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Household cleaning and poor asthma control among elderly women

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Competing interests

The authors declare they have no actual or potential competing interests.

Word count: 2944

Abstract

Background. Asthma control is suboptimal in nearly half of adults with asthma. Household exposure to disinfectants and cleaning products (DCP) has been associated with adverse respiratory effects, but data on their association with asthma control are scant.

Objectives. To investigate the association between household use of DCP and asthma control in a large cohort of French elderly women.

Methods. We used data from a case-control study on asthma (2011-2013) nested in the E3N cohort. Among 3,023 women with current asthma, asthma control was defined by the Asthma Control Test (ACT). We used a standardized questionnaire to assess the frequency of cleaning tasks and DCP use. We also identified household cleaning patterns using a clustering approach. Associations between DCP and ACT were adjusted for age, smoking status, body mass index and education.

Results. Data on ACT and DCP use were available for 2,223 women (70±6 years old). Asthma was controlled (ACT=25), partly controlled (ACT=20-24) and poorly controlled (ACT≤19) in 29%, 46% and 25% of the participants, respectively. Weekly use of sprays and chemicals were associated with poorly controlled asthma (odds ratio [95%CI]: 1 spray: 1.31 [0.94-1.84], ≥2 sprays: 1.65 [1.07-2.53], P-trend: 0.01; 1 chemical: 1.24 [0.94-1.64], ≥2 chemicals: 1.47 [1.03-2.09], P-trend: 0.02). Risk for poor asthma control increased with the patterns “very frequent use of products” (1.74 [1.13-2.70]) and “infrequent cleaning tasks and intermediate use of products” (1.62 [1.05-2.51]).

Conclusion. Regular use of DCP may contribute to poor asthma control in elderly women. Limiting their use may help improve asthma management.

Abstract word count: 250

Highlights

1. What is already known about this topic?

Although avoidance of environmental triggers is recommended in asthma management, environmental determinants of poor asthma control are insufficiently known. Cleaning products may have adverse respiratory effects, but data on their association with asthma control are scant.

2. What does this article add to our knowledge?

In this study of 2,223 elderly women with asthma, weekly use of sprays or chemicals for home cleaning, and frequent use of multiple disinfectants and cleaning products, were associated with poor asthma control.

3. How does this study impact current management guidelines?

Limiting the use of disinfectants and cleaning products may help improve improving asthma control in adult patients. Given the ubiquitous use of these products, our results may have important impact in asthma management.

Key words

Asthma, Asthma control, Cleaning products, Disinfectants, Environmental exposures, Household exposure, Chemicals, Sprays, Women

Abbreviations:

ACT: asthma control test

BMI: body masse index

CI: confidence interval

DCP: disinfectants and cleaning products

E3N: Etude Epidémiologique auprès des femmes de la Mutuelle Générale de l'Education Nationale

EGEA: Epidemiological study on the Genetics and Environment of Asthma

101 OR: odds ratio

102

Introduction

The primary goal of asthma management is to achieve and maintain the control of the disease, through the control of the environment and optimal asthma treatment.^{1,2} However, asthma control may be suboptimal in 40–50% of adults with asthma, with even higher rates among women.^{3,4} In elderly patients with asthma, the disease may be more difficult to control because of comorbidities, aging of the lungs and the immune system, and potentially low treatment adherence.^{5,6} Uncontrolled asthma is associated with a substantial economic and health burden, which is largely preventable.⁷ Although avoidance of environmental triggers is strongly recommended in asthma management guidelines,⁸ environmental determinants of poor asthma control are insufficiently known.²

Concerns regarding the health effects of chemical exposures from consumer products used in everyday life such as disinfectants and cleaning products (DCP) are growing.^{9–11} DCP have been identified as an important source of volatile organic compounds emission and poor air quality.^{12,13} Respiratory health hazard associated with DCP exposures are increasingly recognized, especially among women who are more exposed than men.^{14,15} Associations with respiratory disorders such as asthma have first been evidenced in occupational health studies, mainly among cleaners or healthcare workers.^{15–18} An increasing number of studies suggest that respiratory effects of DCP are not restricted to populations with high exposure level at work, but are also observed in relation to common household exposures.^{14,19,20} Use of DCP at home, in particular cleaning sprays and irritant products, has been associated with asthma incidence,^{21,22} current asthma, or asthma symptoms,^{23–25} and more recently with lung function decline.¹⁹ To our knowledge, only one study examined the association between DCP exposure at home and asthma control.²⁴ In this French cohort, the use of at least two types of cleaning sprays at home was associated with poorly controlled asthma in middle-aged women.

While avoidance of DCP exposures is increasingly recommended,¹⁰ a better knowledge of specific tasks and chemicals that put subjects at risk is needed to establish targeted strategies to improve asthma control. Household cleaning implies various tasks and the possibility of using many chemicals, which makes challenging to disentangle their individual effects. Several approaches can be used. The “*a priori*” approach classifies DCP exposures based on hypotheses regarding their potential health effects, such as respiratory effects associated with product spraying²⁴ or with the use of specific irritant chemicals (e.g., bleach).²⁶ Alternatively, data-driven approaches such as clustering models have been proposed to identify exposure patterns, taking into account the multiplicity and correlations of exposures.^{17,27} Fitting a clustering model on a large subsample of elderly women from the French E3N study (Etude Epidémiologique auprès des femmes de la Mutuelle Générale de l'Education Nationale), based on 24 questions on cleaning tasks and products, we recently identified seven household cleaning patterns.²⁷

In the current study, we aimed to investigate the association of DCP use and household cleaning patterns with asthma control among elderly women from the E3N study.

Material and Methods

Population

The E3N study, initiated in 1990, is a prospective cohort among women affiliated to the Mutuelle Générale de l'Education Nationale, a French national health insurance plan covering mostly teachers.²⁸ A total of 98,997 women aged 40-65 years were included at baseline and have been followed up approximately every 2 years since. The current analysis uses data from a nested case-control study on asthma (Asthma-E3N) conducted in 2011-2013.^{23,29,30} A total of 7,100 women with asthma (positive answer to the question “Have you ever had an asthma attack?” in at least one questionnaire since 1990) and 14,200 age-matched women without asthma were invited to complete a postal questionnaire regarding respiratory health and environmental exposures. Questionnaires were returned by 19,404 participants (92%). The study protocol was approved by the French Institutional Ethics Committee, and all participants provided their written informed consents.

Asthma control

Among women with current asthma (ever asthma, and occurrence of asthma attacks, asthma treatment, or asthma symptoms in the past 12 months), asthma control was defined using the Asthma Control Test (ACT). The ACT score (range 5–25) is based on five questions on activity limitations, frequency of symptoms, and frequency of use of quick-relief medication in the past 4 weeks.³¹ In main analyses, asthma control was classified into three categories based on the ACT score (25: controlled; 20–24: partly controlled; ≤19: poorly controlled).^{18,32} We conducted secondary analyses using the more common ACT two-category classification (20–25; ≤19).³¹

Use of disinfectants and cleaning products

The nested case-control study included a detailed standardized questionnaire^{21,24} on the frequency (never, <1 day/ week, 1-3 days/week, or 4-7 days/week) of cleaning tasks (10 questions), use of specific cleaning products (7 questions), and use of different types of sprays (7 questions) at home.

Weekly use of spray was classified as none, one type of spray, or ≥ 2 types of sprays, based on the seven questions regarding type of spray used (for furniture, windows/mirrors, floor, degreasing/oven, air-refreshing, pesticide, and other). Similarly, weekly use of chemicals was classified as none, one type of chemical, or ≥ 2 types of chemicals, based on the four questions regarding type of chemical used (ammonia, acids, stain removers/solvents, bleach). Weekly use of each of the seven types of spray and four chemicals was also examined individually. In all analyses, we used as reference category (unexposed) participants reporting no weekly use of any of the seven types of spray and four chemicals, to avoid including in the reference category participants with any potentially hazardous exposure.^{18,33}

To identify household cleaning patterns, we used a mixture model of dependency blocks, as described in detail elsewhere.²⁷ Briefly, this approach extends the standard latent class model³⁴ to the case where within-class dependencies occur. Considering the within-class dependency was important because of the high dependencies between the use of different DCP, even within an homogenous subpopulation. The model identified seven household cleaning patterns which differed on the frequency of cleaning tasks and use of specific products.

Statistical analyses

Associations between exposure to DCP and asthma control (controlled, partly controlled, poorly controlled) were evaluated by multinomial logistic regression models. Analyses were adjusted for age, smoking status (nonsmoker, ex-smoker, or current smoker),

body mass index (BMI: <20.0, 20.0-24.9, 25.0-29.9, and ≥ 30.0), and education level (< high school diploma, high school to 2-level university, \geq 3-level university). A two-sided $p < 0.05$ was considered statistically significant. Analyses were run using SAS version 9.3 (SAS Institute, Cary, NC, USA).

As household help (positive answer to the question “does someone help you for household cleaning, e.g., husband, household employee, or family members?”) has previously been suggested to induce misclassification in assessment of exposure to DCP,²³ sensitivity analyses restricted to women with no household help were conducted when examining specific products. In another sensitivity analysis, we used multiple imputation to estimate ACT missing values assuming a missing at random pattern,³⁵ as in previous analyses in Asthma-E3N³⁰ and as detailed in online supplementary material, to evaluate the robustness of our results to missing value issues. Finally, a sensitivity analysis with adjustment for multimorbidity-related medication profiles previously identified using drug administrative databases (see Chanoine et al.³⁶ and online supplementary material) was performed, as these profiles were a strong determinant of poor asthma control in this population of elderly women,³⁶ and may be related to use of DCP.

Results

Among the 7,100 women with ever asthma invited to participate, 6,274 (88%) returned the questionnaire, of whom 3,023 had current asthma (Figure 1). Women with missing data for all questions on household cleaning (n=18), smoking status (n=25), or asthma control (n=747) were excluded. This yielded a population of 2,233 women eligible for analyses. Participants were 69.7 years old on average, 46% were ex-smokers and 4% were current smokers, 13% had a BMI ≥ 30 kg/m², and 37% had a high education level (≥ 3 -level university). Nearly half of the participants (48%) reported household help. Asthma was controlled in 29% of the participants, partly controlled in 46% and poorly controlled in 25%. Women with poorly controlled asthma were older and had lower education level (Table 1). They more often reported household help.

Regarding use of specific DCP, 17% of the participants used one type of spray weekly, and 9% used ≥ 2 types of spray; 35% used one type of chemical, and 15% used ≥ 2 types of chemicals. The most frequently used sprays were air-refreshing sprays (weekly use: 14%) and windows/mirrors sprays (8%), and the most frequently used chemicals were bleach (39%) and acids (19%). The seven household cleaning patterns identified by a clustering approach are described in Table 2. Household cleaning tasks, and use of sprays and chemicals according to household cleaning patterns are described in online supplementary Table E1. Cleaning patterns were ordered by frequency of general cleaning tasks, which did not always correspond to the frequency of product use. For instance, while women in the “medium cleaning” pattern reported less frequent cleaning tasks (weekly household cleaning: 29%) than women in the “frequent general cleaning” pattern (85%), they reported using more sprays (weekly use of ≥ 2 types of spray: 18% vs. 2%) and chemicals (weekly use of ≥ 2 types of chemicals: 19% vs. 9%)

In multivariable models examining specific DCP exposures (Table 3), weekly use of sprays was associated with poorly controlled asthma (1 type of spray: OR: 1.31, 95%CI: 0.94-

1.84; ≥ 2 types of spray: 1.65, 1.07-2.53; P-trend: 0.01). Similarly, weekly use of chemicals was associated with poorly controlled asthma (1 type of chemical: OR: 1.24, 95%CI: 0.94-1.64; ≥ 2 types of chemical: 1.47, 1.03-2.09; P-trend: 0.02). Associations were more pronounced when analyses were restricted to women without household help. Results were similar when ACT was studied in two categories (≤ 19 vs. 20-25, table E2). When examining specific DCP individually, associations with poor asthma control were observed or suggested for several products (online supplementary Table E3 & E4). Weekly use of windows/mirror sprays (1.91, 1.23-2.97), air-refreshing sprays (1.54, 1.07-2.22), acids (1.45, 1.04-2.02), stain removers/solvents (1.89, 1.13-3.17), and bleach (1.34, 1.03-1.74) were associated with poorly controlled asthma in all women. When analyses were restricted to women without household help, associations of weekly use of furniture sprays (2.48, 1.22-5.06) and other sprays (5.99, 1.56-23.0) and poorly controlled asthma were further observed.

In the multivariable model examining household cleaning patterns (Figure 2), the most common pattern (“frequent general cleaning”) was used as reference group. Compared to this pattern, associations with poorly controlled asthma were observed for the “medium cleaning” pattern (Odds Ratio (OR): 1.62, 95% Confidence Interval [CI]: 1.05-2.51), and for the “very frequent use of products” pattern (OR: 1.74, 95%CI: 1.13-2.70).

After multiple imputation, 747 additional women with missing values for ACT score were included in the analyses. Association between DCP exposures and asthma control were similar in the imputed dataset (online supplementary table E5). Association were also similar in sensitivity analysis with adjustment for multimorbidity-related medication profiles (online supplementary table E6).

Discussion

In this study of 2,223 elderly women with asthma, self-reported weekly use of at least 2 types of sprays or at least 2 types of chemicals for home cleaning was associated with poor asthma control. In addition, a household cleaning pattern with very frequent use of multiple disinfectants and cleaning products was associated with poor asthma control.

Our results are consistent and extend results from the only other study that examined the association between use of cleaning sprays at home and asthma control. In this previous study among 683 French women (244 with asthma) from the Epidemiological study on the Genetics and Environment of Asthma (EGEA), weekly use of ≥ 2 types of sprays was associated with poorly controlled asthma.²⁴ In the current study, we found that this association was not restricted to cleaning sprays but was also observed for the use of chemicals. In EGEA, use of bleach for home cleaning was not associated with poor asthma control²⁶. However, analyses were limited by a small sample size, which also limited the investigation of exposure to multiple chemicals. The current results are also in accordance with findings from a few occupational studies reporting an association between occupational exposure to DCP and poor asthma control.^{18,37,38}

We attempted to disentangle the roles of specific products using several approaches. First, we compared contrasted groups of individuals based on *a priori* hypotheses regarding the effect of some products (e.g., sprays vs. chemicals, individual products). However, this approach has limitations as in the “real world”, products are generally not used in isolation; we thus could not build fully contrasted groups defined by the use of only one product or one type of products. Second, we used clustering to identify household cleaning patterns, grouping participants with similar cleaning habits, and reflecting “real world” DCP use. The resulting patterns were distinguished by their general frequency of cleaning tasks and product use, with a gradient from very low to very high frequencies for the use of multiple products. However,

no profile characterized by the use of one or a few specific products emerged. This limited our ability to identify specific patterns of use associated with poor asthma control, beside the use of multiple products. Despite these limitations, our results, in accordance with several previous studies at the workplace,^{16–18} suggest that adverse respiratory effects are not imputable to a single product, but may result from the frequent use of a multitude of products. Moreover, there is a biological plausibility for an effect on the airways of all the specific products investigated. The active compounds of many disinfectants (e.g., bleach, acids) have been described as airway irritants.^{39,40} Inhalation of irritants is thought to cause airway damage, oxidative stress and neutrophilic inflammation.^{26,41,42} A direct disruptive effect of exposure to laundry detergents on the epithelial barrier integrity has recently been suggested, and may be relevant for other household cleaning products.^{11,43,44} DCP also commonly contain skin allergens such as perfumes (e.g., terpenes).^{12,40,45} Finally, product spraying is likely to increase exposure by inhalation. A recent study examining the potential for airway exposure when using cleaning spray showed that the particles generated were in a size range relevant for both nasal and alveolar deposition.⁴⁶ To improve knowledge regarding agents causing respiratory hazards, the use of novel exposure assessment methods, such as a Smartphone application to scan the barcodes of DCP and the development of databases listing all ingredients of DCP may be useful in future studies.⁴⁷

Major strengths of our study include the large population size, the high response rate and the use of standardized and validated definitions to evaluate asthma and asthma control. Our population only included elderly women with relatively high education levels and may not be generalizable to different populations. However, similar results have been observed in a cohort of middle-aged women.²⁴ Although no study has specifically examined the impact of DCP exposures on asthma control in men, associations between DCP and asthma have been reported in populations of both men and women.^{21,22}

We used a standardized questionnaire to evaluate DCP exposures, as in previous studies.^{21,22,24} Use of DCP was self-reported, which may raise concerns regarding a potential differential misclassification bias (recall bias). Such a bias would occur if women with poor asthma control tended either to overestimate or to recall more precisely their use of DCP compared to women with controlled asthma. However, we assume that this bias is less pronounced than when comparing asthmatics to non-asthmatics. Another potential bias would be reverse causation, which would occur if women with poor asthma control were seeking to live in a cleaner environment (e.g., to avoid dust or mold exposures), which would involve more frequent cleaning tasks. Although these biases cannot be completely ruled out, they are unlikely for several reasons. First, when examining household cleaning patterns, two patterns could either result from a recall bias or reflect a behavior of seeking a clean environment: “very frequent use of products” which involved very frequent use of chemicals and cleaning sprays, and “very frequent general cleaning” which involved very frequent general cleaning tasks (e.g., dusting/hovering) but with moderate use of products. However, only the pattern “very frequent use of products” was associated with poor asthma control. Second, our results are consistent with studies on occupational exposure, in which exposures were evaluated by job- or job-task-exposure matrices,^{18,37} less prone to recall bias, and where the frequency of cleaning tasks is driven by workplace requirements rather than by individual behaviors.

In analyses of household cleaning patterns, poor asthma control was associated not only with the “very frequent use of cleaning products” pattern, but also with a pattern of infrequent cleaning tasks and intermediate use of products. We also observed that women with poor asthma control more frequently had household help. These results may reflect a “healthy home cleaning effect”, as suggested in previous studies.^{22,24} Such effect may occur if women with respiratory symptoms or poor asthma control avoid or reduce their use of DCP.^{22,24} Similarly to the healthy worker effect in occupational studies, this bias is difficult to control in cross-

sectional studies.⁴⁸ No question on avoidance of use of DCP was available in the current study. The result of such as bias would be a general underestimation of the associations observed in our study. Despite this potential underestimation, we observed relatively elevated ORs (range 1.3-2.0) for the association between weekly use of several specific DCP and poorly controlled asthma.

In conclusion, we found that the weekly use of several types of DCP for home cleaning was associated with poor asthma control in elderly women. While more research is needed to precisely identify causative agents and mechanisms, reduction in exposure and development of safer methods/products for home cleaning is recommended. Clinicians should be aware of this environmental risk factor for poor asthma control and integrate it in asthma management strategies.⁸ Given the ubiquitous use of disinfectants and cleaning products, our results may have important impact in improving asthma control in adult patients.

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E3N: prospective study among women members of a French health insurance plan

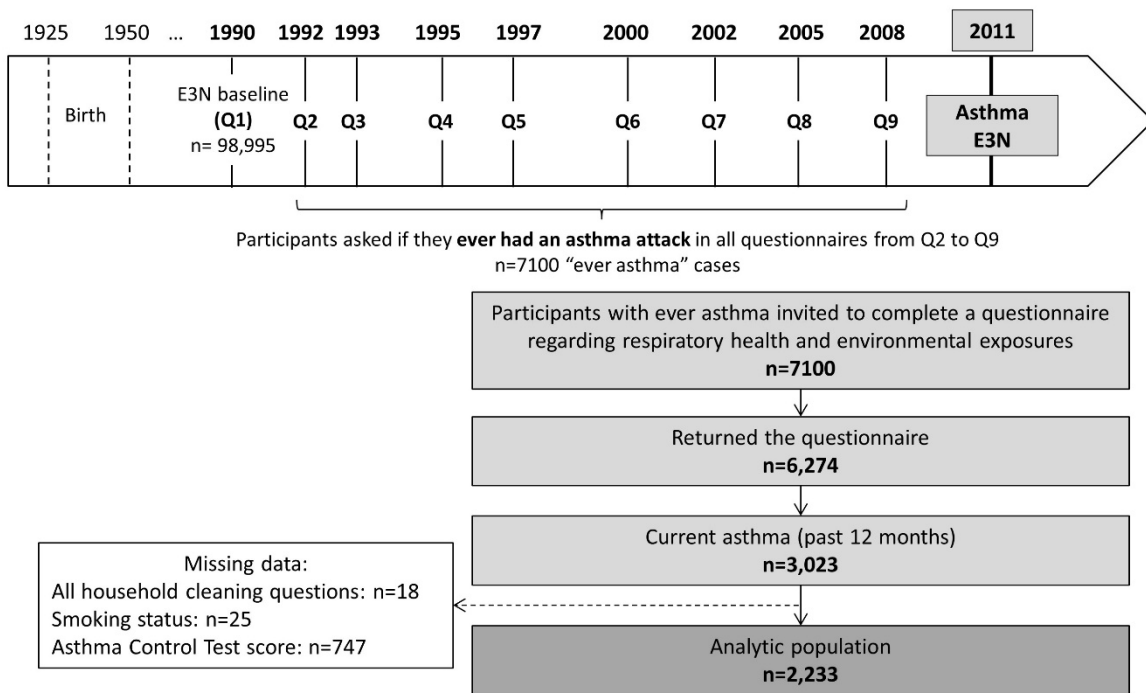


Figure 1. Flow chart of the study population

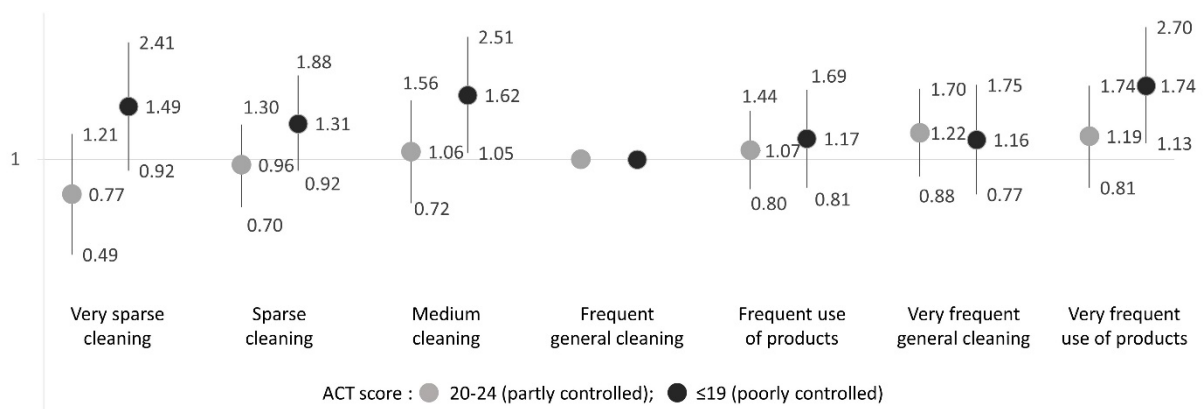


Figure 2. Associations between household cleaning patterns and asthma control. Results are presented as odds ratios and 95% confidence intervals for a decrease in Asthma Control Test (ACT) score category (25: controlled [ref.]; 20–24: partly controlled; <19: poorly controlled) adjusted for age, smoking status, body mass index, and education level. The most common pattern (“frequent general cleaning”) was used as reference category.

Table 1. Characteristics of the participants according to asthma control, among 2,233 women with current asthma

	Asthma Control Test score			P
	25 (controlled)	20-24 (partly controlled)	≤19 (poorly controlled)	
n (%)	650 (29)	1,024 (46)	559 (25)	
Age, m (sd)	68.6 (5.7)	69.4 (5.8)	71.4 (6.3)	< 0.001
Smoking status*, %				
Never smoker	49	49	53	0.38
Ex-smoker	47	47	43	
Current smoker	4	4	4	
BMI (kg/m ²), %				
<20	11	9	10	0.04
20-24.9	49	49	44	
25-29.9	28	31	29	
≥ 30	12	11	17	
Education level, %				
< high school diploma	8	9	15	< 0.001
High school to 2-level university	48	49	50	
≥ 3-level university	40	39	30	
Missing	4	3	5	
Household help, %	47	46	54	0.01

BMI – Body Mass Index.

Table 2. Description of the seven household cleaning patterns identified by a clustering approach, among 2,233 women with asthma

Name	Description	n (%)
Very sparse cleaning	Very infrequent cleaning tasks and use of DCP	155 (7)
Sparse cleaning	Infrequent cleaning tasks and very infrequent use of DCP	376 (17)
Medium cleaning	Infrequent cleaning tasks and intermediate use of DCP	211 (9)
Frequent general cleaning (reference)	High frequency of general cleaning tasks (general cleaning, dusting/sweeping/hovering, humid cleaning), moderate use of general-purpose cleaning products (e.g., general purpose products, bleach, window/mirror), and low use of chemicals and sprays	602 (27)
Frequent use of products	High frequency of cleaning tasks (general cleaning, dusting/ sweeping/hovering, humid cleaning) and use of DCP (bleach, polishing/waxing, windows/mirrors, chemicals, sprays)	389 (17)
Very frequent general cleaning	Very high frequency of cleaning tasks (general cleaning, dusting/sweeping/hovering, humid cleaning), moderate to high use of general cleaning products, medium use of chemicals and low use of sprays	285 (13)
Very frequent use of products	Very high frequency of cleaning tasks and use of DCP, especially bleach, chemicals, and sprays.	215 (10)

Table 3. Associations between types of DCP and asthma control

		Asthma Control Test score					
		25 (ref.; controlled)		20-24 (partly controlled)		≤19 (poorly controlled)	
	n	%	OR*	%	OR* (95% CI)	%	OR* (95% CI)
Weekly use of sprays							
In all participants							
No (ref.)†	863	32	1	46	1	22	1
1 type	372	29	1	44	1.05 (0.78-1.40)	27	1.31 (0.94-1.84)
≥ 2 types	202	24	1	45	1.29 (0.88-1.89)	31	1.65 (1.07-2.53)
<i>P-trend</i>					0.24		0.01
In participants without household help							
No (ref.)†	465	34	1	48	1	18	1
1 type	228	30	1	45	1.03 (0.70-1.50)	25	1.47 (0.93-2.32)
≥ 2 types	108	22	1	48	1.46 (0.85-2.49)	30	2.05 (1.11-3.80)
<i>P-trend</i>					0.24		0.01
Weekly use of chemicals							
In all participants							
No (ref.)†	863	32	1	46	1	22	1
1 type	733	28	1	47	1.15 (0.91-1.45)	25	1.24 (0.94-1.64)
≥ 2 types	316	28	1	42	1.06 (0.78-1.45)	30	1.47 (1.03-2.09)‡
<i>P-trend</i>					0.48		0.02
In participants without household help							
No (ref.)†	465	34	1	48	1	18	1
1 type	413	29	1	48	1.14 (0.83-1.55)	23	1.39 (0.95-2.04)
≥ 2 types	189	30	1	42	0.97 (0.65-1.45)	28	1.59 (1.00-2.54)‡
<i>P-trend</i>					0.89		0.03

* OR from multinomial logistic regressions, adjusted for age, smoking status, body mass index, and education level. OR – odds ratio; CI – confidence interval. †Reference group in all analyses: No weekly use of sprays or chemicals. Results in bold face are statistically significant (comparison with reference group “controlled”). ‡ Statistically significant difference when comparing “poorly controlled” to “partly controlled”.