

## ORIGINAL ARTICLE

**Factors associated with poor control of 9/11-related asthma 10–11 years after the 2001 World Trade Center terrorist attacks**

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**Abstract**

**Objective:** To identify key factors associated with poor asthma control among adults in the World Trade Center (WTC) Health Registry, a longitudinal study of rescue/recovery workers and community members who were directly exposed to the 2001 WTC terrorist attacks and their aftermath. **Methods:** We studied incident asthma diagnosed by a physician from 12 September 2001 through 31 December 2003 among participants aged  $\geq 18$  on 11 September 2001, as reported on an enrollment (2003–2004) or follow-up questionnaire. Based on modified National Asthma Education and Prevention Program criteria, asthma was considered controlled, poorly-controlled, or very poorly-controlled at the time of a 2011–2012 follow-up questionnaire. Probable post-traumatic stress disorder, depression, and generalized anxiety disorder were defined using validated scales. Self-reported gastroesophageal reflux symptoms (GERS) and obstructive sleep apnea (OSA) were obtained from questionnaire responses. Multinomial logistic regression was used to examine factors associated with poor or very poor asthma control. **Results:** Among 2445 participants, 33.7% had poorly-controlled symptoms and 34.6% had very poorly-controlled symptoms in 2011–2012. Accounting for factors including age, education, body mass index, and smoking, there was a dose–response relationship between the number of mental health conditions and poorer asthma control. Participants with three mental health conditions had five times the odds of poor control and 13 times the odds of very poor control compared to participants without mental health comorbidities. GERS and OSA were significantly associated with poor or very poor control. **Conclusions:** Rates of poor asthma control were very high in this group with post-9/11 diagnosed asthma. Comprehensive care of 9/11-related asthma should include management of mental and physical health comorbidities.

**Keywords**

Anxiety, asthma control, cohort study, epidemiology, management/control, post-traumatic stress disorder, World Trade Center

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**Introduction**

It is estimated that over 25 000 persons developed asthma after exposure to the 11 September 2001 World Trade Center (WTC) terrorist attacks (9/11) and the subsequent rescue and recovery efforts [1]. In the years immediately following 9/11, new-onset asthma rates were elevated among both rescue/recovery workers and exposed community members [1]. Many of those affected continued to experience respiratory symptoms years later [1–5].

Although the association between 9/11 exposure and new-onset asthma is well documented [1,2,6,7], the degree of

symptom control among persons with chronic 9/11-related asthma has not been studied systematically. Because poor control of asthma is associated with a substantial decrement in quality of life [8,9] and with sizable increases in healthcare costs [10], it is important to characterize the level of control among people with 9/11-related asthma, and to identify potentially-modifiable factors associated with poor control.

Asthma control is affected by many factors, including inherent inflammatory or remodeling status of the disease [11], adequacy of and adherence to medical treatment [12–14], healthcare access [15], socioeconomic status [13,15], and comorbid physical and mental health conditions [13,14,16,17]. Several of the health conditions which are associated with poor asthma control are common among survivors of the WTC terrorist attacks; these include gastroesophageal reflux disorder (GERD) [2,18,19], obstructive sleep apnea (OSA) [20,21], obesity [22,23], post-traumatic stress disorder (PTSD) [1,2,24,25], depression [2,24,25] and anxiety [2,25]. Previous studies have found close links between respiratory and mental illnesses among persons exposed to 9/11 [26–29], and a study performed six to nine months after 9/11 found an

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Box 1. Definition of asthma control (based on National Asthma Education and Prevention Program, Third Expert Panel on the Diagnosis and Management of Asthma, EPR 3) [31].

Component of control	Controlled <sup>a</sup>	Poorly-controlled <sup>a</sup>	Very poorly-controlled <sup>a</sup>
Shortness of breath, wheezing, and/or cough	≤2 d/week	3–6 d/week	Daily
Nighttime awakenings	≤2x/month	1–3x/week	≥4x/week
Interference with normal activity <sup>b</sup>	None/a little of the time	Some/most of the time	All of the time
Use of a rescue inhaler or nebulizer <sup>c</sup>	<3x/week	1–2x/d	>2x/d

<sup>a</sup>Participants were assigned to the most severe category in which any component was reported.

<sup>b</sup>This differs slightly from the EPR 3 definition, which specifies no interference with normal activity for well-controlled, some limitation for poorly-controlled, and extreme limitation for very poorly-controlled asthma.

<sup>c</sup>This differs slightly from the EPR 3 definition, which specifies inhaler use ≤2 d/week for well-controlled, >2 d a week for poorly-controlled, and several times per day for very poorly-controlled asthma.

association between PTSD and asthma severity [30]. However, the association between comorbid physical and mental health conditions and the level of asthma control among 9/11 survivors has not been examined.

We studied asthma control approximately 10 years after 9/11 among participants in the WTC Health Registry, a longitudinal study of rescue/recovery workers and community members who were directly exposed to the disaster and/or the subsequent cleanup efforts. We sought to determine the extent to which health conditions comorbid with 9/11-related asthma are associated with poor asthma control.

## Methods

The WTC Health Registry is a longitudinal cohort study of rescue/recovery workers and volunteers; lower Manhattan area residents, students, and workers; and passersby and commuters on 9/11. Participants were recruited through lower Manhattan area building or employer lists, or encouraged to enroll via a toll-free telephone number or website. Enrollees are re-surveyed every two to four years. In 2003–2004, 71 431 persons enrolled in the Registry and completed a baseline questionnaire (Wave 1) via telephone (95%) or in person (5%). In 2006–2007, 46 602 (68%) eligible adult Registry enrollees completed telephone, web-based, or paper Wave 2 questionnaires. The Wave 3 survey, conducted in 2011–2012, was completed by 43 134 (65%) eligible adult enrollees. Wave 1 included questions about 9/11-related exposures. All surveys inquired about enrollees' medical history and physical and mental health status. The Registry's protocol was approved by the institutional review boards of the US Centers for Disease Control and Prevention and the New York City Department of Health and Mental Hygiene.

## Study sample

We focused this analysis on asthma diagnosed between 9/11 and the end of 2003 in order to study asthma that was most likely to be associated with 9/11-related exposures [1]. Among active Registry enrollees aged ≥18 years on 11 September 2001 who completed the Wave 3 questionnaire (2011–2012) and reported no history of asthma before 9/11 ( $n = 37\,037$ ), 5405 reported having been diagnosed with asthma by a medical professional after 9/11 on the Wave 1, 2, and/or 3 questionnaire(s). Of these, 2777 reported being diagnosed between 11 September 2001 and 31 December 2003. We excluded 332 enrollees with insufficient data to define the level of asthma control (i.e. missing data on

respiratory symptoms, nighttime awakenings, medication use, or interference with daily activity), leaving a study sample of 2445.

## Study outcome

We categorized study participants as having controlled, poorly-controlled, or very poorly-controlled asthma based on modified criteria from the National Asthma Education and Prevention Program's Third Expert Panel Report (Box 1) [31].

## Additional study variables

Participants were categorized as either rescue/recovery workers (including volunteers) or community members (including lower Manhattan area residents; area workers; passersby or commuters on 9/11; and area school staff or students). Those who reported having been caught in the dust and debris cloud on 9/11 on the Wave 1 questionnaire were considered to have had dust cloud exposure. An affirmative response to this question was strongly associated with post-9/11 respiratory outcomes in previous Registry studies [1,7]. Respiratory symptoms, healthcare seeking for asthma and comorbid conditions were assessed at Wave 3. Smoking history was taken from Wave 3 or, if that was missing, from the most recent questionnaire where smoking data were available. Participants who answered "yes" to the question, "During the last 12 months, have you had an episode of asthma or an asthma attack?" were considered to have had an asthma attack. Self-reported hospitalizations and ER visits for asthma were used as indicators of healthcare utilization.

Mental health conditions were defined based on responses to three validated scales. Participants with a score ≥44 on the PTSD Checklist, Stressor-Specific Version [32,33], a 17-item scale that inquired about 9/11-related psychological symptoms during the 30 d before Wave 3, were considered to have probable PTSD. Probable depression within the two weeks before completion of Wave 3 was defined as a score ≥10 on the 8-item Patient Health Questionnaire depression scale [34]. Probable generalized anxiety disorder (GAD) during the two weeks before Wave 3 was defined as a score ≥10 on the 7-item GAD scale [35]. Because the symptoms of PTSD, depression, and GAD overlap extensively, we created a variable reflecting how many of these conditions (0–3) a participant was experiencing at the time of survey completion.

Participants who reported having heartburn at least once a week during the 12 months preceding Wave 3 were considered to have gastroesophageal reflux symptoms

(GERS). A history of physician-diagnosed OSA was obtained from the Wave 3 questionnaire. Body mass index (BMI) at Wave 3 was calculated from self-reported height and weight data; a BMI <25 was considered under or normal weight; 25–29.9 was considered overweight;  $\geq 30$  was obese. Poor access to medical care was defined as reporting  $\geq$  one of the following: not having health insurance at the time of Wave 3 completion; not having a personal healthcare provider at Wave 3; or having been unable to obtain some type of health care that they needed during the 12 months before Wave 3.

### Statistical analyses

Cochran-Mantel-Haenszel tests of association were used to evaluate the statistical significance of differences in the distribution of independent variables across levels of asthma control. We used multinomial logistic regression to examine factors potentially associated with poor and very poor asthma control, including socio-demographic and lifestyle characteristics, access to medical care, exposure to the 9/11 dust cloud, and comorbid health conditions. Factors that have been associated with asthma control in previous studies and/or were associated with asthma control in bivariable analysis with a  $p$  value less than 0.2 were entered into multivariable models. Independent variables that remained associated with the outcome with a  $p$  value less than 0.05 were retained in the final model. Tests of significance were two-sided and assumed a type 1 error of 5%. We used SAS software (version 9.2, SAS Institute Inc, Cary, NC).

### Results

Characteristics of the study sample are shown in Table 1. Participants had a mean age of 42.9 years on 9/11, were predominantly male (59.1%), non-Hispanic white (64.6%) and highly educated (44.7% college graduate). At the time of Wave 3, most (66.6%) lived with a spouse or partner, and 11.8% smoked. Over half (57.7%) had performed 9/11-related rescue/recovery work, and 62% reported having been exposed to the dust and debris cloud on 9/11. Comorbid GERS (46.9%), OSA (31.2%) and obesity (42.7%) were common among participants.

More than two-thirds of participants had poorly-controlled (33.7%) or very poorly-controlled asthma (34.6%) at the time of Wave 3 completion (2011–2012). A higher proportion of participants with poorly- or very poorly-controlled disease (59.2% and 62.1%, respectively) had performed rescue/recovery work compared to participants with controlled asthma (51.2%; Table 2). Dust cloud exposure was reported by a higher proportion of participants with poorly- or very poorly-controlled asthma (64.0% and 64.9%, respectively) compared to participants with controlled asthma (56.7%). Older age, male sex, lower educational attainment, current smoking and poor access to medical care were also associated with uncontrolled asthma in bivariable analysis, while race/ethnicity did not differ significantly across levels of asthma control.

Consistent with the definition of control used in this analysis, most participants who were categorized as having poorly-controlled asthma reported shortness of breath, wheezing, and/or persistent cough within the 30 d preceding Wave 3; the proportion reporting each of these symptoms

Table 1. Characteristics of 2445 World Trade Center Health Registry enrollees with early post-9/11 asthma<sup>a</sup>.

Variable	Mean $\pm$ SD or $n$ (%) N = 2445
Age on 9/11, years	42.1 $\pm$ 9.9
Sex (male)	1444 (59.1)
Non-Hispanic white	1579 (64.6)
Education	
High school or less	625 (25.6)
Some college	706 (28.9)
College graduate	1093 (44.7)
Cohabiting <sup>b</sup>	1629 (66.6)
Smoking status <sup>b</sup>	
Never	1340 (54.8)
Current	289 (11.8)
Former	807 (33.0)
Registry eligibility group	
Rescue + recovery workers	1410 (57.7)
Non-rescue/recovery participants <sup>c</sup>	1035 (42.3)
Reported dust cloud exposure on 9/11	1516 (62.0)
Probable PTSD <sup>b,d</sup>	926 (37.9)
Probable depression <sup>b,e</sup>	864 (35.3)
Probable GAD <sup>b,f</sup>	661 (27.0)
Gastroesophageal reflux symptoms <sup>b</sup>	1147 (46.9)
Obstructive sleep apnea	762 (31.2)
Body mass index <sup>b</sup>	
Under/normal weight	512 (20.9)
Overweight	834 (34.1)
Obese	1043 (42.7)

PTSD: post-traumatic stress disorder; GAD: generalized anxiety disorder.

Percentages may not sum to 100 due to missing values.

<sup>a</sup>Early post-9/11 asthma was defined as asthma first diagnosed between 11 September 2001 and 31 December 2003.

<sup>b</sup>Measured at Wave 3 (2011–2012).

<sup>c</sup>Community members included lower Manhattan area residents and workers as well as commuters and passersby on 9/11.

<sup>d</sup>Probable PTSD defined as a score  $\geq 44$  on the Post-traumatic Stress Disorder Checklist, Stressor-Specific Version.

<sup>e</sup>Probable depression defined as a score  $\geq 10$  on the 8-item Patient Health Questionnaire.

<sup>f</sup>Probable GAD defined as a score  $\geq 10$  on the 7-item Generalized Anxiety Disorder scale.

was still higher among participants considered to have very poorly-controlled disease (Table 2). A similar gradient was observed with reported asthma attacks; 57.1% of participants with poor control and 66.6% of those with very poor control reported having had at least one asthma attack during the past year, compared to 32.2% of those with controlled asthma. Emergency department visits and hospitalizations for asthma within the preceding year were also much more common among those with poor or very poor control.

Table 2 shows the prevalence of co-morbid mental and physical health conditions according to level of asthma control. The number of mental health conditions present at Wave 3 was inversely correlated with asthma control. GERS and OSA were each significantly more common among those with poor or very poor control compared to those with controlled asthma. BMI tended to be higher in the groups with poorer asthma control.

In multivariable analysis, the number of co-morbid mental health conditions was strongly associated with the level of asthma control in a dose–response fashion: compared with participants with no mental health conditions, participants with one, two and three mental health conditions had

Table 2. Socio-demographic characteristics, symptoms, healthcare utilization and access, and comorbid conditions among 2445 World Trade Center Health Registry enrollees with early post-9/11 asthma<sup>a</sup> according to level of asthma control<sup>b</sup> in 2011–2012.

Variable	Controlled (N = 773) % or mean ± SD	Poorly-controlled (N = 825) % or mean ± SD	Very poorly-controlled (N = 847) % or mean ± SD	p Value
Socio-demographic and exposure characteristics				
Age on 9/11, years	39.8 ± 9.7	42.3 ± 9.3	43.9 ± 10.3	<0.001
Sex (male)	52.8	61.5	62.5	<0.001
Non-Hispanic white	67.8	62.1	64.1	0.13
Education				
High school or less	15.0	27.0	33.8	<0.001
Some college	26.5	29.2	30.7	
College graduate	58.3	42.9	34.0	
Smoking status <sup>c</sup>				
Never	59.9	58.6	46.5	<0.001
Current	7.6	12.1	15.4	
Former	32.2	29.3	37.3	
Registry eligibility group				
Rescue + recovery	51.2	59.2	62.1	<0.001
Non-rescue/recovery participants <sup>d</sup>	48.8	40.9	37.9	
Dust cloud exposure on 9/11	56.7	64.0	64.9	0.001
Symptoms, past 30 d <sup>c</sup>				
Shortness of breath	39.5	80.6	91.4	<0.001
Wheezing	29.6	68.6	82.4	<0.001
Persistent cough	14.8	57.1	75.0	<0.001
Health care access and seeking				
≥1 asthma attack, past year <sup>c</sup>	32.2	57.1	66.6	<0.001
≥1 ER visit, past year <sup>c</sup>	6.0	14.1	26.3	<0.001
≥1 asthma hospitalization, past year <sup>c</sup>	0.3	2.1	6.4	<0.001
Poor access to medical care <sup>e</sup>	16.0	25.2	28.2	<0.001
Comorbid conditions				
Probable PTSD <sup>c,f</sup>	13.8	42.1	55.7	<0.001
Probable depression <sup>c,g</sup>	13.3	35.6	55.1	<0.001
Probable GAD <sup>c,h</sup>	10.1	26.4	43.1	<0.001
No. of mental health conditions <sup>c</sup>				
None	76.2	48.0	32.1	<0.001
One	10.4	14.4	13.5	
Two	5.7	12.0	14.6	
Three	4.8	20.7	35.9	
Gastroesophageal reflux symptoms <sup>c</sup>	29.5	49.3	60.5	<0.001
History of physician-diagnosed OSA	17.6	34.2	40.6	<0.001
Body mass index <sup>c</sup>				
Under/normal weight	27.7	18.1	17.6	<0.001
Overweight	36.2	33.6	32.7	
Obese	34.9	46.1	46.4	

ER: emergency room; GAD: generalized anxiety disorder; PTSD: post-traumatic stress disorder.

Percentages may not sum to 100 due to missing values. P-values are for Cochran-Mantel-Haenszel tests of association.

<sup>a</sup>Early post-9/11 asthma was defined as asthma first diagnosed between 11 September 2001 and 31 December 2003.

<sup>b</sup>Level of control defined based on modified criteria from the National Asthma Education and Prevention Program's Third Expert Panel Report guidelines [31].

<sup>c</sup>Measured at Wave 3 (2011–2012).

<sup>d</sup>Community members included lower Manhattan area residents and workers as well as commuters and passersby on 9/11.

<sup>e</sup>Poor access to medical care was defined as reporting ≥1 of the following: not having health insurance at the time of Wave 3 completion; not having a personal healthcare provider at Wave 3; or having been unable to obtain some type of health care that they needed during the 12 months before Wave 3.

<sup>f</sup>Probable PTSD defined as a score ≥44 on the Post-traumatic Stress Disorder Checklist, Stressor-Specific Version.

<sup>g</sup>Probable depression defined as a score ≥10 on the 8-item Patient Health Questionnaire.

<sup>h</sup>Probable GAD defined as a score ≥10 on the 7-item Generalized Anxiety Disorder scale.

respective adjusted odds ratios (AORs) of 2.00, 2.69 and 5.54 for poor control and 2.75, 4.71 and 13.23 for very poor control (Table 3). The physical health comorbidities examined also remained associated with the level of asthma control. Enrollees with GERS had an elevated odds of poor (AOR 1.78, CI 1.41–2.25) or very poor (AOR 2.28, CI 1.78–2.92) control. Participants with OSA had a 39% higher odd of poor control and a 48% higher odds of very poor control compared with enrollees without OSA. Those who performed rescue/recovery work also had an increased odds of poor or very poor control. Older age, lower educational attainment and current

smoking remained associated with poorer control of asthma symptoms as well. However, exposure to the dust cloud on 9/11, sex and access to medical care lost statistical significance when adjusted for other factors, and were thus removed from the final model.

Because we observed higher AORs for poor or very poor control among persons with more than one mental health condition, we also examined the relationship between each individual mental health condition and the level of asthma control. Probable PTSD, probable depression, and probable GAD were each significantly associated with the level of

Table 3. Multivariable odds ratios<sup>a</sup> for association of level of control of early post-9/11 asthma<sup>b</sup> with selected demographic and medical risk factors.

Characteristic	Poorly-controlled <sup>c</sup> N = 719			Very poorly-controlled <sup>c</sup> N = 725		
	AOR <sup>a</sup>	95% CI		AOR <sup>a</sup>	95% CI	
Age on 9/11 (years)	1.03	1.02	1.04	1.05	1.03	1.06
Education						
High school or less	1.77	1.31	2.39	2.38	1.74	3.27
Some college	1.31	1.01	1.70	1.60	1.21	2.13
College graduate	ref			ref		
Smoking status <sup>d</sup>						
Never	ref			ref		
Current	1.24	0.83	1.86	1.82	1.20	2.76
Former	0.79	0.62	1.01	1.21	0.93	1.57
Registry eligibility group						
Rescue + recovery participants	1.33	1.05	1.67	1.64	1.27	2.11
Community members <sup>e</sup>	ref			ref		
No. of mental health conditions <sup>d,f</sup>						
None	ref			ref		
One	2.00	1.43	2.78	2.75	1.94	3.92
Two	2.69	1.79	4.03	4.71	3.13	7.08
Three	5.54	3.67	8.37	13.23	8.76	19.98
Gastroesophageal reflux symptoms <sup>d</sup>						
Yes	1.78	1.41	2.25	2.28	1.78	2.92
No	ref			ref		
History of physician-diagnosed OSA						
Yes	1.39	1.06	1.82	1.48	1.12	1.97
No	ref			ref		
Body mass index <sup>d</sup>						
Under/normal weight	ref			ref		
Overweight	1.31	0.96	1.77	1.19	0.85	1.65
Obese	1.60	1.18	2.17	1.47	1.05	2.05

AOR: adjusted odds ratio; CI: confidence interval; OSA: obstructive sleep apnea.

<sup>a</sup>Odds ratios are adjusted for all other variables shown in table. Reference group = controlled ( $n = 716$ ). Numbers differ from previous tables because participants with incomplete covariate data were not included in the multivariable analysis.

<sup>b</sup>Early post-9/11 asthma was defined as asthma first diagnosed between 11 September 2001 and 31 December 2003.

<sup>c</sup>Level of control defined based on National Asthma Education and Prevention Program's Third Expert Panel Report guidelines [31].

<sup>d</sup>Measured at Wave 3 (2011–2012).

<sup>e</sup>Community members included lower Manhattan area residents and workers as well as commuters and passersby on 9/11.

<sup>f</sup>Mental health conditions assessed by questionnaire were probable post-traumatic stress disorder, depression, and generalized anxiety disorder.

asthma control (Table 4). The highest AORs were those for the association between PTSD and poor or very poor control, but AORs were generally similar in magnitude for the three mental health conditions. For each mental health condition, the AORs increased across decreasing level of asthma control.

## Discussion

Ten years after the 9/11 WTC terrorist attacks, more than two-thirds of WTC Health Registry enrollees with post-9/11 asthma had poorly- or very poorly-controlled symptoms. Comorbid mental health conditions were strongly associated with sub-optimal asthma control in a dose–response fashion. In addition, GERS, OSA, and obesity, physical health conditions that are common among persons exposed to 9/11, were independent risk factors for poor asthma control. Control of chronic asthma was not related to whether an individual had been exposed to the dust and debris cloud on 9/11.

The concurrent presence of one or more mental health conditions was the strongest risk factor for poor asthma control identified in this study. Each mental health condition

was associated with poorer asthma control individually, but having multiple mental health conditions markedly increased the odds of poor asthma control. This is consistent with previous community-based studies which have identified associations between psychiatric disorders or symptoms and poor control of asthma [17,36], and with the finding of a high prevalence of pathologic health anxiety in a group of patients who were evaluated for occupational asthma [37]. Other studies of persons exposed to the 9/11 disaster have also found links between psychological and lower respiratory symptoms [26–30,38]. Unlike the earlier studies of 9/11-related respiratory illnesses, however, ours controlled for several physical comorbidities known to exacerbate asthma, thus extending the evidence for an association between respiratory and psychological status. Although the explanation for this relationship is uncertain, it is possible that mental health symptoms worsen respiratory symptoms directly, increase the likelihood of perceiving or reporting respiratory symptoms, or interfere with access or adherence to medical treatment for respiratory symptoms. Alternatively, it is conceivable that respiratory symptoms trigger or increase psychological distress, or that concurrent respiratory and psychological symptoms result

Table 4. Multivariable odds ratios<sup>a</sup> for association of level of control of early post-9/11 asthma<sup>b</sup> with comorbid mental health conditions.

Characteristic	Poorly-controlled <sup>c</sup>		Very poorly-controlled <sup>c</sup>			
	AOR <sup>a</sup>	95% CI	AOR <sup>a</sup>	95% CI		
Probable PTSD <sup>d</sup>						
Yes	3.88	2.96	5.09	6.17	4.68	8.13
No	ref			ref		
Probable depression <sup>e</sup>						
Yes	2.83	2.15	3.73	5.93	4.49	7.84
No	ref			ref		
Probable GAD <sup>f</sup>						
Yes	2.80	2.05	3.81	5.53	4.06	7.53
No	ref			ref		

AOR: adjusted odds ratio; CI: confidence interval; GAD: generalized anxiety disorder; PTSD: post-traumatic stress disorder.

<sup>a</sup>AORs shown are from three separate models. Each is adjusted for age, education, smoking, Registry eligibility group, gastroesophageal reflux symptoms, history of obstructive sleep apnea, and category of body mass index.

<sup>b</sup>Early post-9/11 asthma was defined as asthma first diagnosed between 11 September 2001 and 31 December 2003.

<sup>c</sup>Level of control defined based on National Asthma Education and Prevention Program's Third Expert Panel Report guidelines [31].

<sup>d</sup>Probable PTSD defined as a score  $\geq 44$  on the Post-traumatic Stress Disorder Checklist, Stressor-Specific Version.

<sup>e</sup>Probable depression defined as a score  $\geq 10$  on the 8-item Patient Health Questionnaire.

<sup>f</sup>Probable GAD defined as a score  $\geq 10$  on the 7-item Generalized Anxiety Disorder scale.

from joint risk factors. Longitudinal study will be required to clarify the directionality of the association; nonetheless, our findings underscore the importance of integrating physical and psychological health care services for persons directly exposed to 9/11, and for survivors of other incidents that include both psychological and physical exposures.

Although only a minority of participants in this analysis had well-controlled asthma, previous studies conducted in a variety of populations have found similarly low levels of asthma control [13,39,40]. The high level of physical and psychological comorbidity among those with 9/11-related asthma may compound the inherent difficulty of achieving sustained control of respiratory symptoms. Nonetheless, careful titration of maintenance medications has been shown to be effective in clinical trials [41], indicating that there may be opportunities for improved symptom management in this population, particularly if physical and psychological health care are coordinated effectively. Because the level of asthma control is closely tied to health-related quality of life [9], better control could substantially improve the day-to-day experience for many persons with post-9/11 asthma. Improved control could also generate substantial health care savings if asthma-related ER visits and hospitalizations, which were relatively common among participants with poorly or very poorly-controlled asthma, were prevented.

GERS were highly prevalent among persons with poorly or very poorly-controlled asthma (49.3% and 60.5%, respectively), and were a risk factor for poor control in multivariable analysis. The association between GERS and poorer control of asthma is consistent with previous findings that GERD exacerbates asthma symptoms [42,43]. Our results suggest that clinicians caring for persons with 9/11-related asthma

should be aware that GERD is a common co-morbidity, and that treatment of symptomatic GERD may lead to improvement in certain asthma symptoms and measures of asthma-related quality of life [44–46].

We also identified a weaker, yet statistically-significant, association between OSA and poorly- and very poorly-controlled asthma. Based on evidence that treatment of OSA with continued positive airway pressure can improve asthma symptoms in persons with comorbid OSA [47], current asthma treatment guidelines recommend assessing persons with uncontrolled asthma for OSA [31]. Our findings indicate that this may be particularly relevant in persons with 9/11-related asthma.

This analysis was limited by a lack of information on prescription medications and adherence to treatment, which are key determinants of asthma control. We plan to gather data on medication use in future follow-up surveys. We also lacked data on atopic status, and on concurrent upper airway and sinus problems, which are known to exacerbate asthma symptoms. Interpretation of our results also must take into account that all data, including the diagnosis of asthma and co-morbid physical conditions, were self-reported. However, a high level of agreement was found between self-reported and medically-confirmed asthma among New York City firefighters who were exposed to the 9/11 disaster [48].

Strengths of this study include the relatively large sample size, the inclusion of both rescue/recovery workers and community members, and the availability of data on a wide range of comorbid health conditions, including responses to three validated mental health scales. Many of our findings, including the association of lower educational attainment and current smoking with poorer control, are well-documented in previous literature [14,15,40], suggesting that we were able to accurately identify factors associated with poor asthma control in this study population. Therefore, despite some limitations, this study contributes important information on the level of asthma control among persons with chronic post-9/11 asthma, and on factors that are correlated with poor control.

## Conclusions

Only a minority of participants with post-9/11 asthma had well-controlled symptoms approximately a decade after the 9/11 WTC terrorist attacks. Similarly low rates of control have been identified in previous community-based studies of adult-onset asthma; what is unique to persons with post-9/11 asthma, however, is the high rate of comorbid mental and physical health conditions that may make symptom control particularly difficult to achieve. These findings suggest that physicians who care for persons with symptoms of post-9/11 asthma should be aware of the strong relationship between psychological comorbidities and asthma in this population, and that integration of mental and physical health care for those affected by the 9/11 WTC disaster is crucial.

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## Declaration of interest

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