Long-term respiratory symptoms in World Trade Center responders

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**Background**

New York State (NYS) employees who responded to the World Trade Center (WTC) disaster on or after 11 September 2001 potentially experienced exposures that might have caused persistent respiratory effects. NYS responders represent a more moderately exposed population than typical first responders.

**Aims**

To assess whether NYS employees who were WTC responders were more likely than controls to report lower respiratory symptoms (LRS) or a diagnosis of asthma 5 years post-9/11. Persistence and severity of symptoms were also evaluated.

**Methods**

Participants were initially mailed self-administered questionnaires (initial, Year 1, Year 2) and then completed a telephone interview in Year 3. Data were analysed using Poisson’s regression models.

**Results**

WTC exposure was associated with LRS, including cough symptoms suggestive of chronic bronchitis, 5 years post-9/11. When exposure was characterized using an exposure assessment method, the magnitude of effect was greater in those with exposure scores above the mean. WTC exposure was associated with persistence of LRS over the 3 year study period. Results also suggest that participants with the highest exposures were more likely to experience increased severity of their asthma condition and/or LRS.

**Conclusions**

Our findings suggest that even in a moderately exposed responder population, lower respiratory effects were a persistent problem 5 years post-9/11, indicating that some WTC responders require ongoing monitoring.

**Key words**

Asthma; chronic bronchitis; occupational health; respiratory; signs and symptoms; 11 September 2001; World Trade Center disaster.

**Introduction**

New York State (NYS) employees who responded to the World Trade Center (WTC) disaster on or after 11 September 2001 were potentially exposed to a variety of materials and chemicals [1–6]. These exposures continued in the months that followed, resulting from the resuspension of dust from recovery activities and intermittent smoke plumes from ongoing fires. Respiratory effects have been reported among WTC responder populations and among residents and office workers near the WTC site [7–19].

This cohort study was designed to assess asthma and lower respiratory symptoms (LRS) among NYS employees who responded to the WTC disaster (NYS responders), in comparison with a control group of NYS employees, in similar agencies and job titles, who did not respond. Disaster responders were those employees directed by their agency to fulfill one or more work roles in the area of the WTC disaster. They represent a more moderately exposed population than typical first responders [13]. The results reported here include LRS reported in a telephone interview ~5 years post-9/11. In addition, data regarding persistence and severity of LRS reported during the study period (2003–06) are presented.

**Methods**

The New York State Department of Health (NYSDOH) Institutional Review Board approved this study. In 2002, 4533 NYS employees who were directed to respond to the WTC disaster were offered a medical monitoring evaluation and subsequent enrolment in an NYSDOH study, which involved the collection of information from the medical evaluation and a self-administered questionnaire.
Medical evaluations and enrolment into this related study occurred between May 2002 and November 2003 [13]. NYS employees enrolled in that study (n = 1023) were mailed a brief asthma-related questionnaire in 2003 and asked to participate in the cohort study described here. This included completion of the asthma-related questionnaire and use of data from the previously completed questionnaire. The majority of eligible participants were contacted in May 2003, with additional solicitations mailed later, as eligible participants completed their medical evaluations. A non-exposed group was formed by soliciting 5498 non-exposed state employees from the same agencies and job descriptions as NYS responders. Agencies included the State Police, Department of Transportation, Department of Environmental Conservation and others. The non-exposed group was mailed the same asthma-related questionnaire and the original questionnaire completed by the exposed group for the prior study. The solicitation mailing for both the exposed and the non-exposed groups included a consent form. Follow-up mailings to both groups occurred at 2 week intervals and included two postcard reminders and a final mailing that included a second copy of the questionnaires and consent form. In 2004 and 2005, questionnaires were sent to the participants to gather current information on health, including asthma and LRS. These mailings were also followed by two postcard reminders and a final mailing, each occurring at 2 week intervals. Data collection concluded with a telephone interview in 2006. Participants were offered a two-part monetary incentive for participation. Upon completion of the initial questionnaires (2003), participants were mailed a $10 gift check. After completion of the telephone interview (2006), participants were mailed a $30 gift check.

A telephone research company conducted the telephone interviews over a 2 month period. Data were collected using a 130-station computer-assisted telephone interview (CATI) system. The disposition system used is codified by the American Association for Public Opinion Research [20]. Each participant was called a maximum of 15 times. For any initial refusals, a certified letter was mailed by NYSDOH, followed by an additional telephone contact attempt. Two refusals resulted in a final disposition of ‘refused interview’ and they were not contacted again. For participants who were no longer at the provided phone number, attempts were made to obtain an alternative phone number. Survey data were entered and automatically consolidated by the CATI software as each interview was completed. Upon completion of the data collection phase, data were exported from the CATI system and compiled into an SAS data file.

Many of the questions used for this study were based on the National Asthma Survey, sponsored by the National Center for Environmental Health, Centers for Disease Control and Prevention. The initial questionnaire, follow-up surveys and final telephone interview included questions regarding diagnoses of asthma and reactive airways dysfunction syndrome (RADS), potentially asthma-related LRS experienced in the absence of a respiratory infection, asthma severity, asthma-related medication use and a number of potential confounders. Characteristics of cough symptoms were assessed using questions about time of day of cough, difficulty sleeping due to cough and presence of a productive cough for 3 consecutive months in 2 consecutive years, which suggests chronic bronchitis.

Exposure was characterized using an exposure assessment method developed for use in NYSDOH WTC studies, described elsewhere [21]. The exposure scores derived from this method are continuous variables and provide a relative ranking of exposed study participants, based on either smoke or dust exposure. Exposure scores were categorized, as above the mean, or less than or equal to the mean, in an effort to reduce possible misclassification.

Persistence was defined as reporting an individual symptom at each of the four data collection points (initial questionnaire, 1 and 2 year follow-up questionnaire and final interview). LRS were also assessed collectively as the reporting of at least one of the four LRS (cough, wheeze, shortness of breath or chest tightness) in the absence of a respiratory infection at each of the four data collection points.

Severity of asthma was assessed using questions about worsening asthma symptoms, the number of visits to an emergency room or doctor for asthma and the number of workdays lost due to asthma. Severity of respiratory symptoms was also assessed by including questions to ascertain changes in breathing medication use.

Poisson’s regression was used to estimate the relative risks (RR) of reporting an LRS (cough, wheeze, shortness of breath and chest tightness) or any one of these symptoms, 5 years post-9/11, as well as for persistence (symptoms reported at all the four data collection points), for dust exposure and smoke exposure. RR were also calculated for the use of new breathing medications and increased dose of breathing medications among those who reported being prescribed breathing medication for LRS, 2 years post-9/11 (initial) and 5 years post-9/11, as well as for other components defining severity, and cough characteristics 5 years post-9/11. Variables evaluated for potential confounding included age, ethnicity, smoking status (ever smoked, for persistence data and current smoking), for final interview data), education (at least a high school graduate), a personal or family history of allergies or eczema and household conditions such as mould in the home and the presence of pets. To assess potential confounding by psychological factors, 5 years post-9/11, we used the reporting of at least one psychological symptom in the past 12 months. To do so for the persistence analysis, at least one psychological symptom had to be reported at each of the four data collection points.
Reported results were adjusted for the reporting of psychological symptoms, where indicated. All other potential confounders had a negligible effect on the risk estimate and were not included in the final models. We also evaluated possible effect modification by gender and a diagnosis of asthma before 11 September 2001. Results were considered statistically significant when the 95% confidence interval (CI) excluded the null or the P-value was <0.05. All statistical analyses were performed using SAS (version 9.1; SAS Institute, Cary, NC).

Results

Sixty (10%) of the original 578 exposed participants and 76 (11%) of the original 702 non-exposed participants were lost to follow-up between the initial and final phases of the study. A total of 518 exposed subjects and 626 non-exposed subjects participated in the final telephone interview, 5 years post-9/11. The demographic characteristics of those interviewed 5 years post-9/11 did not significantly differ from those surveyed initially, 2 years post-9/11. The exposed population was predominantly male (92%), white (91%) and non-Hispanic (96%), with some college education (89%). Most (94%) did not report being current smokers. The majority reported living outside New York City (96%). The non-exposed population did significantly differ from the exposed population based on gender, age and current smoking status. There was a higher proportion of females among the non-exposed participants (28%) compared to the exposed participants (8%). A lower proportion of non-exposed participants were under the age of 40 years (26%) than exposed participants (46%). A larger proportion (10%) of non-exposed participants reported current smoking compared to exposed participants (6%). While the proportion of exposed and non-exposed participants who self-reported ever having a diagnosis of asthma were similar, there was a statistically significant elevated risk of reporting individual LRS for the exposed group (Table 1).

Gender and a previous diagnosis of asthma before 11 September 2001 were determined to be effect modifiers. Due to the small number of exposed females and participants with a diagnosis of asthma prior to 11 September 2001, these individuals were excluded from analysis for both the final interview data and the persistence data.

After excluding females and individuals with a diagnosis of asthma prior to 11 September 2001, there were 416 exposed participants and 422 non-exposed participants who completed the final interview (2006). Table 2 presents RR and 95% CI for LRS in these participants, by categories of exposure scores (dust and smoke), adjusted for report of any psychological symptom. Those with exposure scores at or below the mean had approximately a 2-fold risk of cough, shortness of breath or any symptom. Those with exposure scores above the mean exhibited a higher risk for each of the symptoms.

WTC exposure was associated with elevated risk for experiencing a productive cough for 3 consecutive months in 2 consecutive years (RR = 3.0, 95% CI: 1.1–8.8). Other characteristics of cough analysed were not significantly associated with WTC exposure.

After excluding females and individuals with a diagnosis of asthma prior to 11 September 2001, there were 399 exposed subjects and 387 non-exposed subjects who participated in all years of follow-up (2003–06). Responding to the WTC disaster was associated with elevated risks of experiencing a persistent cough, persistent wheeze or any combination of persistent LRS (Table 3).

Among 132 participants with a self-reported doctor’s diagnosis of asthma (history of asthma) on the initial questionnaire (2003), 16% reported that a doctor told them their asthma was worse or more severe since 11 September 2001. This was associated with the high smoke (RR = 8.2, 95% CI: 2.1–32.9) and high dust (RR = 4.9, 95% CI: 1.2–19.7) categories. Reporting of at least one asthma-related emergency room visit in the year after 11 September 2001 was also associated with the high smoke (RR = 6.2, 95% CI: 1.4–27.6) and high dust (RR = 4.9, 95% CI: 1.2–19.7) categories. Reporting of at least one workday lost due to asthma in the year after 11 September 2001 was associated with the high smoke category (RR = 4.9, 95% CI: 1.2–20.6).

Among participants with a history of asthma (n = 146) during the final interview (2006), 12% reported that their doctor told them their asthma was worse or more severe in the last 12 months. This was associated with the high dust category (RR = 4.5, 95% CI: 1.4–14.7). Reporting of at least one asthma-related emergency room visit in the prior year was associated with both the high smoke (RR = 6.2, 95% CI: 1.4–30.9) and the high dust (RR = 5.4, 95% CI: 1.1–26.8) categories.

### Table 1. LRS and asthma (%), 5 years post-9/11 among exposed (n = 518) and non-exposed (n = 626) participants, WTC asthma study, NYS, 2006

<table>
<thead>
<tr>
<th>Lower respiratory symptomsa</th>
<th>Exposed, n (%)</th>
<th>Non-exposed, n (%)</th>
<th>p value (χ²-test)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cough</td>
<td>106 (21)</td>
<td>56 (9)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Wheeze</td>
<td>71 (14)</td>
<td>52 (8)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Chest tightness</td>
<td>62 (12)</td>
<td>35 (6)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Shortness of breath</td>
<td>79 (15)</td>
<td>46 (7)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>At least 1 symptom</td>
<td>131 (25)</td>
<td>81 (13)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Self-reported doctor’s diagnosis of asthma (ever)</td>
<td>65 (13)</td>
<td>81 (13)</td>
<td>NS</td>
</tr>
</tbody>
</table>

NS, not significant.

*aSelf-reported symptoms experienced in the absence of a respiratory infection in the prior 12 months.*
Table 2. RR and 95% CI for LRS 5 years post-9/11 among exposed (n = 416) versus non-exposed (n = 422) male participants with no pre-9/11 diagnosis of asthma, by mean exposure score, WTC asthma study, NYS, 2006

<table>
<thead>
<tr>
<th>Exposure score</th>
<th>Any symptom</th>
<th>Cough</th>
<th>Wheeze</th>
<th>Shortness of breath</th>
<th>Chest tightness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dust exposure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-exposed</td>
<td>422</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Exposed, ≤ mean</td>
<td>282</td>
<td>2.1 (1.4–3.2)</td>
<td>2.2 (1.4–3.5)</td>
<td>1.8 (1.0–3.1)</td>
<td>2.5 (1.4–4.4)</td>
</tr>
<tr>
<td>Exposed, &gt; mean</td>
<td>134</td>
<td>2.8 (1.8–4.4)</td>
<td>3.5 (2.1–5.6)</td>
<td>2.3 (1.3–4.3)</td>
<td>3.4 (1.9–6.2)</td>
</tr>
<tr>
<td>Smoke exposure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-exposed</td>
<td>422</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Exposed, ≤ mean</td>
<td>310</td>
<td>2.1 (1.4–3.1)</td>
<td>2.3 (1.5–3.6)</td>
<td>1.6 (0.9–2.7)</td>
<td>2.4 (1.4–4.2)</td>
</tr>
<tr>
<td>Exposed, &gt; mean</td>
<td>106</td>
<td>3.0 (1.9–4.8)</td>
<td>3.6 (2.1–6.0)</td>
<td>3.1 (1.7–5.6)</td>
<td>3.9 (2.1–7.2)</td>
</tr>
</tbody>
</table>

Models were adjusted for current report of any psychological symptom.

a Twenty-one participants were excluded from these analyses for lack of exposure scores.

b Self-reported symptoms experienced in the absence of a respiratory infection in the prior 12 months.

Table 3. RR and 95% CI for persistence of LRS among exposed (n = 399) versus non-exposed (n = 387) male participants with no pre-9/11 diagnosis of asthma, WTC asthma study, NYS, 2003–06

<table>
<thead>
<tr>
<th>LRS</th>
<th>Exposed, n (%)</th>
<th>Unexposed, n (%)</th>
<th>RR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cough</td>
<td>20 (5)</td>
<td>4 (1)</td>
<td>4.3 (1.5–12.6)</td>
</tr>
<tr>
<td>Wheeze</td>
<td>15 (4)</td>
<td>2 (&lt;1)</td>
<td>6.8 (1.5–29.6)</td>
</tr>
<tr>
<td>Chest tightness</td>
<td>8 (2)</td>
<td>2 (&lt;1)</td>
<td>3.3 (0.7–15.9)</td>
</tr>
<tr>
<td>Shortness of breath</td>
<td>7 (2)</td>
<td>1 (&lt;1)</td>
<td>5.9 (0.7–48.1)</td>
</tr>
<tr>
<td>At least one symptom</td>
<td>32 (8)</td>
<td>5 (1)</td>
<td>5.5 (2.2–14.3)</td>
</tr>
</tbody>
</table>

Models were adjusted for experiencing persistent psychological symptoms.

a Among subjects who participated in all 4 years of the study, completing all questionnaires and the final interview. Persistence defined as symptoms present at all four time points in data collection (2003, 2004, 2005 and 2006).

b Persistent self-reported symptoms experienced in the absence of a respiratory infection, 2003–06.

Discussion

Our findings indicate that a cohort of NYS employees who responded to the WTC disaster continued to report a higher rate of LRS than a comparison group of unexposed NYS employees, 5 years after the disaster. Using an exposure assessment method [21], those with an exposure score greater than the mean demonstrated a consistently greater magnitude of effect than those with an exposure score equal to or less than the mean.

The WTC Health Registry has reported that the risk of newly diagnosed asthma in their cohort of responders was 12-fold higher than expected background 3 year risk in the general population [22]. We found that asthma was reported in a similar proportion of exposed and unexposed participants, suggesting that asthma is not associated with WTC exposure in this cohort. This might be due to the moderate overall exposures experienced by this cohort [13]. Considering the association found between exposure and several LRS, it may be hypothesized that some participants have experienced mild obstructive airways disease but have not sought medical diagnosis and treatment. However, symptoms reported as LRS could in fact have been caused by upper respiratory effects, which could be impacted by conditions such as gastroesophageal reflux. It has been reported by de la Hoz et al. [23] that 79% of their responder cohort have experienced upper airway disease, while 49% have experienced lower airway disease.

Among those reporting a cough in the past 12 months, exposed participants were more likely to report symptoms suggestive of chronic bronchitis. This suggests that lower respiratory effects experienced by some WTC responders may be due to a chronic obstructive process. WTC Cough Syndrome has been described as a chronic cough syndrome, occurring as a consequence of upper and lower respiratory disease. Specifically, lower respiratory tract...
disease has been due to RADS or irritant-induced asthma, types of asthmatic bronchitis that often result in chronic obstructive airways diseases [24].

To avoid possible misclassification, we applied a conservative definition of persistence. Thus, the overall number of participants with persistence of symptoms was relatively low, resulting in CI that are somewhat wide. However, given the aforementioned association of symptoms with exposure 5 years post-9/11, our overall results suggest that persistence of LRS is a concern for some WTC responders. This is consistent with reports of symptom persistence in other WTC responder cohorts [10,25].

Some WTC studies have reported increased severity of asthma in those with potential WTC exposures [14,17,26]. We evaluated the severity of symptoms in participants over time. Among participants with a history of asthma, several indicators of increased severity were associated with exposure scores greater than the mean for dust and/or smoke exposure. Changes in breathing medication use were also assessed among participants. Due to the relatively low number of participants in each of the subgroups, CI for these data are wide. However, the overall results suggest greater severity of respiratory effects in some of the most highly exposed responders.

The primary strength of this study is the inclusion of a control group of similar but unexposed NYS employees. An additional strength of this study is that it evaluates response personnel who were not first responders and presumably had lower overall exposures. A limitation is the relatively small number of participants in some subgroups, resulting in wide CI. For those portions of the analysis, our findings are less precise and may be subject to type I error. However, we have attempted to draw broad conclusions based on multiple significant findings, thus avoiding an overemphasis on potentially spurious individual results. Our study cohort may have been affected by selection bias. The exposed participants were all participants in a prior WTC medical monitoring programme. It is possible that those who participated were more likely to have experienced health symptoms or were more highly exposed. Our results may also be subject to recall bias. Responders may be more likely to remember health symptoms experienced over time due to their history of exposure. In addition, ongoing media coverage about WTC-related health effects may have caused some responders to develop concerns about their health, which could lead to a greater likelihood of noticing even minor symptoms. These results should not be generalized to the overall community because our study population consisted primarily of white, non-Hispanic males with some college education. However, our findings may be applicable to other WTC responder cohorts with similar demographics and responder groups in future disasters of a similar nature.

In conclusion, 5 years post-9/11 this moderately exposed cohort of WTC responders continued to demonstrate an elevated risk of several LRS and symptoms suggestive of chronic bronchitis, in comparison with a control group. However, exposure was not associated with reported diagnosis of asthma. Persistence of LRS through the study period was associated with exposure. Results also suggest that asthmatic participants with the highest exposures were more likely to experience increased severity of their asthma symptoms. Our findings

### Table 4. RR and 95% CI for new or increased breathing medication use among exposed versus non-exposed participants prescribed breathing medication for LRS, by mean exposure score, WTC asthma study, NYS, 2003 and 2006

<table>
<thead>
<tr>
<th>Exposure score</th>
<th>N(^c)</th>
<th>Two years post-9/11 (initial)(^a)</th>
<th>5 years post-9/11 (final)(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>New breathing medication</td>
<td>Increased dose of breathing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(since 9/11)</td>
<td>medication (since 9/11)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RR (95% CI)</td>
<td>RR (95% CI)</td>
</tr>
<tr>
<td>Dust exposure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-exposed</td>
<td>64</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Exposed, ≤mean</td>
<td>45</td>
<td>1.3 (0.7–2.3)</td>
<td>2.8 (0.9–9.4)</td>
</tr>
<tr>
<td>Exposed, &gt;mean</td>
<td>18</td>
<td>2.0 (1.0–3.8)</td>
<td>5.3 (1.5–18.9)</td>
</tr>
<tr>
<td>Smoke exposure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-exposed</td>
<td>64</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Exposed, ≤mean</td>
<td>51</td>
<td>1.4 (0.8–2.4)</td>
<td>2.5 (0.8–8.3)</td>
</tr>
<tr>
<td>Exposed, &gt;mean</td>
<td>12</td>
<td>1.9 (0.9–4.1)</td>
<td>8.0 (2.3–28.3)</td>
</tr>
</tbody>
</table>

\(^a\)Includes participants who reported LRS and being prescribed breathing medication by a doctor, on initial questionnaire (2003).

\(^b\)Includes participants who reported LRS and being prescribed breathing medication by a doctor, in final interview (2006).

\(^c\)Four participants were excluded from these analyses for lack of exposure scores.

\(^d\)Two participants were excluded from these analyses for lack of exposure scores.
suggest that even in a moderately exposed responder population [13], lower respiratory effects have been a persistent problem that may require ongoing monitoring. These results help to emphasize the importance of ongoing monitoring for all WTC responders with respiratory symptoms, regardless of their presumed level of exposure. Furthermore, given the lack of an association between exposure and asthma diagnosis, there may be responders with subtle persistent symptoms who would benefit from medical evaluation. It seems prudent to encourage all responders, regardless of arrival time at the disaster site or other measures of exposure, and to seek medical evaluation if they have been experiencing any persistent LRS, even if minor in nature.

Key points

- Moderately exposed World Trade Center responders were at greater risk than controls for reporting lower respiratory symptoms 5 years post-9/11, suggesting persistence of symptoms may be a concern.
- The most highly exposed World Trade Center responders with a history of asthma may have experienced greater severity of asthma symptoms than controls.
- All World Trade Center responders, regardless of arrival time at the disaster site or other measures of exposure, should seek medical evaluation if they have been experiencing any persistent lower respiratory symptoms, even if minor in nature.

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Conflicts of interest

None declared.

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