI). Ref = reference; # p<0.10; *p<0.05; **p<0.01.

^b Only shown for FEV₁. Homes/schools/offices also includes shops and hotels

Supplementary Table 1. Types of business/premises in which cleaning activities were conducted (n=425)

Number of different types of business cleaned	Type of business	Number of cleaners (%)
1	-	315 (74.1%)
	Private homes	7 (1.6%)
	Schools	29 (6.8%)
	Offices	40 (9.4%)
	Hospitals/pharmacies	103 (24.2%)
	Shops	11 (2.6%)
	Cafes, restaurants	5 (1.2%)
	Kitchens	0 (0%)
	Factories	54 (12.7%)
	Bedrooms/accommodation	64 (15.1%)
	Outside	1 (0.02%)
	Other	
2	Combinations of premises	63 (14.8%)
3	“	17 (4.0%)
4	“	9 (2.0%)
5	“	11 (2.6%)
6	“	1 (0.02%)
7	“	3 (0.07%)
8	“	2 (0.05%)
Incomplete data	-	4 (0.09%)

Supplementary Table 2. Number of cleaners reporting the use of cleaning agents in different settings.

Agent	Homes/schools /offices/shops/hotels	Hospital	Café/Restaurant/ Kitchen	Industrial	Outside
Detergent	74	47	15	21	12
Multiuse cleaner	61	37	14	19	7
Polishes	22	26	6	7	4
Bleach	57	54	9	29	9
Ammonia	21	16	7	3	6
Decalcifiers	5	5	0	14	1
Solvents	8	8	2	4	2
Other	144	115	29	52	14
Furniture sprays	30	19	4	6	1
Glass cleaning sprays	117	103	18	8	13
Sprays for carpets, rugs or curtains	7	7	2	0	0
Sprays for mopping the floor	43	23	10	5	9
Oven sprays	4	1	0	1	0
Ironing sprays	2	0	0	0	0
Air refreshing sprays	50	39	13	0	8
Multi-purpose antibacterial cleaning sprays	62	39	12	8	5
Other sprays	16	6	3	11	1

Supplementary Table 3. Associations between exposures, cleaning activities and difference between pre/ postbronchodilator values in cleaners (n=425)

^a Adjusted for age, sex, ethnicity, smoking. Values represent general linear regression coefficients (95%CI). Ref = reference; # p<0.10; *p<0.05; **p<0.01.

Exposure/cleaning activity	Increase in FEV ₁ (L)	Increase in FVC (L)	Increase in FVC (% change)	Increase in PEF (L/s)	Increase in PEF (% change)
Years worked as a cleaner					
<3 years (n=134)	REF	REF	REF	REF	REF
3-10 years (n=141)	0.00(-0.04,0.04)	0.04(-0.03,0.11)	0.73(-1.65,3.11)	-0.11(-0.29,0.07)	-2.6(-5.47,0.26)
>10 years (n=150)	0.01(-0.04,0.05)	0.01(-0.07,0.09)	0.09(-2.72,2.54)	0.01(-0.19,0.21)	-0.96(-4.13,2.22)
Type of cleaning					
Homes/schools/offices/shops/hotels (n=175)	REF	REF	REF	REF	REF
Hospital (n=126)	-0.01(-0.04,0.02)	0.00(-0.06,0.06)	-0.03(-2.03,1.97)	0.11(-0.04,0.26)	2.20(-0.21,4.62)#
Café/restaurant/kitchen (n=32)	0.04(-0.00,0.09)#	0.03(-0.06,0.12)	1.23(-1.77,4.23)	0.14(-0.09,0.36)	1.85(-1.77,5.47)
Industrial (n=67)	0.02(-0.02,0.06)	0.02(-0.05,0.10)	0.59(-1.89,3.08)	-0.02(-0.21,0.17)	-0.03(-3.02,2.96)
Outside (n=21)	-0.02(-0.07,0.04)	0.01(-0.09,0.12)	0.03(-3.42,3.49)	0.03(-0.24,0.29)	-0.14(-4.30,4.02)
Cleaning activity (≥1 day/wk vs <1 day/wk)					
Dusting/sweeping/vacuuuming (n=366)	-0.02(-0.07,0.02)	-0.04(-0.12,0.05)	-0.36(-3.15,2.43)	-0.05(-0.27,0.16)	-1.12(-4.49,2.26)
Mopping/wet cleaning/damp wiping (n=395)	0.01(-0.05,0.08)	0.01(-0.10,0.12)	0.93(-2.86,4.73)	0.13(-0.16,0.42)	2.24(-2.38,6.86)
Cleaning toilets (n=323)	0.00(-0.03,0.04)	-0.01(-0.08,0.05)	0.08(-2.23,2.39)	0.05(-0.12,0.23)	1.03(-1.77,3.82)
Polishing, waxing, shampooing (n=95)	-0.03(-0.06,0.01)	-0.04(-0.11,0.02)	-1.61(-3.82,0.60)	-0.09(-0.26,0.08)	-1.08(-3.77,1.60)
Cleaning windows/mirrors (n=320)	-0.01(-0.05,0.02)	-0.02(-0.08,0.05)	-0.10(-2.29,2.08)	0.08(-0.09,0.25)	1.67(-0.97,4.31)
Cleaning the kitchen (n=243)	0.01(-0.02,0.04)	0(-0.05,0.06)	0.12(-1.79,2.04)	-0.12(-0.27,0.02)	-1.79(-4.10,0.52)
Washing/soaking clothes/linen by hand (n=27)	0.04(-0.02,0.1)	-0.01(-0.12,0.1)	-0.47(-4.16,3.21)	0.12(-0.17,0.4)	0.85(-3.62,5.31)
Washing clothes by machine (n=58)	0.05(0,0.09)*	0.05(-0.03,0.13)	1.50(-1.18,4.17)	-0.12(-0.32,0.09)	-2.41(-5.64,0.83)
Cleaning machinery in an industrial setting (n=57)	0.04(-0.01,0.09)	0.04(-0.04,0.13)	1.15(-1.80,4.11)	0.05(-0.17,0.28)	1.13(-2.46,4.71)
Use of cleaning products (often vs sometimes/never)					
Washing powder (n=386)	0(-0.06,0.05)	-0.05(-0.15,0.05)	-1.93(-5.32,1.45)	0.07(-0.19,0.33)	1.10(-3.02,5.23)
Polishes/waxes (n=81)	0(-0.04,0.03)	-0.04(-0.11,0.03)	-1.04(-3.37,1.30)	0.17(0,0.35)#	2.50(-0.32,5.32)#
Liquid multiuse cleaner (n=280)	0.01(-0.02,0.04)	0.03(-0.03,0.09)	1.30(-0.66,3.27)	0.04(-0.11,0.19)	0.73(-1.66,3.12)
Bleach (n=195)	-0.02(-0.05,0.01)	-0.05(-0.11,0)#	-1.49(-3.33,0.36)	0.09(-0.06,0.23)	1.27(-0.97,3.51)
Ammonia (n=101)	0.03(0,0.07)#	0.05(-0.02,0.11)	1.75(-0.39,3.88)	0.1(-0.06,0.26)	1.32(-1.28,3.93)
Decalcifiers/acids (n=34)	0.03(-0.02,0.09)	0.03(-0.07,0.12)	0.03(-3.20,3.27)	-0.02(-0.27,0.23)	-0.85(-4.79,3.08)
Solvents/stain removers (n=44)	0.04(0,0.09)#	0.06(-0.02,0.15)	1.81(-1.14,4.75)	0.2(-0.03,0.42)#	2.64(-0.95,6.22)
Other unspecified cleaning products (n=41)	0.02(-0.03,0.08)	0(-0.1,0.09)	0.35(-2.96,3.66)	0.27(0.02,0.51)*	3.88(0.04,7.72)*
Furniture sprays (n=60)	0(-0.04,0.04)	0.04(-0.04,0.12)	1.86(-0.7,4.43)	-0.1(-0.3,0.1)	-1.71(-4.81,1.40)
Glass cleaning sprays (windows, mirrors) (n=262)	-0.02(-0.05,0.01)	0(-0.05,0.06)	0.67(-1.21,2.55)	0.02(-0.13,0.16)	0.65(-1.63,2.93)
Sprays for carpets, rugs or curtains (n=16)	-0.05(-0.12,0.03)	-0.02(-0.16,0.12)	-0.66(-5.29,3.97)	-0.12(-0.48,0.23)	-1.7(-7.32,3.91)
Sprays for mopping the floor (n=90)	0.04(0,0.07)#	0.03(-0.03,0.1)	1.27(-0.96,3.50)	-0.03(-0.2,0.14)	0.06(-2.64,2.77)
Oven sprays (n=6)	-0.1(-0.22,0.02)	-0.21(-0.43,0.01)#	-6.23(-13.67,1.22)	-0.49(-1.06,0.08)#	-5.25(-14.29,3.8)
Ironing sprays (n=2)	-0.05(-0.26,0.16)	0.1(-0.28,0.48)	2.82(-9.96,15.60)	-0.34(-1.32,0.64)	-5.43(-20.95,10.10)
Air refreshing sprays (n=111)	-0.02(-0.05,0.02)	0(-0.07,0.06)	0.02(-2.09,2.13)	-0.03(-0.19,0.13)	-0.56(-3.10,1.98)
Multi-purpose antibacterial cleaning sprays (n=128)	0.02(-0.02,0.05)	0.02(-0.04,0.08)	1.15(-0.81,3.11)	0.03(-0.12,0.18)	0.49(-1.88,2.86)
Other sprays (n=37)	0.03(-0.02,0.09)	0.01(-0.09,0.11)	0.84(-2.54,4.23)	0.15(-0.1,0.41)	3.03(-1.02,7.09)