

ORIGINAL ARTICLE

Association of household cleaning agents and disinfectants with asthma in young German adults

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ABSTRACT

Objectives We scrutinised the association of private use of household sprays and disinfectants with asthma incidence in young adults in the transition from school to working life.

Methods Between 2007 and 2009, 2051 young adults aged 19–24 years living in two major German cities took part in the Study on Occupational Allergy Risks II. Self-reported exposure to household sprays and disinfectants was characterised according to a composite score for frequency of use as no use (score=0), low use (score between 1 and the median), medium use (score between the median and the 90th percentile) and high use (score above the 90th percentile). Two outcome variables (current asthma and current wheezing) with four mutually exclusive categories (never, incident, persistent and remittent) were used for the risk analyses. Multinomial logistic regression models examined the association between the frequency of using household sprays and disinfectants with asthma and wheezing adjusting for potential confounders.

Results Compared with no use, high use of disinfectants was associated with a more than twofold increased odds of incident asthma (OR 2.79, 95% CI 1.14 to 6.83). In addition, low/medium use of disinfectants was associated with remittent asthma (OR 2.39, 95% CI 1.29 to 4.47). The evidence for an association between high usage of household sprays and asthma incidence was weak (OR 2.79, 95% CI 0.84 to 9.20).

Conclusion Our results support the hypothesis of an association between the use of cleaning products and elevated risks for asthma and wheezing in young adults at the start of working life.

INTRODUCTION

With more than 300 million people being affected, asthma is a major cause of morbidity on a global scale.¹ Among children, it is the most frequent chronic disease leading to a considerable number of disability-adjusted life-years.² It also builds a substantial economic burden due to direct and indirect medical costs.³ Its prevalence, however, varies remarkably between different regions of the world.⁴ This fact may be explained by sizeable regional differences in the presence of risk factors for the disease.⁵ Potential determinants that are discussed include genetic, lifestyle, occupational and environmental factors.^{6,7}

What this paper adds

- Studies examining health risks in cleaners suggest that exposure to cleaning agents is associated with an increased risk of asthma and wheezing.
- This is one of the first studies to investigate the effects of domestic use of cleaning products and respiratory outcomes in young adults.
- Our results point towards an association between the private use of disinfectants and asthma incidence in young adults.
- While further research should disentangle the underlying pathological mechanisms, awareness campaigns to enhance the general knowledge about detrimental health effects of sprays and disinfectants as well as development of less harmful products could be useful preventive measures in the mean time.

Among the latter, indoor exposures constitute an especially meaningful group as people spend the vast majority of their time within buildings—at the workplace and in their home environment.⁶ One group of agents that are mainly used indoors are household cleaning sprays and disinfectants. Their role in the aetiology of asthma has been scrutinised by several studies.^{8–11} A systematic review published in 2014 identified 24 such studies and concluded that there is sufficient evidence to postulate an association between occupational exposure to cleaning products and elevated risks for asthma and rhinitis.¹²

However, almost all published studies so far included professional cleaners as study population while the number of studies targeting non-professional use of cleaning products is much smaller. One analysis within the European Community Respiratory Health Survey examined the role of non-professional use of household cleaners and observed good indication to assume an association of these products with new-onset asthma in adults.¹³ The Epidemiological Study on the Genetics and Environment of Asthma (EGEA) investigated this association in middle-aged women and yielded similar results.¹⁴ Nevertheless, further confirmation by other studies is required and the underlying pathological mechanisms are largely unknown.^{15,16}

In addition, as far as the authors are aware, all studies until now included adult populations. To



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our knowledge, there are no studies yet that elucidated the association between the private use of household cleaning products and asthma in young adults. One very recently published study examined the effects of cleaning products on rhinitis in Chinese primary school children and observed good evidence for such an association. However, no data on additional respiratory outcomes such as asthma were available.¹⁷ Investigating this association in young adults might be especially interesting as this is the age when they start to live on their own and thus to use cleaning products themselves.

The aim of this analysis was, thus, to investigate the potential association of the private use of household cleaning sprays and disinfectants with asthma incidence in young adults in the transition from school to working life. To achieve this goal, we analysed longitudinal data from a population-based cohort study conducted in two major German cities.

METHODS

Study sample

The present analysis forms part of the Study on Occupational Allergy Risks (SOLAR) II. The study design has been described in detail elsewhere.¹⁸ In short, SOLAR II is the second follow-up of a cohort that was initially recruited between 1995 and 1996 for the German part of Phase II of the International Study of Asthma and Allergies in Childhood (ISAAC).¹⁹ The ISAAC study collected information on potential risk factors for wheezing, atopic rhinitis and eczema in a sample of 6399 children at the age of 9 to 11 years living in the cities of Dresden and Munich. The first follow-up (SOLAR I) was conducted in 2002 and 2003 and included 3785 participants between 16 and 18 years of age. SOLAR I investigated the course of asthma and atopy and their potential association with environmental as well as occupational factors such as current state of employment or holiday jobs.^{20 21} Between 2007 and 2009, 2051 young adults (response: 70.6%) aged 19–24 years took part in SOLAR II. Participation included clinical examination and answering a questionnaire that assessed the same environmental and occupational factors as SOLAR I while collecting additional information on family status, parenthood, work-related stress, hand eczema and private as well as occupational exposure to cleaning sprays, disinfectants, fumes and gas. The main outcomes of interest were asthma, allergic rhinitis and atopic dermatitis in early work life.^{7 22} As for the present analysis, the main exposure of interest was private use of cleaning agents and disinfectants, participants that reported to work in healthcare or cleaning services were excluded (n=356). Thus, we analysed data from 1695 young adults. [Figure 1](#)

illustrates the follow-up process from ISAAC Phase II to SOLAR II.

Exposure assessment

The questions on use of sprays and disinfectants are based on the European Community Respiratory Health Survey.²³ They can be found in detail at <http://www.ecrhc.org>. Participants were asked if they used one or more of the following sprays/disinfectants on 0, <1, 1–3 or 4–7 days per week:

- ▶ Sprays: furniture spray, glass cleaner, sprays for carpets or drapes, oven cleaner, ironing spray, room spray, cleaning spray, personal hygiene spray, any other spray.
- ▶ Disinfectants: spray disinfection, hand wash disinfection, disinfection with the machine, cleaning surfaces with a sponge with disinfectant, scrubbing the floor with disinfectant, other disinfection methods.

Following the approach used by other projects with similar research questions,^{17 24 25} we constructed a composite score variable for sprays and disinfectants, respectively. For each agent, the participants received a score based on the frequency of use per week: never use=0, <1 day=1, 1–3 days=2 and 4–7 days=3. The composite score was the sum of the scores for each agent. As the questionnaire asked for nine different sprays, the range for the composite score of sprays was 0–27 while the range for the total score of the six different disinfectants was 0–18. Ultimately, these two scores were used to classify subjects into one of four categories for the frequency of use of sprays and disinfectants, respectively: ‘no use’ (score=0), ‘low use’ (score between 1 and the median), ‘medium use’ (score between the median and the 90th percentile) and ‘high use’ (score above the 90th percentile). This categorisation was used for the primary statistical analysis.

Outcome definition

‘Current asthma’ considered the participants as diseased if they reported physician-diagnosed asthma and either wheezing without cold or use of asthma medication within the last 12 months prior to the survey. ‘Current wheezing’ took into account if the participant indicated wheezing without cold or use of asthma medication within the last 12 months prior to the survey irrespective of a physician’s diagnosis. This definition was used at all stages of follow-up throughout the study.

To analyse the development of asthma from ISAAC II to SOLAR II, we built four mutually exclusive categories (never, incident, persistent and remittent) for asthma and wheezing. The group ‘never asthma’ comprises those participants who did not

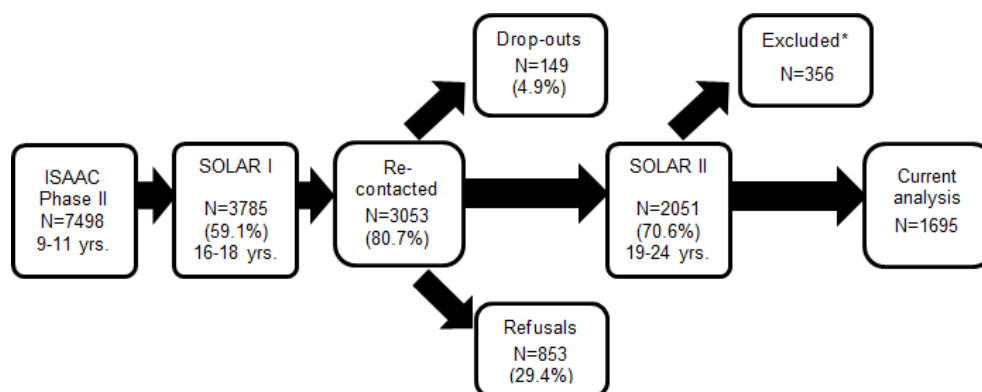


Figure 1 Flow chart of follow-up from ISAAC Phase II to SOLAR II and the current analysis including number of participants, participation rate and participant’s age at each period of follow-up.

report the respective outcome at any of the three stages. Those subjects who did not indicate asthma in ISAAC II and SOLAR I but gave a positive answer in SOLAR II build the group 'incident asthma'. In case of presence of asthma in ISAAC II and/or SOLAR I, participants were categorised as 'persistent asthma' if they also reported asthma in SOLAR II and classified as 'remittent asthma' in case of a negative response during the last stage. The same approach was chosen to classify wheezing into 'never wheezing', 'incident wheezing', 'persistent wheezing' and 'remittent wheezing' (see online supplementary S1).

Potential confounders

As potential confounders we considered sex, age, socioeconomic status (SES), study location, smoking status, occupational status and previous job-related exposure to sensitising agents. SES was derived from information on participants' educational level with at least 12 years of school attendance considered as high SES and less than 12 years as low SES. Regarding smoking, participants were asked if they had ever smoked (ie, at least one cigarette per day for 1 year or longer) and if they currently smoked (ie, within the last month). For further analysis, they were classified as never, former or current smokers. Regarding their occupational status, participants could choose one of the following categories: apprentice, student, employed, self-employed, job seeking, not working due to poor health, homekeeper, parental leave and other. Moreover, an asthma-specific job exposure matrix based on the International Standard Classification of Occupations, ISCO-88, was used to categorise all the jobs reported by the participants as no risk, low-risk or high-risk occupation for asthma according to the job-related exposure to sensitising and irritative agents.²⁶ Participants reporting a job with high-risk exposure were classified into the high-risk group, while those who did not have any high-risk job but at least one with low-risk exposure were considered as having low-risk occupational exposure. Those subjects who did not report any job with either low risk or high risk for asthma were included in the no risk group.

Sensitivity analysis

Although we excluded participants working in the health sector or cleaning services and took asthma-specific job exposures into account as potential confounders, we aimed at validating our results by specifically looking at a subgroup most likely free of any relevant occupational exposure. Therefore, we conducted a sensitivity analysis including only those participants who reported to currently be students and who had not had any high-risk job for asthma so far.

Statistical analysis

The first part of the statistical analysis describes the distribution of the variables in the study sample showing absolute numbers (n) and percentages (%) for the categorical variables and arithmetical mean and SD for the continuous variable age. Then, multinomial logistic regression models were used to compare the groups incident asthma, persistent asthma and remittent asthma to the group never asthma as well as incident wheezing, persistent wheezing and remittent wheezing to the group never wheezing. All models calculated regression coefficients, ORs and 95% CI for the association between the exposure and the two outcome variables. The main exposure variables were the above-described frequency categories for spray and disinfectant use (no, low, medium and high use) with the 'no use' category serving as the reference group in all analyses. For the models examining disinfectants as exposure variable, the classification

of frequency of the exposure had to be changed to the effect that low and medium use of disinfectants were merged into one common category to have sufficient numbers of subjects in every exposure category. All models were adjusted for the a priori chosen confounders sex (female/male), age (continuous in years), socioeconomic status (low/high), study centre (Dresden/Munich) and smoking status (never/former/current smoker). The other potential confounders were included based on a change-in-estimate-criterion with a cut-off of 10%. For the sensitivity analysis, the analysis strategy and technique remained the same. Missing data were assumed to be missing at random and imputed using Markov chain Monte Carlo methods with $m=10$ imputations.

The statistical analyses were performed with SPSS V.23 and STATA V.12.

RESULTS

Descriptive statistics

Slightly more participants (55.6%) were female and about two-thirds of the subjects were classified as having high SES (table 1). With respect to the exposure variables, about 20% of the sample reported no use of sprays while more than two-thirds used sprays at least once a week. Concerning disinfectants, the vast majority of the study sample (83.8%) reported having not used any of them (table 1). A detailed description of the usage patterns of sprays and disinfectants can be found in online supplementary S2.

For both outcome variables, all study subjects were allocated to one of the four outcome groups as defined above. Of the participants, 5.4% reported current asthma; 28 (1.7% of the total sample) did not report asthma prevalence during the earlier stages and were thus counted as incident cases while 62 subjects (3.7%) indicated persistent asthma (figure 2). Regarding the second outcome variable, 289 participants (17.1%) indicated wheezing without cold or use of asthma medication within the last 12 months. Of these, 123 (7.3% of the total sample) reported new onset of wheezing. Slightly more subjects (9.9%) were classified into the persistent wheezing group (figure 2).

Association between exposure variables and current asthma

The adjusted multinomial logistic regression models yielded no clear indications for the association of spray use and asthma occurrence (table 2). Only for incident asthma versus never asthma, those with high use of sprays tended to have elevated odds compared with the no use group (OR 2.79, 95% CI 0.84 to 9.20). With regards to disinfectants, the OR for high use versus no use was statistically significantly related to incident asthma (OR 2.79, 95% CI 1.14 to 6.83) with some hints towards a dose-response relationship. In addition, the results indicated that low/medium use of disinfectants is associated with remission of asthma (OR 2.39, 95% CI 1.29 to 4.47).

Association between exposure variables and current wheezing

The results from the adjusted multinomial logistic regression analysis for current wheezing as outcome variable are shown in table 3. We observed no clear associations between exposure variables and current wheezing. However, there was a hint towards increased odds of incident asthma in association with low (OR 1.53, 95% CI 0.88 to 2.65), medium (OR 1.34, 95% CI 0.75 to 2.39) and high (OR 1.71, 95% CI 0.80 to 3.67) use of sprays compared with no use of sprays.

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Table 1 Description of the demographic and exposure variables in the study sample (n=1695)

	Missing	Mean	SD
Age (years)	0	21.8	0.75
	Missing	n	%
Sex	0		
Female		938	55.6
Study centre	0		
Dresden		845	49.9
Socioeconomic status	8		
High		1103	65.1
Smoking status	15		
Never smoker		926	55.1
Ex-smoker		156	9.3
Current smoker		598	35.6
Current occupation	0		
Apprentice		259	15.3
Student		829	48.9
Employed		459	27.1
Self-employed		19	1.1
Job seeking		77	4.5
Not working due to poor health		6	0.4
Homekeeper		2	0.1
Parental leave		24	1.4
Other		20	1.2
Occupational exposure to sensitising agents	0		
Never worked		399	23.5
Only no risk jobs		558	32.9
At least one low risk job		330	19.5
At least one high risk job		408	24.1
Spray use*	27		
No use		341	20.4
Low use		653	39.1
Medium use		535	32.1
High use		139	8.3
Disinfectant use*	131		
No use		1310	83.8
Low/medium use		127	8.1
High use		127	8.1

*No use: composite score=0; low use: score between 1 and the median; medium use: score between the median and the 90th percentile; high use: score above the 90th percentile.

Table 2 Results from the multinomial logistic regression models for the association between spray/disinfectant use and incident asthma versus never asthma, persistent asthma versus never asthma and remittent asthma versus never asthma (n=1695)

	Incident asthma*		Persistent asthma*		Remittent asthma*	
	OR	95% CI	OR	95% CI	OR	95% CI
Spray use						
No use	Reference		Reference		Reference	
Low use	0.70	0.23 to 2.06	0.66	0.34 to 1.28	0.91	0.46 to 1.80
Medium use	0.78	0.26 to 2.36	0.65	0.32 to 1.29	0.99	0.50 to 1.97
High use	2.79	0.84 to 9.20	0.55	0.18 to 1.63	1.52	0.65 to 3.55
	95% CI					
Disinfectant use						
No use	Reference		Reference		Reference	
Low/medium use	1.55	0.51 to 4.71	1.79	0.82 to 3.91	2.39	1.29 to 4.47
High use	2.79	1.14 to 6.83	1.70	0.79 to 3.65	1.15	0.49 to 2.70

*Compared with never asthma.

All models adjusted for age, sex, socioeconomic status, smoking and study centre.

Sensitivity analysis

Overall, 633 participants reported currently being students and not to have had any high-risk job for asthma so far. In this subgroup, no evidence for an association between spray use and incident asthma was found while high use of sprays was associated with remittent asthma (OR 4.18, 95% CI 1.13 to 15.48). Concerning disinfectants use, due to insufficient absolute numbers, we had to dichotomise this variable into 'use versus no use' for the sensitivity analysis with asthma as outcome. No association between disinfectants use and asthma was indicated by the regression models. In regards to the endpoint wheezing only, low (OR 2.60, 95% CI 1.01 to 6.67) and high use of sprays (OR 3.32, 95% CI 1.05 to 10.43) were associated with increased odds of this outcome. In addition, those participants with low/medium use of disinfectants had more than two times the odds of wheezing than those with no disinfectants use (OR 2.59, 95% CI 1.05 to 6.34) (see online supplementary S3).

DISCUSSION

The present paper investigated the association between the use of cleaning products and asthma in young adults. Longitudinal data from a cohort of 1695 young people living in two major

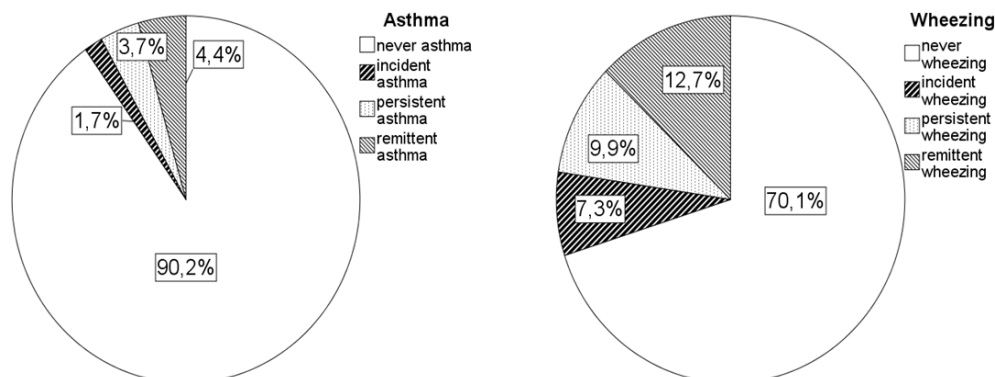
**Figure 2** Distribution of the outcome categories never asthma/wheezing, incident asthma/wheezing, persistent asthma/wheezing and remittent asthma/wheezing in the study sample.

Table 3 Results from the multinomial logistic regression models for the association between spray/disinfectant use and incident wheezing versus never wheezing, persistent wheezing versus never wheezing and remittent wheezing versus never wheezing (n=1695)

	Incident wheezing*		Persistent wheezing*		Remittent wheezing*	
	OR	95% CI	OR	95% CI	OR	95% CI
Spray use						
No use	Reference		Reference		Reference	
Low use	1.53	0.88 to 2.65	1.02	0.65 to 1.61	0.97	0.64 to 1.46
Medium use	1.34	0.75 to 2.39	0.97	0.60 to 1.57	1.03	0.67 to 1.58
High use	1.71	0.80 to 3.67	1.24	0.65 to 2.39	1.30	0.73 to 2.30
Disinfectant use						
No use	Reference		Reference		Reference	
Low/medium use	1.08	0.60 to 1.98	1.22	0.74 to 2.01	0.79	0.47 to 1.30
High use	0.79	0.40 to 1.56	0.98	0.56 to 1.70	0.94	0.58 to 1.52

*Compared with never wheezing.

All models adjusted for age, sex, socioeconomic status, smoking and study centre.

German cities were used to analyse the effects of two different categories of cleaning agents (sprays and disinfectants) on two separate definitions of asthma—one based on a physician's diagnosis and wheezing or asthma medication and one based on wheezing only.

Our results support the hypothesis that high frequency of disinfectants use is associated with increased odds of asthma incidence. In addition, we observed some evidence for a similar risk increment due to domestic usage of sprays. The latter was especially evident in the sensitivity analysis only regarding students without prior occupational exposure to sensitising agents. This finding is especially interesting as in this subgroup we can be mostly sure that the effects are not influenced by any occupational exposure. However, this effect could only be seen for wheezing as an outcome, not for asthma incidence. This is likely due to insufficient statistical power in the sensitivity analysis.

In general, our findings are in line with other studies investigating health effects of cleaning agents. For example, the EGEA study reported similar effect estimates for the association between domestic use of cleaning products and asthma occurrence in a slightly older sample.¹⁴ Whereas other studies, for example, the European Community Respiratory Health Survey, observed an effect of weekly use compared with no weekly use of cleaning agents on asthma,¹³ our investigation yielded evidence for an association only in those participants categorised as having a high use of cleaning products. The most likely explanation is that the general level of exposure in our sample is comparatively low so that an effect can only be seen in the highest exposure group.

The strength of our study is that our sample is composed of non-professional users of cleaning products. Therefore, we can be reasonably confident that we had a truly unexposed reference group. A related strength is the age of our participants. As all our subjects were in the age of 19–24 years, we captured the period when—at least in Germany—young people start to live on their own and thus most likely start to use cleaning products regularly. Hence, we could observe the effects of these products right at the beginning of users' exposure.

What is somewhat harder to explain is the observed association between low to medium use of disinfectants and remittent asthma since a protective effect of cleaning agents would obviously stand in stark contrast to the assumed deleterious effect. This observation results from the comparison never asthma versus remittent asthma because we chose never asthma as the comparison group for the multinomial regression models. We took this comparison group because our main interest was the potential effect of cleaning agents on incident asthma versus never asthma. However, comparing remittent to persistent asthma, no substantial differences can be seen as the effect estimates are very similar and the confidence intervals are overlapping. This indicates that cleaning products do not significantly determine whether asthma abates or not. An alternative explanation might be a 'healthy home-cleaning effect' in the sense that some people who developed asthma at some point stop or reduce their use of cleaning agents and therefore report less exposure than people without asthma.¹⁴

Furthermore, it might seem surprising that we observed some effects for asthma incidence as an outcome while less clear associations for wheezing can be seen. As the latter has a more relaxed definition, it also encompasses the larger absolute number of diseased subjects and subsequently more statistical power to detect associations. On the downside, a more unspecific outcome definition also bears the hazard of non-differential misclassification and thus bias towards the null. This can be especially a problem when relying on self-reports rather than objective measures as it is the case in our study. In addition, for the association between spray usage and incident wheezing, all effect estimates for low, medium and high frequency of use point towards an effect, although the statistical evidence was weak.

A related limitation of our study is that exposure assessment was also based on self-reports that may be prone to recall bias. This could distort the results in any direction, depending on the question if there is a systematic difference in recall between diseased and non-diseased. As usage of cleaning products was not declared as the main exposure under investigation in the invitation letters to the participants, it seems unlikely that there is substantial overestimation of usage among the diseased. Thus, if there is misreporting, it is more probable that it is non-differential between diseased and non-diseased leading to an underestimation of the true effects of cleaning agents on the outcome. Another limitation regarding exposure assessment is that we do not have information on participants' exposure to cleaning agents at their parent's home or the potential use of such agents by their flatmates at their new homes. Having said this, as for recall bias, it seems unlikely that any such effect differs systematically between diseased and non-diseased participants. What would have been very interesting is to include data on use of cleaning products from the earlier stages of follow-up to make even better use of the longitudinal data. Unfortunately, ISAAC phase II and SOLAR I did not include such questions and the nature of our analysis does not allow to draw causal inferences. As another follow-up is currently in the works, further longitudinal analyses will be possible in the future. In addition, as we will also collect information on the offspring of the cohort members, potential transgenerational effects will be able to be investigated.²⁷ This is a very promising approach as there is already some indication that the use of cleaning agents during pregnancy might also influence the risk of respiratory disease in the offspring.²⁸

Another limitation of our study is that we could only use composite scores for all sprays and all disinfectants because we

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did not have sufficient absolute numbers to examine specific effects of single cleaning agents. This might have been helpful to enhance the knowledge regarding underlying mechanisms which is relatively scarce.⁹ In general, it is not fully clarified yet if the putative effects can be mainly explained by airway irritation or sensitisation or by an interplay of both mechanisms.⁸ One hypothesis is that inhalation of cleaning products could lead to the onset of asthma by airway irritation, which would induce bronchial epithelial damage, and by inducing sensitisation to specific agents such as amine compounds (eg, monoethanolamine).^{10 16 24} In addition, studies from occupational settings point towards bronchial reactions consistent with sensitiser-induced occupational asthma, localised airway inflammation, lower respiratory tract symptoms as potential mechanisms.^{15 29–31} Studies including specific methods for detailed exposure assessment may help to better understand these mechanisms.⁹

Concerning the potential of selection bias, previous analyses from the SOLAR cohort imply that this type of bias does not play a major role in this study.^{7 32} On top of this, as cleaning products were not mentioned in the invitation letters, it seems very implausible that especially those people with extremely low or high use of cleaning agents were more likely to participate. Thus, we can be reasonably confident that selection bias will not have had a major influence on our results.

Because the association of cleaning agents with respiratory disease is still not fully understood, it is difficult to say if our results are affected by yet unknown confounding variables. Given the current scientific knowledge, we do not assume that confounding has considerable impact on our results, especially as adjusting for current occupation and prior exposure to sensitising agents did not change our effect estimates.

Considering the potential public health impact, given the assumed association is indeed causal, due to their widespread use in the general population, any deleterious health effects of cleaning agents may have considerable consequences on the population level.^{14 24} To prevent new cases of respiratory disease related to spray products, campaigns to increment the awareness about potential detrimental health effects and the development of less harmful cleaning products might be useful measures.¹⁷

CONCLUSION

Although no causal conclusion can be drawn, our results support the hypothesis of an association between the use of cleaning products and elevated risks for respiratory disease. Moreover, this is one of the first studies that specifically scrutinised domestic use of sprays and disinfectants in a younger age group. Future studies with more detailed exposure assessment may help to illuminate the underlying pathological mechanisms. In the mean time, awareness campaigns to enhance the general knowledge about detrimental health effects of cleaning agents and developing less harmful products could be useful preventive measures.

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Contributors TW was primarily responsible for data analysis and drafting the manuscript. CV, JG, KR and SH are principle investigators of SOLAR (Study on Occupational Allergy Risks) being in charge of the design, coordination and conduct of the study. DN, EvM and JG contributed to the planning and conception of the study. IM, SA-K, SL, TL and VW were involved in planning and conducting the statistical analysis and drafting the paper. All authors critically appraised and approved the final manuscript.

Competing interests None declared.

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