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Household use of green and home-made cleaning products, wipe application mode and asthma among French adults from the CONSTANCES cohort

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Abstract

While exposure to irritant and sprayed cleaning products at home is known to have a harmful role in asthma, the potential health effect of other categories or forms has not been investigated.

We studied the associations of household use of cleaning products, including green, home-made products and disinfecting wipes, with asthma based on data from the large French population-based Constances cohort.

Participants completed standardized questionnaires on respiratory health and household use of cleaning products. Cross-sectional associations of cleaning products with current asthma, adjusted for gender, age, smoking status, BMI and educational level, were evaluated by logistic regressions.

Analyses were conducted in 41,570 participants (mean age: 47 years, 56% women, weekly use of the six specific products/forms studied varied from 11% to 37%). Weekly use of irritants (OR=1.23[1.13-1.35]), scented (OR=1.15[1.06-1.26]), green (OR=1.09[1.00-1.20]) and home-made products (OR=1.19[1.06-1.34]), as well as sprays (OR=1.18[1.08-1.29]), disinfecting wipes (OR=1.21[1.09-1.34]) were significantly associated with asthma, with significant trends according to the frequency of use. When they were not co-used with irritants/sprays, associations were reduced and persisted only for disinfecting wipes.

Weekly use of disinfecting wipes at home was associated with current asthma, but fewer risks were observed for the use of green and home-made products.

Keywords: Asthma; Household cleaning; Disinfecting wipes; Green products; Home-made cleaning products; Irritants

Practical implications:

- Green and home-made products or disinfecting wipes, are increasingly attracting the interest of consumers, at the expense of conventional products, but their respiratory health risks have not been investigated.
- Weekly use of disinfecting wipes at home was associated with asthma, similarly to irritants and sprays, in this study of 41,570 French adults from the CONSTANCES cohort.
- These associations persisted only for disinfecting wipes and were no longer observed for green and home-made products, when considering the co-use of irritants and sprayed products at home.
- Our results suggest that using green and home-made products may induce fewer risk for respiratory health than using conventional ones.

1. Introduction

Cleaning products are widely used, at home and in the workplace, and contribute significantly to chemical exposure in the indoor environment ^{1,2}. These products consist of a complex and diverse mixture of ingredients, with various physical and chemical properties, which can have irritant or sensitizing effects ^{1,3-7}. Evidence of the harmful role of these products on respiratory health, especially on asthma, comes largely from epidemiological studies carried out in populations highly exposed at work ^{3,8}. Over the past fifteen years, a growing number of studies have investigated the effects of indoor exposure to household cleaning products and similar results have been observed. Most studies so far have considered the potential impact of the personal use of cleaning products containing irritant agents ⁹⁻¹³ or applied in a spray form ^{9,11,13-18}. Personal use of these two categories of cleaning products at home has been shown to be associated with the development ^{13,18}, clinical expression ^{10-12,14,16} and poor control of asthma ^{9,16}. The clinical expression of asthma was mainly studied through the evaluation of current asthma ^{10,12,14,16} and the asthma symptom score ^{11,12,14,16}. Studies have suggested that risks for respiratory health could be even more important for women who are more involved in household tasks, and therefore also more exposed to cleaning products ¹⁹. In addition, the female lungs might be more susceptible to the harmful damages of environmental exposures ²⁰. However, only few studies have assessed the associations between the use of cleaning products and asthma on mixed gender populations ^{13,18}.

A wide variety of cleaning products, in several application modes and for various uses, are available to consumers ². More recently, “eco-friendly” certified cleaning products are increasingly attracting the interest of consumers, manufacturers and distributors. However, although the formulations of these products are considered to be less harmful, especially for the environment, their potential health effects have not been studied for household use ^{6,8,21}. An occupational study investigated for the first time the health effects of environmentally preferable products and did not show increased respiratory symptoms associated with this exposure, in contrast to exposure to traditional products ²². More recently, an experimental study found that green products used during bathroom cleaning generated less total volatile organic compounds than other conventional products ²³. In addition, an interventional study showed a significant decrease in air concentrations of multiples volatile organic compounds when using green products, instead of using conventional ones ²⁴. While an increasing number of people are making their own products for home cleaning, e.g. from white vinegar ²⁵, baking soda, soap and sometimes essential oils, their health consequences have not yet been assessed.

Exposure to cleaning products depends on both the physico-chemical characteristics of the product and its application mode ^{1,6,21,26}. Spray formulations increase the risk of inhalation and facilitates the penetration of sprayed particles into the lower respiratory tract ^{19,27,28}. Respiratory health risks associated with spraying application mode have been well-established and studies found consistent associations with asthma both at home ^{9,14,16,18} and at work ^{29–33}. While a German study showed an association between a high level use of disinfectants at home, regardless of application mode, and a risk of incident asthma in young adults ¹³, no study has investigated the potential impact of applying disinfectants in wipes form. Because ready-to-use wipes consist of towels saturated with diluted disinfectant and other chemical products ³⁴, with both irritant and sensitizing properties ³, they may contain much more products compared to a product applied with a cloth and then wiped.

Thus, despite the accumulation of evidence on the adverse effects of the household use of cleaning products on asthma, evidence is lacking for some products including green and home-made products, and for some application modes, such as wipes, which are all increasingly used but their impact has never been studied to date in epidemiological surveys. We aimed to investigate the associations between household use of six large categories of cleaning products, current asthma and the asthma symptom score among French adults from the CONSTANCES cohort, after considering potential co-exposures at home to irritants and sprays for which respiratory health effects have been shown. We hypothesized that applying disinfectants in a wipe form would have adverse effect on respiratory health and using green and home-made products would have less adverse effect on respiratory health, compared to conventional products.

2. Methods

2.1. Population

The CONSTANCES study is a French prospective and generalist epidemiological cohort initiated in 2012, which focuses on occupational, behavioral and social factors related to chronic diseases and aging ³⁵. The study enrolled 214,816 adults, aged between 18 and 69 years at inclusion, randomly selected among the insured subjects of the general social security scheme of 21 departments of metropolitan France. Information on respiratory health, including asthma, was collected by self-administered standardized questionnaires at inclusion. Follow-up questionnaires are sent every year. Household exposure to cleaning products was estimated during the follow-up in 2019, by a standardized questionnaire.

As respiratory health and household exposures were evaluated at different time-points, we only included participants who completed the baseline (including respiratory health) and 2019 (including household exposures) questionnaires within a timeframe of two years or less. Thus, the analyses focused on participants included in the cohort in 2017 and 2018 with available data on household exposure in 2019. In our study, we assume no major change in household cleaning habits in two years.

2.2. Current asthma and the asthma symptom score

Participants who answered positively to the question “Have you ever had asthma?” were considered as “ever asthma”, and otherwise as “never asthma”. Among participants with “ever asthma”, those who reported asthma symptoms (wheezing, woken up by a feeling of chest tightness or an attack of shortness of breath, attack of shortness of breath at rest or after exercise), asthma attacks or asthma treatment in the past 12 months were classified as “current asthma” ^{10,12,14,16}. Participants with remission asthma were excluded from these analyses (Figure 1).

The asthma symptom score was calculated as described in the literature ^{36,37}, regardless of asthma status. It corresponds to the number of asthma symptoms out of five reported in the standardized questionnaire in the past 12 months (wheezing with shortness of breath, woken up by a feeling of chest tightness or an attack of shortness of breath, attack of shortness of breath at rest or after exercise). It was studied as a continuous variable (0 to 5).

2.3. Household use of cleaning products

The household exposure questionnaire evaluated the participants' weekly use of various products at home in the past 12 months. We studied household exposure to six large categories including four type of compounds: irritants (maximum frequency reported for bleach, ammonia, acids and solvents), scented products (maximum frequency reported for scented cleaning products, home fragrances, scented candles, electric or spray air freshener), green products and home-made products, and two application modes: sprays (maximum frequency reported for furniture, glass, floor, bath, oven, ironing, air freshener, insecticide, or other use) and disinfecting wipes.

The frequency of use of home cleaning products was reported according to four categories: never, less than one day a week, 1-3 days a week or 4-7 days a week. In the analyses, "never" and "less than one day a week" were grouped together to define the "unexposed" group, as it is commonly done^{10-12,14,16,18}. For a given cleaning product, participants classified as "unexposed" but who are weekly exposed to one of the others five large categories studied were excluded from the analyses. Thus, the reference group (not weekly exposed to any of the six large categories) was the same for all analyses, as previously done^{9,38}. Frequency of use was studied as a variable in three classes (reference, 1-3 days a week, 4-7 days a week) in the main analyses and as a binary variable (reference, ≥ 1 day a week) in stratified analyses.

The number of cleaning products used was calculated for irritants, sprays and scented products (composite variables). The number of irritants used per week was assessed in three classes (reference, 1 irritant per week, ≥ 2 irritants per week). The number of sprays and the number of scented products were defined in four classes (reference, 1 product per week, 2 products per week, ≥ 3 products per week).

2.4. Statistical analysis

Associations between household exposure to cleaning products, current asthma and the asthma symptom score were evaluated by logistic and negative binomial regression models, respectively. All analyses were adjusted for gender, age (continuous), smoking status (never smoker, ex-smoker, current smoker), Body Mass Index (BMI; <24.9 , $25-29.9$, >30 kg/m²) and educational level ($<$ high school diploma, high school to 1-level university, 2-level university to 4-level university, ≥ 5 -level university). As associations of household exposure to irritants⁹⁻¹³ and sprays^{9,14,16,18} with asthma were previously observed in the literature, we conducted a

sensitivity analysis to examine whether the potential associations observed for newly-studied products (scented products, disinfecting wipes, green and home-made products) reflect the co-exposure to irritants and/or sprays. For this analysis, we defined a three-class variable (reference, exposed to a given product without being co-exposed to irritants and sprays, co-exposed to irritants and/or sprays for a given product). In order to examine whether the six large categories have an influence on the age of onset of asthma, we also studied the associations between household exposure to cleaning products and the age of the onset of asthma (never asthma, current asthma developed before 18 years, current asthma developed after 18 years) by multinomial logistic regression models. In addition, analyses were stratified by sex, smoking status, educational level and by household help (binary variable (yes/no) according to the answer to the question “Are you getting help to do home cleaning, e.g., husband, household employee, family members, friends,...?”) to evaluate the robustness of the results. Finally, we performed another sensitivity analysis to consider occupational exposures to cleaning products, which could be much more important than household exposures. Therefore, we repeated the main analyses after exclusion of participants professionally exposed to cleaning products over the last two years, estimated after a preliminary application of the OAsJEM (Occupational Asthma specific Job-Exposure Matrix ³⁹) for jobs exposed to “high level chemicals disinfectants”, “indoor cleaning” or “bleach” (49 job codes). A full transcoding (international job codes to French job codes) of the OAsJEM by experts is still in progress for future finale application in CONSTANCES.

The analyses were performed using the statistical analysis software SAS version 9.4 (SAS Institute, Cary, NC, USA).

3. Results

Among the 68,168 participants included in the CONSTANCES cohort in 2017 and 2018, 47,643 had household exposure data available in 2019. Participants with missing data on smoking status (n=1,443), BMI (n=1,332) or both on ever asthma status and asthma symptom score (n=98) were excluded. Therefore, our study population consisted of 44,770 participants (Figure 1). Participants non-included in 2017 or 2018, slightly differed from those included in the present study: they were older, more often men and with a lower educational level, with less current asthma and symptoms (Supplemental material, Table S1). Participants who did not complete questionnaire for household exposure differed from the studied population: they were younger, more often men, current smokers, obese, with a lower educational level, with more current asthma and symptoms. The analyses related to current asthma were carried out on 41,570 participants without missing data on asthma status, including 4,144 with current asthma. Analyses related to the asthma symptom score were conducted in 43,503 participants without missing data on this outcome.

Participants were 46.8 years old on average (Table 1), 56% were women, 34% were ex-smokers and 15% were current smokers, 30% were overweight (BMI > 25 kg/m²) and 28% had a high educational level (≥5-level university). Regarding exposures to cleaning products, weekly use of the six specific products/forms studied varied from 11% to 37% and 27% of participants reported no weekly use at home. Around 50% reported having help to do home cleaning and 8% had a potential occupational exposure to cleaning products. Among participants not weekly exposed to cleaning products at home, 4% reported never using any of the six categories of cleaning products studied, whereas 96% used at least of one these products less than one day per week (Supplemental material, Table S2). Participants with current asthma were more often women, younger and current smokers, had a higher BMI and educational level, and were more exposed to cleaning products than participants without asthma (Table 1). These characteristics were also described according to the asthma symptom score (Supplemental material, Table S3).

3.1. Household use of cleaning products and asthma

Weekly use of cleaning products was significantly associated with current asthma, regardless of the categories of products used (Table 2). Indeed, we observed a significant dose-response association between the frequency of use of irritants, sprays, scented products, disinfecting

wipes, green products, home-made products and current asthma, before and after adjustment for potential confounders. A dose-response association was also observed for the number of irritants, sprays, scented products used and current asthma (Supplemental material, Figure S1). These associations were slightly stronger for participants with an adult onset asthma, especially for disinfecting wipes, compared to participants with asthma onset in childhood (Supplementary material, Figure S2). The associations between weekly use of cleaning products, studied in two classes, and current asthma were of similar magnitude after stratification by gender, smoking status, educational level and household help, without statistically significant interactions (Supplementary material, Table S4). In addition, after exclusion of participants with potential occupational exposure in the last two years (n = 2,699), the same associations remained significant (Supplementary material, Table S5).

Regarding the asthma symptom score, we observed a consistent dose-response association with the frequency of use of the six large categories of cleaning products (Figure 2). A dose-response association was also observed for the number of irritants (1 irritant: 1.19 [1.13-1.26]; ≥ 2 irritants: 1.27 [1.19-1.37]), sprays (1 spray: 1.17 [1.11-1.24]; 2 sprays: 1.22 [1.14-1.31]; ≥ 3 sprays: 1.27 [1.19-1.36]) and scented products used (1 perfume: 1.16 [1.09-1.22]; 2 perfumes: 1.30 [1.21-1.40]; ≥ 3 perfumes: 1.55 [1.42-1.69]). The associations appeared slightly stronger than those previously noticed for current asthma. These results persisted after stratification by several factors (gender, smoking status, educational level, household help and the asthma status) and after exclusion of participants with potential occupational exposure in the last two years (results not shown).

3.2. Co-exposure to irritants and sprays

The associations between a given cleaning product (disinfecting wipes, scented, green and home-made products) used without irritants and sprays and current asthma were generally weaker and not significant, compared to the co-use of these two products (Table 3), except for disinfecting wipes which showed a significant association with current asthma whether used alone (OR=1.16 [1.00-1.36]) or together with irritants or sprays (OR=1.21 [1.09-1.35]). Furthermore, associations between these four cleaning products used at the highest frequency (4-7 days a week), without co-exposure to irritants/sprays and current asthma remained not significant (Supplementary material, Table S6).

215 Regarding the asthma symptom score, when the co-exposure was considered, the associations
216 for disinfecting wipes and scented products used without irritants or sprays were weaker, but
217 still significant (Figure 3). However, for the use of green and home-made products, the
218 associations were weaker and no longer significant.

4. Discussion

In this cross-sectional analysis of data from the CONSTANCES cohort, consistent significant associations were found between weekly use of six large categories of cleaning products, both for current asthma and the asthma symptom score, with a dose-response trend according to frequency of use. Moreover, we found a dose-response association with the number of irritants, sprays and scented products used. After considering the co-exposure to irritants or sprayed products at home, well-established risk factors for asthma, significant associations persisted for disinfecting wipes for both outcomes, whereas no association were observed for green and home-made products.

Our findings are consistent with previous epidemiological studies on household exposure to irritants, sprays and asthma. As in our study, a dose-response association was recently observed between the frequency, the number of irritants used and current asthma in a large cohort of elderly French women (Étude Épidémiologique de l'Éducation Nationale – E3N)¹⁰. Regarding sprays, our results are consistent with those of ECRHS, the first study focusing on this issue¹⁸, in which a dose-response association between the frequency of use of sprays and new-onset asthma was identified. Regarding gender, borderline significant associations were observed among men in ECRHS¹⁸. Given that we reported significant associations of the same magnitude in both men and women, their finding can probably be explained by the smaller number of men using at least two sprays per week. As in our study, in another French cohort (Epidemiological study on the Genetics and Environment of Asthma – EGEA), weekly use of at least two sprays was associated with current asthma and a high asthma symptom score (at least two symptoms of asthma)¹⁶. Furthermore, current asthma was associated with the weekly use of only one spray. Also in E3N, weekly use of at least one spray was significantly associated with current asthma only among women without household help¹⁴, while in CONSTANCES we found significant associations for both participants with and without household help. Since the E3N cohort consists exclusively of elderly women, the help they benefit from is likely provided by a household employee, so that they are likely to do less home cleaning themselves. In the CONSTANCES cohort, as participants are younger, the household help could correspond to a family member as well as a household employee, which the questionnaire does not allow to determine. Our results for sprayed products add additional evidence on the negative impact of this application mode on respiratory health. However, the sale of products in this form has increased over the last decades and is still at high level^{18,40}.

To our knowledge, this is one of the first epidemiological studies testing the associations between the household use of scented products and asthma and the first examining disinfecting wipes, green, home-made products. For scented products, we first observed a dose-response association between their frequency of use, current asthma and the asthma symptom score. After considering co-exposures, the association with current asthma was no longer observed but the one with the asthma symptom score persisted. Our results are consistent with those of Lemire et al. in E3N ¹⁰ who found that weekly use of scented products identified using two exposure assessment methods (self-questionnaire and a smartphone application linked to a product compounds database) was significantly associated with at least one symptom of asthma. Our results also suggest a deleterious effect of disinfecting wipes on asthma since we found a dose-response association between the frequency of use of this product, current asthma and the asthma symptom score. Moreover, this association is robust because it persisted in most sensitivity analyses. For green products, our results are consistent with those of Garza et al. ²² as we found less evidence for an association with asthma. Indeed, the associations observed were lower than for other products and were no longer present after considering co-exposures, nor among never smokers. Thus, in addition of being safer for the environment ⁸, green products may be the category of cleaning products to be less harmful for respiratory health, compared to the other products studied. For home-made products, the strength of the association with asthma was close to those found in conventional products but this association disappeared after considering co-exposures.

The underlying mechanisms involved in the respiratory effects of cleaning products are still poorly understood ^{27,41}. The assumptions are that cleaning products can have two different effects: some will have an irritating effect and others a sensitizing effect on the respiratory tract ^{4,5,7}. However, some products may induce both effects, depending on whether exposure occurs at a low or high concentration, as suspected for quaternary ammonium compounds, for example ^{1,4,27}. Furthermore, products applied in a spray form contain perfumes and may therefore have a sensitizing effect and induce asthma through allergic mechanisms ^{42,43}. In the scientific literature, associations of the same magnitude for allergic and non-allergic asthma were once reported with the use of sprays ¹⁶. In addition, another study reported strong association between weekly use of at least one spray and current asthma among women without allergic rhinitis, whereas no association was shown among women with allergic rhinitis ¹⁴. The other cleaning products may rather operate by an irritating mechanism and would be more associated with

non-allergic asthma as previously shown ¹². The inhalation of irritating compounds may cause epithelial damage, increase lung permeability and oxidative stress ^{4,7,8,42,44}.

The main strength of our study is that it is based on data from the large CONSTANCES cohort, which allowed us to assess the effect of cleaning products in a large number of participants, randomly selected among the general French population, and thus limits potential problems of statistical power. Moreover, these data also allowed us to perform analyses on a mixed gender population, with a wide range of age, whereas most epidemiological studies were only able to study the impact of the household use of cleaning products on asthma among women ^{9,10,12,14,16}. Secondly, we took into account the co-use of products for which associations with the respiratory health were previously shown, including irritants ^{9–13} and sprays ^{9,14,16,18}. Another strength of our study is the use of the asthma symptom score, which is an alternative method recommended to assess asthma risk factors with greater statistical power ^{36,37}. By using this definition, we showed more significant associations than with the traditional dichotomous definition. Lastly, the results persisted after performing several sensitivity analyses, which underlines their robustness. In addition, results for childhood and adult onset asthma are consistent with other epidemiological studies in occupational context suggesting that the use of cleaning products can induce asthma incidence but also exacerbate a pre-existing asthma ²¹.

Our study also has some limitations. First, household exposure to cleaning products was only assessed by questionnaire, thus relying on participant statement, which could induce differential and non-differential misclassification biases. Eight epidemiological studies have discussed this type of bias, some of them estimated household exposure to cleaning products by different methods (Principal Component Analysis – PCA ^{14,16}, composite score ¹⁴, scanning cleaning products barcodes by a smartphone application linked to a product compounds database ¹¹, ...) and observed similar results for irritants and sprays to those obtained by crude questionnaire-based assessments. In addition, it was recently highlighted that almost all cleaning products contain perfumes ¹¹. It is then possible that, when assessing exposure to scented products by questionnaire, participants may not be aware that some contain perfumes and may underestimate their exposure. In general, it would be important to develop more objective methods to estimate household exposure to cleaning products. A recently developed smartphone application ¹¹ may allow to identify the chemical compounds specifically causing the health effect to better understand the mechanisms by which they can induce or exacerbate asthma. Secondly, the use of green and home-made cleaning products could be influenced by

participants' lifestyle and socio-economic level. Indeed, participants with a healthier lifestyle may perceive such products to cause the least adverse effects on the environment and the health and rather use them than conventional ones. In addition, these products can be less affordable than conventional ones. However, to consider this possibility, associations were adjusted on major lifestyle risk factors known for asthma. Finally, because of the cross-sectional design of our study and the assessment of respiratory health and household exposures 2 years apart, we were not able to consider the temporal relationship between the use of cleaning products and asthma. A possible reverse causation phenomenon, i.e. participants with current asthma using more frequently cleaning products at home than non-asthmatic participants in order to eliminate dust or molds which may cause symptoms, might partly explain our results. However, significant associations were observed for sprays and irritants, but not for green and home-made products when used alone, and it seems unlikely that participants with current asthma use specifically more irritants and sprays than green and home-made products. In addition, our results are consistent with literature in occupational settings^{45,46} where workers do not choose the frequency of cleaning tasks, and with associations observed between household use of sprays or disinfectants and new-onset asthma in longitudinal studies^{13,18}. Therefore, a reverse causation phenomenon is unlikely to explain associations assessed in our manuscript.

5. Conclusions

In conclusion, household use of cleaning products with various application modes, was associated with asthma among French adults. Based on our results, it seems less harmful to use liquid products than sprays or ready-to-use disinfecting wipes and to use green products than conventional ones. Further research is needed on this issue, in particular to clarify the impact of green and home-made products on respiratory health. This will eventually allow the development of preventive measures targeting the use of certain products with the final goal to reduce the world's asthma-related morbidity.

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Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Author contribution

E.P.D.S contributed to the analysis and interpretation of the data, and primary manuscript preparation. M.G., C.R. and M.Z. contributed to acquisition and interpretation of the data and critical revision of the manuscript. G.S, B.L., R.N., N.R., R.V. were involved in the data interpretation and critical revision of the manuscript. N.L.M. and O.D. developed the study hypotheses, and contributed to data interpretation, primary manuscript preparation and critical revision of the manuscript. All authors approved the final version of the manuscript. All authors have read and agreed to the published version of the manuscript.

Data availability

Data were obtained from the CONSTANCES group. It can be provided upon reasonable request after approval by the CONSTANCES scientific committee.

The CONSTANCES cohort received ethical approval from the French National Data Protection Authority (authorisation no. 910486) and the Institutional Review Board of the National Institute for Medical Research (authorisation no.01-011). All participants gave informed consent to participate.

The participants provided their written consent to participate in this study.

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Table 1. Population characteristics according to current asthma status

	All n = 41,570	Never asthma n = 37,426	Current asthma n = 4,144	p-value
Gender, n (%)				
Male	18,348 (44.1)	16,577 (44.3)	1,771 (42.7)	0.056
Female	23,222 (55.9)	20,849 (55.7)	2,373 (57.3)	
Age (years), mean $\pm$ s.d	46.8 $\pm$ 13.2	47.1 $\pm$ 13.2	44.1 $\pm$ 13.2	< 0.0001
Smoking status, n (%)				
Never smoker	20,900 (50.3)	18,924 (50.6)	1,976 (47.7)	< 0.0001
Ex-smoker	14,258 (34.3)	12,891 (34.4)	1,367 (33.0)	
Current smoker	6,412 (15.4)	5,611 (15.0)	801 (19.3)	
BMI (Body Mass Index - kg/m²), n (%)				
< 24.9	24,422 (58.7)	22,196 (59.3)	2,226 (53.7)	< 0.0001
[25 – 29.9[	12,345 (29.7)	11,048 (29.5)	1,297 (31.3)	
$\geq$ 30	4,803 (11.6)	4,182 (11.2)	621 (15.0)	
Educational level, n (%)				
<high school diploma	8,142 (19.8)	7,413 (20.0)	729 (17.8)	0.0061
high school to 1-level university	6,113 (14.9)	5,513 (14.9)	600 (14.7)	
2-level university to 4-level university	15,398 (37.4)	13,836 (37.3)	1,562 (38.3)	
>5-level university	11,478 (27.9)	10,284 (27.8)	1,194 (29.2)	
Asthma symptom score, n (%)				
0 symptom	28,060 (69.5)	27,437 (75.4)	623 (15.7)	< 0.0001
1 symptom	7,736 (19.2)	6,322 (17.4)	1,411 (35.7)	
$\geq$ 2 symptoms	4,567 (11.3)	2,645 (7.2)	1,922 (48.6)	
Weekly use of cleaning products, n (%)				
<1 day/week	10,760 (26.8)	9,790 (27.1)	970 (24.0)	< 0.0001
$\geq$ 1 day/week	29,464 (73.2)	26,398 (72.9)	3,066 (76.0)	
Household help, n (%)	21,000 (51.2)	18,868 (51.1)	2,132 (52.1)	< 0.0001
Potential occupational exposure*, n (%)	2,699 (8.1)	2,394 (8.1)	305 (9.0)	0.0524

Results presented in bold are significant

*to cleaning products according to a preliminary transcoding for applying the OAsJEM (Occupational Asthma specific Job-Exposure Matrix ³⁹) to 49 job codes in CONSTANCES.

Table 2. Associations between the frequency of use of household cleaning products and current asthma

	All n = 41,570	Never asthma n = 37,426	Current asthma n = 4,144	Crude OR [95% CI]	Adjusted OR ^a [95% CI]	p trend
Not weekly exposed to any of the six large categories (ref)	n=10,760	n=9,790	n=970	1.00	1.00	
Irritants						
1-3 days/week	n=11,670	47.0%	51.5%	1.25 [1.15-1.37]	1.22 [1.11-1.34]	< 0.0001
4-7 days/week	n=2,172	8.7%	9.7%	1.27 [1.10-1.47]	1.30 [1.11-1.52]	
Sprays						
1-3 days/week	n=11,304	43.2%	44.6%	1.19 [1.09-1.30]	1.13 [1.02-1.24]	< 0.0001
4-7 days/week	n=4,005	14.9%	19.1%	1.47 [1.31-1.65]	1.37 [1.22-1.55]	
Scented products						
1-3 days/week	n=9,628	37.9%	40.6%	1.23 [1.12-1.35]	1.14 [1.03-1.25]	0.0018
4-7 days/week	n=4,847	18.9%	21.7%	1.32 [1.18-1.47]	1.19 [1.06-1.33]	
Disinfecting wipes						
1-3 days/week	n=6,442	33.3%	37.9%	1.32 [1.19-1.46]	1.18 [1.06-1.31]	< 0.0001
4-7 days/week	n=1,896	9.6%	12.7%	1.52 [1.31-1.76]	1.32 [1.13-1.55]	
Green products						
1-3 days/week	n=10,039	42.2%	43.4%	1.10 [1.00-1.21]	1.07 [0.97-1.18]	0.0182
4-7 days/week	n=2,939	12.2%	14.0%	1.22 [1.07-1.40]	1.18 [1.03-1.36]	
Home-made products						
1-3 days/week	n=3,429	21.8%	24.9%	1.24 [1.09-1.41]	1.15 [1.01-1.31]	0.0017
4-7 days/week	n=1,303	8.2%	10.6%	1.41 [1.18-1.69]	1.31 [1.08-1.58]	

^a Adjusted Odds Ratio (OR) for gender, age, smoking status, BMI and educational level of associations between the frequency of use of household cleaning products and current asthma, obtained by logistic regression models; results presented in bold are significant

Table 3. Associations between weekly use of cleaning products and current asthma according to the co-use of irritants and sprays at home

Adjusted OR ^a [95% CI]	Scented products	Disinfecting wipes	Green products	Home-made products
Not weekly exposed to any of the six large categories (ref)	1.00	1.00	1.00	1.00
Weekly exposed any of the six large categories	1.15 [1.06-1.26]	1.21 [1.09-1.34]	1.09 [1.00-1.20]	1.19 [1.06-1.34]
Co-exposure to risks previously identified ^b (irritants or sprays):				
Not co-exposed	0.97 [0.85-1.10]	1.16 [1.00-1.36]	0.94 [0.83-1.07]	0.99 [0.83-1.19]
Co-exposed	1.23 [1.12-1.35]	1.21 [1.09-1.35]	1.16 [1.05-1.29]	1.30 [1.14-1.49]

^a Adjusted Odds Ratio (OR) for gender, age, smoking status, BMI and educational level of associations between weekly use of cleaning products and current asthma according to the co-use of irritants and sprays at home, obtained by logistic regression models; results presented in bold are significant

^b exposure to irritants ⁹⁻¹³ and sprayed ^{14,16,18} cleaning products were associated to asthma in the literature

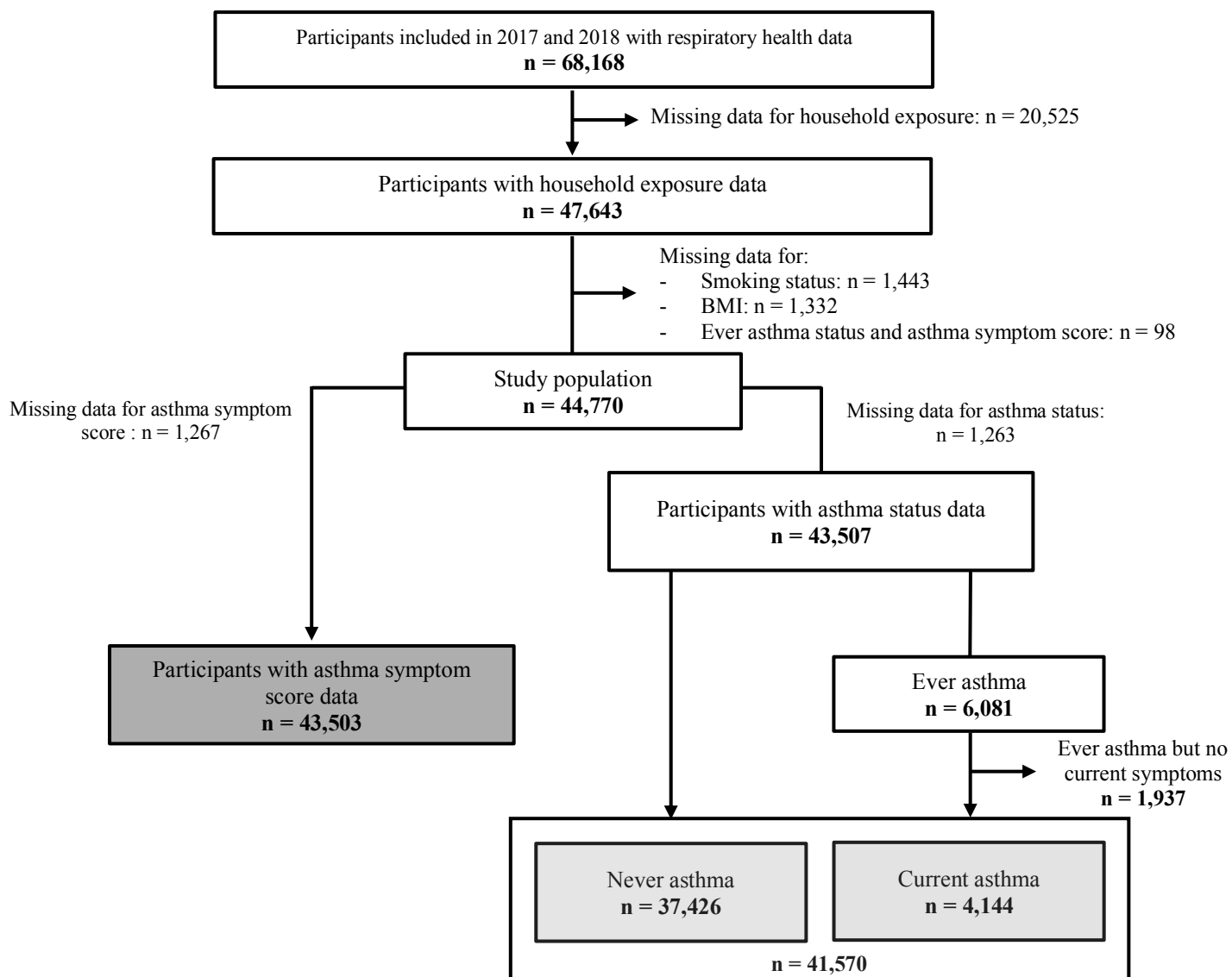


Figure 1. Flowchart of the study population

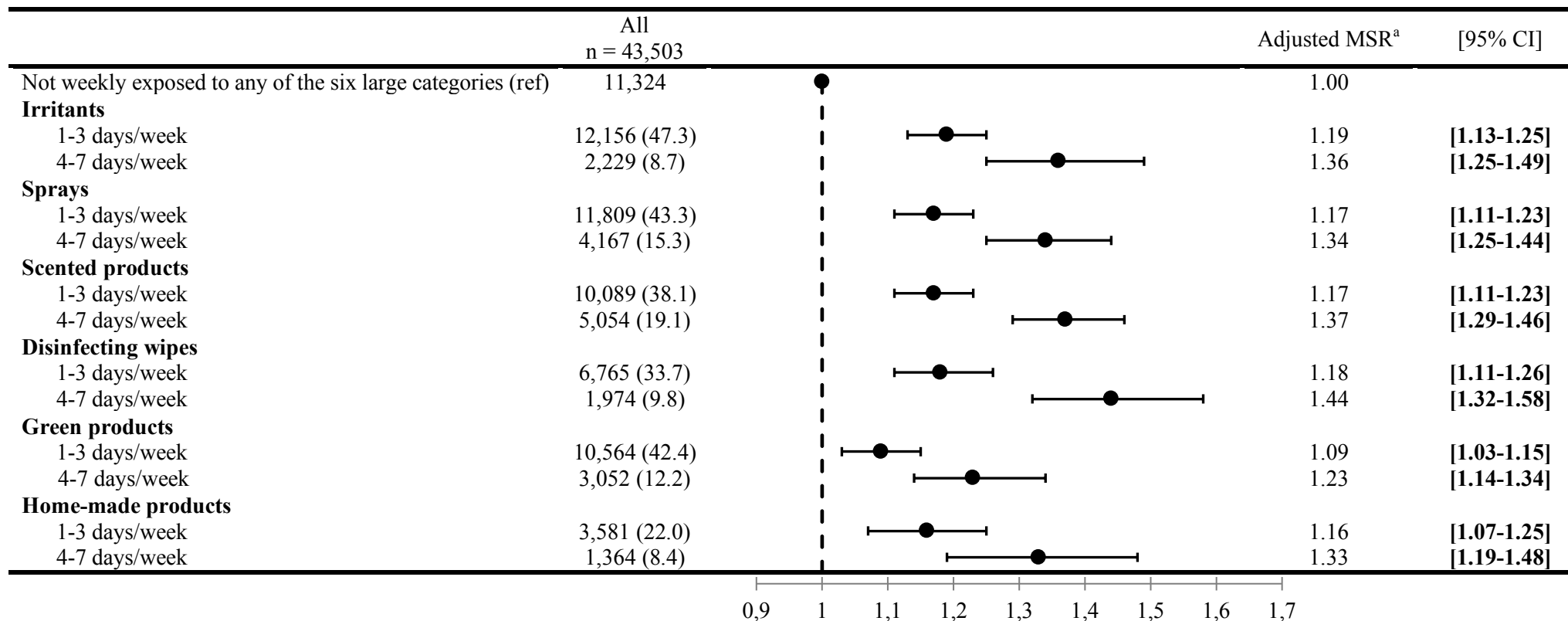


Figure 2. Associations between the frequency of use of cleaning products and the asthma symptom score

Mean Score Ratio (MSR) adjusted for gender, age, smoking status, BMI and educational level of associations between the frequency of use of cleaning products and the asthma symptom score, obtained by negative binomial regression model

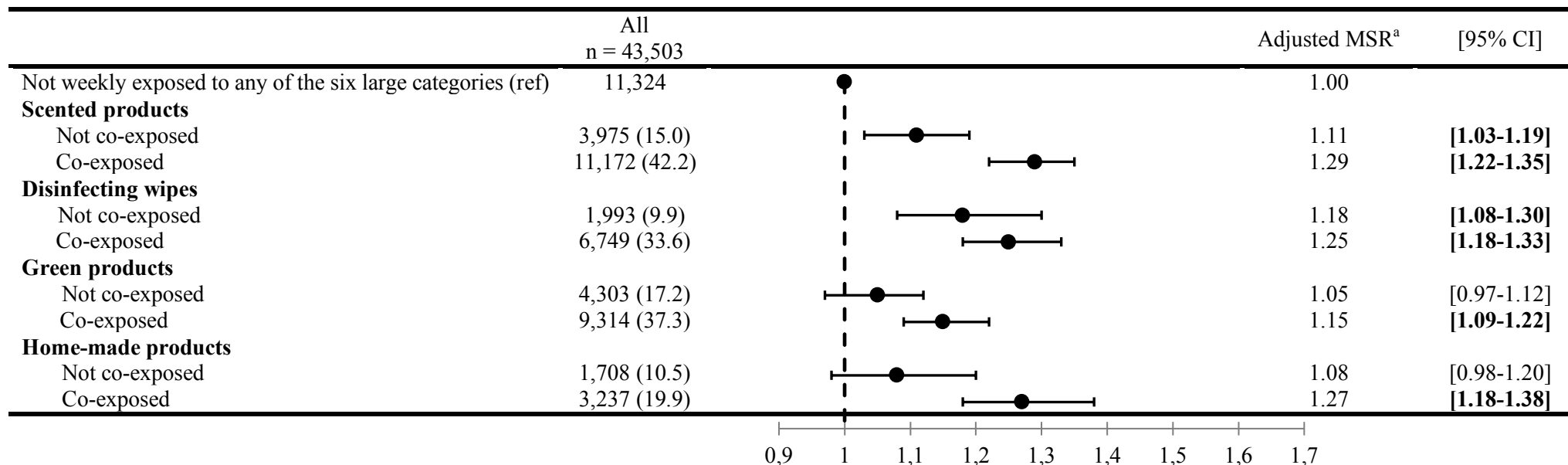


Figure 3. Associations between weekly use of cleaning products and the asthma symptom score, according to the co-use of irritants and sprays at home
Mean Score Ratio (MSR) adjusted for gender, age, smoking status, BMI and educational level of associations between weekly use of cleaning products and the asthma symptom score, according to the co-use of irritants and sprays at home, obtained by negative binomial regression models

Supplementary material

Household use of green and home-made cleaning products, wipe application mode and asthma among French adults from the CONSTANCES cohort

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Table S1. Description of the study population and those excluded from the analysis

	Study population (n = 44,770)	Participants non-included in 2017 or 2018 (n = 69,915)	p-value	Missing data for household exposure (n = 20,525)	p-value
Gender, n (%)					
Male	19,943 (44.5)	32,231 (46.1)	< 0.0001	9,951 (48.5)	< 0.0001
Female	24,827 (55.5)	37,684 (53.9)		10,574 (51.5)	
Age (years), mean $\pm$ s.d	46.7 (13.2)	49.5 (13.2)	< 0.0001	44.2 (13.5)	< 0.0001
Smoking status, n (%)					
Never smoker	22,554 (50.4)	33,035 (49.1)	< 0.0001	8,608 (44.1)	< 0.0001
Ex-smoker	15,392 (34.4)	24,225 (36.0)		6,032 (30.9)	
Current smoker	6,824 (15.2)	10,014 (14.9)		4,875 (25.0)	
BMI (kg/m²), n (%)					
< 24.9	26,394 (58.9)	39,159 (57.5)	< 0.0001	10,427 (52.9)	0.0003
[25 – 29.9[	13,277 (29.7)	21,225 (31.2)		6,218 (31.6)	
≥ 30	5,099 (11.4)	7,689 (11.3)		3,064 (15.5)	
Educational level, n (%)					
<high school diploma	8,690 (19.6)	15,816 (22.9)	< 0.0001	6,077 (30.4)	0.0005
high school to 1-level university	6,556 (14.8)	11,284 (16.4)		3,644 (18.2)	
2-level university to 4-level university	16,526 (37.4)	24,456 (35.5)		6,224 (31.2)	
>5-level university	12,476 (28.2)	17,382 (25.2)		4,031 (20.2)	
Asthma status, n (%)					
Never asthma	37,426 (90.0)	59,452 (91.3)	< 0.0001	16,798 (88.8)	0.0030
Current asthma	4,144 (10.0)	5,653 (8.7)		2,121 (11.2)	
Asthma symptom score, n (%)					
0 symptom	30,856 (70.9)	47,462 (70.8)	< 0.0001	12,502 (64.6)	< 0.0001
1 symptom	7,952 (18.3)	12,803 (19.1)		3,840 (19.8)	
2 symptoms	2,765 (6.4)	3,998 (6.0)		1,625 (8.4)	
3 symptoms	1,082 (2.5)	1,558 (2.3)		733 (3.8)	
4 symptoms	529 (1.2)	784 (1.2)		394 (2.0)	
5 symptoms	319 (0.7)	407 (0.6)		276 (1.4)	

BMI = Body Mass Index; results presented in bold are significant

Table S2. Description of participants non-weekly-exposed to any of the six large categories and participants weekly exposed

	Not weekly exposed n = 11,584		Weekly exposed Use ≥ 1 day/week n = 31,711	p-value
	No use n = 421	Use <1 day/week n = 11,163		
Gender, n (%)				
Male	376 (89.3)	6,573 (58.9)	12,049 (38.0)	< 0.0001
Female	45 (10.7)	4,590 (41.1)	19,662 (62.0)	
Age (years), mean $\pm$ s.d	49.1 $\pm$ 13.9	47.2 $\pm$ 13.2	46.3 $\pm$ 13.2	< 0.0001
Smoking status, n (%)				
Never smoker	194 (46.1)	5,858 (52.5)	15,784 (49.8)	< 0.0001
Ex-smoker	181 (43.0)	3,766 (33.7)	10,893 (34.3)	
Current smoker	46 (10.9)	1,539 (13.8)	5,034 (15.9)	
BMI (Body Mass Index - kg/m²), n (%)				
< 24.9	215 (51.1)	6,884 (61.7)	18,568 (58.6)	< 0.0001
[25 – 29.9[	160 (38.0)	3,265 (29.2)	9,306 (29.3)	
≥ 30	46 (10.9)	1,014 (9.1)	3,837 (12.1)	
Educational level, n (%)				
<high school diploma	89 (21.5)	1,671 (15.1)	6,394 (20.4)	0.0061
high school to 1-level university	52 (12.5)	1,338 (12.1)	4,960 (15.8)	
2-level university to 4-level university	101 (24.3)	3,900 (35.4)	12,115 (38.6)	
>5-level university	173 (41.7)	4,127 (37.4)	7,884 (25.2)	
Asthma status, n (%)				
Never asthma	341 (87.2)	9,449 (91.1)	26,398 (89.6)	< 0.0001
Current asthma	50 (12.8)	920 (8.9)	3,066 (10.4)	
Asthma symptom score, n (%)				
0 symptom	309 (74.6)	8,132 (74.5)	21,399 (69.5)	< 0.0001
1 symptom	66 (16.0)	1,863 (17.1)	5,783 (18.8)	
≥ 2 symptoms	39 (9.4)	915 (8.4)	3,589 (11.7)	
Household help, n (%)	332 (78.1)	5,952 (53.9)	15,754 (50.3)	< 0.0001

Results presented in bold are significant

Table S3. Population characteristics according to the asthma symptom score

	All n = 43,503	0 symptom n = 30,856	1 symptom n = 7,952	≥2 symptoms n = 4,695	p-value
Gender, n (%)					
Male	19,451 (44.7)	14,212 (46.1)	3,298 (41.5)	1,941 (41.3)	< 0.0001
Female	24,052 (55.3)	16,644 (53.9)	4,654 (58.5)	2,754 (58.7)	
Age (years), mean ± s.d	46.6 ± 13.2	46.8 ± 13.1	46.8 ± 13.5	45.2 ± 13.2	< 0.0001
Smoking status, n (%)					
Never smoker	21,936 (50.4)	16,448 (53.3)	3,531 (44.4)	1,957 (41.7)	< 0.0001
Ex-smoker	14,959 (34.4)	10,505 (34.1)	2,838 (35.7)	1,616 (34.4)	
Current smoker	6,608 (15.2)	3,903 (12.6)	1,583 (19.9)	1,122 (23.9)	
BMI (kg/m²), n (%)					
< 24.9	25,745 (59.1)	19,260 (62.4)	4,168 (52.4)	2,317 (49.3)	< 0.0001
[25 – 29.9[	12,865 (29.6)	8,881 (28.8)	2,476 (31.1)	1,507 (32.1)	
≥ 30	4,893 (11.3)	2,711 (8.8)	1,308 (16.5)	871 (18.6)	
Educational level, n (%)					
<high school diploma	8,358 (19.5)	5,785 (19.0)	1,485 (18.9)	1,088 (23.4)	< 0.0001
high school to 1-level university	6,340 (14.7)	4,337 (14.2)	1,215 (15.5)	788 (17.0)	
2-level university to 4-level university	16,085 (37.4)	11,484 (37.6)	2,955 (37.7)	1,646 (35.5)	
>5-level university	12,232 (28.4)	8,930 (29.2)	2,186 (27.9)	1,116 (24.1)	
Weekly use of cleaning products, n (%)					
<1 day/week	11,324 (26.9)	8,441 (28.3)	1,929 (25.0)	954 (21.0)	< 0.0001
≥1 day/week	30,771 (73.1)	21,399 (71.7)	5,783 (75.0)	3,589 (79.0)	
Household help, n (%)	22,125 (51.5)	15,827 (51.9)	4,000 (51.0)	2,298 (49.7)	0.0098
Potential occupational exposure*, n (%)	2,816 (8.1)	1,945 (7.8)	515 (8.2)	356 (12.6)	0.0035

BMI = Body Mass Index; results presented in bold are significant

*to cleaning products according to a preliminary transcoding for applying the OAsJEM (Occupational Asthma specific Job-Exposure Matrix; Le Moual et al. 2018) to 49 job codes in CONSTANCES.

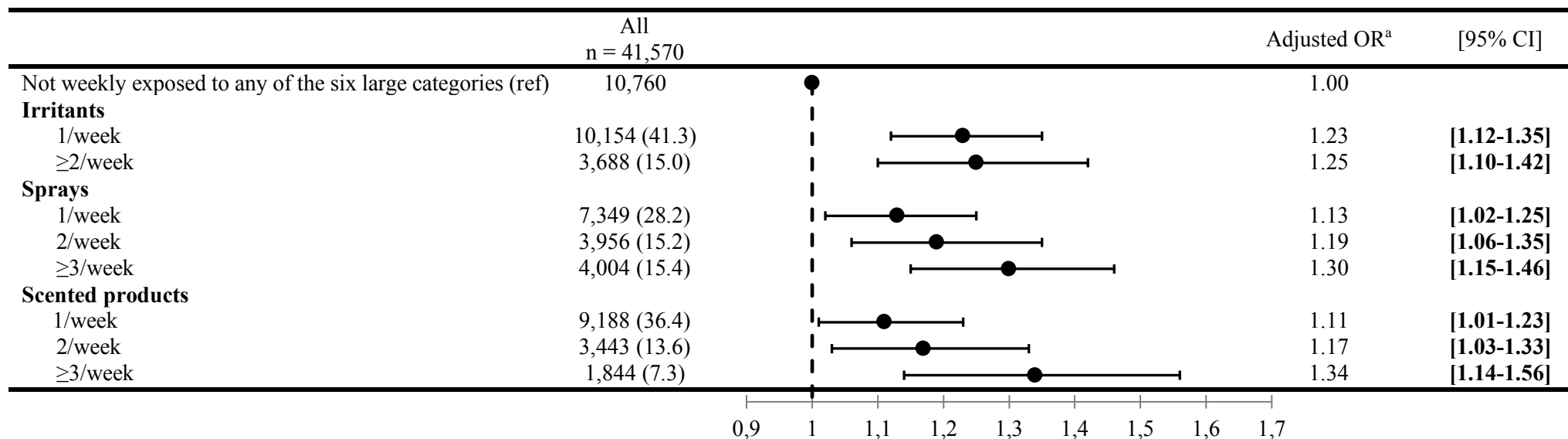


Figure S1. Associations between the number of products weekly used and current asthma

Adjusted Odds Ratio (OR) for gender, age, smoking status, BMI and educational level of associations between the number of products used and current asthma, obtained by logistic regression models

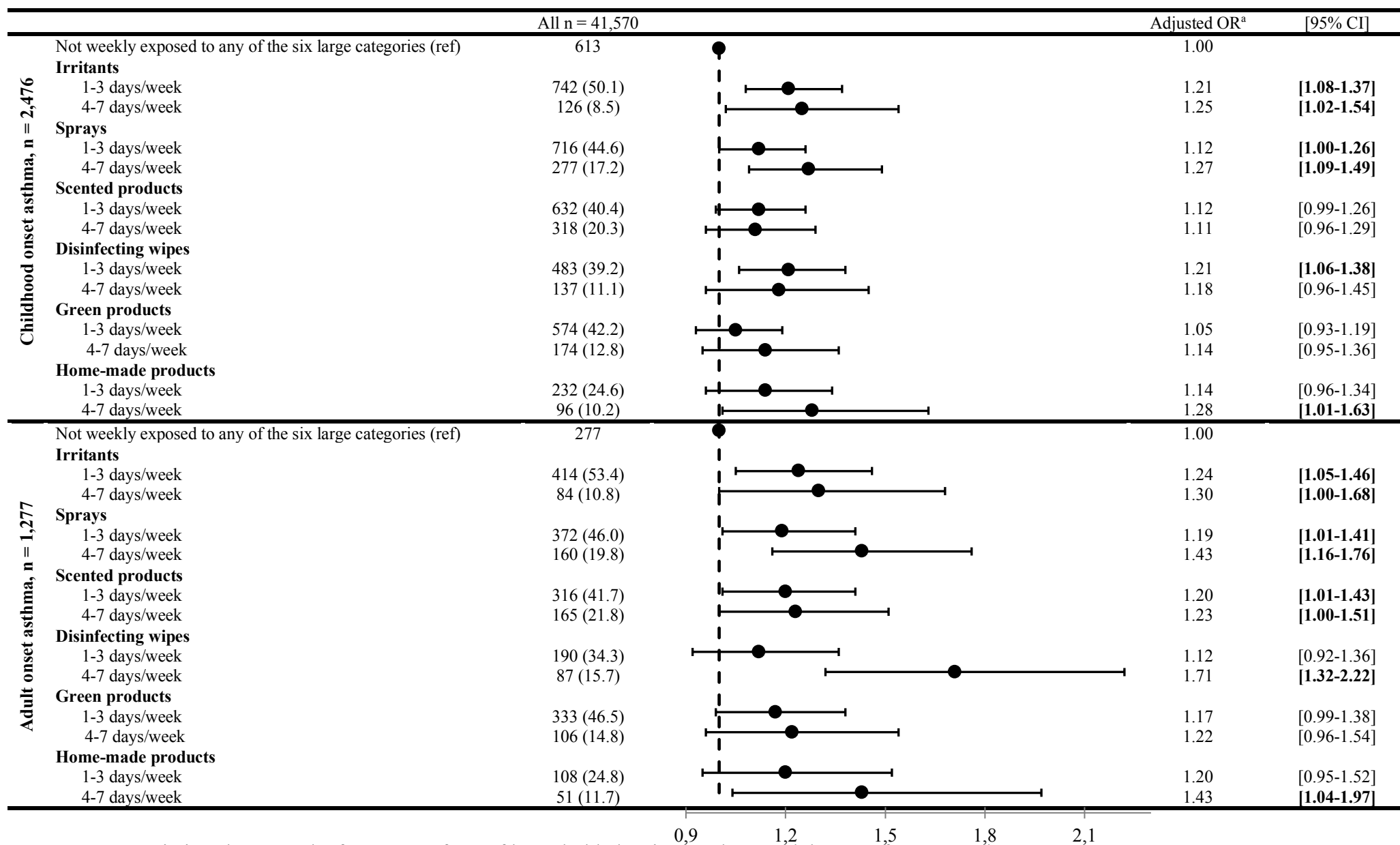


Figure S2. Associations between the frequency of use of household cleaning products and the age of current asthma onset

Adjusted Odds Ratio (OR) for gender, age, smoking status, BMI and educational level of associations between the frequency of use of household cleaning products and the age of onset of current asthma, obtained by multinomial logistic regression model

Table S4. Associations between weekly use of cleaning products and current asthma, stratified by gender, smoking status, educational level and household help

	Irritants	Sprays	Scented products	Disinfecting wipes	Green products	Home-made products
Not weekly exposed to any of the six large categories (ref)	1.00	1.00	1.00	1.00	1.00	1.00
Weekly exposed to any of the six large categories	1.23 [1.13-1.35]	1.18 [1.08- 1.29]	1.15 [1.06-1.26]	1.21 [1.09-1.34]	1.09 [1.00-1.20]	1.19 [1.06-1.34]
Gender ^a :						
Male, n = 18,348	1.27 [1.12-1.45]	1.16 [1.03-1.32]	1.16 [1.02-1.31]	1.16 [1.00-1.33]	1.04 [0.91-1.20]	1.23 [1.02-1.49]
Female, n = 23,222	1.20 [1.06-1.36]	1.20 [1.06-1.36]	1.15 [1.02-1.31]	1.26 [1.10-1.44]	1.14 [1.00-1.29]	1.16 [1.00-1.35]
Smoking status ^b :						
Never smoker, n = 20,900	1.23 [1.08-1.40]	1.22 [1.08-1.38]	1.23 [1.09-1.40]	1.22 [1.06-1.42]	1.07 [0.93-1.22]	1.06 [0.89-1.26]
Ex-smoker, n = 14,258	1.17 [1.00-1.36]	1.11 [0.96-1.29]	1.04 [0.89-1.21]	1.15 [0.97-1.37]	1.07 [0.92-1.25]	1.23 [1.00-1.51]
Current smokers, n = 6,412	1.35 [1.09-1.67]	1.19 [0.97-1.47]	1.15 [0.93-1.42]	1.23 [0.97-1.55]	1.20 [0.96-1.49]	1.49 [1.14-1.94]
Educational level ^c :						
≤1-level university, n = 14,255	1.18 [1.00-1.39]	1.16 [0.99-1.36]	1.12 [0.95-1.31]	1.26 [1.06-1.51]	0.99 [0.82-1.18]	1.01 [0.80-1.28]
≥2-level university, n = 26,876	1.25 [1.12-1.39]	1.19 [1.07-1.32]	1.16 [1.05-1.29]	1.17 [1.04-1.32]	1.13 [1.01-1.25]	1.26 [1.09-1.44]
Household help ^d :						
No, n = 20,044	1.27 [1.11-1.45]	1.20 [1.06-1.37]	1.19 [1.04-1.36]	1.32 [1.14-1.53]	1.11 [0.97-1.28]	1.22 [1.02-1.45]
Yes, n = 21,000	1.20 [1.06-1.36]	1.17 [1.04-1.32]	1.12 [1.00-1.26]	1.13 [0.98-1.29]	1.08 [0.95-1.22]	1.16 [0.99-1.36]

^a Adjusted Odds Ratio (OR) for age, smoking status, BMI and educational level of associations between weekly use of cleaning products and current asthma stratified by gender, obtained by logistic regression models; results presented in bold are significant

^b Adjusted Odds Ratio (OR) for gender, age, BMI and educational level of associations between weekly use of cleaning products and current asthma stratified by smoking status, obtained by logistic regression models; results presented in bold are significant

^c Adjusted Odds Ratio (OR) for gender, age, smoking status and BMI of associations between weekly use of cleaning products and current asthma stratified by educational level, obtained by logistic regression models; results presented in bold are significant

^d Adjusted Odds Ratio (OR) for gender, age, smoking status, BMI and educational level of associations between weekly use of cleaning products and current asthma stratified by household help, obtained by logistic regression models; results presented in bold are significant

Table S5. Associations between the frequency of use of household cleaning products and current asthma after exclusion of participants with potential occupational exposure

	All n = 38,871	Never asthma n = 35,032	Current asthma n = 3,839	Adjusted OR ^a [95% CI]	p trend
Not weekly exposed to any of the six large categories (ref)	n=10,308	n=9,383	n=925	1.00	
Irritants					
1-3 days/week	n=10,769	46.3%	50.8%	1.23 [1.11-1.35]	< 0.0001
4-7 days/week	n=1,935	8.3%	9.4%	1.35 [1.15-1.59]	
Sprays					
1-3 days/week	n=10,432	42.7%	44.4%	1.13 [1.03-1.25]	< 0.0001
4-7 days/week	n=3,590	14.4%	18.0%	1.36 [1.20-1.54]	
Scented products					
1-3 days/week	n=8,884	37.4%	40.1%	1.13 [1.03-1.25]	0.0034
4-7 days/week	n=4,395	18.4%	21.0%	1.18 [1.05-1.33]	
Disinfecting wipes					
1-3 days/week	n=5,959	32.7%	37.1%	1.17 [1.05-1.31]	< 0.0001
4-7 days/week	n=1,687	9.1%	12.4%	1.38 [1.17-1.63]	
Green products					
1-3 days/week	n=9,369	41.7%	43.4%	1.08 [0.98-1.20]	0.0400
4-7 days/week	n=2,686	11.9%	13.1%	1.15 [0.99-1.33]	
Home-made products					
1-3 days/week	n=3,166	21.4%	24.1%	1.13 [0.99-1.30]	0.0037
4-7 days/week	n=1,163	7.7%	10.1%	1.31 [1.07-1.59]	

^a Adjusted Odds Ratio (OR) for gender, age, smoking status, BMI and educational level of associations between the frequency of use of household cleaning products and current asthma after exclusion of participants with potential occupational exposure to cleaning products according to a preliminary transcoding for applying the OAsJEM (Occupational Asthma specific Job-Exposure Matrix; Le Moual et al. 2018) to 49 job codes in CONSTANCES, obtained by logistic regression models; results presented in bold are significant

Table S6. Associations between frequent use of cleaning products and current asthma according to the co-use of irritants and sprays at home

Adjusted OR ^a [95% IC]	Scented products	Disinfecting wipes	Green products	Home-made products
Not weekly exposed to any of the six large categories (ref)	1.00	1.00	1.00	1.00
Frequent use of cleaning products	1.19 [1.06-1.33]	1.32 [1.13-1.55]	1.18 [1.03-1.36]	1.31 [1.08-1.58]
Co-exposure to risks previously identified ^b (irritants or sprays):				
Not co-exposed ^c	0.92 [0.74-1.14]	1.13 [0.77-1.65]	1.09 [0.85-1.39]	1.22 [0.87-1.70]
Co-exposed ^d	1.26 [1.11-1.43]	1.35 [1.14-1.61]	1.24 [1.06-1.46]	1.34 [1.08-1.66]

^a Adjusted Odds Ratio (OR) for gender, age, smoking status, BMI and educational level of associations between frequent use of cleaning products (4-7 days/week) and current asthma according to the co-use of irritants and sprays at home, obtained by logistic regression models; results presented in bold are significant

^b exposure to irritants (Dumas et al. 2021; Lemire et al. 2020, 2021; Matulonga et al. 2016; Weinmann et al. 2017) and sprayed (Bédard et al. 2014; Dumas et al. 2021; Le Moual et al. 2012; Zock et al. 2007) cleaning products were associated to asthma in the literature

^c 1,008 never asthma/99 current asthma not co-exposed to scented products, 247 never asthma/31 current asthma not co-exposed to disinfecting wipes, 758 never asthma/83 current asthma not co-exposed to green products, 327 never asthma/42 current asthma not co-exposed to home-made products

^d 3,280 never asthma/460 current asthma co-exposed to scented products, 1,401 never asthma/217 current asthma co-exposed to disinfecting wipes, 1,863 never asthma/235 current asthma co-exposed to green products, 816 never asthma/118 current asthma co-exposed to home-made products