Eur Respir J 2012; 40: 1381–1389
DOI: 10.1183/09031936.00197611

Domestic use of cleaning sprays and asthma activity in females

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ABSTRACT: We aimed to study the associations between the household use of cleaning sprays and asthma symptoms and control of asthma, in females from the Epidemiological Study on the Genetics and Environment of Asthma (EGEA).

Data were available for 683 females (mean age 44 yrs, 55% never smokers, 439 without asthma and 244 with current asthma). Both domestic exposures and asthma phenotypes (asthma symptom score, current asthma, poorly-controlled asthma (56%)) were evaluated as previously described in the European Community Respiratory Health Survey. Associations between the use of sprays and asthma phenotypes were evaluated using logistic and nominal regressions, adjusted for age, smoking, body mass index and occupational exposures.

Significant associations were observed between the weekly use of at least two types of sprays and a high asthma symptom score (OR (95% CI) 2.50 (1.54–4.03)) compared with a null score. Consistent results were observed for current asthma (1.67 (1.08–2.56)) and poorly-controlled asthma (2.05 (1.25–3.35)) compared with females without asthma. The association for current asthma was higher in females not reporting avoidance of polluted places (2.12 (1.27–3.54)) than in those reporting such avoidance (0.99 (0.53–1.85)).

The common use of household cleaning sprays is positively associated with a high asthma symptom score, current asthma and poorly-controlled asthma in females.

KEYWORDS: Asthma control, asthma symptoms, cleaning sprays, EGEA, epidemiology, household exposure

Previous studies have reported an excess risk for asthma in cleaners working in offices, hospitals or employed in private houses [1]. Results are consistent with an effect of cleaning agents both in the aggravation and new onset of asthma [1, 2]. Household cleaning substances are classified in the top five substances most frequently involved in exposure complaints in the 2009 report of the American National Poison Data System [3]. BELLO *et al.* [4], who studied detailed tasks among hospital cleaners, classified the use of cleaning sprays as high risk for inhalation exposure. The use of cleaning products in spray form, at work and at home, may be an important risk factor for asthma [1, 5, 6]. One study has reported a dose–response relationship between the frequency of use and number of cleaning sprays used at home and asthma incidence [6].

Exposure to cleaning agents may represent an important public health issue, especially in females. Involvement in domestic tasks and home cleaning is a sex-related behaviour [7, 8]. Uncontrolled asthma was more frequent in females than in males [9], and domestic exposures might partly explain gender differences in asthma control [10]. Both at work and at home, females are likely to be at high risk, based on the potential deleterious effect of cleaning products, including those in spray form [11]. Other studies are necessary to confirm this deleterious role of household cleaning sprays on asthma activity and clinical expression of the disease.

The ''healthy worker effect'' is an important bias in occupational asthma [12, 13]. For domestic exposures, we hypothesise that a similar phenomenon of selection might be present but has not yet been studied. A ''healthy home-cleaning effect'' would be induced by the fact that people with cleaning task-related asthma symptoms may modify their behaviour to reduce the use of cleaning products, sprays or tasks.

This article has supplementary material available from www.erj.ersjournals.com

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Received:
Nov 13 2011
Accepted after revision:
March 15 2012
First published online:
April 10 2012

European Respiratory Journal
Print ISSN 0903-1936
Online ISSN 1399-3003

In the Epidemiological Study on the Genetics and Environment of Asthma (EGEA), a detailed questionnaire regarding current domestic tasks was used along with precise asthma phenotypes. The aim of the present analysis was to assess, in females from the EGEA study, the associations between home cleaning, particularly the use of household cleaning sprays, and asthma activity. Specific hypotheses were: the use of household sprays as a risk factor for 1) poorly-controlled asthma, 2) a high asthma symptom score and 3) a potential ''healthy home-cleaning effect'', evaluated by the avoidance of polluted places, in the association between domestic exposures and asthma.

MATERIAL AND METHODS

Population

EGEA is a cohort study based on an initial group of patients with asthma recruited (1991–1995) in chest clinics (probands, n=388) along with their first-degree relatives (n=1,244) and a group of population-based subjects (n=415). At the second survey (1,601 subjects with detailed questionnaires), detailed phenotyping was performed with lung function tests including methacholine challenge, skin prick tests (SPT) to 12 aeroallergens and total serum immunoglobulin (Ig)E (see flow chart and descriptive data in the online supplementary material) [9, 14]. The analysis is based on 683 females examined at the second survey, for whom detailed information regarding domestic exposures, in particular to sprays, was collected in 2003–2007 (244 with current asthma and 439 without asthma, with detailed phenotyping). The main analysis was focused on females, because few males used cleaning products and no associations were observed in males (online supplementary material).

Asthma and related phenotypes

Based on five asthma symptoms over the previous 12 months (wheezy breathlessness, woken up by chest tightness or by an attack of shortness of breath, attack of shortness of breath at rest or after exercise) the asthma symptom score was computed as previously proposed [15, 16]. A high score was defined by two or more symptoms. As in the European Community Respiratory Health Survey (ECRHS) [17, 18], current asthma referred to the report of asthma attacks or asthma treatment or asthma-like symptoms in the past 12 months [9]. Asthma control was assessed as described by CAZZOLETTI *et al.* [17] and already used in EGEA by SIROUX *et al.* [9], based on the Global Initiative for Asthma (GINA) 2006–2010 guidelines combining diurnal and nocturnal respiratory symptoms, asthma attacks, lung function, hospitalisation for asthma and the use of reliever medication. Females with current asthma were classified as poorly controlled (*i.e.* uncontrolled or partly controlled) or controlled. Sensitivity analyses were performed for the following asthma subphenotypes: asthma severity, low lung function (forced expiratory volume in 1 s (FEV_1) <80% predicted), bronchial hyperresponsiveness (BHR) (provocative dose causing a 20% fall in FEV_1 <4 mg methacholine), positive skin prick tests (SPT+, any of 12 allergens), high total IgE ($\geqslant$100 $IU \cdot mL^{-1}$) and blood eosinophilia ($\geqslant$250 $cells \cdot mm^{-3}$). See online supplementary material for more details.

Assessment of exposure

Current domestic exposures (last 12 months) were recorded as in ECRHS [6], based on 24 domestic exposure variables including nine cleaning tasks and 15 cleaning agents (see online supplementary material). Exposure to home cleaning referred to the report of this task at least weekly as in ZOCK *et al.* [6]. Exposure to sprays was defined by the exposure to any of the eight types of sprays (furniture, glass-cleaning, carpet, mopping the floor, oven, ironing, air-refreshing, other use) at least once a week. Detailed analyses of those exposed (weekly) to two types of sprays were performed.

For a more comprehensive approach, domestic exposure patterns were defined through principal component analysis (PCA) based on the 24 exposure variables. PCA evidenced three domestic exposure patterns entitled ''essential tasks'', ''domestic wizard'', and ''chemical products'' (table 1).

In order to assess a potential ''healthy home-cleaning effect'', we analysed a proxy of avoidance of cleaning products, *i.e.* ''avoidance of polluted places'', assessed by four questions on the activity limitation domain (passive smoking, dust, pollution, perfume/odour) from the Asthma Quality-of-Life Questionnaire [19]. Participants with asthma were classified as ''without avoidance of polluted places'' if, from the seven-point scale of each of the questions, they reported ''none of the time'', ''hardly/any of the time'' or ''a little of the time''. Working as a cleaner or occupationally exposed to cleaning agents, assessed through an asthma job exposure matrix with an expert re-evaluation step [13, 20], was used for sensitivity analysis.

Statistical analysis

Associations between reported domestic exposures, exposure patterns and asthma-related phenotypes were evaluated using logistic regression, taking into account the familial structure of the data (Genmod; SAS, Cary, NC, USA) and nominal logistic regression analyses. In all the analyses on asthma subphenotypes, the females with a given asthma phenotype were compared to those without asthma. All analyses were adjusted for age, smoking status, body mass index (BMI) and occupational exposure to asthmogens.

RESULTS

The mean age of the females was 44 yrs, 55% were never smokers, and 36% had current asthma, of which 56% was poorly controlled asthma (table 2). Home cleaning, but not spray use, was significantly associated with age, BMI and diploma level, but not with other covariates.

Most of the females with asthma had childhood-onset asthma (<16 yrs). As expected, females with asthma had significantly more frequently low FEV_1, BHR and SPT+, and high IgE and eosinophilia compared with females without asthma (online supplementary table E1).

Avoidance of polluted places

Among the females with current asthma (n=244), 83 avoided passive smoking, dust, pollution, and perfume/odours (60, 41, 24 and 24, respectively), half of them for at least two reasons. The avoidance of polluted places was not significantly associated with home cleaning but was significantly associated with the use of sprays (table 2). The subjects who reported avoiding exposure to inhaled irritants also used sprays weekly less frequently than those who did not avoid polluted places

TABLE 1 Factor-loading matrix for domestic exposure patterns in females

Questions on tasks, cleaning products or sprays used	Factor 1 "essential tasks"	Factor 2 "domestic wizard"	Factor 3 "chemical products"
Cleaning the house	0.80		
Dusting, sweeping, hoovering, rug beating	0.80		
Mopping, wet cleaning, damp wiping	0.79		
Cleaning the toilet bowl	0.72		
Cleaning the kitchen	0.68		
Liquid multi-use cleaning products	0.64		
Washing clothes by machine	0.56		
Washing powders	0.50		
Bleach	0.48		0.45
Furniture sprays		0.77	
Cleaning windows or mirrors		0.70	
Polishes, waxes		0.69	
Polishing, waxing, shampooing		0.66	
Glass cleaning sprays		0.61	
Ammonia			0.75
Decalcifiers, acids			0.68
Solvents, stain removers			0.64
Sprays for carpets, rugs or curtains		0.52	0.54

Values <0.40 after orthogonal transformation are not listed in the table for clarity. Principal component analysis evidenced three domestic exposure patterns for the females. They were labelled "essential tasks", "domestic wizard" and "chemical products" (online supplementary table E2). The first factor ("essential tasks") was defined by domestic tasks or the use of cleaning products essential for common home cleaning. The second factor ("domestic wizard") was defined by specific tasks to dust the home perfectly. The third factor ("chemical products") was defined by the use of chemical products. The score obtained for each domestic exposure pattern was divided into tertiles to study the associations between exposure and asthma phenotypes.

(39% *versus* 57%). A significantly higher prevalence of avoidance of polluted places was observed in non-users of sprays (44% *versus* 27% in weekly users, p=0.01), in non-smokers (41% *versus* 14% in current smokers, p=0.001) and in females with adult-onset asthma (44% in adult-onset *versus* 31% in childhood-onset asthma, p=0.04). No associations were observed between avoidance of polluted places and atopy and diploma level.

Home cleaning

Using self-report assessment of home cleaning, no significant associations were observed (OR (95% CI) 1.38 (0.91–2.11)) with the asthma symptom score in univariate analysis. After adjustment for age, smoking habits, BMI, and occupational exposure, home cleaning (1.85 (1.16–2.94)) was significantly related to a high asthma symptom score (table 3).

No significant associations were observed between home cleaning and current asthma or asthma control (table 3), nor with any of the other studied asthma phenotypes (data not shown). Using PCA exposure assessment, "essential tasks" (second tertile, table 3) were positively and significantly associated with a high asthma symptom score and poorly controlled asthma. A significant negative association was observed for moderate exposure to the category of "domestic wizard" and current asthma (OR 0.61 (0.39–0.97)), whereas no associations were observed for the third derived factor.

Spray use

The use of at least two types of sprays per week was significantly associated with a high asthma symptom score before (2.68 (1.70–4.24)) and after adjustment (2.50 (1.54–4.03)) (table 3). For the use of at least two types of sprays, there was a significant trend according to the frequency of use (p-value for trend=0.0002) (table 4). Exclusion of the 40 females occupationally exposed to cleaning agents led to a significant association of similar magnitude (2.47 (1.50–4.07)). Odds ratios were close to 1 for participants with only one symptom. Stronger significant associations were observed between both the use of one and at least two types of sprays and a high asthma symptom score (3.20 (1.48–6.91) and 4.20 (1.78–9.93), respectively) when the analyses were performed only in females without asthma (n=54 females with a high symptom score and without asthma).

For current asthma, no significant associations were observed with the use of one spray weekly with an OR lower than one (0.68 (0.44–1.04)), whereas a significant association was observed for the weekly use of at least two types of sprays (1.67 (1.08–2.56)). The association was of borderline significance (1.50 (0.97–2.32), p=0.07) after exclusion of the females occupationally exposed.

For asthma control, similar results were observed: odds ratios were higher for poorly controlled asthma (table 3) and associations remained significant after the exclusion of females occupationally exposed, with similar magnitudes.

Analyses were also performed using the three most commonly used sprays. Significant associations were observed between exposure to furniture (n=92) and air refreshing (n=160) sprays

TABLE 2 Characteristics of the population according to spray use

	All	Spray use			p-value
		<1 day per week	⩾1 day per week		
			1 spray	⩾2 types of sprays	
Subjects n	683	346	184	145	
Age yrs	43.8±15.5	43.6±15.3	44.1±16.2	43.0±15.2	>0.10
BMI					
<25 kg·m^{-2}	450 (69.4)	239 (72.9)	120 (68.6)	88 (64.2)	
⩾25 kg·m^{-2}	198 (30.6)	89 (27.1)	55 (31.4)	49 (35.8)	>0.10
Smoking habits					
Non-smokers	376 (55.1)	191 (55.4)	112 (60.9)	68 (46.9)	
Ex-smokers	168 (24.6)	91 (26.4)	35 (19.0)	40 (27.6)	
Smokers	138 (20.2)	63 (18.3)	37 (20.1)	37 (25.5)	0.07
Diploma level					
Primary	154 (22.6)	74 (21.5)	36 (19.6)	41 (28.3)	
Secondary	177 (26.0)	87 (25.3)	47 (25.5)	40 (27.6)	
University	350 (51.4)	183 (53.2)	101 (54.9)	64 (44.1)	>0.10
Status at the first survey					
Cases	109 (16.0)	50 (14.5)	20 (10.9)	36 (24.8)	
Relatives	388 (56.8)	209 (60.4)	105 (57.1)	72 (49.7)	
Spouses	49 (7.2)	20 (5.8)	17 (9.2)	10 (6.9)	
Controls	137 (20.1)	67 (19.3)	42 (22.8)	27 (18.6)	0.01
Asthma symptom score[#]					
0	284 (41.6)	155 (44.8)	82 (44.6)	42 (29.0)	
1	171 (25.0)	92 (26.6)	48 (26.1)	31 (21.4)	
⩾2	228 (33.3)	99 (28.6)	54 (29.3)	72 (49.6)	0.0001
Asthma					
Never	439 (64.3)	227 (65.6)	130 (70.7)	77 (53.1)	
Current	244 (35.7)	119 (34.4)	54 (29.3)	68 (46.9)	0.003
Asthma control					
Subjects n	227	113	47	65	
Controlled	99 (43.6)	53 (46.9)	22 (46.8)	24 (36.9)	
Poorly controlled	128 (56.4)	60 (53.1)	25 (53.2)	41 (63.1)	0.003
Avoidance of a polluted place[¶]					
Subjects n	236	115	55	63	
No	153 (64.8)	64 (55.6)	41 (74.6)	45 (71.4)	
Yes	83 (35.2)	51 (44.4)	14 (25.4)	18 (28.6)	0.02
Occupational exposure, last job					
Asthma JEM					
Asthmogens (high probability)	94 (14.2)	47 (14.2)	31 (17.2)	16 (11.3)	>0.10
Cleaning agents	23 (3.5)	10 (3.0)	7 (3.9)	6 (4.2)	>0.10
Employed in a cleaning job	20 (2.9)	6 (1.7)	6 (3.3)	8 (5.5)	0.08
Cleaning products (JEM or job)	40 (5.9)	14 (4.1)	12 (6.5)	14 (9.7)	0.05

Data are presented as mean±SD or n (%), unless otherwise stated. BMI: body mass index; JEM: job exposure matrix. [#]: females with current asthma (n=244) had a higher symptom score than those without (n=439) and percentages of females with 0, 1 or ⩾2 symptoms were 7.8, 20.9 and 71.3% *versus* 60.4, 27.3 and 12.3%, respectively ($p<0.001$); [¶]: avoidance of an exposed situation or place, available only in participants with asthma, was evaluated by a positive response to at least one of the four questions on avoidance (passive smoking, dust, pollution, perfume or odour) from the Asthma Quality-of-Life Questionnaire [19]. There were eight missing values for the number of sprays used per week, 35 for BMI, one for smoking habits and three for diploma level. In females with current asthma, there were 17 missing values for asthma control and eight for avoidance of polluted places. p-value is indicated if $p\leqslant0.10$; $p>0.10$ is indicated for other non-significant associations.

and a high symptom score (2.06 (1.20–3.55) and 1.77 (1.14–2.73), respectively), and between glass cleaning sprays (n=161) and current asthma (1.46 (1.00–2.13)). No significant associations were observed with asthma control.

Selection bias

To evaluate selection bias, we classified females with asthma according to ''avoidance of a polluted place'' (yes/no) (table 5). For current asthma, ORs were higher in females

TABLE 3 Domestic cleaning exposure and asthma phenotypes

	Subjects n	Self-reported exposure			Principal component analysis					
		Home cleaning	Spray use (≥1 day per week)		Factor 1 "essential tasks"		Factor 2 "domestic wizard"		Factor 3 "chemical products"	
		≥1 day per week	1 type of spray	≥2 types of sprays	2nd tertile	3rd tertile	2nd tertile	3rd tertile	2nd tertile	3rd tertile
Symptom score										
0	284	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	171	1.17 (0.73–1.88)	0.93 (0.59–1.47)	0.99 (0.56–1.73)	1.32 (0.78–2.26)	1.45 (0.85–2.48)	0.89 (0.54–1.47)	0.85 (0.50–1.44)	0.89 (0.53–1.49)	0.97 (0.58–1.62)
≥2	228	**1.85 (1.16–2.94)**	0.92 (0.59–1.45)	**2.50 (1.54–4.03)**	**1.68 (1.02–2.76)**	1.57 (0.93–2.64)#	0.75 (0.46–1.22)	1.21 (0.75–1.96)	0.90 (0.56–1.45)	0.97 (0.59–1.59)
Current asthma										
Never	439	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
All	244	1.34 (0.87–2.05)	0.68 (0.44–1.04)¶	**1.67 (1.08–2.56)**	1.42 (0.92–2.20)	1.27 (0.78–2.06)	**0.61 (0.39–0.97)**	1.17 (0.76–1.81)	0.97 (0.64–1.46)	0.84 (0.54–1.30)
Controlled	99	1.12 (0.66–1.90)	0.67 (0.38–1.18)	1.32 (0.75–2.34)	0.78 (0.42–1.46)	1.24 (0.66–2.30)	**0.52 (0.28–0.97)**	1.04 (0.54–1.84)	0.85 (0.47–1.52)	0.87 (0.48–1.59)
Poorly controlled	128	1.50 (0.88–2.52)	0.65 (0.38–1.12)	**2.04 (1.25–3.32)**	**2.06 (1.19–3.54)**	1.25 (0.69–2.26)	0.72 (0.42–1.25)	1.36 (0.81–2.28)	1.08 (0.64–1.82)	0.84 (0.48–1.45)

Data are presented as OR (95% CI), unless otherwise stated. Significant associations are presented in bold. Odds ratios were adjusted for age, smoking habits, body mass index and occupational exposure. Principal component analysis evidenced three domestic exposure patterns for the females (see online supplementary table E1) labelled "essential tasks" (factor 1), "domestic wizard" (factor 2) and "chemical products" (factor 3). In females with current asthma, there were 17 missing values for asthma control. #: p=0.09; ¶: p=0.07.

without avoidance of polluted places than in those with avoidance, especially for the use of at least two types of sprays (ORs 2.12 (1.27–3.54) *versus* 0.99 (0.53–1.85)). A significant negative association was observed for the use of only one spray per week in females with current asthma and with an avoidance of polluted places compared with females without asthma (OR 0.38 (0.19–0.74)). Similar trends were observed for asthma control (table 4).

Spray use and asthma sub-phenotypes

Sensitivity analyses regarding the associations between the use of at least two types of sprays and asthma sub-phenotypes are presented in figures 1 and 2. Compared with the odds ratio for current asthma (OR 1.67 (1.08–2.56)), the odds ratios were higher for asthma with low FEV_1 (2.67 (1.31–5.48)), for severe asthma (2.20 (1.20–4.04)), for asthma with high IgE (2.11 (1.25–3.57)), for asthma with a high symptom score (2.04 (1.30–3.22)) and for non-eosinophilic asthma (1.88 (1.16–3.06)). The weekly use of at least two types of sprays was significantly related to SPT+ asthma (1.66 (1.03–2.68)), with an odds ratio of similar magnitude for SPT- asthma (1.63 (0.78–3.39)), compared with females without asthma. Whatever the neutrophil levels, similar odds ratios were observed with the weekly use of at least two sprays (1.66 (1.05–2.65), 1.54 (0.75–3.13), for ≤5,000 cells·mm^{-3} and >5,000 cells·mm^{-3}, respectively).

Significant or borderline significant associations were observed between the weekly use of at least two sprays and childhood- and adult-onset asthma (2.02 (1.20–3.40), 1.60 (0.91–2.81), respectively), with a higher odds ratio for poorly controlled adult-onset asthma (2.29 (1.15–4.54)).The associations between asthma symptom score, asthma status and the use of sprays have been investigated after stratifying on smoking habits, diploma and SPT, and led to similar results. Significant associations were observed between the use of at least two sprays (*versus* no spray) and a high asthma symptom score (*versus* no symptom) in never smokers (3.17 (1.60–6.29)) and in smokers (2.54 (1.57–4.10)), in females without (3.69 (1.82–7.48)) and with university diploma (1.87 (0.94–3.71); p=0.07), as well as in females without (2.59 (1.19–5.67)) and with atopy (2.76 (1.32–5.78)). Significant associations were observed between the use of at least two types of spray (*versus* no spray) and current asthma in never smokers (1.96 (1.08–3.55)) and in smokers (2.79 (1.12–6.99)), in females without university-level diplomas (1.91 (1.06–3.44)) and with a lower odds ratio (1.55 (0.83–2.91)) for those with university-level diplomas. Associations remained similar after adjustment for diploma level (instead of occupational exposure).

DISCUSSION

The domestic use of at least two types of spray per week was significantly and positively associated with a high asthma symptom score and asthma activity (assessed either by current asthma or poorly controlled asthma). Consistent results were observed after stratification on smoking habits, diploma level and atopy. Our results also suggest a selection bias in the use of domestic sprays which may mask or underestimate the associations between sprays and asthma phenotypes. Our results are consistent with those from the single previous epidemiological survey, in which a dose–response relationship was observed between household cleaning sprays and

TABLE 4 Self-reported exposure to sprays and asthma symptom score

Symptom score	Subjects n	Exposure to one spray ⩾1 day·week^{-1}		Exposure to at least two types of sprays ⩾1 day·week^{-1}#	
		1–3 days·week^{-1}	4–7 days·week^{-1}	1–-3 days·week^{-1}	4–7 days·week^{-1}
0	284	1.00	1.00	1.00	1.00
1	171	0.84 (0.51–1.40)	1.26 (0.58–2.72)	0.87 (0.43–1.77)	1.18 (0.52–2.67)
⩾2	228	0.92 (0.56–1.51)	0.91 (0.40–2.10)	**2.04 (1.13–3.68)**	**3.27 (1.65–6.45)**

Data are presented as OR (95% CI). Significant associations are presented in bold. Odds ratios were adjusted for age, smoking habits, body mass index and occupational exposure. #: p-value for trend=0.0002 for the weekly use of ⩾2 types of sprays.

adult-onset asthma [6]. No association was observed among men, probably because only a small number of them (7%) use at least two sprays per week, with an odds ratio of 0.90 for current asthma. The present work suggests that domestic exposure to cleaning sprays, for which increasing use has been observed [23], may represent a public health issue in females.

Domestic use of sprays and asthma in females

Our results are consistent with a deleterious effect in the use of cleaning sprays on asthma phenotypes and with previous results on household exposure [6], from nurse cohorts [5] and cleaners in offices or private homes [1]. The lack of association between home cleaning, evaluated both by self-report and by PCA, and asthma phenotypes, is an argument in favour of the specific effect of products in spray form.

The use of cleaning sprays involved a high risk for inhalation exposure [4]. Peak concentrations of 2-buthoxyethanol (major ingredient of their selected sprayed products) may approach occupational exposure limits and remain in the air after completion of the cleaning task [24]. The deleterious effect of products in spray form such as waterproofing sprays [25], pesticide/insecticide sprays [26, 27] or hair sprays [28] has been established for several diseases.

We observed an association between the use of at least two sprays and IgE-dependent asthma and non-eosinophilic asthma. Further analyses are needed to clarify the underlying mechanisms that may lead to a deleterious effect of sprays on asthma.

Exposure assessment

One limitation of our study relates to the self-reporting of spray exposure, which may lead to misclassification errors, recall bias and biased estimates [2]. One could hypothesise that those with asthma and bronchial hyperactivity may feel uncomfortable using sprays and may therefore remember more details and provide a more precise report or exaggerate the use of sprays (self-report). However, in a recent paper comparing self-reported occupational exposure to cleaning/disinfecting agents and an expert assessment in the EGEA

TABLE 5 Role of avoidance of polluted places in the association of domestic cleaning exposures and current asthma

	Subjects	Exposed home cleaning/⩾1/1/⩾2 sprays	Self-reported exposure			
			Home cleaning	Spray use (⩾1 day·week^{-1})		
			⩾1 day·week^{-1}	⩾1 spray	1 spray·week^{-1}	2 sprays·week^{-1}
Never asthma (reference)	439		1.00	1.00	1.00	1.00
Current asthma, no avoidance						
All	149	112/82/37/45	1.39 (0.82–2.34)	1.33 (0.89–1.98)	0.90 (0.55–1.47)	**2.12 (1.27–3.54)**
Controlled asthma	70	49/36/17/19	1.04 (0.57–1.90)	1.15 (0.68–1.96)	0.84 (0.44–1.61)	1.72 (0.89–3.32)
Poorly controlled	67	54/39/14/25	1.80 (0.90–3.63)	1.61 (0.93–2.79)	0.89 (0.43–1.81)	**2.87 (1.53–5.40)**
Current asthma, avoidance						
All	83	66/32/14/18	1.19 (0.64–2.22)	**0.59 (0.36–0.98)**	**0.38 (0.19–0.74)**	0.99 (0.53–1.85)
Controlled asthma	22	18/6/2/4	1.59 (0.51–5.02)	0.39 (0.15–1.03)#	**0.20 (0.04–0.89)**	0.75 (0.24–2.34)
Poorly controlled	57	46/24/11/13	1.14 (0.55–2.35)	0.77 (0.43–1.37)	0.52 (0.24–1.10)¶	1.21 (0.59–2.48)

Data are presented as n or OR (95% CI). Significant associations are presented in bold. Odds ratios were adjusted for age, smoking habits, body mass index and occupational exposure. Avoidance of an exposed situation or place was evaluated by a positive response to at least one of the four questions on avoidance in the Asthma Quality-of-Life Questionnaire for participants with asthma (passive smoking, dust, pollution, perfume or odour). Females with asthma, with and without avoidance, were compared with those who had never had asthma. In females with current asthma, there were 17 missing values for asthma control, eight for avoidance of polluted places. #: p=0.06; ¶p=0.09.

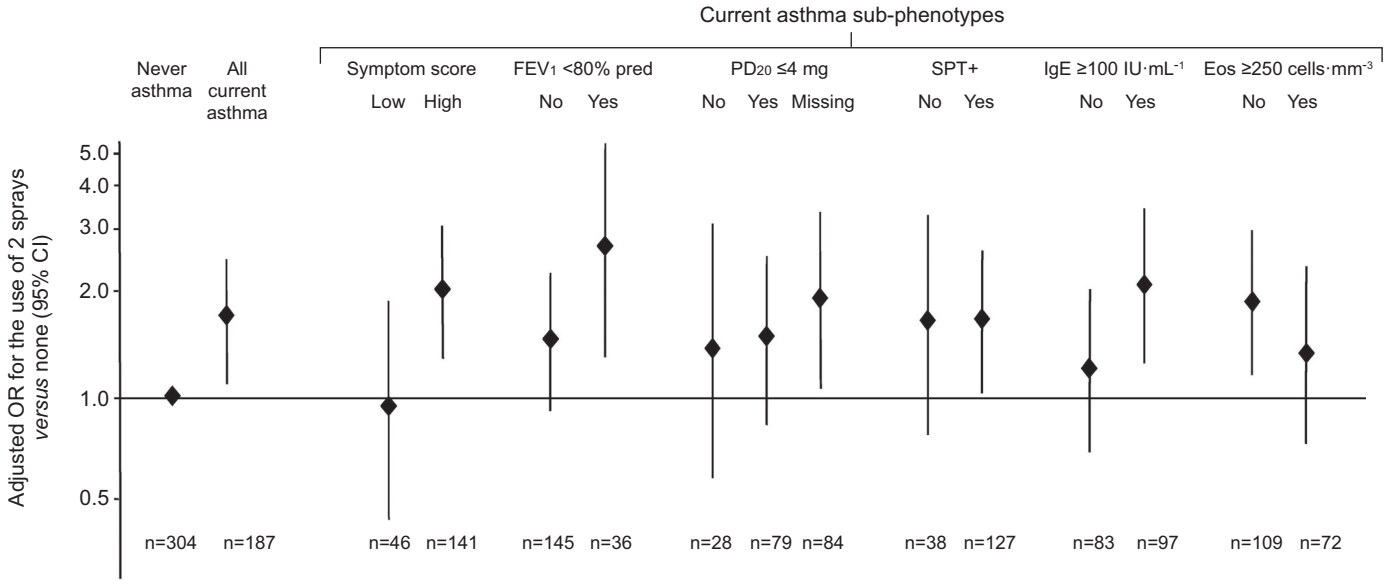

FIGURE 1. Association of domestic exposures to two sprays with current asthma sub-phenotypes. Odds ratios (95% CI), expressed with ''never asthma'' as reference, were adjusted for age, smoking habits, body mass index and occupational exposure to asthmogens. Symptom score was defined following SUNYER *et al.* [15] and PEKKANEN *et al.* [16]. Low/high symptom scores referred to score <2/⩾2 asthma-like symptoms (out of a maximum of five, see methods), respectively. Per cent predicted forced expiratory volume in 1 s (FEV_1) was based on values from STANOJEVIC *et al.* [21]. Missing data for provocative dose causing a 20% fall in FEV_1 (PD_{20}) to methacholine challenge were mostly due to low FEV_1 values (challenge not performed when FEV_1 % pred <80%). Skin prick test positivity (SPT+) refers to a wheal >3 mm for any of 12 allergens. Blood eosinophilia (Eos) (⩾250 cells·mm^{-3}) was defined as previously reported in the Epidemiological Study on the Genetics and Environment of Asthma by NADIF *et al.* [22].

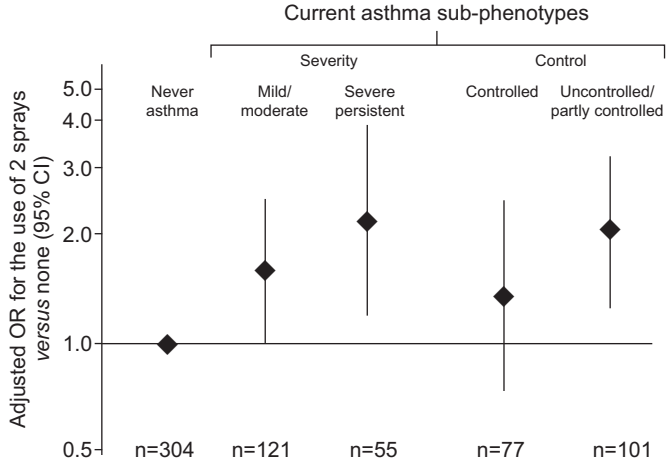

FIGURE 2. Association of domestic exposures to ⩾2 sprays with current asthma sub-phenotypes, defined by composite scores (severity and control). Odds ratios (95% CI), expressed with ''never asthma'' as reference, were adjusted for age, smoking habits, body mass index and occupational exposure to asthmogens. Asthma severity was assessed, as previously described in detail by DE MARCO *et al.* [18], following the 2002–2006 Global Initiative for Asthma (GINA) principles, combining clinical features of the patients and asthma treatment level at the time of examination. Asthma control was assessed, as described by CAZZOLETTI *et al.* [17] and already used in the Epidemiological Study on the Genetics and Environment of Asthma by SIROUX *et al.* [9], based on the GINA 2006–2010 guidelines, combining diurnal and nocturnal respiratory symptoms, asthma attacks, lung function, hospitalisation for asthma and use of reliever medication.

study, we observed that the validity of self-reported exposure to sprays was good (Cohen's κ coefficient 0.84; sensitivity 95%; specificity 91%) [29]. For home cleaning, results were similar whatever the exposure assessments (self-report, ''essential tasks'') and asthma phenotypes. No associations were observed between the three most common sprays taken separately and poorly controlled asthma. It was not possible to study specific types of sprays any further due to sample size.

Selection bias or protective effect

Recent European studies [13, 30, 31] support the importance of the healthy worker effect in occupational asthma [12]. This phenomenon might even be more important for domestic exposures because it is easier to alter behaviour in domestic habits as opposed to occupational ones. A ''healthy home-cleaning effect'' implies that females with asthma might use fewer sprays or cleaning products than those without asthma.

For home cleaning, a significant association was only observed with a high asthma symptom score, and the lack of association for asthma might be explained by a healthy home-cleaning effect (which might be more important for diagnosed asthma than for symptoms). Odds ratios for associations between exposures and disease were always higher for a high asthma symptom score than for current asthma, consistent with a selection bias. It was not possible to study the association between health status and avoidance of polluted places only recorded for participants with asthma, which is a limitation of our study.

For exposure to at least two types of spray, odds ratios were higher in females without avoidance of polluted places than in

those with avoidance. The potential selection bias might be higher for sprays than for home cleaning in general. Females may choose which type of products they will use to clean their home. The Asthma Quality-of-life Questionnaire, not originally designed to study avoidance, has been shown to be valid and reproducible [19]. However, to study selection bias in an optimal way all domestic exposure histories need to be taken into account, as performed previously to study the healthy hire effect in the EGEA survey [13]. We hypothesise that a selection bias could explain the lack of association of asthma characteristics with the use of one spray. Such a selection bias could also occur, at a lesser extent, for the use of two sprays and underestimate the association. As it has not been explored before, the hypothesis of a selection bias needs to be considered with caution.

An alternative hypothesis is the protective effect of moderate use of cleaning products on asthma. Individuals with asymptomatic asthma or poorly-controlled asthma might use, in order to keep their home clean, cleaning products and sprays more often than those without asthma. Studies among children with asthma have shown that an improvement of cleaning practices (to have a ''clean'' home) reduces asthma symptoms [32]. In our study, odds ratios <1 for the use of one spray per week and the first tertile of ''domestic wizard'' and ''chemical products'' is consistent with this hypothesis. It remains possible that an unstudied confounding factor may explain the finding. Further studies are needed to clarify this point.

Asthma phenotypes

One strength of the EGEA survey is that participants with asthma were well phenotyped. Asthma status at follow-up has been checked carefully by respiratory epidemiologists and clinicians (F. Kauffmann, V. Siroux and I. Pin) and was defined to favour specificity (if there was any doubt, the participant was classified as being without asthma). The asthma symptom score showed a good ability to detect risk factors [15, 16] and was used in both the ECRHS [33] and the EGEA surveys [13]. Current asthma and asthma control were defined as previously in both the EGEA [9] and ECRHS surveys [17]. For the use of at least two sprays, consistent results were observed with sub-phenotypes such as severe asthma, high symptomatic asthma, asthma with low FEV_1, IgE-dependent asthma and non-eosinophilic asthma. However, in the current study, due to the sample size issue, it is difficult to disentangle whether the use of domestic sprays is associated more with a high asthma symptom score, poorly controlled or more severe asthma, as all phenotypes are strongly correlated.

Public health implications

An excess risk of asthma in cleaners has been reported for cleaners in offices, hospitals, private homes and in home-makers doing their own domestic work [1], with a potentially high risk in females typically exposed to household cleaning products [11]. Many people are exposed worldwide, both at work and at home, to cleaning agents in spray form, with an increase of use in the last decade [23]. Personal care and household products represented three-quarters of the aerosol products in Europe, which is the world's largest producer, with 5.1 billion aerosols produced in 2009 out of the 12 billion worldwide [23]. Domestic products might be less toxic than industrial cleaning agents. However, household cleaning substances are classified in the top five substances most frequently involved in all human exposure complaints [3]. Whereas occupational exposure is controlled and monitored, this is not the case for the general consumer [34]. Furthermore, homemakers have no training on the potential toxicity of the products used. In conclusion, more research is needed on hazards related to domestic use of cleaning sprays.

SUPPORT STATEMENT

This study was funded by the French Agency of Health Safety, Environment and Work (AFSSET, EST-09-15); Merck Sharp & Dohme; Hospital Program of Clinical Research (PHRC)-Paris; and the National Research Agency - Health Environment, Health-Work Program (ANR-SEST 2005).

STATEMENT OF INTEREST

A statement of interest for the present study can be found at www.erj.ersjournal.com/site/misc/statements.xhtml

ACKNOWLEDGEMENTS

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The authors would like to thank all those who participated in the setting of the study and in the various aspects of the examinations involved: interviewers, technicians for lung function testing and skin prick tests, blood sampling, IgE determinations, coders, those involved in quality control, data and sample management and all those who supervised the study in all centres. The authors are grateful to the three CIC-Inserm at Necker, Grenoble and Marseille, (France) who supported the study and in which participants were examined. They thank O. Montanguon and P. Carteron for statistical analysis, G. Vasseur for job coding, V. Bassot (all from INSERM, Villejuif, France), A. Bedbrook (INSERM, Montpellier, France) and anonymous reviewers for their helpful suggestions. They are indebted to all the individuals who participated, without whom the study would not have been possible.

REFERENCES

1 Zock JP, Vizcaya D, Le Moual N. Update on asthma and cleaners. *Curr Opin Allergy Clin Immunol* 2010; 10: 114–120.
2 Le Moual N, Siroux V, Pin I, *et al.* Asthma severity and exposure to occupational asthmogens. *Am J Respir Crit Care Med* 2005; 172: 440–445.
3 Bronstein AC, Spyker DA, Cantilena LR Jr, *et al.* 2009 Annual Report of the American Association of Poison Control Centers' National Poison Data System (NPDS): 27th Annual Report. *Clin Toxicol (Phila)* 2010; 48: 979–1178.
4 Bello A, Quinn MM, Perry MJ, *et al.* Characterization of occupational exposures to cleaning products used for common

cleaning tasks – a pilot study of hospital cleaners. *Environ Health* 2009; 8: 11.
5 Mirabelli MC, Zock JP, Plana E, *et al.* Occupational risk factors for asthma among nurses and related healthcare professionals in an international study. *Occup Environ Med* 2007; 64: 474–479.
6 Zock JP, Plana E, Jarvis D, *et al.* The use of household cleaning sprays and adult asthma: an international longitudinal study. *Am J Respir Crit Care Med* 2007; 176: 735–741.
7 Bauer D. Entre maison, enfant(s) et travail: les diverses formes d'arrangement dans les couples. www.drees.sante.gouv.fr/IMG/pdf/er570.pdf Date last accessed: October 10, 2012.
8 Khawaja M, Habib RR. Husbands' involvement in housework and women's psychosocial health: findings from a population-based study in Lebanon. *Am J Public Health* 2007; 97: 860–866.
9 Siroux V, Boudier A, Bousquet J, *et al.* Phenotypic determinants of uncontrolled asthma. *J Allergy Clin Immunol* 2009; 124: 681–687.
10 Hunninghake GM, Gold DR. Sexual dimorphism: is it relevant to steroid resistance or asthma control? *J Allergy Clin Immunol* 2009; 124: 688–690.
11 Blanc PD. The role of household exposures in lung disease among women. *Eur Respir Monogr* 2003; 25: 118–130.
12 Le Moual N, Kauffmann F, Eisen EA, *et al.* The healthy worker effect in asthma: work may cause asthma, but asthma may also influence work. *Am J Respir Crit Care Med* 2008; 177: 4–10.
13 Dumas O, Smit LAM, Pin I, *et al.* Do young adults with childhood asthma avoid occupational exposures at first hire? *Eur Respir J* 2011; 37: 1043–1049.
14 Kauffmann F, Dizier MH, Pin I, *et al.* Epidemiological study of the genetics and environment of asthma, bronchial hyperresponsiveness, and atopy: phenotype issues. *Am J Respir Crit Care Med* 1997; 156: S123–S129.
15 Sunyer J, Pekkanen J, Garcia-Esteban R, *et al.* Asthma score: predictive ability and risk factors. *Allergy* 2007; 62: 142–148.
16 Pekkanen J, Sunyer J, Anto JM, *et al.* Operational definitions of asthma in studies on its aetiology. *Eur Respir J* 2005; 26: 28–35.
17 Cazzoletti L, Marcon A, Janson C, *et al.* Asthma control in Europe: a real-world evaluation based on an international population-based study. *J Allergy Clin Immunol* 2007; 120: 1360–1367.
18 de Marco R, Marcon A, Jarvis D, *et al.* Prognostic factors of asthma severity: a 9-year international prospective cohort study. *J Allergy Clin Immunol* 2006; 117: 1249–1256.
19 Juniper EF, Guyatt GH, Epstein RS, *et al.* Evaluation of impairment of health related quality of life in asthma: development of a questionnaire for use in clinical trials. *Thorax* 1992; 47: 76–83.
20 Kennedy SM, Le Moual N, Choudat D, *et al.* Development of an asthma specific job exposure matrix and its application in the Epidemiological Study of Genetics and Environment in Asthma (EGEA). *Occup Environ Med* 2000; 57: 635–641.
21 Stanojevic S, Wade A, Stocks J, *et al.* Reference ranges for spirometry across all ages: a new approach. *Am J Respir Crit Care Med* 2008; 177: 253–260.
22 Nadif R, Siroux V, Oryszczyn MP, et al. Heterogeneity of asthma according to blood inflammatory patterns. *Thorax* 2009; 64: 374–380.
23 Annual Report 2009–2010. European Aerosol Federation (FEA) 2010. www.aerosol.org/uploads/Modules/Publications/fea_annrep2010.pdf Date last accessed: October 10, 2012.
24 Bello A, Quinn MM, Perry MJ, *et al.* Quantitative assessment of airborne exposures generated during common cleaning tasks: a pilot study. *Environ Health* 2010; 9: 76.
25 Vernez D, Bruzzi R, Kupferschmidt H, *et al.* Acute respiratory syndrome after inhalation of waterproofing sprays: *a posteriori* exposure-response assessment in 102 cases. *J Occup Environ Hyg* 2006; 3: 250–261.
26 Tomenson JA, Matthews GA. Causes and types of health effects during the use of crop protection chemicals: data from a survey of over 6,300 smallholder applicators in 24 different countries. *Int Arch Occup Environ Health* 2009; 82: 935–949.
27 Hofmann JN, Keifer MC, De Roos AJ, *et al.* Occupational determinants of serum cholinesterase inhibition among organophosphate-exposed agricultural pesticide handlers in Washington State. *Occup Environ Med* 2010; 67: 375–386.
28 Ormond G, Nieuwenhuijsen MJ, Nelson P, *et al.* Endocrine disruptors in the workplace, hair spray, folate supplementation, and risk of hypospadias: case-control study. *Environ Health Perspect* 2009; 117: 303–307.
29 Donnay C, Denis MA, Magis R, *et al.* Under-estimation of self-reported occupational exposure by questionnaire in hospital workers. *Occup Environ Med* 2011; 68: 611–617.
30 Olivieri M, Mirabelli MC, Plana E, *et al.* Healthy hire effect, job selection and inhalation exposure among young adults with asthma. *Eur Respir J* 2010; 36: 517–523.
31 Butland BK, Ghosh R, Strachan DP, *et al.* Job choice and the influence of prior asthma and hay fever. *Occup Environ Med* 2011; 68: 494–501.
32 Wu F, Takaro TK. Childhood asthma and environmental interventions. *Environ Health Perspect* 2007; 115: 971–975.
33 Macsali F, Real FG, Plana E, *et al.* Early age at menarche, lung function, and adult asthma. *Am J Respir Crit Care Med* 2011; 183: 8–14.
34 Basketter DA, Broekhuizen C, Fieldsend M, *et al.* Defining occupational and consumer exposure limits for enzyme protein respiratory allergens under REACH. *Toxicology* 2010; 268: 165–170.