Frequent use of household cleaning products is associated with rhinitis in Chinese children

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Background: Despite the popular use of household cleaning products worldwide, there is no published study investigating the health effects of these products on rhinitis in children.
Objective: We sought to investigate the household use of cleaning products and rhinitis patterns in Chinese children.
Methods: A total of 2299 children were recruited from 21 primary schools with wide geographic coverage in Hong Kong. Self-administered questionnaires were completed by parents/guardians to collect detailed information on respiratory symptoms and household use of 14 types of chemical cleaning products, as well as clean water. Students were categorized into 4 mutually exclusive rhinitis patterns (never, occasional, frequent, and persistent). The total chemical burden (TCB) score was used as the exposure indicator by calculating the total time of exposure to the 14 cleaning products. Multinomial logistic regression was used to assess the relationship between rhinitis patterns and the use of household cleaning products.
Results: Every 10-unit increment of TCB score was associated with an increase in the odds of occasional (odds ratio [OR], 1.21; 95% CI, 1.05-1.41), frequent (OR, 1.36; 95% CI, 1.13-1.60), and persistent (OR, 1.21; 95% CI, 1.01-1.56) rhinitis after adjustment for a wide range of potential confounders. Compared with the children within the lowest tertile of TCB scores, the adjusted ORs of occasional, frequent, and persistent rhinitis in children within the highest tertile were 1.29 (95% CI, 1.01-1.65), 1.97 (95% CI, 1.40-2.76), and 1.67 (95% CI, 1.10-2.54), respectively.
Conclusion: Frequent use of chemical cleaning products at home is associated with an increase in the odds of rhinitis in Chinese primary school children. (J Allergy Clin Immunol 2016;138:754-60.)

Key words: *Rhinitis, household cleaning products, school-age children*

Household cleaning products are commonly used worldwide to enhance domestic cleanliness and hygiene. Despite their apparent benefits, they can also be of significant concern with regard to indoor air pollution. With their different functions and the various scents added to many of them, a wide range of chemicals could be involved in the active ingredients.[1]

Despite their common use among the general population, there is limited information on the health effects of such cleaning products. Studies of occupational exposure to cleaning products have shown that there is an increased risk of asthma and rhinitis among cleaning workers,[2] and this suggests that there is potential hazardous exposure to cleaning products in the general population. Studies in adult women, who are generally the primary users of these household cleaning products in the home, indicate that the frequent use of cleaning products and hypochlorite bleach might be important factors in adult asthma and respiratory symptoms.[3-6] Children are certainly vulnerable because of their longer stay time at home, smaller lung airways, and immature immune system.[7] We speculate that the health effect of the exposure to household cleaning products in children can be significant. Several birth cohorts have shown that prenatal use of cleaning products might increase the risk of wheezing, infections, and other respiratory symptoms in early life[8,9] and in preschool children.[10,11] Only a few studies have investigated the respiratory health effect of the current use of cleaning products, and the controversy remains: Nickmilder et al[12] found a protective effect of cleaning products on asthma and allergic sensitization, whereas Casas et al[13,14] showed adverse effects on wheezing and pulmonary function.

To our knowledge, there are no published studies that assess the health effects of cleaning products on rhinitis in children. Rhinitis is one of the most common respiratory conditions. It is an irritation and inflammation of the mucous membrane lining of the nose characterized by stuffy nose, runny nose, sneezing, rhinorrhea, and postnasal drip for 2 or more consecutive days and lasting for more than an hour on most days.[15] Rhinitis causes a considerable global burden with significant damage to the economy, and it has a remarkable influence on the quality of the life.[16] It has also emerged as a common condition associated with substantial morbidity in childhood.[17-19] The International Study of Asthma and Allergies in Childhood has reported that the prevalence of lifetime and current rhinitis has increased significantly in school-age children.[20] Therefore we investigated the health effects of common cleaning products on rhinitis in a large population of Chinese children.

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Abbreviations used
OR: Odds ratio
PCFA: Principal components and factor analysis
$PM_{2.5}$: Particulate matter of less than 2.5 μm in diameter
TCB: Total chemical burden

METHODS

Setting and participants

The present data analysis is from an ongoing longitudinal prospective cohort study[21,22] that aims to investigate the respiratory health effects of indoor air pollution. The sample size was calculated by using EpiTools calculators.[23] The rhinitis prevalence in our pilot study was about 20%, the effect size for rhinitis was 1.30 (95% CI, 1.20-1.40) among children,[24] and a total of 2058 students were estimated to reach a statistical power of 90% with a confidence level of 0.95. To compensate for possible attrition and take into account the needs of other research questions, we planned to recruit around 2400 students at the beginning of the study.

During the study, a total of 21 primary schools were randomly selected in the 4 regions (Hong Kong/outlying islands, Kowloon, New Territories East, and New Territories West) of Hong Kong. To facilitate spirometry and the follow-up, all students from grades 2 to 4 in each school were invited to participate in the study. A total of 2477 students were recruited, and baseline data were successfully collected for 2415 (97.5%) students in 2012 and 2013. We plan to follow-up the students twice during a 2-year period (once per year). The first round of follow-up was completed at the end of 2014. One school withdrew from the study during the first round of follow-up, but the follow-up data collection was successfully completed for a total of 2299 children.

In both the baseline and first follow-up surveys, the parents or guardians of each participant were required to complete a detailed self-administered questionnaire. The questionnaire was composed mainly of items adopted from the questionnaires of the American Thoracic Society, the International Study of Asthma and Allergies in Childhood studies, and the European Community Respiratory Health Survey.[25-28] The questionnaire collected extensive information on each child's respiratory health status, including respiratory symptoms, allergic symptoms, and respiratory problems. Each participant also received a health examination that measured anthropometric parameters and pulmonary function in both the baseline and first follow-up surveys. This study was approved by the Joint Chinese University of Hong Kong–New Territories East Cluster Clinical Research Ethics Committee. The students' parents or guardians were required to sign a written informed consent form for their children to participate in the study.

Data collection

Rhinitis. Questionnaires were completed by parents or guardians at baseline and follow-up to collect information on noninfectious rhinitis in the children. Noninfectious rhinitis was defined as affecting those children who have "ever had nasal symptoms such as nasal blockage, sneezing, and running nose as well as itching eye or lachrymation in the absence of common cold in previous 12 months." Those who answered "yes" were asked to state the months when they experience rhinitis. The baseline questionnaire collected information from the previous 12 months before the baseline interview. The follow-up questionnaire collected information during the 1-year follow-up period. The 24-month period was then divided into 8 mutually exclusive seasons relevant to Hong Kong's weather: 2012 winter (December 2011 to February 2012), 2012 spring (March 2012 to May 2012), 2012 summer (June 2012 to August 2012), 2012 autumn (September 2012 to November 2012), 2013 winter (December 2012 to February 2013), 2013 spring (March 2013 to May 2013), 2013 summer (June 2013 to August 2013), and 2013 autumn (September 2013 to November 2013). Each student was categorized into one of the 4 mutually exclusive rhinitis patterns, namely never (no rhinitis in any season), occasional (had rhinitis in <3 seasons), frequent (had rhinitis in ≥3 seasons but did not have rhinitis in ≥4 consecutive seasons), and persistent (had rhinitis in ≥4 consecutive seasons).

Exposure to household cleaning products. Information on exposure to household cleaning products was collected by questionnaire. "Did you use the following household cleaning products at home in the previous 12 months?" was one of the required questions on the baseline survey. The 14 common types of chemical cleaning products included those for cleaning the bathroom, floor, glass, kitchen, tiles, and leather; multipurpose cleaners; nonchlorinated bleach; chlorinated bleach; sanitizers; scented air fresheners; nonscented air fresheners; insecticides; and others. If the response was "yes" to any type of these cleaners, then information on the weekly use frequency (<1 time, 1-3 times, 4-6 times, and ≥7 times) and the average duration of each use (<15 minutes, 15-30 minutes, 31-45 minutes, 46-60 minutes, and >60 minutes) was collected. In addition, information on the use of clean water only for cleaning the home environment was also sought.

Potential confounding factors. Information on a wide range of potential confounders was also collected. We used a questionnaire to collect information on age (years), sex (male and female), average house size for each member (in square meters), present at home when using cleaning products (yes vs no), windows opened when using cleaning products (yes vs no), keeping a pet at home (yes vs no), keeping a plant at home (yes vs no), burning incense or mosquito coil at home (yes vs no), home renovation (yes vs no), passive smoking at home (yes vs no), exercise per week (never/less than once per week, once to twice per week, or ≥3 times per week), education of mother and father (primary school or lower, secondary school, tertiary school, or greater), and atopic status. Atopic status was defined based on self-reported doctor-diagnosed eczema, asthma, or both (yes vs no). In addition, each student received a simple health examination to measure weight and height at school in baseline and follow-up surveys, and then body mass index (in kilograms per meter squared) was calculated by using data from the latest survey. The level of particulate matter of less than 2.5 μm in diameter ($PM_{2.5}$; in microgram per cubic meter) in the school environment was measured in the first year by using the DustTrak (TSI, Shoreview, Minn) aerosol monitor. To address seasonal variation, we conducted 2 measurements; one in the cool season (winter and spring), and the other in the warm season (summer and autumn). The average level was used in the present analysis.

Statistical analysis

Statistical analyses were performed with R software (version 3.1.2). All *P* values were derived from 2-sided statistic tests, and a value of less than .05 was considered statistically significant.

Because the use frequency and duration variables were categorical, we used the midpoint value of each category for score calculation (ie, frequency: we used 0.5, 2.0, 5.0, and 8.5 for <1 time, 1-3 times, 4-6 times, and ≥7 times, respectively; duration: we used 7.5, 23.0, 38.0, 52.5, and 75 for <15 minutes, 15-30 minutes, 31-45 minutes, 46-60 minutes, and >60 minutes, respectively). The total chemical burden (TCB) score was calculated to indicate exposure level to the 14 types of chemical cleaning agents for each participant. The TCB score was defined as the cumulative time of exposure to 14 chemical products, and the formula was as follows:

$$TCB = \sum_{i=1}^{14} (Fre_i \times Dur_i),$$

where *Fre* refers to the weekly frequency of use of a certain chemical product, *Dur* refers to the average duration of each use, and *i* represents the specific chemical cleaning product.

Cleaning product use patterns were extracted by using the principal components and factor analysis (PCFA) method based on 14 types of chemical cleaning products, as well as clean water (package "princomp"). The statistical score of each participant in each use pattern was generated by using the regression method. Orthogonal (varimax) transformation was adopted to achieve a simple structure with greater interpretability. In determining the number of factors to retain, eigenvalues (>1.0), the scree plot construction, the Kaiser-Meyer-Olkin measure of sampling, the Bartlett test of sphericity, and the interpretability of the factors were considered.[29,30] Cleaning products with absolute rotated factor loadings of 0.50 or greater are referred to as dominant components hereafter. The labeling of factors was based on our interpretation of the data. A positive loading for a cleaning product indicated a direct

TABLE I. General characteristics of the students at baseline

Variables	Value
	Mean (SD)
Age (y)	10.1 (0.9)
BMI* (kg/m^2)	17.9 (3.3)
Average size of house for each member (m^2)	13.2 (7.6)
Concentration of $PM_{2.5}$ in each school ($\mu g/m^3$)	42.1 (32.4)
	No. (%)
Male sex	1,114 (48.5)
Present at home when cleaning products used, yes	978 (42.5)
Atopic status, yes	326 (14.2)
Windows opened during cleaning, yes	2278 (99.1)
Keeping a pet at home, yes	305 (13.3)
Keeping a plant at home, yes	1207 (52.5)
Burning incense/mosquito coil at home, yes	760 (33.1)
Home renovation, yes	953 (41.5)
Passive smoking at home, yes	580 (25.2)
Exercise per week	
Never/less than once per week	337 (14.7)
Once or twice per week	1401 (60.9)
At least 3 times per week	561 (24.4)
Education of father	
Primary school or lower	305 (13.3)
Secondary school	1626 (70.7)
Tertiary school or greater	368 (16.0)
Education of mother	
Primary school or lower	259 (11.3)
Secondary school	1574 (68.5)
Tertiary school or greater	466 (20.3)

*Body mass index equal to weight/height squared.

association with the pattern, whereas a negative loading suggested that the cleaning product contributed inversely to the pattern.

Multinomial logistic regression models (package "nnet") were used to assess the relationship between the use of cleaning products and the rhinitis pattern, with the "never" rhinitis pattern as the reference category. Separate models were conducted by using the score as continuous and categorical variables (tertiles). A stepwise strategy was adopted to select the confounding factors. Unadjusted and adjusted odds ratios (ORs) with 95% CIs were calculated for all rhinitis patterns by comparing them with the "never" rhinitis pattern. The likelihood ratio test statistic was used to determine whether there was a linear relationship between TCB score and rhinitis patterns.[10] For each rhinitis pattern, there was no evidence against the hypothesis that the effect of the TCB score is linear (occasional rhinitis: $P = .039$; frequent rhinitis: $P < .001$; and persistent rhinitis: $P = .001$). The test for trend was performed when the tertile was taken as a numeric variable in the model.

RESULTS

A total of 2299 children with complete information were included in the analysis. Table I presents the general characteristics of the participants at baseline. Mean age was 10.1 years (SD, 0.9 years), and mean body mass index was 17.9 kg/m^2 (3.3 kg/m^2). Of total participants, 48.5% were boys.

Regarding the rhinitis pattern, 1260 (54.8%) students were grouped into the never, 798 (34.7%) occasional, 135 (5.9%) frequent, and 106 (4.6%) persistent rhinitis categories. No significant difference was found between boys and girls in the distribution of rhinitis patterns ($P = .443$).

The students had higher exposure to clean water (2.51 h/wk), floor cleaners (1.30 h/wk), kitchen cleaners (1.15 h/wk), and bathroom cleaners (0.91 h/wk) but less exposure to nonscented air fresheners (0.04 h/wk), insecticides (0.07 h/wk), and other chemical cleaners (0.06 h/wk). The weekly exposure duration is presented in Table E1 in this article's Online Repository at www.jacionline.org. No significant differences were observed between boys and girls (all $P > .05$).

The TCB score of each participant was calculated based on the aforementioned formula. The median of the TCB score was 3.86 h/wk (interquartile, 6.34 h/wk) for boys and 3.93 h/wk (interquartile, 6.18 h/wk) for girls. There was no significant difference between boys and girls ($P = .723$). Therefore the combined data of boys and girls were used for data analysis. Fig E1 in this article's Online Repository at www.jacionline.org displays the distribution of TCB scores for all students. Five students had TCB scores of greater than 50 h/wk.

Four major factors were extracted and labeled as cleaning product use patterns I, II, III, and IV (see Table E2 in this article's Online Repository at www.jacionline.org). Pattern I was characterized by a higher factor loading of bathroom cleaners, floor cleaners, glass cleaners, kitchen cleaners, tile cleaners, leather cleaners, multipurpose cleaners, and nonchlorinated bleach; pattern II was characterized by a higher factor loading of nonscented air fresheners and insecticides; pattern III was characterized by a higher factor loading of sanitizers and scented air fresheners; and pattern IV was characterized by a higher factor loading of clean water.

The relationships between rhinitis and TCB scores are presented in Tables II and III. Every 10-unit increase in TCB score was associated with an increase in the odds of occasional rhinitis (OR, 1.21; 95% CI, 1.05-1.41), frequent rhinitis (OR, 1.36; 95% CI, 1.13-1.60), and persistent rhinitis (OR, 1.12; 95% CI, 1.01-1.56) after adjustment for potential confounders (Table II). Compared with children within the lowest tertile of TCB scores, the adjusted OR of occasional, frequent, and persistent rhinitis in children within the highest tertile was 1.29 (95% CI, 1.01-1.65), 1.97 (95% CI, 1.40-2.76), and 1.67 (95% CI, 1.10-2.54), respectively (Table III). However, no significant associations were found when comparing the middle tertile with the lowest tertile when adjusting for covariates.

Analyses of the association between the TCB score and the rhinitis patterns were repeated 14 times, each time removing one of the product types from the score, to determine whether a single type of cleaning product was responsible for any observed effect. In all cases there was no significant change in effect size. Sensitivity analysis was conducted by removing the 5 participants whose TCB scores were greater than 50 h/wk, and no significant change was observed. We also conducted analyses in atopic and nonatopic students separately, and the results are presented in Tables E3 and E4 in this article's Online Repository at www.jacionline.org. Significant positive associations were observed in nonatopic students, but no significant association was found in atopic students.

Relationships between rhinitis and the 4 use patterns of cleaning products are presented in Tables IV and V. After adjusting for potential confounders, every 1-unit increase of pattern I score was significantly associated with an increase in the odds of occasional rhinitis (OR, 1.12; 95% CI, 1.01-1.24), frequent rhinitis (OR, 1.15; 95% CI, 1.01-1.30), and persistent rhinitis (OR, 1.03; 95% CI, 1.01-1.35); similar results were observed for pattern III but not for patterns II and IV (Table IV). When TCB scores were categorized into tertiles for analysis, similar results were observed after adjustment for confounders (Table V).

Because chlorinated bleach exposure was not taken as the principle component in any patterns defined, a separate analysis was conducted, and the results are shown in Table E5 in this

TABLE II. Relationship between rhinitis pattern and TCB score (continuous)

		Unadjusted model†		Multivariable model†‡	
	No. (%)*	OR (95% CI)	*P* value	OR (95% CI)	*P* value
Never	1260 (54.8)	1.00	—	1.00	—
Occasional	594 (25.8)	1.26 (1.09-1.46)	.002	1.21 (1.05-1.41)	.012
Frequent	282 (12.3)	1.46 (1.24-1.72)	<.001	1.36 (1.13-1.60)	.001
Persistent	163 (7.1)	1.28 (1.07-1.64)	.032	1.12 (1.01-1.56)	.037

*Numbers (percentages) of students in each group.
†OR for a 10-unit increase in TCB score.
‡Adjustment for age, body mass index, sex, present at home when cleaning, average size of house for each member, concentration of $PM_{2.5}$ in each school, education of father, education of mother, windows open when cleaning, passive smoking at home, keeping a pet at home, keeping a plant at home, home renovation, burning incense/mosquito coil at home, atopic status, and frequency of exercise.

TABLE III. Relationship between rhinitis pattern and TCB score (tertile category)

	No.*			Unadjusted model‡				Multivariable model†§			
				T2 vs T1		T3 vs T1		T2 vs T1		T3 vs T1	
Rhinitis	T1	T2	T3	OR (95% CI)	*P* value	OR (95%CI)	*P* value	OR (95% CI)	*P* value	OR (95% CI)	*P* value
Never	462	431	367	1.00	—	1.00	—	1.00	—	1.00	—
Occasional	193	194	207	1.08 (0.85-1.37)	.540	1.35 (1.06-1.72)	.014	1.03 (0.81-1.31)	.811	1.29 (1.01-1.65)	.045
Frequent	68	92	122	1.45 (1.03-2.04)	.032	2.26 (1.63-3.13)	<.001	1.35 (0.96-1.91)	.088	1.97 (1.40- 2.76)	<.001
Persistent	44	48	71	1.17 (0.76-1.80)	.476	2.03 (1.36-3.03)	.001	1.08 (0.70-1.67)	.730	1.67 (1.10-2.54)	.016

*Number of students in each group. Students were divided into 3 categories according to the tertiles of TCB scores (*T1*, tertile 1; *T2*, tertile 2; and *T3*, tertile 3). Cutoff points were 2.41 and 3.16 h/wk.
†Adjustment for age, body mass index, sex, present at home when cleaning, average size of house for each member, concentration of $PM_{2.5}$ in each school, education of father, education of mother, windows open when cleaning, passive smoking at home, keeping a pet at home, keeping a plant at home, home renovation, burning incense/mosquito coil at home, atopic status. and frequency of exercise.
‡*P* values for trend tests in the unadjusted model were .015, less than .001, and less than .001 for occasional, frequent, and persistent rhinitis, respectively.
§*P* values for trend tests in multivariable models were .047, less than .001, and less than .014 for occasional, frequent, and persistent rhinitis, respectively.

article's Online Repository at www.jacionline.org. Compared with children within the lowest tertile of scores for chlorinated bleach exposure, the adjusted OR of occasional, frequent, and persistent rhinitis in children within the highest tertile was 1.16 (95% CI, 0.92-1.46), 1.29 (95% CI, 0.96-1.73), and 2.52 (95% CI, 1.73-3.66), respectively.

DISCUSSION

Despite the popular use of household cleaning products, there is little information on their health effects in primary school children. To our knowledge, this is the first study on the health effects of household cleaning products in Asian children. The results from this large population-based study indicate that frequent use of household cleaning products increases the risk of rhinitis in primary school children after controlling for a wide range of potential confounding factors.

We also examined whether a single type of chemical product has dominant effects by repeating the analysis 14 times, each time removing the chemical burden score of one type of cleaning product. No significant change was found in effect sizes, which suggests that the health effects on rhinitis might be synergic or due to total exposure to all or several types of cleaning products.

The PCFA method was applied in the present study to extract the use pattern of the cleaning products. The patterns defined by PCFA can reflect the true exposure models of using cleaning products. Pattern I represented the most common pattern of using household cleaning products, and it was significantly associated with frequent/persistent rhinitis. It was expected that there was no relationship between use pattern IV and rhinitis, because pattern IV was characterized by a factor loading of clean water. However, we did not observe a significant relationship for use pattern II but did observe a significant relationship for pattern III. We speculated that this phenomenon was possibly related to the exposure level of the chemical agents. The cumulative exposure time of sanitizers (0.60 h/wk) and scented air fresheners (0.32 h/wk) was much larger than that of nonscented air fresheners (0.04 h/wk) and insecticides (0.07 h/wk), which might explain why no significant association was observed for pattern II.

In addition to exposure level, the nature of the chemicals of each pattern also matters. To assess the role of the chemicals in each pattern, we adjusted for total pattern exposure level in the model. The significant associations remained for pattern III but disappeared for pattern I. There were no changes for patterns II and IV (data not shown). This suggested that the chemicals in pattern III might be more toxic or volatile and have a higher adverse effect on rhinitis.

Chlorinated bleach did not fall into any of the patterns, but its use was not uncommon (0.23 h/wk). Hence we assessed the effects of use of chlorinated bleach separately. Our results are consistent with those of the study by Casas et al,[14] showing that cleaning bleach has adverse respiratory health effect, but it is contrary to the study by Nickmilder et al[12] showing protective effects.

We found that TCB scores were associated with increased risk of rhinitis in nonatopic students. This is in line with the results from the Avon Longitudinal Study of Parents and Children, which showed that higher exposure to domestic chemicals during pregnancy was related to persistent wheezing and lung function abnormalities in children without atopy.[11] We did not find a significant association in atopic students. This is possibly because the number of atopic students was small in the present study.

Cleaning products consist of a number of chemical ingredients.[31] It is has been concluded that some ingredients, such as propylene glycol and glycol ethers, alkyl phenol ethoxylates, volatile organic

TABLE IV. Relationship between rhinitis patterns and scores of cleaning product use patterns (continuous)

		Unadjusted model†		Multivariable model†‡	
Rhinitis	**No. (%)***	**OR (95% CI)**	***P* value**	**OR (95% CI)**	***P* value**
Pattern I					
Never	1260 (54.8)	1.00		1.00	
Occasional	594 (25.8)	1.14 (1.04-1.26)	.008	1.12 (1.01-1.24)	.034
Frequent	282 (12.3)	1.20 (1.06-1.35)	.003	1.15 (1.01-1.30)	.041
Persistent	163 (7.1)	1.11 (0.95-1.31)	.197	1.03 (1.01-1.35)	.047
Pattern II					
Never	1260 (54.8)	1.00		1.00	
Occasional	594 (25.8)	1.07 (0.97-1.18)	.193	1.07 (0.95-1.19)	.296
Frequent	282 (12.3)	0.75 (0.57-0.99)	.043	0.80 (0.61-1.04)	.085
Persistent	163 (7.1)	0.91 (0.68-1.21)	.529	0.94 (0.73-1.21)	.576
Pattern III					
Never	1260 (54.8)	1.00		1.00	
Occasional	594 (25.8)	1.04 (0.93-1.16)	.468	1.03 (0.93-1.15)	.583
Frequent	282 (12.3)	1.27 (1.14-1.41)	<.001	1.24 (1.11-1.39)	<.001
Persistent	163 (7.1)	1.19 (1.04-1.38)	.014	1.16 (1.02-1.35)	.048
Pattern IV					
Never	1260 (54.8)	1.00		1.00	
Occasional	594 (25.8)	1.01 (0.91-1.11)	.907	0.99 (0.89-1.09)	.780
Frequent	282 (12.3)	1.20 (0.95-1.24)	.003	1.15 (0.97-1.26)	.123
Persistent	163 (7.1)	1.10 (0.94-1.28)	.254	1.04 (0.88-1.22)	.661

*Numbers (percentages) of students in each group.
†OR for a 1-unit increase in pattern score.
‡Adjustment for age, body mass index, sex, present at home when cleaning, average size of house for each member, concentration of $PM_{2.5}$ in each school, education of father, education of mother, windows open when cleaning, passive smoking at home, keeping a pet at home, keeping a plant at home, home renovation, burning incense/mosquito coil at home, atopic status, and frequency of exercise.

TABLE V. Relationship between rhinitis patterns and scores of cleaning product use patterns (tertile category)

	No.*			Unadjusted model			Multivariable model†		
	T1	**T2**	**T3**	**T2 vs T1, OR (95% CI)**	**T3 vs T1, OR (95% CI)**	P_{trend} ‡	**T2 vs T1, OR (95% CI)**	**T3 vs T1, OR (95% CI)**	P_{trend} ‡
Pattern I									
Never	456	426	378	1.00	1.00	—	1.00	1.00	—
Occasional	192	188	214	1.05 (0.82-1.33)	1.34 (1.06-1.71)§	.015	0.99 (0.78-1.27)	1.26 (0.99-1.61)	.063
Frequent	70	99	113	1.51 (1.08-2.11)§	1.95 (1.40-2.70)¶	<.001	1.36 (0.96-1.92)	1.62 (1.15-2.28)‖	.006
Persistent	49	52	62	1.14 (0.75-1.72)	1.53 (1.22-2.37)§	.037	1.03 (0.68-1.58)	1.21 (1.01-2.17)§	.033
Pattern II									
Never	400	441	419	1.00	1.00	—	1.00	1.00	—
Occasional	191	189	214	0.90 (0.70-1.14)	1.07 (0.84-1.36)	.560	0.93 (0.73-1.20)	1.09 (0.86-1.39)	.474
Frequent	124	79	79	0.58 (0.42-0.89)§	0.61 (0.51-1.00)	.061	0.64 (0.56-1.00)	0.72 (0.55-1.06)	.103
Persistent	51	57	55	1.01 (0.68-1.51)	1.03 (0.69-1.54)	.889	1.15 (0.76-1.74)	1.04 (0.68-1.58)	.872
Pattern III									
Never	457	424	379	1.00	1.00	—	1.00	1.00	—
Occasional	190	198	206	1.12 (0.88-1.43)	1.31 (1.03-1.66)§	.029	1.10 (0.86-1.4)	1.27 (0.99-1.62)	.059
Frequent	77	87	118	1.22 (0.87-1.70)	1.85 (1.34-2.54)¶	<.001	1.12 (0.79-1.58)	1.67 (1.21-2.33)‖	.002
Persistent	42	57	64	1.46 (0.96-2.23)	1.84 (1.22-2.78)‖	.004	1.39 (0.90-2.14)	1.63 (1.07-2.50)§	.025
Pattern IV									
Never	438	416	406	1.00	1.00	—	1.00	1.00	—
Occasional	198	210	186	1.12 (0.88-1.41)	1.01 (0.80-1.29)	.898	1.08 (0.85-1.38)	0.97 (0.76-1.24)	.823
Frequent	85	80	117	0.99 (0.71-1.38)	1.48 (0.89-1.83)	.110	1.01 (0.71-1.42)	1.44 (0.94-1.89)	.122
Persistent	45	60	58	1.40 (0.93-2.11)	1.39 (0.92-2.10)	.119	1.44 (0.95-2.20)	1.34 (0.87-2.05)	.195

*Numbers of students in each group. Students were divided into 3 categories according to the tertiles of pattern scores (*T1*, tertile 1; *T2*, tertile 2; and *T3*, tertile 3). Tertile 1 was taken as the reference.
†Adjustment for age, body mass index, sex, present at home when cleaning, average size of house for each member, concentration of $PM_{2.5}$ in each school, education of father, education of mother, windows open when cleaning, passive smoking at home, keeping a pet at home, keeping a plant at home, home renovation, burning incense/mosquito coil at home, atopic status, and frequency of exercise.
‡*P* value for trend test.
§$P < .05$.
‖$P < .01$.
¶$P < .001$.

compounds, EDTA, and nitrilotriacetic acid, have harmful effects.[32-35] Although to date there are no published studies that specifically focus on the use of cleaning products and rhinitis in children, our results are in line with those that have reported the adverse effects of cleaning products on various respiratory health outcomes, such as infection, wheezing, and pulmonary function.[8-11]

The present study took into account a number of potential confounding factors (including the information collected in the questionnaire and the air quality measurements in the school environment). Other strengths include a relatively large population of children and 14 types of commonly used cleaning products. In addition, we categorized the rhinitis patterns seasonally instead of monthly, and this might help reduce misclassification. The frequent/persistent patterns might minimize the confounding effect of accidental stimulus and seasonal variation because they have more serious patterns, and the persistent rhinitis pattern was defined as having rhinitis in 4 or more consecutive seasons. However, there are limitations.

First, except for the chlorinated bleach, our study could not identify specific chemical agents in the cleaning products.

Second, the temporal relationship was difficult to determine because of the cross-sectional data analysis. Families might have used more cleaning agents because their children had rhinitis. However, we did not find a relationship between pattern dominated with clean water and rhinitis, suggesting that frequent use of cleaning products might not be due to rhinitis. It is also not appropriate to use the cohort design to study rhinitis because rhinitis can occur repeatedly and it is difficult to determine the onset of rhinitis. A cohort study on the relationship between cleaning product and other respiratory outcomes (pulmonary function development) might help determine the temporal relationship.

Finally, objective measurement of the chemical level would be ideal, but it is not practical in a study with a large sample size. Many previous epidemiologic studies have adopted a questionnaire for exposure information collection, and this approach should not affect our results.

In conclusion, our study indicates that the frequent use of household cleaning products increases the risk of rhinitis, especially frequent and persistent rhinitis, which are the more serious patterns of rhinitis. Because household cleaning products are part of domestic life for most persons, their health effects are an important public health problem. More research is warranted to investigate the effects of household cleaning products on various respiratory health outcomes, such as wheezing, asthma, and pulmonary function. Our findings suggest that it is necessary to develop healthier cleaning products, and we should advise our patients to prefer clean water for cleaning their home environment.

We thank the school principals, teachers, students, and their parents/guardians for supporting this project. We also thank 2 anonymous reviewers and the editor for their valuable comments.

Key messages

- **Frequent use of chemical cleaning products at home is associated with an increase in the odds of rhinitis in primary school children.**
- **Clean water should be preferred for cleaning the home environment.**

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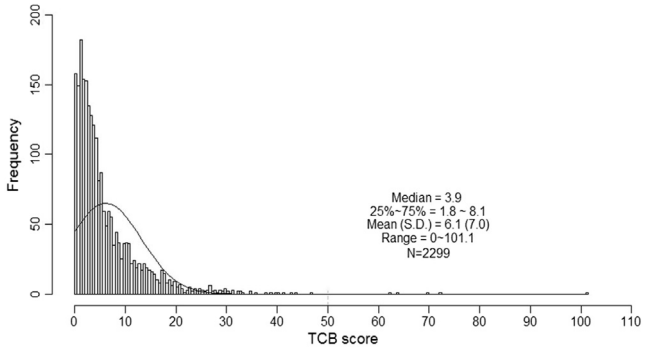

FIG E1. Histogram of TCB score.

TABLE E1. Weekly exposure of the 14 types of cleaning products and clean water

	Total*	Boys*	Girls*	*P* value†
Bathroom cleaners	0.91	0.90	0.92	.897
Floor cleaners	1.15	1.16	1.14	.989
Glass cleaners	0.22	0.22	0.23	.857
Kitchen cleaners	1.30	1.32	1.29	.422
Tile cleaners	0.29	0.31	0.27	.488
Leather cleaners	0.11	0.11	0.11	.306
Multipurpose cleaners	0.48	0.46	0.49	.168
Nonchlorinated bleach	0.34	0.34	0.34	.911
Chlorinated bleach	0.23	0.21	0.25	.651
Sanitizers	0.60	0.56	0.64	.190
Scented air fresheners	0.32	0.27	0.36	.093
Nonscented air fresheners	0.04	0.02	0.06	.211
Insecticides	0.07	0.06	0.09	.200
Other chemical cleaners	0.06	0.04	0.09	.241
Clean water	2.51	2.58	2.45	.896

*The mean value of cumulative time of exposure to each type of cleaning product (in hours/week).
†*P* values for Wilcoxon rank sum tests between boys and girls were all greater than .05.

TABLE E2. Rotated loading for the major factors through principle component factor analysis*

	Pattern I	Pattern II	Pattern III	Pattern IV
Bathroom cleaners	0.70	0.15	0.09	0.04
Floor cleaners	0.70	−0.10	0.23	−0.17
Glass cleaners	0.62	0.43	−0.05	−0.05
Kitchen cleaners	0.69	0.04	0.14	0.12
Tile cleaners	0.68	0.10	−0.04	0.00
Leather cleaners	0.54	0.41	−0.04	−0.03
Multipurpose cleaners	0.50	0.18	0.30	0.20
Nonchlorinated bleach	0.57	−0.05	0.00	0.16
Chlorinated bleach	0.33	0.44	0.24	0.07
Sanitizers	0.25	0.09	0.68	0.04
Scented air fresheners	0.02	−0.09	0.63	0.04
Nonscented air fresheners	0.01	0.75	0.01	0.08
Insecticides	0.10	0.78	0.02	−0.01
Other chemical cleaners	−0.09	0.34	0.43	−0.15
Clean water	0.09	0.05	0.02	0.94
Proportion variance	0.23	0.13	0.09	0.07
Cumulative variance	0.23	0.35	0.44	0.51
Proportion explained	0.44	0.25	0.17	0.14
Cumulative proportion	0.44	0.70	0.86	1.00

*Factor loadings of equal to or greater than 0.50 were the dominant components. Kaiser-Meyer-Olkin factor adequacy was 0.867 (>0.5 is regarded as acceptable), and the *P* value for Bartlett test of sphericity was less than .001 (<0.001 is regarded as acceptable).

TABLE E3. Relationship between rhinitis pattern and TCB scores in stratified analysis (continuous)

		Unadjusted model†		Multivariable model†‡	
	No. (%)*	OR (95% CI)†	*P* value	OR (95% CI)†‡	*P* value
Atopic status, no (n = 1973)					
Never	1144 (58)	1.00	—	1.00	—
Occasional	504 (25.5)	1.24 (1.06-1.46)	.009	1.21 (1.03-1.43)	.021
Frequent	211 (10.7)	1.53 (1.26-1.85)	<.001	1.42 (1.17-1.74)	.001
Persistent	114 (5.8)	1.36 (1.05-1.77)	.019	1.19 (1.02-1.69)	.022
Atopic status, yes (n = 326)					
Never	116 (35.6)	1.00	—	1.00	—
Occasional	90 (27.6)	1.20 (0.87-1.67)	.262	1.17 (0.84-1.62)	.360
Frequent	71 (21.8)	1.17 (0.83-1.66)	.379	1.11 (0.78-1.60)	.557
Persistent	49 (15)	0.94 (0.58-1.52)	.807	0.91 (0.53-1.54)	.713

*Numbers (percentages) of students in each group.

†OR for a 10-unit increase in TCB score.

‡Adjustment for age, body mass index, sex, present at home when cleaning, average size of house for each member, concentration of $PM_{2.5}$ in each school, education of father, education of mother, windows open when cleaning, passive smoking at home, keeping a pet at home, keeping a plant at home, home renovation, burning incense/mosquito coil at home, and frequency of exercise.

TABLE E4. Relationship between rhinitis pattern and TCB scores in stratified analysis (tertile category)

	No.*			T2 vs T1†		T3 vs T1†		
	T1	T2	T3	OR (95% CI)	*P* value	OR (95% CI)	*P* value	P_{trend}‡
Atopic status, no (n = 1973)								
Never	412	391	341	1.00	—	1.00	—	—
Occasional	169	163	172	0.97 (0.74-1.26)	.802	1.18 (0.91-1.54)	.218	.228
Frequent	50	70	91	1.37 (0.92-2.03)	.123	1.91 (1.30-2.80)	.001	.001
Persistent	30	31	53	0.95 (0.56-1.61)	.838	1.69 (1.04-2.74)	.035	.025
Atopic status, yes (n = 326)								
Never	49	33	34	1.00	—	1.00	—	—
Occasional	24	32	34	2.09 (1.01-4.34)	.047	1.99 (0.98-4.05)	.056	.052
Frequent	21	24	26	1.87 (0.86-4.09)	.116	1.70 (0.79-3.63)	.173	.158
Persistent	15	19	15	1.92 (0.81-4.58)	.141	1.31 (0.54-3.20)	.549	.504

*Numbers of students in each group. Students were divided into 3 categories according to the tertiles of TCB scores (*T1*, tertile 1; *T2*, tertile 2; and *T3*, tertile 3).
†Adjustment for age, body mass index, sex, present at home when cleaning, average size of house for each member, concentration of $PM_{2.5}$ in each school, education of father, education of mother, windows open when cleaning, passive smoking at home, keeping a pet at home, keeping a plant at home, home renovation, burning incense/mosquito coil at home, and frequency of exercise.
‡*P* values for trend tests by calculating the Wald statistics, including tertile as a continuous variable in the model.

TABLE E5. Relationship between rhinitis patterns and chlorinated bleach exposure

	No.*			Unadjusted model‡				Multivariable model†§			
				T2 vs T1		T3 vs T1		T2 vs T1		T3 vs T1	
	T1	T2	T3	OR (95% CI)	*P* value	OR (95% CI)	*P* value	OR (95% CI)	*P* value	OR (95% CI)	*P* value
Never	772	157	331	1.00	—	1.00	—	1.00	—	1.00	—
Occasional	331	92	171	1.36 (1.02-1.82)	.034	1.20 (0.96-1.51)	.105	1.33 (1.00-1.79)	.053	1.16 (0.92-1.46)	.207
Frequent	156	31	95	0.98 (0.64-1.49)	.917	1.42 (1.07-1.89)	.016	0.96 (0.62-1.47)	.845	1.29 (0.96-1.73)	.092
Persistent	61	30	72	2.42 (1.51-3.86)	<.001	2.75 (1.91-3.96)	<.001	2.32 (1.43-3.77)	.001	2.52 (1.73-3.66)	<.001

*Numbers of students in each group. Students were divided into 3 categories according to the tertiles of pattern scores (*T1*, tertile 1; *T2*, tertile 2; and *T3*, tertile 3). The cutoff points were 0.01 h/wk and 0.20 h/wk.

†Adjustment for age, body mass index, sex, present at home when cleaning, average size of house for each member, concentration of $PM_{2.5}$ in each school, education of father, education of mother, windows open when cleaning, passive smoking at home, keeping a pet at home, keeping a plant at home, home renovation, burning incense/mosquito coil at home, atopic status, and frequency of exercise.

‡*P* values for trend tests in unadjusted models were .063, .020, and less than .001 for occasional, frequent, and persistent rhinitis, respectively.

§*P* values for trend tests in multivariable models were .139, .105, and less than .001 for occasional, frequent, and persistent rhinitis, respectively.