ORIGINAL ARTICLE

Cleaning at Home and at Work in Relation to Lung Function Decline and Airway Obstruction

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Abstract

Rationale: Cleaning tasks may imply exposure to chemical agents with potential harmful effects to the respiratory system, and increased risk of asthma and respiratory symptoms among professional cleaners and in persons cleaning at home has been reported. Long-term consequences of cleaning agents on respiratory health are, however, not well described.

Objectives: This study aimed to investigate long-term effects of occupational cleaning and cleaning at home on lung function decline and airway obstruction.

Methods: The European Community Respiratory Health Survey (ECRHS) investigated a multicenter population-based cohort at three time points over 20 years. A total of 6,235 participants with at least one lung function measurement from 22 study centers, who in ECRHS II responded to questionnaire modules concerning cleaning activities between ECRHS I and ECRHS II, were included. The data were analyzed with mixed linear models adjusting for potential confounders.

Measurements and Main Results: As compared with women not engaged in cleaning ($\Delta FEV_1 = -18.5$ ml/yr), FEV_1 declined more rapidly in women responsible for cleaning at home (-22.1; $P = 0.01$) and occupational cleaners (-22.4; $P = 0.03$). The same was found for decline in FVC ($\Delta FVC = -8.8$ ml/yr; -13.1, $P = 0.02$; and -15.9, $P = 0.002$; respectively). Both cleaning sprays and other cleaning agents were associated with accelerated FEV_1 decline (-22.0, $P = 0.04$; and -22.9, $P = 0.004$; respectively). Cleaning was not significantly associated with lung function decline in men or with FEV_1/FVC decline or airway obstruction.

Conclusions: Women cleaning at home or working as occupational cleaners had accelerated decline in lung function, suggesting that exposures related to cleaning activities may constitute a risk to long-term respiratory health.

Keywords: occupational medicine; spirometry; lung diseases

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At a Glance Commentary

Scientific Knowledge on the Subject: It is known that cleaning tasks may imply exposure to chemical agents with potential harmful effects to the respiratory system. Furthermore, increased risk of asthma and respiratory symptoms among professional cleaners and in persons cleaning at home is reasonably well documented.

What This Study Adds to the Field: This study suggests that long-term respiratory health is also impaired 10 to 20 years after cleaning activities. We found accelerated lung function decline in women after both occupational cleaning and cleaning at home. The effect size was comparable to the effect size related to 10 to 20 pack-years of tobacco smoking.

Cleaning tasks are associated with exposure to several chemical agents with potential harmful effects to the respiratory system (1) and on cardiovascular markers (2). Excess risk of asthma and respiratory symptoms among professional cleaners (3, 4) as well as asthma and respiratory symptoms in persons cleaning their own homes (5–8) have been reported in several studies. Both specific immunological mechanisms and nonspecific inflammatory responses have been suggested (9).

The long-term consequences of cleaning agents on respiratory health are not well described, however, and there is a need for further studies (10). It seems biologically plausible that exposure to cleaning chemicals could result in accelerated lung function decline and chronic airway obstruction. Low-grade inflammation over many years could possibly lead to persistent damage to the airways; alternatively, persistent damage could result from continued exposure after onset of cleaning-related asthma. To our knowledge, there is no previous investigation of long-term effects of cleaning at home on lung function decline and respiratory health. A previous study has shown increased risk of self-reported chronic obstructive pulmonary disease (COPD) among occupational cleaners (11), and a newly published large population-based cohort-study from the United Kingdom showed cleaners to be among the occupations with the highest risk of spirometry-defined COPD (12).

The European Community Respiratory Health Survey (ECRHS) provided an opportunity for longitudinal assessment of cleaning exposure in a large population-based cohort that included information about occupational cleaning and cleaning at home as well as spirometry performed at three time points. The aim of this study was to investigate associations of both professional cleaning and cleaning at home with lung function decline and chronic airway obstruction. In addition, the type and frequency of applied cleaning agents were analyzed.

Some of the results of this study have been previously reported in the form of an abstract (13).

Methods

Study Design and Population

ECRHS is an international multicenter population-based cohort, established from random population samples of men and women aged 20 to 44 years in 1992 to 1994 (ECRHS I), reinvestigated from 1998 to 2002 (ECRHS II) and 2010 to 2012 (ECRHS III). Each survey included interviews, spirometry, and anthropometric measurements, among others. Written consent was obtained from all participants in each survey, and ethical approval was obtained from the regional ethic committee of each center.

In ECRHS II, 22 study centers included questionnaire modules for selected occupations. This article presents data from participants who answered entrance questions to questionnaire modules assessing cleaning activities between ECRHS I and II and had lung function measured at least once (*see* Figure E1 in the online supplement).

Cleaning Exposure

On the basis of the entrance questions (for wording, *see* Reference 14), participants were categorized as "not cleaning," "cleaning at home," and "occupational cleaning." Participants responding "yes" to at least one module entrance question answered a questionnaire concerning use of cleaning agents (sprays, other cleaning agents), defining the exposure categories "not cleaning," "one or more cleaning spray once or more per week," and "one or more other cleaning product once or more per week."

Lung Function

Maximum FVC and maximum FEV_1 were determined by spirometry; in ECRHS III, a bronchodilator test was performed. Decline in prebronchodilator FEV_1 and FVC was defined as the slope of change between each measurement in milliliters. Post-bronchodilator airway obstruction at ECRHS III was defined as FEV_1/FVC less than the lower limit of normal (LLN) predicted using the National Health and Nutrition Examination Survey equations (15). Persons with any airway obstruction

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at ECRHS I were excluded from analyses with airway obstruction as outcome variable ($n = 314$).

Covariates

Pack-years were calculated as (cigarettes per day × years smoked)/20; body mass index (BMI) was calculated from weight per squared height. Age at attained education was used as proxy for socioeconomic status (SES) (16, 17). Father's and mother's educational backgrounds and an occupational-based socioeconomic variable (18) were used as proxies for SES in sensitivity analyses.

Statistical Analyses

Possible effect on decline in lung function from cleaning exposure was analyzed with mixed-effect models adjusting for age at baseline and its square, number of years from baseline to each follow-up, height, BMI, lifetime pack-years at each time point, age at completed education, spirometer type, and center. Absolute lung function (FEV_1 or FVC) was the outcome variable in all models. Effects of exposures on longitudinal lung function decline were estimated by including interaction terms of exposure with time since baseline. Study participants with only one observation were included in the analyses; although not contributing direct information about the effect of the exposures, they informed the effect of the other fixed covariates on lung function, thereby raising the overall statistical power of the analysis. Change in FEV_1 and FVC was expressed as milliliters per year; a negative value represented a decline.

Associations between cleaning exposure and airway obstruction were analyzed with multiple logistic regression adjusting for BMI, height, age at completed education, pack-years, spirometer, and center. Associations were reported as odd ratios with 95% confidence intervals.

A more detailed description of methods can be found in the online supplement.

Results

The study population included 6,235 participants with a mean age of 34 years at baseline and 54 years at the second follow-up (ECRHS III). Fifty-three percent of the participants were women, 44% were lifelong nonsmokers, and ever-smokers had smoked a mean of 7.0 pack-years at baseline (Table 1). The prevalence of asthma confirmed by a doctor increased from the first to the second study wave, and the prevalence of spirometry-defined any airway obstruction (on the basis of prebronchodilator spirometry) increased from the second to the third study wave. The mean FEV_1 and FVC at baseline were 3.8 and 4.5 L, respectively (Table 1).

Of 6,235 participants, 2,693 (43.2%) and 2,740 (44.0%), respectively, performed satisfactory FEV_1 and FVC maneuvers in two study waves (Table 2). A total of 2,717 (43.6%) and 2,597 (41.7%), respectively, performed FEV_1 and FVC maneuvers in all three study waves, and 825 (13.2%) and 898 (14.4%), respectively, performed spirometry maneuvers in one study wave (Table 2).

Among 3,298 female participants, the majority reported to be the person cleaning at home (85.1%), as compared with 46.5% of 2,932 male participants (Table 3). There were 293 (8.9%) women and 57 (1.9%) men who reported working with occupational cleaning. Persons cleaning at home were more often never-smokers and had smoked fewer pack-years than the other two exposure groups. The occupational cleaners had a lower age at attained education than others, independent of sex. Women cleaning at home and female occupational cleaners had more doctor-diagnosed asthma than women not cleaning. Furthermore, men cleaning at home had more doctor-diagnosed asthma than men not cleaning and male occupational cleaners. There was not substantially higher prevalence of spirometry-defined chronic airway obstruction in either of the exposure groups as compared with the unexposed group (Table 3).

Women not working as cleaners and not involved in cleaning at home showed the lowest decline in FEV_1 and FVC (Table 4). Female occupational cleaners, including those who also cleaned at home, had the highest mean decline in FEV_1 and FVC. The differences between each of the two exposed groups and the reference group were statistically significant (Table 4). In relation to exposure, the increase in decline was similar for FEV_1 and FVC, and therefore no apparent difference in the decline of the FEV_1/FVC ratio was seen. The average annual decline was 0.5% in all three exposure groups. Male occupational cleaners and men cleaning at home did not have accelerated lung function decline as compared with men who reported no cleaning activities between ECRHS I and ECRHS II (Table E1).

Among women, the use of sprays or other cleaning products (i.e., nonsprays) at least one once per week was associated with accelerated decline in FEV_1 as compared with not performing cleaning activities (Table 4). Use of other cleaning products at least once per week was also associated with accelerated decline in FVC (Table 4). Among male cleaners, neither sprays nor other cleaning products were significantly associated with lung function decline (Table E1).

There was no apparent increased risk of chronic airway obstruction in either of the cleaning exposure groups. Likewise, there was no apparent increased risk of chronic airway obstruction with regard to use of cleaning sprays or other cleaning products (Table 5).

Discussion

This longitudinal analysis observed that women who had either cleaned at home or worked as professional cleaners had accelerated decline in FEV_1 and FVC as compared with women not regularly engaged in cleaning activities. Furthermore, compared with women not engaged in cleaning activities, women who used sprays or other cleaning agents at least one time per week had significantly accelerated decline in FEV_1, whereas women who used other cleaning products at least one time per week had increased decline in FVC. No association between lung function and cleaning was seen for men.

To the best of our knowledge, this analysis is the first to address lung function decline in relation to cleaning exposure in occupational life or at home. In general, our findings of poorer respiratory health outcomes in relation to cleaning exposures are supported in the literature on cleaning-related asthma (4, 19). Previous longitudinal studies on occupational cleaning have shown increased risk of COPD (11, 12). In the present study, there were relatively few cases of incident COPD, and associations with cleaning activities did not reach statistical significance. Our study suggested a steeper decline in FVC than in FEV_1 in relation to cleaning. FVC is an outcome of particular interest, as survival in asymptomatic adults without a chronic respiratory diagnosis or persistent

Table 1. Characteristics of the Study Population at Each Survey

	ECRHS I (*n* = 6,235)*	ECRHS II (*n* = 6,235)*	ECRHS III (*n* = 3,804)*
Sex, women	52.9	52.9	53.2
Age, yr	33.8 ± 7.2	42.7 ± 7.2	54.1 ± 7.2
Height, m	1.7 ± 0.10	1.7 ± 0.10	1.7 ± 0.10
BMI, kg/m^2	23.8 ± 3.7	25.4 ± 4.3	26.9 ± 4.8
Never-smokers	44	41	40
Pack-years	7.0 ± 11.0	9.9 ± 16.1	11.1 ± 19.4
Age at completed education, yr	19.7 ± 4.5	20.8 ± 5.4	—
FVC, L	4.5 ± 1.0	4.4 ± 1.0	4.0 ± 1.0
FVC % predicted, based on NHANES	100.4 ± 11.9	99.9 ± 12.4	97.3 ± 13.2
FVC < LLN	5.6	6.3	8.9
FEV_1, L	3.8 ± 0.8	3.5 ± 0.8	3.1 ± 0.8
FEV_1 % predicted, based on NHANES	101.2 ± 12.8	99.8 ± 13.6	95.4 ± 14.4
Asthma (“Asthma confirmed by a doctor?”)	6.1	9.5	7.0
Airway obstruction, defined by LLN†	5.0	5.3	9.8
Chronic airway obstruction, defined by LLN‡			5.6
Cleaning at home§, *n* (%)		4,486 (72)	
Occupational cleaning §, *n* (%)		350 (6)	

Definition of abbreviations: BMI = body mass index; ECRHS = European Community Respiratory Health Survey; LLN = lower limit of normal; NHANES = National Health and Nutrition Examination Survey.
Data presented as mean ± SD or percentage, unless otherwise noted.
*Study participants in each study wave who gave information on cleaning activities in ECRHS II and had at least one acceptable measurement of lung function at one of the three study waves.
†LLN, prebronchodilator.
‡LLN, post-bronchodilator.
§Persons who performed cleaning activities between ECRHS I and ECRHS II.

respiratory symptoms has been shown to be associated with FVC rather than airway obstruction as defined by the lower than normal FEV_1/FVC ratio (20). Brodkin and colleagues showed that increased decline in the FEV_1/FVC ratio might signify accelerated obstructive changes even when the ratio was not below the fixed ratio or LLN (21). However, in our study there was no difference in yearly FEV_1/FVC decline among the three exposure groups. This might in part be due to our studying a relatively young population, in whom airway obstruction has not yet manifested as spirometric changes.

The excess decline in the exposed groups amounted to 3.6 ml/yr (cleaning at home) and 3.9 ml/yr (occupational cleaning) for FEV_1, and 4.3 and 7.1 ml/yr, respectively, for decline in FVC. The absolute decline in lung function over time may possibly be underestimated (22) because of the multicenter design of our study with 22 participating centers, with different spirometers and technical personnel. This could possibly attenuate true differences between groups, and our study could also be less sensitive to small changes. For comparison within our study population, similar models with similar adjustments showed that heavy smokers (>20 pack-years) had excess decline of 6.1 ml/yr in FEV_1 and 8.9 ml/yr in FVC (as compared with the excess decline in occupational cleaners of 4.3 and 7.1 ml/yr). The effect of occupational cleaning was thus comparable to smoking somewhat less than 20 pack-years.

Most cleaning agents have an irritative effect on the mucous membranes of the airways (23, 9). One possible mechanism for the accelerated decline in cleaners is the repetitive exposure to low-grade irritative cleaning agents over time, thereby causing persistent changes in the airways. Also, some cleaning agents may have sensitizing properties through specific immunological mechanism; quaternary ammonium compounds are known to have sensitizing effects in the airways, as well as also having an irritative effect (23). Repeated exposure could lead to remodeling of the airways, thereby over time causing an accelerated decline in FVC and FEV_1. Also, one could hypothesize that long-term exposure to airway irritants such as ammonia and bleach used when cleaning at home could cause fibrotic or other interstitial changes in the lung tissue, thereby leading to accelerated decline of FVC (24).

Earlier studies have shown that people with asthma, regardless of sex and smoking status, show greater decline in FEV_1 than people without (25). In the present analysis, asthma was more prevalent in the exposed groups (12.3 [cleaning at home] and 13.7% [occupational cleaning] vs. 9.6% [not cleaning], respectively, for women; Table 3); however, adjusting for ever had asthma in either of the three study waves in a sensitivity analysis did not change the associations (Table E2). Furthermore, the effects were similar when excluding subjects with asthma (Table E3), suggesting that the observed accelerated lung function decline is generally not mediated by

Table 2. Number of Spirometry Tests

	FEV_1	FVC
Spirometry in one study wave	825 (13.2)	898 (14.4)
Spirometry in two study waves	2,693 (43.2)	2,740 (44.0)
Spirometry in three study waves	2,717 (43.6)	2,597 (41.7)

Data are presented as *n* (%).

Table 3. Covariates at European Community Respiratory Health Survey II According to Exposure to Cleaning (from Module Entrance Questions in European Community Respiratory Health Survey II)

	Not Cleaning (Reference)		Cleaning at Home		Occupational Cleaner	
	Men (*n* = *1,512*)	Women (*n* = 197)	Men (*n* = *1,363*)	Women (*n* = *2,808*)	Men (*n* = *57*)	Women (*n* = *293*)
Age, yr	43.4 ± 7.2	40.3 ± 7.5	42.1 ± 7.3	42.9 ± 7.1	41.3 ± 6.8	42.8 ± 7.0
Height, m	1.8 ± 0.07	1.6 ± 0.07	1.8 ± 0.07	1.6 ± 0.07	1.7 ± 0.07	1.6 ± 0.07
BMI, kg/m^2	26.4 ± 3.6	24.6 ± 4.9	25.6 ± 3.5	24.7 ± 4.6	26.6 ± 3.8	25.9 ± 5.4
Never-smokers	32	41	43	45	28	44
Pack-years	15.8 ± 22.0	9.1 ± 14.2	9.6 ± 15.1	6.9 ± 11.7	15.3 ± 17.1	8.9 ± 13.7
Age at completed education, yr	20.0 ± 4.7	22.2 ± 4.3	21.6 ± 5.2	21.0 ± 5.6	19.9 ± 5.1	18.1 ± 6.0
FVC, L	5.0 ± 0.8	3.7 ± 0.7	5.2 ± 0.8	3.7 ± 0.6	5.1 ± 0.8	3.6 ± 0.6
FVC % predicted, NHANES	99.2 ± 12.1	99.8 ± 13.7	99.1 ± 12.3	100.6 ± 12.5	101.1 ± 10.2	100.2 ± 12.6
FVC < LLN*	6.8	8.1	7.6	5.2	2.0	7.0
FEV_1, L	4.0 ± 0.7	3.1 ± 0.5	4.1 ± 0.7	3.0 ± 0.5	4.1 ± 0.7	2.9 ± 0.5
FEV_1 % predicted, NHANES	100.7 ± 13.7	100.3 ± 14.2	99.3 ± 13.9	99.7 ± 13.3	102.1 ± 11.0	98.3 ± 13.4
Asthma (“Asthma confirmed by a doctor?”)	7.0	9.6	10.3	12.3	7.0	13.7
Airway obstruction, defined by LLN*	5.0	3.1	6.1	5.1	5.3	6.1

Definition of abbreviations: BMI = body mass index; LLN = lower limit of normal; NHANES = National Health and Nutrition Examination Survey.
Data presented as mean ± SD or percentage.
*LLN, prebronchodilator.

cleaning-related asthma. This sensitivity analysis also suggests that the association with cleaning exposure was not limited to, mediated by, or confounded by asthma treatment.

Spirometric chronic airway obstruction is defined according to the Global Initiative for Chronic Obstructive Lung Disease (26) as individuals with a fixed FEV_1/FVC ratio less than 0.70. However, there is concern that using a fixed cutoff as a definition of airway obstruction can misdiagnose cases of obstruction, because the FEV_1/FVC ratio varies with age, height, and sex (27). Therefore, using the fixed ratio may result in overdiagnosis of elderly patients whose lung volumes may be reduced as a result of the normal aging process; hence, any airway obstruction was defined as an FEV_1/FVC ratio less than LLN.

The major strengths of this study include the long-term follow-up with spirometry measurements at three time points in a large number of participants with

Table 4. Associations of Decline in FEV_1 and FVC with Cleaning at Home and Occupational Cleaning in Women

	Adjusted* Decline in FEV_1 and FVC					
	ΔFEV_1 (95% CI) (*ml/yr*)	*P* Value†	ΔFVC (95% CI) (*ml/yr*)	*P* Value†	ΔFEV_1/FVC (95% CI) (*%/yr*)	*P* Value†
No cleaning activities between ECRHS I and ECRHS II (reference) (*n* = 197)	−18.5 (−21.3 to −15.7)		−8.8 (−12.4 to −5.1)		−0.5 (−0.58 to −0.45)	
Cleaning at home (*n* = 2,808)	−22.1 (−23.2 to −21.0)	0.01	−13.1 (−14.6 to −11.7)	0.02	−0.5 (−0.57 to −0.52)	0.39
Occupational cleaner (*n* = 293)	−22.4 (−24.8 to −20.0)	0.03	−15.9 (−19.0 to −12.7)	0.002	−0.5 (−0.59 to −0.48)	0.60
No cleaning activities between ECRHS I and ECRHS II (reference) (*n* = 197)	−18.7 (−21.6 to −15.7)		−9.5 (−13.3 to −5.7)			
⩾1 spray ⩾1 time/wk (*n* = 569)	−22.0 (−23.9 to −20.1)	0.04	−13.3 (−15.8 to −10.9)	0.07		
⩾1 other cleaning product ⩾1 time/wk (*n* = 1,567)	−22.9 (−24.4 to −21.5)	0.004	−14.3 (−16.2 to −12.5)	0.01		
Never-smoker (reference) (*n* = 1,670)	−21.1 (−22.4 to −19.9)		−11.8 (−13.4 to −10.2)			
<10 pack-years (*n* = 769)	−21.8 (−23.3 to −20.3)	0.4	−12.2 (−14.2 to −10.2)	0.7		
10–20 pack-years (*n* = 442)	−23.3 (−25.2 to −21.4)	0.03	−12.8 (−15.3 to −10.3)	0.4		
>20 pack-years (*n* = 411)	−27.2 (−29.3 to −25.2)	<0.001	−20.7 (−23.3 to −18.0)	<0.001		

Definition of abbreviations: CI = confidence interval; ECRHS = European Community Respiratory Health Survey.
Association between smoking and decline in FEV_1 and FVC given for comparison.
*Adjustments: age at ECRHS II (centered), age at ECRHS II squared, number of years since baseline, height at baseline, body mass index at each study wave, lifetime pack-years, age at completed education, spirometer model used at each study wave, and study center.
†*P* value from mixed effect models for difference in lung function decline between reference group and exposed groups.

Table 5. Associations between Different Cleaning Exposures and Incident Airway Obstruction in Women and Men

	Chronic Airway Obstruction*			
	Women		Men	
	OR† (95% CI)	*P* Value‡	OR† (95% CI)	*P* Value‡
Cleaning at home	5.20 (0.67–40.71) ($n = 86$)	0.1	0.89 (0.38–2.13) ($n = 32$)	0.8
Occupational cleaner	1.93 (0.14–20.89) ($n = 7$)	0.6	1.45 (0.17–12.49) ($n = 2$)	0.7
⩾1 spray ⩾1 time/wk	5.87 (0.68–51.04) ($n = 16$)	0.1	0.68 (0.79–5.76) ($n = 2$)	0.7
⩾1 other cleaning product ⩾1 time/wk	4.78 (0.56–40.10) ($n = 51$)	0.2	1.05 (0.38–2.87) ($n = 22$)	0.9
<10 pack-years	1.16 (0.54–2.47) ($n = 22$)	0.7	2.07 (0.67–6.38) ($n = 10$)	0.2
10–20 pack-years	1.51 (0.63–3.61) ($n = 11$)	0.4	1.79 (0.55–5.84) ($n = 11$)	0.3
>20 pack-years	3.31 (1.56–7.03) ($n = 28$)	0.002	7.16 (2.91–17.64) ($n = 36$)	<0.001

Definition of abbreviations: CI = confidence interval; ECRHS = European Community Respiratory Health Survey; OR = odds ratio.
Association between smoking and incident chronic airway obstruction given for comparison. *n* signifies the number of persons with spirometry-defined chronic airway obstruction in each exposure group.
*Participants with obstructive spirometry in ECRHS I ($n = 314$) excluded from the analysis.
†Adjustments: body mass index and height at baseline, age at attained education, lifetime pack-years, spirometer model, and center. In the analyses on smoking, adjustment is made for cleaning.
‡*P* value for the association between different exposure groups and OR of chronic airway obstruction.

extensive data. The population-based design and the multicenter structure make the results applicable to a general population rather than to specific groups. Furthermore, the data from the participants were extensive, ensuring that each participant was well characterized, with ample possibilities to adjust for potential confounders. Post-bronchodilator spirometry values in ECRHS III provided the preferred measure for diagnosing chronic airway obstruction (28, 29). Cleaning activities were recorded in the ECRHS II, thereby making it possible to establish a temporal relationship between cleaning activities and long-term outcomes. Our data did not allow for a detailed exploration between years of or onset of cleaning activities in relation to lung function decline.

This analysis has some methodological challenges. First, cleaning at home or work by social class may have differential associations across centers; for example, it stands to reason that the custom of having someone to clean at home varies between countries. To account for this, center has been used as an adjustment variable to take into account social-cultural differences. Thus, the multicultural structure of the study makes it possible to take into account heterogeneous cultural differences between centers. Second, occupational cleaning may be related to an unhealthy lifestyle, where smoking might be one factor, even though this was not apparent in this study population. To account for possible confounding, smoking, in terms of pack-years, has been adjusted for in the analyses. Furthermore, age at attained education was used to further adjust for confounding by SES. Third, the reference group with women not cleaning at home or working as occupational cleaners was small ($n = 197$), and one could suspect that this group would constitute a selected socioeconomic group. However, adjusting for SES (age at attained education) in the main analysis did not alter the associations, and SES itself was not a significant predictor ($P = 0.17$) of decline in lung function. Furthermore, sensitivity analysis with adjustment for mother's and father's educational level (each in three categories) did not influence the associations of cleaning exposure with lung function decline, and these markers did not have significant effects on lung function decline. Additional sensitivity analysis with adjustment for the occupational-based socioeconomic variable (on the basis of "United Kingdom social class") did not alter the associations either, and this social class variable was not a significant independent predictor for accelerated lung function decline.

Smoking in terms of pack-years was included as a time-varying variable in the model to account for the effect of smoking over time on lung function decline. To account for possible residual confounding of smoking on accelerated FEV_1 decline, we performed a sensitivity analysis including an interaction term between pack-years and time in the model. This did not alter the estimates of annual decline in FEV_1 or the confidence intervals in the two exposure groups. Differential misclassification bias with regard to occupational cleaning is possible and could cause positive or negative confounding. However, a reporting error in cleaning exposure assessment is more likely to give nondifferential bias. The exposure assessment in the present analysis is crude ("person doing the cleaning and/or washing at home"; "having worked as a cleaner"), but overall, although the analyses have several methodological challenges, these are likely to have attenuated the associations and cannot easily explain the accelerated decrease in lung function in women cleaning at home or working as occupational cleaners.

There was no apparent accelerated decline in lung function in men, but it seems likely that the exposures in men who work as cleaners may be different from those in women. Also, the low number of male occupational cleaners ($n = 57$) gave little power to discover accelerated decline in lung function as compared with men not cleaning. Our entrance questions might possibly not have picked up male industrial cleaners. Furthermore, it is possible that occupational groups with other, but equally or more, harmful exposures, such as industrial cleaners and other industrial workers, were included in the reference category, thereby leading to an underestimation of the excess loss in lung function due to cleaning activities. Finally, the greater impact seen in women (both cleaning at home and occupational cleaners) could be mediated by a different susceptibility according to sex, as is reported for other mixed chemical exposures, such as tobacco smoke, and other occupational exposures, such as wood dust, where studies have indicated that less exposure in women is needed to develop illness (30–32).

In conclusion, this longitudinal analysis of a cohort followed over 20 years found that women cleaning at home or working as occupational cleaners had accelerated decline in FVC and FEV_1, but no apparent accelerated decline in the FEV_1/FVC ratio. A causal effect might be biologically plausible, because cleaning agents have known irritative effects and potential for causing inflammatory changes in the airways (9). The effect of treatment for asthma was not investigated in this study. The findings suggest that cleaning activities in women, whether at home or as an occupation, may constitute a risk to respiratory health not only in terms of asthma, as previously shown, but also in terms of long-term impact on lung function decline. Our findings advocate a need for further focus on preventing harmful exposure to the airways from exposure in cleaning activities. ■

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