

Respiratory Symptoms Were Associated With Lower Spirometry Results During the First Examination of WTC Responders

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Objective: Determine if World Trade Center (WTC) disaster responders had lower lung function and higher bronchodilator responsiveness than those with respiratory symptoms and conditions. **Methods:** We evaluated cardinal respiratory symptoms (dyspnea, wheezing, dry cough, productive cough) and determined the difference in FEV₁, FVC, and bronchodilator responsiveness. **Results:** All respiratory symptoms were associated with a lower FEV₁ and FVC, and a larger bronchodilator response. Responders reporting chronic productive cough, starting during WTC work and persisting, had a mean FEV₁ 109 mL lower than those without chronic persistent cough; their odds of having abnormally low FEV₁ was 1.40 times higher; and they were 1.65 times as likely to demonstrate bronchodilator responsiveness. **Conclusions:** Responders reporting chronic persistent cough, wheezing or dyspnea at first medical examination were more likely to have lower lung function and bronchodilator responsiveness.

Workers with exposures to products of combustion (such as those who responded to the World Trade Center disaster) and who report new and persistent respiratory symptoms are more likely to have abnormal lung function (even years later) when compared to those without respiratory symptoms.

INTRODUCTION

Tens of thousands of rescue and recovery workers were exposed to toxic pollutants and caustic materials following the tragedy of 9/11/01. More than half of these workers reported respiratory symptoms at least 3 years after exposure; 55% were considered upper airway symptoms (sinus, nose, and throat) and 44% were considered lower airway symptoms (cough, SOB, and wheezing). These symptoms were persistent and upper and lower respiratory illnesses were the leading referral diagnoses for treatment. Early arrival at WTC was associated with newly incident and worsened respiratory symptoms. In addition to an excess of symptoms, this population had an excess of abnormal spirometry results, and often a low vital capacity (20% of WTC responders compared to 4% of adults in the NHANES III survey).¹ In a small sample of 183 WTC workers, the mean forced expiratory volume in 1 second (FEV₁) was 6% lower in those who developed a cough while working at the site.²

Previous studies have reported modest correlations between respiratory symptoms and spirometry results in occupationally-

exposed workers^{3,4} and population-based samples of adults.^{5,6} Many cigarette smokers develop chronic bronchitis and a susceptible subset also develop chronic airway obstruction.⁷ Never-smokers exposed to sensitizers and respiratory irritants in their workplace can develop airway inflammation which causes both respiratory symptoms and intermittent airway obstruction or asthma.⁸ The WTC medical monitoring and treatment program has now examined over 24,000 workers. Spirometry was performed pre- and postbronchodilator (BD) to aid in the identification and early treatment of asthma in patients with respiratory symptoms. This article establishes a relationship between respiratory symptoms reported by the responders, abnormal spirometry results, and increased BD responsiveness.

METHODS

Study Design and Recruitment

The design of this screening and surveillance program has been described previously.¹ Only data from participants providing written informed consent and, after April 14, 2003, Health Insurance Portability and Accountability Act (HIPAA) authorization for data use were analyzed. Baseline examinations (exam 1) occurred between July 2002 and December 2008. Data collected included demographics, occupational and WTC-related exposure history, smoking status, upper and lower respiratory symptoms and history of receiving medical treatment for specific respiratory conditions (i.e., asthma) and their temporal relationship to 9/11, and pre/post-BD spirometry. The study was approved by the Institutional Review Boards of the consortium members and the Population Protection Committee of the WTC Medical Monitoring and Treatment Program. All data used in this analysis were supplied by the Data Coordinating Center of the monitoring program in response to structured data requests.

Participants

Program participants were eligible for inclusion in this analysis if: (1) they made at least one visit to the monitoring program; (2) They had pulmonary function tests administered at or shortly after that visit; (3) They provided demographic and anthropometric data, and completed the medical questionnaire; and (4) They consented to the use of their data for research. Individual participants included in this report as a whole may be excluded from particular subanalyses because of missing information regarding relevant variables, or because they do not meet additional criteria imposed for the subanalysis.

Questionnaires

A trained health care practitioner administered a medical questionnaire, interviewer administered medical questionnaires (IAMQ) on receiving treatment for selected diagnoses and upper and lower respiratory conditions (e.g., sinusitis and asthma); occurrence of symptoms in the year before 9/11/01, while working at the WTC site, for the month before the screening examination and whether preexisting symptoms and diagnoses worsened during their WTC work; smoking history. Respiratory questions were adapted from standardized instruments whenever possible.⁹ No assessment of causal relationship to work at the disaster site was made.

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We used an interviewer-administered survey instrument, exposure assessment questionnaire (EAQ), to obtain pre- and post-9/11 occupational and environmental exposure histories, including dates that responders reported for first working or volunteering for 9/11-related duties and, for those present on 9/11, whether they were exposed to the cloud of dust from the building collapses.

Symptoms & Conditions

In the IAMQ, participants were asked to provide histories of many common symptoms. These histories included information about the onset and termination of symptoms in relation to the 9/11 WTC disaster. In this report, we focus on the following symptoms: dry cough, productive cough, wheezing or chest tightness, and shortness of breath. We looked at new symptoms with onset after 9/11 that are persistent to the month preceding the screening visit, and conditions, not active prior to 9/11, for which the participant received medical treatment in the 6 months preceding the screening visit. Conditions are those for which treatment was received in the month preceding the visit and which were not present in the year prior to 9/11. See the Appendix for the exact wording of these questions and how they were used to define the symptom and condition variables. Participants were asked if a physician had told them that they had a respiratory condition. We did not attempt to verify these self-reports by a review of the participants' medical records; therefore, we do not consider these conditions to be diagnoses.

Spirometry

Spirometric examinations used standard techniques¹⁰ for performance of a maximal expiratory flow volume loop with a forced expiratory vital capacity maneuver (FVC), followed immediately by a forced inspiratory vital capacity maneuver (FIVC). The maneuvers were repeated 3 to 8 times, with a goal of meeting American Thoracic Society (ATS) acceptability and repeatability criteria for FVC (quality grade A or B). The best three flow volume loops (defined as the highest sum of FEV₁ and FVC) were stored by the spirometer. The spirometer model (EasyOne™ 2001 diagnostic, ndd Medical Technologies, Zurich, Switzerland, firmware version 02.09.00.00) was chosen for accuracy, quality feedback, storage capacity, and minimizing the risk of cross-contamination when performing both FVC and FIVC maneuvers. The inspiratory and expiratory volume accuracy of each spirometer was verified every day of testing to be better than 3% using a 3 L calibration syringe (Hans Rudolph, Kansas City).

Following baseline spirometry (pre-BD), all participants were administered two puffs of albuterol from a metered-dose inhaler, (200 mcg total) using a dual-valve, disposable holding chamber (LiteAire, Thayer Medical, Tucson, Arizona). Technologists then waited 15 minutes before repeating spirometry (post-BD).

Statistical Analyses

Only spirometry tests with quality grades A or B were retained for the analyses reported here. The exclusion of lower quality pulmonary function data resulted in a loss of 19.1% of all spirometry tests, and led to the exclusion of 8% of otherwise eligible participants. The outcome variables considered were FEV₁, FVC, and BD responses of FEV₁ and FVC, (as absolute and percentage changes from pre-BD spirometry). A clinically significant BD response was defined as an increase in FEV₁ (or FVC) of more than 12% and more than 200 mL.¹⁸

Contrasts were performed using the Mann-Whitney *U* test. Spirometry results (percent predicted and percent change post-BD) were compared for each of the following symptoms: dry cough, productive cough, any cough (dry or productive), dyspnea, and wheezing or chest tightness. Further analyses were performed using differences in mean pulmonary function (FVC and FEV₁) as dependent variables and persistent symptoms described above, as independent variables.

TABLE 1. Demographic Characteristics of 18,685 WTC Responders With Spirometry Data From Their First Medical Exam

	<i>N</i>	%
Gender		
Male	15,893	85.1
Female	2,792	14.9
Race/Ethnicity		
White	10,423	55.8
Black	2,146	11.5
Asian	280	1.5
Hispanic	4,802	25.8
Other/Unknown	1,034	5.5
Language of examination		
English	15,674	85.2
Spanish	2,052	11.2
Polish	600	3.3
Other	64	0.4

We also present analyses with dichotomous outcomes: abnormal spirometry results, and a clinically significant BD response. Ordinary least squares linear regression was used for continuous outcome variables, and logistic regression for dichotomous outcomes. In all cases, the main predictor variable was an indicator for the presence of the corresponding symptom or condition. The regression models also included covariates to control for the effects of smoking (current vs. former vs. never), number of pack-years smoked (0 for nonsmokers), race/ethnicity (white, black, or Hispanic), sex, height (including a quadratic term), age (including a quadratic term) and interaction terms between sex and the age and height variables. Adjustments for age and height incorporated quadratic terms, following the methods used by Hankinson and coworkers when developing spirometry reference values.¹¹ Due to the large sample size and multiple hypothesis testing, we do not report *P* values. Instead, the precision of the results is indicated with confidence intervals. Analyses were done using Stata versions 9.2 and 11.

RESULTS

Demographics: The responders screened in this program were predominantly male (85%) and white (56%), with a mean age of 43 years (range: 14 to 85 years), with 84% living in the tri-state (New York, New Jersey, and Connecticut) area: 56% from New York City and 12% on Long Island. We conducted more than 14% of the examinations in languages other than English. A total of 20,549 visit one participants provided and consented to use of their data for research. Of these, 18,685 had spirometry done at or shortly after that visit, and they constitute the basic population of this analysis. See Table 1 for the demographic characteristics of these responders.

There were some differences between the 18,685 responders with good quality spirometry tests who are included in this analysis and the remainder who were excluded. In particular, those with spirometry data were younger (mean age $\pm$ SD 43.0 $\pm$ 9.0 vs. 44.5 $\pm$ 9.2, $P < 0.00005$), somewhat shorter (height 68.6 $\pm$ 3.7 in vs. 68.8 $\pm$ 3.7 in, $P = 0.006$), leaner (body mass index [BMI] 29.6 $\pm$ 5.1 kg/m² vs. 30.6 $\pm$ 5.6 kg/m², $P < 0.00005$); more likely to be union members (83.2% vs. 80.1%, $P = 0.01$); more likely to be construction workers (26.88% vs. 17.8%); less likely to be law enforcement personnel (39.5% vs. 48.1%, $P < 0.0005$); and more likely to be NYC residents (56% vs. 36%, $P < 0.0005$). African American responders were more likely to have completed spirometry than others. The proportions of current, former, and never-smokers among the two groups did not differ.

TABLE 2. Prevalence of Persistent* Upper and Lower Respiratory Symptoms (With Onset After 9/11/01 and Persisting During the 12 Months Prior to the Exam) From All Consenting WTC Responders ($N = 20,549$)†, and Receipt of Medical Treatment Within the Preceding 6 months for Conditions Not Present in the Year Prior to 9/11/2001

Lower Respiratory Symptoms	
Dry cough	26.1%
Productive cough	14.7%
Dyspnea	28.1%
Chest tightness	25.6%
Wheezing	19.8%
Upper Respiratory Symptoms	
Sinus‡	42.4%
Nasal§	51.3%
Throat	42.7%
Recent Treatment for Conditions	
Acute bronchitis	0.57%
Chronic bronchitis	0.29%
GERD	1.81%
Rhinitis	1.00%
Pneumonia	0.11%
Asthma/RADS	0.46%
Sinusitis	2.33%

*Persistent was defined as a report of the respiratory symptom with onset after 9/11/01 and persisting during the month prior to the first examination.

† Missing responses were counted as asymptomatic.

‡Facial pain or pressure, head of sinus congestion, or postnasal discharge.

§Blowing your nose more than usual, stuffy nose, sneezing, runny nose, or irritation in nose.

||Throat irritation, hoarseness, sore throat, or losing your voice (laryngitis).

Prevalence of Respiratory Symptoms and Conditions

About three-fifths of the responders reported at least one persistent lower respiratory symptom since 9/11/01, and about two-thirds reported at least one persistent upper respiratory symptom since 9/11/01. Just under 5% reported recent medical treatment for a condition not present in the year preceding 9/11/01. See Table 2 for details.

Association of Symptoms and Conditions with Spirometry

Overall, the mean FEV₁ and FVC values were about 91% predicted. See Table 3. The prevalence of a low FEV₁ or low FVC ranged from 19% to 29% (depending on symptom status). The contrasts examined involved symptoms of dry cough, productive cough, any cough, shortness of breath, chest tightness, and wheezing as either new, or new and persistent, and the percent predicted FEV₁ and FVC, were compared.

The FEV₁ and the FVC, adjusted for age, gender, race, height, BMI, smoking status, and pack-years, were lower (mean differences ranged from -80 to -124 mL) for participants who reported any persistent respiratory symptom (Table 4). Mean FEV₁ and FVC were also lower in participants reporting lower respiratory conditions. For example, for responders who reported symptoms of a chronic productive cough, starting during their WTC work, the odds ratio of having an abnormally low FEV₁ was 1.40 compared to those not reporting a chronic productive cough. Mean FEV₁ and FVC were also

TABLE 3. Spirometry Results, Mean, and Standard Deviation

	Mean	SD	%pred*	SD
FVC	4.32 L	0.93	91%	14
FEV ₁	3.44 L	0.77	91%	15
Post-BD change	absolute	SD	%change	SD
FEV ₁	+ 134 mL	197	+ 4.4%	7.8
FVC	+ 51 mL	267	+ 1.5%	7.4

$n = 18,685$ with valid FVC and FEV₁, $n = 13,794$ with good quality on both pre- and post-BD spirometry.

*%pred, percent predicted.

lower in responders reporting recent lower respiratory conditions. See Table 5. The odds for abnormal spirometry results were similar for those reporting new respiratory symptoms or conditions which started with 9/11/01 exposures, but not persisting during the month prior to the first examination (results not shown). The odds of having an abnormally low FVC for those with each respiratory symptom were slightly lower than for having a low FEV₁.

Association of Symptoms and Conditions With BD Response

Many persistent respiratory symptoms and conditions (except for pneumonia and chronic bronchitis) were associated with a clinically significant BD response in univariate analyses (Table 6). For example, responders who reported a chronic, persistent cough (wet or dry) were about 1.7 times more likely to have a significant BD response in FEV₁. These respiratory symptoms are not specific for a single condition. There is overlap in the presence of these symptoms and conditions. A logistic regression model, controlling for smoking status, with all of the conditions entered as predictors, revealed that two of the conditions were independently associated with a significant BD response in FEV₁: persistent asthma (Odd Ratio [OR] = 2.82, $P < 0.01$), and persistent sinusitis (OR = 1.84, $P < 0.05$).

In the subset of participants who denied ever having a diagnosis of asthma and who also denied ever wheezing ($n = 10,242$), those with a chronic, persistent cough ($n = 4056$) were more likely to have a significant BD response (OR = 1.35, $P < 0.005$) when compared to those without a persistent cough. Those with chronic rhinitis or chronic sinusitis (but without asthma or wheezing) were no more likely as others to have a significant BD response (OR = 0.9 and 1.3, $P > 0.05$).

DISCUSSION

The key finding was that the subjective respiratory symptoms and conditions reported by the WTC responders were validated by their associations with objective lung function test results. Respiratory symptoms and conditions were associated with lower lung function and a higher rate of BD responsiveness. Mechanisms for these associations may include inflammation of the upper and lower airways, such as rhino-sinusitis, reactive airways disease syndrome (RADS), asthma, COPD, and pneumonias caused by Ground Zero exposures to respiratory irritants. Asthma, acute or chronic bronchitis, rhinosinusitis, and gastro-esophageal reflux are major causes of a chronic cough.¹²⁻¹⁴

In the 1970s, investigators reported modest associations between respiratory symptoms and reduced FVC in asbestos-exposed workers⁴ and in smokers from general population-based samples.¹⁵ More recently, in a large population-based study of 20 to 44-year-old adults from many European cities, cardinal respiratory symptoms were associated with lower spirometry values.⁶ The investigators used factor analysis to determine the "cardinal" symptoms

TABLE 4. Mean Differences in FEV₁ and FVC Associated With Persistent* Respiratory Symptoms, Adjusted for Age, Height, Gender, Race, BMI, Pack Years, and Smoking Status. Symptoms Are of New Onset Since 9/11 and Persistent to the Month Leading Up To the Visit. Conditions Are Those for Which Treatment was Received in the Month Preceding the Visit and Which Were not Present in the Year Prior to 9/11

	FEV ₁			FVC		
	Adjusted Mean Δ (mL)	95% Lower Limit	95% Upper Limit	Adjusted Mean Δ (mL)	95% Lower Limit	95% Upper Limit
Symptom						
Dyspnea	−120	−140	−101	−109	−131	−86
Wheezing	−124	−144	−103	−99	−123	−76
Dry cough	−83	−103	−64	−85	−108	−62
Productive cough	−109	−133	−84	−86	−114	−58
Any cough	−86	−103	−68	−80	−100	−60
Condition						
Asthma	−230	−358	−102	−175	−323	−26
Pneumonia	−229	−494	36	−334	−641	−27
Acute bronchitis	−176	−291	−61	−142	−275	−8
Chronic bronchitis	−186	−360	−13	−205	−406	−3
Chronic rhinitis	−80	−166	6	−68	−167	32
Chronic sinusitis	−68	−123	−12	−96	−160	−32

* Persistent was defined as a report of the respiratory symptom with onset after 9/11/01 and persisting during the month prior to the first examination.

Δ denotes adjusted mean value among those with symptom/condition minus adjusted mean value among those without symptom/condition.

BMI, body mass index.

TABLE 5. Odds Ratios for a Low FEV₁ or Low FVC by Persistent* Respiratory Symptom, Adjusted for Age, Height, Gender, Race, BMI, Pack Years, and Smoking Status. The Prevalence of a Low FEV₁ or Low FVC (Stratified by Symptom) Ranged From 19% to 28%

	FEV ₁			FVC		
	Adjusted Odds Ratio	95% Lower Limit	95% Upper Limit	Adjusted Odds Ratio	95% Lower Limit	95% Upper Limit
Symptom						
Dyspnea	1.52	1.39	1.65	1.36	1.25	1.48
Wheeze	1.59	1.46	1.74	1.34	1.22	1.46
Dry cough	1.33	1.22	1.45	1.29	1.19	1.41
Cough with phlegm	1.40	1.26	1.55	1.29	1.16	1.43

* Persistent was defined as a report of the respiratory symptom with onset after 9/11/01 and persisting during the month prior to the first examination.

which were associated with BD responsiveness, atopy (positive allergen skin tests), or smoking.¹⁶ These factors were (1) wheezing and shortness of breath, (2) cough, (3) phlegm, and (4) asthma. The specific questions with the highest associations (factor loadings) were “wheezing or whistling during the last 12 months,” “usually cough during day or night in winter,” “usually bring up phlegm on most days, as much as 3 months per year,” and “ever had asthma” (whether or not confirmed by a doctor). For example, they found that a report of wheezing was associated with a mean FEV₁ 114 mL and 124 mL lower (for women and men, respectively), while the mean FEV₁ difference in our participants (with new wheezing) was −131 mL (Table 4). The results of associations of symptoms with spirometry in our study were also similar to theirs, even though only a minority were women, the age range of our participants was higher, and we did not measure atopy.

Patients with asthma may have normal baseline spirometry if they are not experiencing respiratory symptoms on the day of the test,¹⁷ but in those with a history of intermittent respiratory symptoms, a large BD response confirms asthma.^{18,19} We found that responders with a history of wheezing or chest tightness were more likely to have a larger BD response in FEV₁ and FVC.

Some patients with a chronic cough deny wheezing or a history of asthma, but inhalation challenge testing shows that they have airway hyperresponsiveness, and their chronic cough is suppressed by asthma therapy (daily inhaled corticosteroids).¹² These patients are said to have “cough variant asthma.” Although we did not routinely perform inhalation challenge testing for participants with a chronic, persistent cough but without a history of wheezing or asthma, they were more likely than other participants to have a significant BD response (after correcting for smoking status). Significant BD responses and significant responses to inhalation challenge tests are common features of asthma, but are not highly correlated with each other in population-based samples of adults.²⁰

Bronchodilator responses have been measured in population-based samples of adults.^{21–23} In a recent study of 633 adults who were selected from a random postal survey of the residents of Helsinki, Finland,²⁴ a mean FEV₁ increase was 2.5% (77.2 mL). In a subset of 219 healthy asymptomatic nonsmokers, the average BD response was 1.8% (62.0 mL). In comparison, the mean FEV₁ BD response was + 4.3% (134 mL) in our participants.

Limitations of this study include the lack of questionnaire or spirometry data prior to 9/11/01, an unexposed contemporary control

TABLE 6. Odds Ratios for a Significant FEV₁ Response to Albuterol by Persistent Respiratory Symptoms and Respiratory Conditions, Adjusted for Smoking Status. Symptoms Are of New Onset Since 9/11 and Persistent to the Month Leading Up To the Visit. Conditions are Those for Which Treatment Was Received in the Month Preceding the Visit and Which Were not Present in the Year prior to 9/11

	FEV ₁ Response to Albuterol			FVC Response to Albuterol		
	Adjusted Odds Ratio	95% Lower Limit	95% Upper Limit	Adjusted Odds Ratio	95% Lower Limit	95% Upper Limit
Symptom						
Dyspnea	1.70	1.47	1.96	1.91	1.61	2.27
Wheeze	1.84	1.59	2.14	1.89	1.58	2.26
Any cough (wet or dry)	1.65	1.43	1.89	1.57	1.33	1.85
Condition						
Asthma	2.86	1.43	5.73	3.63	1.74	7.56
Pneumonia	0.97	0.13	7.45	3.26	0.72	14.74
Acute bronchitis	2.03	1.00	4.12	3.00	1.47	6.13
Chronic bronchitis	2.13	0.73	6.20	3.02	1.03	8.87
Chronic rhinitis	1.66	0.94	2.92	1.46	0.73	2.92
Chronic sinusitis	1.80	1.26	2.57	1.91	1.27	2.87

The American Thoracic Society criteria for response¹⁸ are an increase in FEV₁ (or FVC) of more than 12% and more than 200 mL. The prevalence of BD responsiveness (stratified by symptom or condition) ranged from 5% to 25%.

FEV₁, forced expiratory volume in 1 second; FVC₁, forced expiratory vital capacity.

group, the lack of quantitative exposure data, the lack of tests of airway inflammation, and the relatively long delays between the initial exposures and the first examination. Self-reports of symptoms and conditions prior to and after 9/11/01 were subject to recall bias, compensability for bronchial disease, and self-selection bias for the subset of WTC responders with respiratory symptoms. Not all of the WTC responders participated in the medical examinations, some did not consent to allow their questionnaire or test results to be reported (even in aggregate), and results from firefighters were analyzed and reported separately. Not all of the responders completed good-quality spirometry tests both before and after BD. Inhalation challenge testing, as done in a small sample of firefighters following 9/11/01 exposures²⁵ was not available to confirm bronchial hyperresponsiveness in those with a history suggesting asthma but normal spirometry results. Some WTC responders gained weight during the follow-up period and weight gain was an independent predictor of reductions in FVC [Skloot 2009]. Weight gain can also increase the risk of dyspnea on exertion, thus potentially confounding the association of dyspnea with FEV₁ and FVC; however, our adjustment for BMI in the models reduced the effect of this confounding.

Statistically, the occurrence of various symptoms and conditions studied exhibits correlation (correlation coefficients ranged from 0.17 to 0.64). Accordingly, the similarity of findings across different symptoms and conditions does not carry the weight that would derive from fully independent tests. However, the strengths of the study include the excellent quality of the spirometry tests, the inclusion of post-BD spirometry (unavailable in studies of WTC firefighters), the use of standardized questionnaires, and the large number of responders who completed the exams, enabling high statistical power to determine associations between symptoms, conditions, and lung function, even after correcting for multiple potential confounders (such as smoking status, gender, age, and weight).

In summary, respiratory symptoms were associated with lower lung function and increased BD responsiveness. The clinical implication of this finding is that when workers are referred to medical providers with a chronic cough, wheezing, or dyspnea following exposures to respiratory irritants and sensitizers, pulmonary function testing should be done because of the increased risk of airway disease.

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APPENDIX: THE EXACT WORDING OF THE RESPIRATORY QUESTIONS.

Dyspnea, new = In the year prior to 9/11/01, were you troubled by shortness of breath when hurrying on the level or walking up a slight hill? (No) Did you have shortness of breath while you were working or volunteering on the WTC effort? (Yes)

Persistent dyspnea = new Dyspnea AND Within the past 1 month, were you troubled by shortness of breath when hurrying on the level or walking up a slight hill? (Yes)

Wheezing, new = In the year prior to 9/11/01, did your chest occasionally sound wheezy or whistling apart from when you had a cold? (No) While you were working or volunteering on the WTC effort, did your chest occasionally sound wheezy or whistling apart from when you had a cold? (Yes)

Persistent wheezing = new Wheezing AND Has your chest sounded wheezy or whistling in the past month? (Yes)

Dry cough, new = Did you usually have a dry cough in the 1 year before 9/11/01? (No) Did you usually have a dry cough while you were working or volunteering on the WTC effort? (Yes)

Persistent dry cough = new Dry cough AND Within the past 1 month, have you *usually* had a dry cough? (Yes)

Productive cough (new) = In the 1 year before 9/11/01, did you *usually* have a cough with phlegm (wet cough)? (No) AND Did you usually have a wet cough while you were working or volunteering on the WTC effort? (Yes)

Persistent productive cough = New Productive cough AND Within the past 1 month, have you *usually* had a cough with phlegm (wet cough)? (Yes)

*The dyspnea and wheezing questions were modified from the ATS/DLD-78 standardized respiratory questionnaire [9], in order to add the relationship to the 9/11/01 event.

Questions about respiratory conditions during the previous month, which had been diagnosed by a physician:

Have you had attacks of bronchitis? (ATS Q#17–1A)

Have you had pneumonia? (ATS Q#17–2A)

Have you had chronic bronchitis? (ATS Q#18A)

Have you had asthma (cough variant or RADS)? (ATS Q#20A)