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ORIGINAL ARTICLE

Reported Respiratory Symptoms and Adverse Home Conditions after 9/11 among Residents Living near the World Trade Center

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This study investigated whether self-reported damage, dust, and odors in homes near the World Trade Center (WTC) after September 11, 2001, were related to increased rates of respiratory symptoms among residents and if multiple sources of exposure were associated with greater health risk. We mailed questionnaires to homes within 1.5 km of the WTC site (affected area) and in upper Manhattan (control area). Surveys asked about respiratory symptoms, unplanned medical visits, physician diagnoses, medication use, and conditions in the home after 9/11. Adverse home conditions were associated with new-onset (i.e., began after 9/11) and persistent (i.e., remained 1 year after 9/11) upper and lower respiratory symptoms in the affected area (Cumulative Incidence Ratios [CIRs] 1.20–1.71). Residents reporting longer duration of dust/odors or multiple sources of exposure had greater risk for symptoms compared to those reporting shorter duration and fewer sources. These data suggest that WTC-related contamination in the home after 9/11 was associated with new and persistent respiratory symptoms among residents living near the site. While we cannot eliminate potential biases related to self-reported data, we took strategies to minimize their impact, and the observed effects are biologically plausible.

Keywords World Trade Center, 9/11, respiratory health, asthma, community health

INTRODUCTION

The attacks on the World Trade Center (WTC) on September 11, 2001 (9/11), resulted in extensive environmental contamination of the surrounding area. The collapse of the towers and combustion products from the fires resulted in dust and odors that lasted for months afterward. Dust particles released into the air contained known respiratory irritants, including cement, asbestos, and glass fibers (1). Subsequently, as WTC dust eventually settled on surfaces and inside buildings, the indoor environment of homes around the site was contaminated (2). Residents near the site who were home on 9/11 were evacuated through the dust and smoke and may have had significant exposure to pollutants. Official recommendations for cleaning after residents returned included the use of high-efficiency particulate air (HEPA) filter vacuums, wet mops, and other self-cleaning methods (3).

Surface dust can be suspended in the air and inhaled and may stimulate or exacerbate respiratory symptoms or allergies. Dusts and other indoor contaminants have been associated with increased rates of respiratory symptoms (4, 5). Our previous studies found that residents in the affected area reported higher rates of new-onset (i.e., began after 9/11) upper and lower respiratory symptoms compared to residents in a control area and that most symptoms were persistent 1 year after 9/11 (6, 7). This finding was consistent with a study of New York City (NYC) transit workers who still had increased rates of lower respiratory symptoms 7 months after 9/11 (8). Studies of firefighters involved in the response showed positive associations between intensity of exposure and the development and persistence of airway hyper-reactivity (9, 10). No studies have specifically addressed the post-9/11 home environment and its relationship to respiratory health among residents living near the WTC site.

This study investigated whether specific adverse conditions in the home after 9/11 were related to increased incidence and persistence of upper and lower respiratory symptoms among residents near the former WTC site. Using home condition as a surrogate for exposure, we focused on characteristics that related to the disaster: settled dusts, odors, and building damage. We examined whether conditions in the home were associated with increases in medical care utilization, lower respiratory diagnoses, or respiratory medication use after 9/11. Furthermore, we examined whether duration, frequency, or multiple sources of exposure were associated with a greater risk for symptoms in residents.

METHODS

Study Design and Population

As described in our previous papers (6, 7), this retrospective cohort study was conducted among residents in selected "affected" and "control" areas during the 8- to 16-month period after 9/11. The affected area included 49 buildings within approximately 1.5 km of the WTC site, and control area residents lived in five buildings located further than 9 km north of the site (a map of our study areas has been published) (7). Self-administered individual and household questionnaires were mailed to residences in both areas, and study packets were delivered to residences or left in buildings where postal service was problematic. As described previously (6, 7), outreach and publicity to improve the response rate were intensive. To estimate potential selection bias, one building

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in the affected area and two buildings in the control area were targeted for additional outreach activities by staff. We compared information collected from these target areas to the rest of the cohort to determine if the associations remained.

All residents of the study buildings were eligible to participate. To reduce exposure misclassification and impacts from relocation, we excluded individuals who (1) were born after 9/11; (2) did not live at their current residence on 9/11; (3) moved from their residence and returned after December 31, 2001; and (4) lived in the control area but worked in the affected area. We also excluded individuals who reported a post-9/11 diagnosis of unspecified cardiovascular disease because symptoms might mimic respiratory illness. To minimize the effect of a potential reporting bias between the study areas, we restricted most analyses to the affected area only.

Study Procedures and Data Collection

Study packets containing a household survey and individual surveys were mailed and hand-delivered to 9,168 residences in the affected area and to 962 in the control area. The individual survey requested information on each resident's respiratory symptoms, unplanned medical visits, medication use, physician diagnoses of respiratory illness, and respiratory comfort. For each symptom, we asked whether it occurred in the past 12 months, started or worsened after 9/11, and about its frequency and severity. Surveys for children under 12 years of age were completed by an adult.

The household survey contained questions about conditions in the home immediately after 9/11, including physical damage, dusts, odors, and their frequency and duration. Residents also reported cleaning, sampling, and inspection activities in the home after 9/11.

Outcome Definitions

We defined health outcomes based on reported upper and lower respiratory symptoms and the time period when symptoms occurred. Upper respiratory symptoms included eye, nose or throat irritation, nasal or sinus congestion, nosebleeds, and recurring headaches. Lower respiratory symptoms included wheeze, chest tightness, shortness of breath, and cough. To estimate incidence of new disease, we assessed lower respiratory symptoms among "previously healthy" residents (i.e., no diagnoses of asthma, chronic obstructive pulmonary disease [COPD], chronic bronchitis, or other lung disease before 9/11). We defined "any new-onset" upper or lower respiratory symptom as at least one symptom that began after 9/11. "Any persistent new-onset" symptom was at least one new-onset symptom that bothered the respondent with some frequency in the past 4 weeks, i.e., "some" or "a lot" (upper respiratory symptoms), and "2 to 6 days each week" or "every day" (lower respiratory symptoms). Self-reported respiratory comfort at different levels of exertion included shortness of breath (SOB) when walking "up a slight hill," "with other people of your own age on level ground," and "at your own pace on level ground."

To reduce bias from self-reported information, we assessed more objective indicators of respiratory health among previously healthy individuals. These measures included unplanned medical visits after 9/11 (i.e., to a doctor, emergency room [ER] or urgent care center, or an overnight hospital stay because of asthma, wheezing, cough, shortness of breath, chest tightness, or other breathing problem) and new diagnoses of lower respiratory illness (i.e., a diagnosis of asthma, COPD, chronic bronchitis, or other lung disease after 9/11). We also obtained information on the initiation, increased dose, and frequency/continued use of oral or inhaled medication for relief of breathing symptoms. We assessed results from a screening spirometry test (including forced expiratory volume in 1 second [FEV_1], forced vital capacity [FVC],FEV_1/FVC, and forced expiratory flow [FEF_{25-75}]) in a subset of participants to determine if there was any association between reported conditions after 9/11 and lung function.

Exposure Definitions

Home conditions variables were created based on responses from the household questionnaire. "Any physical damage" included the report of any of the following: windows broken, broken building pieces present, and structural, interior wall, or furnishings damage. We also asked residents if they experienced dust or odors in the home that they perceived to be a result of the disaster or clean-up. Quantitative questions addressed the duration ("none," "less than 1 month," "1 to 3 months," "3 to 6 months," and "still going on") and frequency ("once in a while," "at least once a week," "at least once a day," and "all the time") of these dusts or odors after 9/11. Finally, we asked if the home had been "professionally cleaned," if a resident had "cleaned myself," if ventilation ducts were cleaned, and if any inspections were completed (i.e., by a city or other agency or building management) after 9/11.

To assess dose-response relationships between levels of exposure and respiratory symptoms, longer durations or greater frequency of exposure to dust or odors in the home were compared to the reference groups (answering "less than once per month" or "once in a while," respectively). A "combined exposure index" was defined as follows: (1) residence exposure only (live below [i.e., South of] Canal Street); (2) both live and physically present below Canal Street on 9/11; (3) all three exposures (live, work, and present below Canal Street on 9/11). The reference group included control area residents who did not work below Canal Street and were not present there on 9/11 (i.e., none of the three exposures). Other combinations of the exposure, including residents who worked but did not live in the affected area, were too few to be analyzed or met exclusion criteria.

Statistical Methods

The responses to the household questionnaire were linked to the individual surveys containing the health data. To ensure independent reporting of symptoms by home conditions, we randomly selected one individual per household for analysis (SAS Institute Inc., Cary, NC) (11).

In the bivariate comparisons, χ^2 analysis was applied to test for significant differences. We computed Cumulative Incidence Ratios (CIRs) and used 95% confidence intervals (95% CI) to estimate the precision of risk estimates. Reference groups included residents who did not report the conditions. We applied categorical tests for trend to assess dose-response relationships. Multivariate analysis was performed with unconditional logistic regression to control for

potential confounders, including age, gender, race, education, and smoking. The highest level of education attained in the household was used as an indicator of socioeconomic status (SES) because education was reported more completely than other indicators, such as income. Due to correlations between some of the home conditions, we introduced each exposure variable into the regression model separately. Because the respiratory outcomes measured are not rare events, odds ratios from logistic regression probably overestimate true risk. For this reason, we report crude CIRs and used logistic regression only to determine if the associations in the bivariate analyses remained significant after controlling for confounders. Significance was indicated if the association remained and $p < 0.05$.

RESULTS

Response and Resident Mobility

As reported previously, the household response rates were 22.3 and 23.3% in the affected and control areas, respectively, and 43.8 and 40.3% in the target areas (6,7). There were 1,480 respondents eligible for analysis, including 1,317 residents of the affected area and 113 in the control area. Occupational status (i.e., working or not) and physical presence below Canal Street on 9/11 was well-reported (2.8% and 0.9% missing, respectively), although work location among those employed on 9/11 was not (19.1% missing). Because many affected area residents were evacuated and some remained away for an extended period of time, we assessed their mobility patterns. The majority of affected area residents reported being home (84.3%) and present below Canal Street (90.8%) on 9/11. Of those who reported moving and who left the area on 9/11 (75.8%), 49.8% had returned by September 30th, 72.9% by October 31st, and 89.1% by November 30th. There was no association between time spent at the residence and reported respiratory symptoms.

Home Conditions and Respiratory Disease

A total of 30.7% of affected area residents reported some physical damage to their home after 9/11, in contrast to the control area, where there were no reports of damage (Table 1). Affected area residents reported significantly higher rates of dust present (86.4%) compared to control subjects (23.3%), higher rates of odors (77.9% vs. 39.9%), and duration of dust or odors for 3 months or longer (60.7% vs. 9.1%). Dust or odors present "all the time" was reported in 62.8% of affected area and 14.1% of control area residents. Differences in cleaning activities after 9/11 were also apparent, including professional cleaning (31.5% vs. 6.8%), self-cleaning (74.3% vs. 43.6%), and ventilation duct cleaning (28.8% vs. 8.6%). Finally, affected area residents reported more air sampling (10.0% vs. 0.6%), debris or dust sampling (5.6% vs. 0%), and inspections completed (20.3% vs. 2.5%) than control area residents.

Table 2 describes the association between reported conditions, cleaning, or inspections completed and new-onset respiratory symptoms among affected area residents (crude CIRs reported). After adjusting for multiple confounders, all conditions remained significantly associated with reporting any new-onset upper respiratory symptom (CIRs 1.20–1.35). Nosebleeds and recurring headaches had the highest CIRs (data not shown). Dust present showed the strongest association with any upper respiratory symptom (CIR 1.35, 95% CI: 1.18,1.54). Home conditions were also associated with new-onset lower respiratory symptoms (CIRs 1.31–1.50), and symptoms were most strongly associated with duration of dust or odor in the home for 3 months or longer (CIR 1.50, 95% CI:1.33,1.68). SOB and chest tightness were most strongly associated with these conditions (data not shown). Associations found in the target areas were generally similar or stronger (data not shown). Self-reported SOB (i.e., respiratory comfort) at varying levels of exertion was also significantly associated with home conditions. Cleaning and inspection activities were not significantly related to respiratory symptoms (CIRs 0.98–1.10).

TABLE 1.—Home conditions, cleaning, sampling and inspection activities after 9/11, by area.

Home conditions, cleaning, sampling and inspection activities	Affected ($n = 1317$)		Control ($n = 163$)		
	n	%	*n*	%	p^*
Any physical damage‡	404	30.7	0	0.%	<0.0001
Dust present on surfaces or in air	1138	86.4	38	23.3	<0.0001
Odor present	1026	77.9	65	39.9	<0.0001
Duration of dust or odors†					<0.0001
<1 month	143	12.6	81	81.8	
1–3 months	305	26.8	9	9.1	
3–6 months	493	43.3	5	5.1	
>6 months	198	17.4	4	4.0	
Frequency of dust or odors†					<0.0001
Once in a while	131	11.8	35	49.3	
Once a week	97	8.7	9	12.7	
Once a day	185	16.7	17	23.9	
All the time	697	62.8	10	14.1	
Home professionally cleaned	415	31.5	11	6.8	<0.0001
Home self-cleaned	978	74.3	71	43.6	<0.0001
Ventilation ducts cleaned	379	28.8	14	8.6	<0.0001
Air samples collected	132	10.0	1	0.6	<0.0001
Debris/dust samples collected	74	5.6	0	0.0	0.0019
Inspected by agency or professional	267	20.3	4	2.5	<0.0001

‡Includes reports of broken windows, broken building pieces present inside, structural damage, and damage to interior walls or furniture immediately after the World Trade Center disaster.

*p values from χ^2 or Fisher's exact test.

†N not equal to total for affected area due to missing data and because some categories are not mutually exclusive.

Adverse home conditions after 9/11 were also associated with the persistence of respiratory symptoms (Table 3). The rate of persistent new-onset upper respiratory symptoms was significantly higher among residents reporting any adverse home condition (CIRs 1.23–1.71), and physical damage was the strongest risk factor for persistence (CIR 1.71, 95% CI: 1.52,1.92). Residents reporting any of these conditions also had higher rates of at least one persistent new-onset lower respiratory symptom (CIRs 1.38–1.61), which were most strongly associated with duration of dust or odors for 3 months or longer (CIR 1.61, 95% CI: 1.39,1.86). The persistent symptoms most strongly associated with any of the conditions were nosebleed, SOB, and chest tightness.

Other Measures of Outcomes

The relationship between home conditions after 9/11 and unplanned medical visits ($n = 1,085$) or new diagnoses of

TABLE 2.—New-onset upper and lower respiratory symptoms among affected area residents, by home conditions, cleaning, and inspection activities after 9/11.

Home conditions, cleaning and inspections	Any new-onset upper respiratory symptoms*		Any new-onset lower respiratory symptoms†	
	n (%)	CIR (95% CI)	*n* (%)	CIR (95% CI)
Any physical damage‡	343 (84.9%)	1.27 (1.19–1.34)§	225 (67.6%)	1.31 (1.18–1.45)§
Dust present on surfaces or in air	856 (75.2%)	1.35 (1.18–1.54)§	548 (58.9%)	1.41 (1.16–1.70)§
Odor present	778 (75.8%)	1.24 (1.12–1.37)§	503 (60.2%)	1.37 (1.18–1.59)§
Dust/odor duration ≥ 3 months	562 (81.3%)	1.29 (1.21–1.39)§	370 (66.9%)	1.50 (1.33–1.68)§
Dust/odor frequency at least once a day	674 (76.4%)	1.20 (1.10–1.31)§	445 (62.0%)	1.35 (1.17–1.56)§
Ventilation ducts cleaned	282 (74.4%)	1.04 (0.96–1.11)	181 (56.9%)	1.01 (0.90–1.13)
Self-cleaned	717 (73.3%)	1.04 (0.96–1.13)	462 (57.0%)	1.04 (0.92–1.17)
Professionally cleaned	307 (74.0%)	1.03 (0.96–1.10)	189 (55.6%)	0.98 (0.87–1.09)
Inspected by agency or professional	209 (78.3%)	1.10 (1.02–1.19)	129 (59.2%)	1.06 (0.94–1.20)

*Includes reports of eye, nose or throat irritation, nasal or sinus congestion, nosebleeds, and recurring headaches.
†Includes reports of wheezing, chest tightness, shortness of breath, and coughing among previously healthy (no physician diagnosis of asthma, chronic obstructive pulmonary disease, chronic bronchitis, or other lung disease before 9/11).
‡Includes reports of broken windows, broken building pieces present inside, structural damage, and damage to interior walls or furniture.
§The effect was still statistically significant ($p < 0.05$) after adjustment for age, race, education, gender, and smoking.
The reference group includes residents who did not report the specific home condition.

respiratory disease ($n = 245$) in previously healthy residents of the affected area is presented in Table 4. The incidence of unplanned medical visits was associated with physical damage (CIR 1.68, 95% CI: 1.26,2.24), dust present (CIR 1.85, 95% CI: 1.07,3.17), and duration of dust or odors for 3 months or longer (CIR 1.88, 95% CI: 1.37,2.57). Rates of new lower respiratory disease diagnoses were significantly higher among individuals reporting a frequency of dust or odors in the home of at least once a day (CIR 1.85, 95% CI: 1.03,3.34).

Adverse home conditions were also associated with respiratory medication use (Table 5). Physical damage was significantly associated with medication use that began after 9/11 (CIR 1.47, 95% CI: 1.12,1.94), increased after 9/11 (CIR 2.10, 95% CI 1.08,4.10), and with use in the past 4 weeks (CIR 1.72, 95% CI: 1.28,2.32). Duration of dust and odors for 3 months or longer was associated with medication use that began after 9/11 (CIR 1.39, 95% CI: 1.04,1.85), but not with increased or recent use. There were no significant differences in lung function measures between residents reporting adverse home conditions and those who did not (data not shown).

Dose-Response

Since positive associations were found between reported home conditions after 9/11 and respiratory symptoms, we assessed potential dose-response relationships. As demonstrated in Figure 1, a dose-response curve was found for reported duration of dust or odors and all four disease indicators, including new-onset and persistent upper and lower respiratory symptoms. Equivalently, as the reported length of time of dust or odors in the home increased, so did the risk for respiratory symptoms. Similar trends were observed for the association between respiratory symptoms and an increasing frequency of dust or odors but were not significant after adjusting for multiple confounders (data not shown).

Using the combined exposure index, we assessed the association between exposure proxies and respiratory symptoms (Table 6). Residence in the affected area was an important risk factor, and the risk for respiratory symptoms increased

TABLE 3.—Persistent new-onset upper and lower respiratory symptoms among residents of the affected area, by home conditions, cleaning, and inspection activities after 9/11.

Home conditions, cleaning and inspections	Any persistent new-onset upper respiratory symptoms*		Any persistent new-onset lower respiratory symptoms†	
	n (%)	CIR (95% CI)	*n* (%)	CIR (95% CI)
Any physical damage‡	243 (60.2%)	1.71 (1.52–1.92)§	192 (57.7%)	1.44 (1.27–1.64)§
Dust present on surfaces or in air	512 (45.0%)	1.52 (1.20–1.92)§	440 (47.3%)	1.38 (1.10–1.74)§
Odor present	471 (45.9%)	1.42 (1.19–1.70)§	408 (48.9%)	1.44 (1.19–1.73)§
Dust/odor duration ≥3 months	350 (50.7%)	1.51 (1.32–1.73)§	306 (55.3%)	1.61 (1.39–1.86)§
Dust/odor frequency at least once a day	401 (45.6%)	1.23 (1.05–1.46)§	364 (50.7%)	1.45 (1.21–1.74)§
Ventilation ducts cleaned	154 (40.6%)	0.93 (0.81–1.07)	162 (50.9%)	1.18 (1.03–1.35)
Self-cleaned	423 (43.3%)	1.03 (0.89–1.19)	378 (46.7%)	1.12 (0.95–1.31)
Professionally cleaned	171 (41.2%)	0.94 (0.82–1.08)	152 (44.7%)	0.98 (0.85–1.13)
Inspected by agency or professional	122 (45.7%)	1.08 (0.93–1.26)	108 (49.5%)	1.12 (0.96-1.30)

*Includes reports of eye, nose or throat irritation, nasal or sinus congestion, nosebleeds, and recurring headaches.
†Includes reports of wheezing, chest tightness, shortness of breath, and coughing among previously healthy (no physician diagnosis of asthma, chronic obstructive pulmonary disease, chronic bronchitis, or other lung disease before 9/11).
‡Includes reports of broken windows, broken building pieces present inside, structural damage, and damage to interior walls or furniture.
§The effect was still statistically significant ($p < 0.05$) after adjustment for age, race, education, gender, and smoking.
The reference group includes residents who did not report the specific home condition.

TABLE 4.—Unplanned medical visits* and new diagnoses of lower respiratory disease†, among previously healthy‡ residents of the affected area, by home conditions after 9/11.

Home conditions	Unplanned medical visit(s) for respiratory problems in past 12 months		New (since 9/11) diagnosis of lower respiratory disease	
	n (%)	CIR (95% CI)	*n* (%)	CIR (95% CI)
Any physical damage§	67 (20.1)	1.68 (1.26–2.24)**	36 (32.1)	0.97 (0.68–1.40)
Dust present on surfaces or in air	144 (15.5)	1.85 (1.07–3.17)**	72 (33.3)	1.21 (0.65–2.24)
Odor present	127 (15.2)	1.27 (0.87–1.83)	66 (36.9)	1.74 (1.05–2.87)
Dust/odor duration ≥3 months	105 (19.0)	1.88 (1.37–2.57)**	53 (37.3)	1.38 (0.92–2.04)
Dust/odor frequency at least once a day	114 (15.9)	1.25 (0.87–1.79)	61 (36.3)	1.85 (1.03–3.34)**

*Includes unplanned visits to a doctor, an emergency room or urgent care center, or overnight hospital stays because of asthma, wheezing, cough, shortness of breath, chest tightness, or other breathing problem.

†Includes asthma, chronic obstructive pulmonary disease, chronic bronchitis, or other lung disease.

‡No physician diagnosis of asthma, chronic obstructive pulmonary disease, chronic bronchitis, or other lung disease before 9/11.

§Includes reports of broken windows, broken building pieces present inside, structural damage, and damage to interior walls or furniture.

**The effect was still statistically significant ($p < 0.05$) after adjustment for age, race, education, gender, and smoking.

The reference group includes residents who did not report the specific home condition.

with each additional exposure reported. Residents reporting all three exposure proxies had the highest risk of respiratory symptoms (CIRs 2.98–5.14).

DISCUSSION

Home Environment and Respiratory Disease

The 9/11 attacks on the WTC generated dusts that settled into buildings nearby. Over one third of the homes in the affected area reported physical damage, and rates of dust and odors in the home after 9/11 were three to four times higher among affected area residents compared to control subjects. Over 40% of residents in the affected area reported dust and odors remaining for 3 to 6 months after 9/11. Rates of any new-onset upper respiratory symptom were 20% to 35% higher among affected area residents reporting dust and odors exposure, and rates of new lower symptoms were 31% to 50% higher compared to those not reporting such exposures. Studies showing that dust from the WTC contained a mix of particulate matter and potential respiratory irritants, including synthetic vitreous fibers, heavy metals, and other inorganic substances(12,13), provide biologic plausibility. These findings are also consistent with increased rates of new-onset and persistent respiratory symptoms in affected area residents (6, 7) and increased respiratory health problems in workers involved in the recovery and clean-up at the WTC site (9, 14).

In addition to new-onset symptoms, we found a 23% to 71% elevation in persistent upper respiratory symptoms and a 38% to 61% elevation in persistent lower symptoms among residents reporting adverse home conditions related to 9/11. Residence in the affected area may reflect a potential for greater dust and odor exposures, as many residents reported dust or odor lasting for several months. Building condition and its relationship to persistent respiratory symptoms is well documented in working populations (15, 16) where identified sources of exposure include dust and mold, chemicals from cleaning products, and building materials such as cement and asbestos. Similar irritants were present in the dust that resulted from the attacks on the WTC (2) and may have contributed to symptoms that continued to bother residents with considerable frequency nearly a year after 9/11. This finding is supported by the persistence of respiratory symptoms in firefighters 6 months after 9/11 (9).

Because self-reported symptoms may be biased, we investigated whether more objective indicators of respiratory health would yield similar associations with home conditions. We identified a significantly higher rate of new, increased, and recent respiratory medication use for relief of symptoms among residents reporting damage to the home. Unplanned medical visits were elevated by 88% with respect to some conditions. This is consistent with findings from Szema et al. (17), showing that clinic visits and medication use for asthma increased in a pediatric population of asthmatics after 9/11. New lower respiratory diagnoses were associated with reported frequency of dust or odor in the home, indicating a consistent relationship between respiratory health and persisting exposure.

We also observed a positive dose-response between surrogates for exposure and both new and persistent respiratory symptoms. As the reported duration or frequency of dust or odors in the home increased, so did the rate of respiratory symptoms, indicating a relationship between symptoms and exposure intensity. The combined exposure index analyses also indicated a positive trend; residents reporting several potential exposure sources had as much as twice the rate of new and persistent symptoms as those reporting a single source. Despite the absence of objective exposure measurements,

TABLE 5.—Respiratory medication use* among previously healthy† residents of the affected area, by home conditions after 9/11.

Home conditions	Med use started after 9/11 CIR (95% CI)	Med use increased after 9/11 CIR (95% CI)	Med use in past 4 weeks CIR (95% CI)
Any physical damage‡	1.47 (1.12–1.94)§	2.10 (1.08–4.10)§	1.72 (1.28–2.32)§
Dust present on surfaces/air	1.41 (0.89–2.22)	5.28 (0.73–38.3)	2.04 (1.13–3.68)
Odor present	1.18 (0.83–1.67)	0.91 (0.42–2.00)	1.30 (0.88–1.92)
Dust/odor duration ≥3 months	1.39 (1.04–1.85)§	2.25 (1.05–4.82)	1.64 (1.18–2.27)
Dust/odor frequency at least once a day	1.46 (1.01–2.10)	2.33 (0.82–6.61)	1.47 (0.98–2.20)

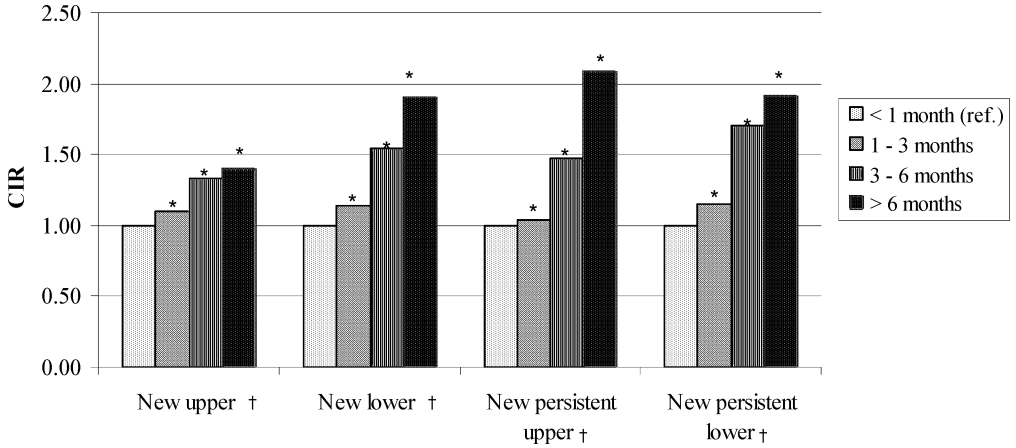
*Includes medicine, pills, pump, or inhaler for relief of breathing symptoms.

†No physician diagnosis of asthma, chronic obstructive pulmonary disease, chronic bronchitis, or other lung disease before 9/11.

‡Includes reports of broken windows, broken building pieces present inside, structural damage, and damage to interior walls or furniture.

§The effect was still statistically significant ($p < 0.05$) after adjustment for age, race, education, gender, and smoking.

**The reference group includes residents who did not report the specific home condition.



[1]Includes reports of eye, nose or throat irritation, nasal or sinus congestion, nosebleeds, and recurring headaches.
[2]Includes reports of wheezing, chest tightness, shortness of breath, and coughing among previously healthy (no physician diagnosis of asthma, chronic obstructive pulmonary disease, chronic bronchitis, or other lung disease before 9/11).
*The effect was still statistically significant ($p < 0.05$) after adjustment for age, race, education, gender, and smoking.
†Trend test (using categorical variable) was statistically significant ($p < 0.05$).

FIGURE 1.—New-onset and persistent new-onset upper[1] and lower[2] symptoms, by duration of dust or odors in home.

these findings suggest that residents who experienced multiple exposures may have had greater risk of respiratory symptoms than those with single or no exposures.

We did not find cleaning activities to be significantly associated with respiratory symptoms. One explanation for our results might be that the questions related to cleaning were not specific enough to differentiate between protective (e.g., removal of an irritant) and harmful (e.g., disturbing settled dust) cleaning activity. More detailed information on use of cleaning products, timing of dust removal, methods (wet or dry dust removal), or use of dust masks while cleaning might prove useful in identifying potential hazards, as observed in working populations (15, 18).

Strengths and Limitations

This was a large community survey and is one of the few studies of residents living near the WTC site. Despite a lack of baseline health or exposure data, we undertook several strategies to minimize bias in both study design and in the data analysis, as partially described previously (19). The low household response rate, although similar between the areas, raises concerns of selection bias. We estimated the impact of this bias by comparing the results from the entire affected area to the target areas, where the response rate was nearly double that of the original survey. In these areas, similar and stronger positive associations were found between home conditions and respiratory symptoms. In addition, we encouraged people with and without respiratory symptoms to participate.

Reporting bias was addressed in several ways. Many affected area residents were concerned about health risks related to the disaster and may have been more likely than control subjects to report both symptoms and poor conditions in the home. To minimize the impact of this bias, we limited our analyses to the affected area. We also randomly selected one individual survey per household to reduce the effect of potential intra-household correlation between respiratory

TABLE 6.—New–onset and persistent new–onset upper and lower respiratory symptoms among affected area residents, by combined exposure index (residence, work location, and presence below Canal Street on 9/11) ($n = 1,232$)*.

	Any new–onset		Any persistent new–onset	
Combined exposure index	*n* (%)	CIR (95% CI)	*n* (%)	CIR (95% CI)
Upper respiratory symptoms†				
Resident + work + below Canal St.	174 (78.0)	2.98 (2.15–4.13)§	98 (44.0)	3.62 (2.13–6.15)§
Resident + no work + below Canal St.	496 (72.1)	2.76 (2.00–3.80)§	308 (44.8)	3.68 (2.20–6.17)§
Resident + no work + not below Canal St.	46 (66.7)	2.55 (1.78–3.65)§	21 (30.4)	2.51 (1.34–4.67)§
Not resident + no work + not below Canal St.	28 (26.2)	1.00 (reference)	13 (12.2)	1.00 (reference)
Lower respiratory symptoms‡				
Resident + work + below Canal St.	115 (63.5)	4.02 (2.50–6.49)§	98 (54.1)	5.14 (2.82–9.39)§
Resident + no work + below Canal St.	320 (57.0)	3.61 (2.26–5.78)§	241 (43.0)	4.08 (2.25–7.39)§
Resident + no work + not below Canal St.	26 (44.1)	2.79 (1.61–4.82)§	23 (39.0)	3.70 (1.90–7.22)§
Not resident + no work + not below Canal St.	15 (15.8)	1.00 (reference)	10 (10.5)	1.00 (reference)

*Included only participants 18 years of age or older.
†Includes reports of eye, nose or throat irritation, nasal or sinus congestion, nosebleeds, and recurring headaches.
‡Includes reports of wheezing, chest tightness, shortness of breath, and coughing among previously healthy (no physician diagnosis of chronic obstructive pulmonary disease, chronic bronchitis, or other lung disease before 9/11).
§The effect was still statistically significant ($p < 0.05$) after adjustment for age, race, education, gender, and smoking.
**Trend test (using categorical variable) was statistically significant ($p < 0.05$).

symptoms and a shared home environment. The symptom questions were separate from the household questionnaire and were never open-ended. We specifically asked about the home conditions "immediately after the World Trade Center disaster," and asked symptom frequency, severity, and exacerbation questions, which are less prone to bias because of their specificity. We removed individuals who responded affirmatively to every question. In addition, we assessed lower respiratory symptoms among previously healthy residents to minimize misclassification of disease status. To estimate reporting bias, we compared the proportion of unplanned medical visits among participants with specific respiratory symptoms and found them to be similar among those reporting or not reporting exposures. We found no correlation between building proximity to the site and reporting of symptom frequency and found no differences in variables not likely related to 9/11 (i.e., physical disabilities) between those reporting and not reporting adverse home conditions, suggesting there were no significant reporting biases.

Assessing exposures related to the WTC disaster was a challenge for this study. As reported previously (6, 7), the air monitoring site near the WTC was destroyed on 9/11. Available ambient air monitoring data from government and local agencies was limited and could not provide adequate information from monitors closest to the study buildings. Therefore, we could not use monitoring or indoor sampling data to objectively represent exposure in the home environment. Baseline health information and objective health measures were likewise unavailable. Lung function testing conducted 1 year after 9/11 would not be a sensitive indicator of reactive airway disease related to the event. For these reasons, we relied on self-reported information for both exposure and health outcome data. To reduce exposure misclassification, we excluded individuals who were not in the area immediately afterward or who returned to the area after several months. Although our combined exposure index can only serve as a surrogate for exposure, the results consistently suggest that the risk of respiratory symptoms was greater for residents reporting multiple sources of exposure. These analyses are also probably limited by the nature of the questions asked; e.g., work location rather than if they actually were able to go to work after 9/11. In addition, reporting of work location was poor and some residents were not employed, so sample sizes were small. Because of these limitations, our crude measure does not capture activities that may have altered their exposure.

Finally, we do not know what role psychological stress may have played in respiratory symptoms. Stress is a suspected contributor to respiratory illness, including asthma (20, 21), and has been attributed to an increase in cardiac events and posttraumatic stress disorder after 9/11 (22, 23). We collected information about stress in a follow-up survey and will report on the relationship between stress and respiratory health in this cohort at a later date.

Conclusion

This study suggests that adverse conditions in the home immediately after 9/11, including physical damage and the presence of dust or odors, were related to new-onset upper and lower respiratory symptoms in residents living near the site. More importantly, these conditions were also associated with symptom persistence in residents nearly 1 year later. Additionally, the dose-response observed suggests a relationship between exposure intensity and symptom risk. We also suggest that residents reporting multiple sources of potential exposure had a greater risk for new and persistent respiratory symptoms compared with those reporting a single source. We cannot rule out the potential contribution of reporting and selection biases on our results, but several measures were used to minimize their impact, and the findings are both plausible and consistent with other publications.

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