Comorbid Persistent Lower Respiratory Symptoms and Posttraumatic Stress Disorder 5–6 Years Post-9/11 in Responders Enrolled in the World Trade Center Health Registry

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Background *Co-occurrence of lower respiratory symptoms (LRS) and posttraumatic stress disorder (PTSD) has been increasingly recognized among responders and survivors of the World Trade Center (WTC) disaster. Information is limited on the degree which comorbidity intensifies symptoms and compromises quality of life across exposed groups.*
Methods *Among responders who completed the first and second Registry surveys, measures of respiratory illness, psychological distress, and diminished quality of life were compared between responders comorbid for LRS and PTSD and responders with only LRS or PTSD.*
Results *Of 14,388 responders, 40% of those with LRS and 57% of those with PTSD were comorbid. When demographic and WTC exposure-related factors were controlled, comorbid responders compared to those with LRS alone were twice as likely to have frequent dyspnea and to have sought care for dyspnea. Compared to responders with PTSD alone, comorbid responders were 2.1 times more likely to report intense re-experiencing of the disaster, 2.5 times more likely to express feelings of significant non-specific psychological distress, and 1.4 times more likely to have received mental health care. Comorbid responders were approximately three times more likely to report only fair or poor general health and more than twice as likely to report being unable to perform usual activities for ≥14 of 30 days before interview.*
Conclusions *Outcomes in comorbid responders were similar to or more severe than in comorbid survivors. Health care and disaster relief providers must suspect comorbid illness when evaluating responders' respiratory or mental illnesses and consider treatment for both.* Am. J. Ind. Med. 56:1251–1261, 2013. *© 2013 Wiley Periodicals, Inc.*

KEY WORDS: comorbidity; disaster response; longitudinal study; mental health; posttraumatic stress disorder; respiratory illness; World Trade Center

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INTRODUCTION

Exposure to the World Trade Center (WTC) disaster has been associated with adverse respiratory and mental health outcomes in rescue and recovery workers [Brackbill et al., 2009]. A history of lower respiratory tract symptoms (LRS) of wheezing, persistent cough, and shortness of breath has been consistently and widely reported by 9/11 responders [Perlman et al., 2011]. LRS, pulmonary function test abnormalities, and diagnosed asthma and chronic bronchitis have been linked to being caught in the cloud of dust from the WTC Towers' collapse, arrival on or immediately after 9/11, and longer duration of work at the site [Banauch et al., 2006; Herbert et al., 2006; Wheeler et al., 2007; Brackbill et al., 2009]. Post-9/11 onset of symptoms of posttraumatic stress disorder (PTSD), depression, and generalized anxiety disorder were also closely correlated with WTC exposures [Galea et al., 2002; Gross et al., 2006; Perrin et al., 2007; Farfel et al., 2008; Stellman et al., 2008; Berninger et al., 2010; Cukor et al., 2011].

Psychological stress and physical illness have been shown to be interrelated in clinical, physiologic, and epidemiologic studies [Wright et al., 1998; Wagner et al., 2000; Weisberg et al., 2002; Blechert et al., 2007; Dirkzwager et al., 2007]. Co-occurrence of mental and physical illness following exposure to the WTC disaster has increasingly been documented in firefighters and other rescue/recovery workers (responders) and in area workers and residents (survivors) [Gross et al., 2006; Jordan et al., 2011; Li et al., 2011; Wisnivesky et al., 2011; Luft et al., 2012; Nair et al., 2012]. PTSD was a significant predictor of self-reported moderate to severe asthma symptoms, seeking care for asthma at an emergency room, and unscheduled physician visits for asthma since 9/11 [Fagan et al., 2003]. WTC cough syndrome and PTSD symptoms were moderately associated in NYC firefighters, even after accounting for exposure cofactors [Niles et al., 2011]. PTSD statistically mediated the link between exposure and comorbid respiratory symptoms among WTC rescue, recovery, and cleanup workers [Luft et al., 2012].

The compounding effect of comorbid LRS and PTSD on reported symptom intensity and diminished quality of life was demonstrated among survivors enrolled in the WTC Health Registry [Nair et al., 2012]. Survivors comprised area workers who had a usual workplace south of Chambers Street in lower Manhattan and were present south of Canal Street between the first attack and noon on 9/11, residents who lived in lower Manhattan south of Canal Street, and passersby who were in lower Manhattan during the attacks but were not area workers, residents, or involved in the rescue and recovery effort. Survivors with LRS and PTSD were more likely to seek treatment for shortness of breath or wheezing than those with LRS alone. Survivors with PTSD and LRS experienced more symptoms of PTSD and had more severe illness than those with PTSD alone. Those with comorbid LRS and PTSD had worse quality of life and more unmet healthcare needs than those with either condition alone.

Since the duration, intensity, and range of 9/11-related exposures of responders differed from those of survivors [Brackbill et al., 2009], the effect of these exposures on comorbid respiratory and mental health symptoms in responders warrants separate examination. Furthermore, although the co-occurrence of respiratory symptoms and PTSD in responders has been well documented [Niles et al., 2011; Luft et al., 2012], data are lacking on how the presence of both of these conditions affects the manifestations of each illness and quality of life. Building on the analysis of Nair et al. [2012], this study of responders sought to determine the effect of WTC exposures on the prevalence of comorbid illness among responders with either LRS or PTSD; evaluate the impact of comorbid illness on the prevalence of reported symptoms, physician diagnosed conditions, and quality of life; and compare the compounding effects of comorbidity in responders with those found in survivors.

MATERIALS AND METHODS

The Registry comprises residents, area workers, passers-by, and rescue/recovery workers exposed to the disaster on 9/11/2001 and its aftermath [Farfel et al., 2008]. Individuals were solicited from lists of potentially exposed adults provided by employers and government agencies (list-identified) or enrolled through an outreach and media campaign (self-identified). A total of 68,444 adults responded to the first Registry survey (Wave 1 or W1) from 2003 to 2004, and 46,602 (68.1%) of these responded to the second Registry survey (Wave 2 or W2) from 2006 to 2007 [Nair et al., 2012]. The Institutional Review Boards of the New York City Department of Health and Mental Hygiene and the Centers for Disease Control and Prevention approved the Registry protocols.

Study Sample

Adult responders in the Registry were defined as workers or volunteers 18–64 years of age on 9/11/2001 who reported being involved in rescue, recovery, cleanup, or other activities at the WTC site for at least one shift between September 11, 2001 and June 30, 2002 and participated in W1 and W2 ($n = 21,046$). In order to focus on illness more likely to be attributable to WTC disaster exposures, only responders with symptom onset or disease diagnosis post-9/11 were included. Responders who reported a pre-9/11 history of persistent cough, wheezing, or shortness of breath, pre-9/11 diagnosed chronic respiratory disease (asthma, reactive airways dysfunction syndrome [RADS], or chronic bronchitis) or pre-9/11 diagnosed PTSD, depression, or generalized anxiety were

excluded, leaving a total of 14,867 responders. Also excluded were 479 responders who met the screening criteria for PTSD at W1 but not at W2. The final sample numbered 14,388.

Analysis Variables

LRS was defined as reported post-9/11 onset of persistent cough, wheezing, or shortness of breath at W1 and reported experiencing of the same symptom for at least 8 of the 30 days prior to answering W2 [Friedman et al. online data supplement, 2011; Global Initiative for Asthma, 2011]. PTSD was defined conservatively based on W2 responses as both (a) scoring 44 or higher on the PTSD checklist-Civilian Version (PCL) with questions specific to WTC experiences; and (b) reporting the moderate or greater presence of at least one re-experiencing symptom ([American Psychiatric Association, 2000] DSM-IV criterion B), three avoidance or numbing symptoms (criterion C), and two hyperarousal symptoms (criterion D) [Blanchard et al., 1996; Ruggiero et al., 2003].

Demographic variables included age on 9/11/2001, gender, racial ethnic group, educational level at W1, smoking, marital status, and availability of social support at W2. Social support was defined as having both at least one close friend to speak to and having contact with friends or relatives at least twice a month. The effect of mode of enrollment into the Registry (self-identified or list-identified) and survey mode (mail, internet, or computer-assisted telephone interview [CATI]) at W2 were also measured. Exposure variables included intensity of envelopment by the dust cloud [Brackbill et al., 2009], day of arrival at one of the WTC sites, duration of work at the site, 9/11-related injury (laceration, sprain, bone fracture, or concussion), and four disaster-related events: loss of a job, fear of being injured on 9/11, losing a friend or family member on 9/11, or witnessing a traumatic event (specifically, an airplane hitting the WTC, collapse of a building, people fleeing the dust cloud, someone injured or killed, or someone falling or jumping from the WTC).

Outcome variables reflecting the severity of respiratory illness included the number of days each LRS symptom was experienced during the 30 days prior to W2 and whether the enrollees had sought physician care for LRS, had been diagnosed after 9/11 with asthma, RADS, chronic bronchitis or other obstructive lung disease, or had used a physician prescribed inhaler in the 30 days before responding to W2. Because physician diagnosis of asthma is considered a more specific indicator of severe respiratory illness than LRS alone, asthmatics with LRS were analyzed as a subgroup. Among this subset of responders, outcome variables included the proportion seeking care for asthma symptoms and the proportion with asthma morbidity in the 12 months prior to W2.

Measures of the severity of psychological illness at W2, 5–6 years after 9/11 included (a) individual PCL score; (b) median PCL score by comorbidity status; (c) number of questions within each of the three DSM-IV symptom categories where the responder reported at least moderate symptoms; (d) presence of post-9/11 diagnosed depression or anxiety disorder; (e) summary score on the Kessler-6 test scale for non-specific psychological distress, grouped as 0–7, 8–12, and 13–24 (a score of 13 or higher predicts meeting DSM-IV criteria for an anxiety or mood disorder [Kessler et al., 2002]); (f) whether the responder had talked to a mental health professional in the past 12 months; and (g) whether the responder was prescribed medication for a mental health condition in the past 12 months.

Three standardized questions measured quality of life (QOL): number of days in the past 30 days that (a) physical health was not good, (b) mental health was not good, and (c) daily activities were limited because of these problems [Centers for Disease Control and Prevention, 2000]. These measures were dichotomized as <14 and ≥ 14 not good days [Zahran et al., 2005]. Unmet healthcare need was also assessed by asking whether the responder needed but did not receive health care, including mental health care or counseling, during the last 12 months.

Statistical Analysis

Analyses used SAS statistical software, version 9.2 (SAS Institute, Inc., Cary, NC). Two-tailed tests were used in all analyses. In bivariate analyses, demographic variables significantly associated with comorbid LRS and PTSD versus LRS alone and PTSD alone were identified. The chi-square test was used to determine group differences on categorical variables, and a maximum P-value of 0.05 was chosen for statistical significance. Next, the relationship of exposure variables to comorbidity status versus LRS only or PTSD only was examined while adjusting for demographic variables shown to be significant in our data and in the WTC disaster literature. Then the additional effect of comorbid LRS and PTSD on various respiratory health, mental health, and quality of life outcomes compared to the effect of either LRS or PTSD alone was determined in multivariable logistic regression models, assessed by odds ratios with 95% confidence intervals (CI), while adjusting for significant demographic and disaster exposure variables. Specifically, the extent to which co-occurring PTSD and LRS versus LRS alone heightened the reporting of respiratory health problems was determined for each of the respiratory health outcomes. In addition, among asthmatics, the frequency of days with LRS in the 30 days prior to W2 was compared between comorbid responders and those with LRS alone using a non-parametric test (Wilcoxon two-samples test) because the distribution of affected days was non-normal.

PTSD severity based on median PCL score was compared between comorbid responders and those with PTSD alone using the Wilcoxon two-samples test. For all

other measures of the severity of psychological illness, the relative difference between comorbid and PTSD alone was assessed by odds ratios adjusted for demographic and exposure variables.

Finally, the relative effect of comorbidity on quality of life was assessed for comorbid responders compared separately to those with PTSD alone and with LRS alone in multivariable logistic regression models adjusting for demographic and exposure variables.

RESULTS

The criteria for LRS alone were met by 2,157 (15.0%) of responders and for PTSD alone by 1,058 (7.4%); 1,413 (9.8%) were comorbid for LRS and PTSD (Table I). Of the 3,570 with LRS, 39.6% were comorbid, and of the 2,471 with PTSD, 57.2% were comorbid. Given a prevalence of 24.8% for LRS and 17.2% for PTSD in this Registry responder population, the expected number of comorbid individuals would have been 613 if these conditions were independent, whereas 1,413 were observed, 2.3 times as many as expected. The odds ratio for comorbid LRS and PTSD was 6.0 (95% CI: 5.5, 6.6).

Most (81.7%) of the 14,388 responders were men. The mean age on September 11, 2001, for responders in the sample was 40.6 years, range 18–64 years. The most common racial ethnic group was non-Hispanic whites (78.0%), followed by Hispanics (10.8%) and non-Hispanic blacks (6.6%). Nearly three quarters reported some college education, although only 41.3% completed college. Only 13.5% reported that they currently smoked cigarettes, and 77.5% said they were married or living with a partner at W2.

Compared with those with LRS only, comorbid responders were more likely to be female, have only a high school education, be a smoker, widowed, divorced, separated, or never married rather than married, and lack social support at W2 (Table I). Comorbid responders compared to those with PTSD only were more likely to be male, older (45–64 years), not to have completed college, to currently smoke, and to be widowed, divorced, or separated rather than married at W2. The distribution of race/ethnicity was similar in those with PTSD alone and with both conditions, but differed significantly from the distribution among those with LRS alone, due primarily to the disproportionately high percent of Hispanics with comorbid LRS and PTSD compared to LRS alone (17.8% vs. 11.0%).

Just over half of the responders (52.3%) reported arriving at the WTC site by September 12, and slightly more than one quarter of responders (26.1%) reported intense exposure to the dust cloud (Table II). When physical and emotional exposure variables were compared between comorbid responders and those with LRS alone or PTSD alone (adjusting for demographic variables), intense dust cloud, earlier arrival at the WTC site, longer duration of work at the site, experiencing injury, losing one's job after 9/11, fearing personal injury, losing a friend or relative, and witnessing a traumatic event on 9/11 were significantly associated with comorbidity (Table II).

When compared to responders with LRS alone, comorbid responders were not significantly more likely to have reported persistent cough, but they were more than twice as likely than those with LRS alone to have reported dyspnea (adjusted odds ratio [aOR] 2.4, 95% CI: 1.9, 2.9) and 1.5 times as likely to have reported wheezing for at least 8 of the 30 days prior to W2 (aOR 1.5, 95% CI: 1.3, 1.9) (Table III). Comorbid responders were significantly more likely to have ever reported seeking care from a physician for dyspnea, wheezing, or persistent cough. They were also significantly more likely to have reported being diagnosed after 9/11 with chronic bronchitis or other obstructive lung disease, and to have reported using a physician prescribed inhaler during the 30 days prior to W2. However, reported history of post-9/11 diagnosed asthma was not significantly associated with comorbidity.

Among the 1,510 responders who reported a post-9/11 diagnosis of asthma, those comorbid with LRS and PTSD ($n = 440$) were nearly three times more likely to report having experienced dyspnea (aOR 2.9, 95% CI: 1.8, 4.6) and 1.5 times as likely to report wheezing on at least 8 of the 30 days prior to W2 (aOR 1.5, 95% CI: 1.1, 2.2), and were more likely to have sought care for dyspnea (aOR 3.2, 95% CI: 1.5, 6.9) or persistent cough (aOR 2.0, 95% CI: 1.3, 3.1) than were responders with asthma and LRS but not PTSD ($n = 548$) (Table III). Responders with all three conditions also reported significantly more days of symptoms than those without PTSD. Median days of dyspnea, wheezing, and cough were 25, 19, and 15, respectively, in comorbid asthmatic responders compared to 15, 10, and 10 among those with asthma and LRS but not PTSD ($P < 0.001$ for each comparison, Wilcoxon two-samples test).

Responders with PTSD who were comorbid for LRS consistently reported more intense PTSD and additional mental health problems than those with PTSD alone (Table IV). Regarding the 30 days prior to W2, responders with LRS and PTSD scored significantly higher on the PCL in all three PTSD criteria than responders with PTSD alone. They were twice as likely to report at least moderate upset in all five re-experiencing questions (aOR 2.1, 95% CI: 1.6, 2.8). They were also significantly more likely to report at least moderate difficulty in six or more of the avoidance questions (aOR 1.4, 95% CI: 1.1, 1.8) and in all five arousal items (aOR 1.6, 95% CI: 1.3, 1.9). Comorbid responders were more likely to score significantly higher on the Kessler-6 scale for non-specific psychological distress during the 30 days prior to W2 (median 13 vs. 11, $P < 0.001$ by Wilcoxon two-samples test), and to score in the upper distress range of 13 or higher versus 0–7 (aOR 2.5, 95% CI: 1.8, 3.3). Responders with PTSD and LRS were significantly were more likely to report

TABLE I. Associations Between Comorbid Lower Respiratory Symptoms and Posttraumatic Stress Disorder and Demographic Factors

	Total	Neither condition	%	LRS only	%	PTSD only	%	Both LRS and PTSD	%	LRS and PTSD vs. LRS alone[a,b]	LRS and PTSD vs. PTSD alone[a,b]
All responders	14,388	9,760	67.8	2,157	15.0	1,058	7.4	1,413	9.8		
Sex										**0.031**	**0.001**
Female	2,638	1,985	20.3	252	11.7	201	19.0	200	14.2		
Male	11,750	7,775	79.7	1,905	88.3	857	81.0	1,213	85.8		
Age (in years) on 9/11/2001										n.s.[c]	**0.012**
18–24	620	476	4.9	57	2.6	50	4.7	37	2.6		
25–44	8,910	5,927	60.7	1,378	63.9	690	65.2	915	64.8		
45–64	4,858	3,357	34.4	722	33.5	318	30.1	461	32.6		
Race Ethnicity										**<0.001**	n.s.
Asian	302	212	2.2	36	1.7	26	2.5	28	2.0		
Hispanic	1,551	893	9.2	238	11.0	168	15.9	252	17.8		
Non-Hispanic Black	951	647	6.6	115	5.3	95	9.0	94	6.7		
Other	358	198	2.0	60	2.8	51	4.8	49	3.5		
Non-Hispanic White	11,226	7,810	80.0	1,708	79.2	718	67.9	990	70.1		
Education										**<0.001**	**<0.001**
High school or less	3,831	2,336	24.0	652	30.4	314	29.9	529	37.7		
Some college	4,578	2,924	30.0	823	38.3	349	33.2	482	34.3		
College/post-graduate	5,927	4,473	46.0	673	31.3	388	36.9	393	28.0		
Smoking history										**<0.001**	**<0.001**
Current smoker	1,942	986	10.1	385	17.9	201	19.0	370	26.3		
Past smoker or never smoked	12,409	8,752	89.9	1,767	82.1	855	81.0	1,035	73.7		
Marital status										**<0.001**	**0.025**
Widowed/divorced/separated	1,632	931	9.6	270	12.6	160	15.2	271	19.4		
Never married	1,579	1,101	11.4	182	8.5	133	12.6	163	11.7		
Married/living with partner	11,062	7,650	79.0	1,688	78.9	760	72.2	964	69.0		
Social support										**<0.001**	n.s.
Both a close friend and contact with friends $\geq$ twice/month	7,940	5,991	62.3	1,146	54.0	364	34.8	439	31.4		
Lacking either or both	6,251	3,632	37.7	976	46.0	683	65.2	960	68.6		
Mode of recruitment Wave 1										n.s.	n.s.
Self-identified	9,969	6,390	65.5	1,681	77.9	804	76.0	1,094	77.4		
List-identified	4,419	3,370	34.5	476	22.1	254	24.0	319	22.6		
Survey mode at Wave 2										**0.002**	**0.012**
Mail	7,016	4,659	47.7	1,081	50.1	510	48.2	766	54.2		
Web	5,850	3,983	40.8	857	39.7	461	43.6	549	38.9		
CATI	1,522	1,118	11.5	219	10.2	87	8.2	98	6.9		

LRS, lower respiratory symptoms; PTSD, posttraumatic stress disorder.
[a]Chi-square *P*-value.
[b]Statistically significant results are bolded.
[c]n.s. if $P \geq 0.05$.

being diagnosed post-9/11 with PTSD and depression than responders with PTSD alone. Finally, in the 12 months prior to W2, responders with both LRS and PTSD reported talking to a mental health professional significantly more often than responders with PTSD alone (aOR 1.4, 95% CI: 1.1, 1.7).

Nearly two-thirds (65.1%) of comorbid responders reported less than good general health (Table V) compared with only 32.1% for those with only LRS and 34.1% for those with only PTSD (aORs 2.7, 95% CI: 2.3, 3.3, and 3.7, 95% CI: 3.0, 4.7, respectively). Over half (53.2%) of comorbid

TABLE II. Adjusted Odds Ratios for Associations Between Exposure Variables and Comorbid Outcomes

Factor	Total	Neither condition	%	LRS only	%	PTSD only	%	Both LRS and PTSD	%	aOR LRS and PTSD vs. LRS[a,c]	aOR, LRS and PTSD vs. PTSD[b,c]
Dust cloud exposure											
None	7,473	5,816	67.4	859	47.4	403	46.1	395	33.4	Ref	Ref
Some	1,768	1,148	13.3	318	17.5	146	16.7	156	13.2	1.2 (0.9, 1.5)	1.2 (0.9, 1.5)
Intense	3,264	1,670	19.3	636	35.1	326	37.3	632	53.4	**2.4 (2.0, 2.9)**	**2.2 (1.8, 2.7)**
Arrival at WTC											
9/18/01–6/30/02	3,785	3,061	32.6	328	15.6	189	18.2	207	14.8	Ref	Ref
9/13-9/17	2,862	2,001	21.3	378	18.0	250	24.1	233	16.7	1.1 (0.8, 1.4)	0.9 (0.7, 1.2)
9/12	2,867	1,812	19.3	507	24.1	237	22.8	311	22.3	1.0 (0.8, 1.3)	1.2 (0.9, 1.5)
9/11	4,407	2,510	26.8	889	42.3	363	34.9	645	46.2	**1.4 (1.1, 1.8)**	**1.7 (1.3, 2.2)**
Duration of work at WTC											
1–7 days	3,386	2,541	29.9	359	18.9	235	25.8	251	19.7	Ref	Ref
8–30 days	2,488	1,813	21.4	348	18.3	144	15.8	183	14.3	0.8 (0.6, 1.0)	1.2 (0.9, 1.6)
31–90 days	2,056	1,343	15.8	329	17.3	177	19.4	207	16.2	0.98 (0.8, 1.3)	1.1 (0.8, 1.4)
>90 days	4,646	2,790	32.9	866	45.5	355	39.0	635	49.8	1.2 (0.94, 1.4)	**1.7 (1.3, 2.1)**
Any injury on 9/11											
No	12,074	8,670	89.1	1,683	78.3	815	77.5	906	64.3	Ref	Ref
Yes	2,267	1,061	10.9	467	21.7	237	22.5	502	35.7	**2.2 (1.9, 2.6)**	**1.9 (1.6, 2.3)**
Lost job after 9/11											
No	12,543	8,941	92.5	1,900	88.9	790	75.4	912	65.7	Ref	Ref
Yes, but not due to 9/11	945	512	5.3	126	5.9	126	12.0	181	13.0	**2.7 (2.1, 3.4)**	1.2 (0.94, 1.6)
Yes, due to 9/11	754	215	2.2	112	5.2	132	12.6	295	21.3	**4.7 (3.7, 6.0)**	**1.9 (1.5, 2.4)**
Thought might be injured or killed on 9/11											
No	8,569	6,579	68.4	1,138	53.9	408	39.2	444	32.2	Ref	Ref
Yes	5,590	3,045	31.6	974	46.1	634	60.8	937	67.8	**2.6 (2.3, 3.1)**	**1.4 (1.2, 1.6)**
Know someone who died on 9/11											
No	5,455	4,298	44.5	578	27.1	302	29.0	277	19.9	Ref	Ref
Yes	8,776	5,371	55.5	1,552	72.9	740	71.0	1,113	80.1	**1.8 (1.5, 2.2)**	**1.7 (1.4, 2.1)**
Witnessing a traumatic event on 9/11											
No	7,079	5,444	55.8	865	40.1	396	37.5	374	26.5	Ref	Ref
Yes	7,294	4,304	44.2	1,290	59.9	661	62.5	1,039	73.5	**2.0 (1.7, 2.3)**	**1.7 (1.5, 2.1)**

LRS, lower respiratory symptoms; PTSD, posttraumatic stress disorder; aOR, adjusted odds ratio.

[a]Comorbid LRS and PTSD versus LRS alone, adjusting for age, race/ethnicity, sex, education, marital status, current smoking, social support, recruitment method, and survey mode.

[b]Comorbid LRS and PTSD versus PTSDS alone, adjusting for age, race/ethnicity, sex, education, marital status, current smoking, social support, recruitment method, and survey mode.

[c]Statistically significant results are bolded.

responders reported experiencing poor physical health for at least 14 of the 30 days before W2; they were twice as likely to so report than were responders with LRS but not PTSD. Comorbid responders were also significantly more likely to report having at least 14 days of poor mental health than responders with PTSD but not LRS (aOR 1.7, 95% CI: 1.4, 2.1). Nearly half (48.4%) of comorbid responders reported that poor health kept them from doing their usual activities for at least 14 of the last 30 days before W2. Comorbid responders were considerably more likely than those with LRS alone or PTSD alone to report $\geq$14 days lost to poor health (aORs 4.0, 95% CI: 3.3, 5.0, and 2.3, 95% CI: 1.8, 2.9, respectively).

Comorbid responders were more likely than those with either LRS or PTSD alone to report not getting health care that they needed during the 12 months prior toW2 (aORs 2.1, 95% CI: 1.7, 2.5, and 1.8, 95% CI: 1.5, 2.3, respectively).

TABLE III. Comorbid LRS and PTSD and Respiratory Symptoms and Conditions

		LRS		LRS and PTSD		LRS and PTSD
	Total	No.	%	No.	%	vs. LRS aOR[a,b]
All Workers	14,388	2,157	15.0	1,413	9.8	
Experienced ≥8 days of symptom in last 30 days						
Dyspnea	2,233	1,153	54.5	1,080	78.1	**2.4 (1.9, 2.9)**
Wheezing	1,588	853	40.4	735	54.3	**1.5 (1.3, 1.9)**
Persistent cough	2,044	1,230	58.0	814	58.7	0.94 (0.8, 1.1)
Ever sought care for						
Dyspnea	4,593	1,403	65.7	1,152	82.8	**2.0 (1.6, 2.5)**
Wheezing	3,631	1,171	55.3	962	70.4	**1.6 (1.3, 1.9)**
Persistent cough	4,209	1,118	52.0	859	61.1	**1.3 (1.1, 1.6)**
Chronic conditions[c]						
Asthma	1,510	548	25.4	440	31.1	1.1 (0.93, 1.4)
Chronic bronchitis	1,145	359	16.9	390	28.0	**1.7 (1.4, 2.2)**
Any obstructive disease[d]	2,274	758	35.2	638	45.2	**1.3 (1.1, 1.6)**
Inhaler use in last 30 days	1,805	660	30.8	583	41.7	**1.3 (1.1, 1.6)**
Workers with diagnosed asthma						
Experienced ≥8 days of symptom in last 30 days						
Dyspnea	767	384	71.6	383	88.5	**2.9 (1.8, 4.6)**
Wheezing	646	339	63.4	307	73.1	**1.5 (1.1, 2.2)**
Persistent cough	530	262	48.7	268	61.5	1.3 (0.90, 1.8)
Ever sought care for						
Dyspnea	1,286	492	90.1	417	95.2	**3.2 (1.5, 6.9)**
Wheezing	1,218	483	89.4	387	89.8	1.5 (0.8, 2.5)
Persistent cough	1,023	376	69.1	362	82.8	**2.0 (1.3, 3.1)**
Asthma events in past 12 months						
Asthma attack	1,010	393	73.7	354	83.3	1.3 (0.8, 1.9)
Inhaler use	1,103	433	81.4	373	88.0	1.1 (0.7, 1.8)
ER visit for asthma	306	115	21.6	129	30.2	1.4 (0.95, 2.2)

LRS, lower respiratory symptoms; PTSD, posttraumatic stress disorder; aOR, adjusted odds ratio.
[a]Comorbid LRS and PTSD versus LRS alone, adjusting for age group at 9/11, sex, race/ethnicity, education level, marital status, social support, smoking, recruitment method, survey mode, dust cloud intensity, earliest work period, duration of work, loss of job due to 9/11, fear of being injured, experiencing injury, loss of a friend or relative, and witnessing trauma on 9/11.
[b]Statistically significant results bolded.
[c]First diagnosed after 9/11.
[d]Asthma, chronic bronchitis, COPD, emphysema.

However, there were no significant differences between comorbid responders and those with PTSD alone in expressing an unmet need for mental health counseling.

DISCUSSION

Co-occurring LRS and PTSD in this study was significantly associated with severity of respiratory and mental illnesses, disability, and poor quality of life. These associations held while controlling for WTC exposures that have been shown in previous studies to be correlated with comorbidity, including dust cloud intensity, date of arrival at the WTC site, duration of work, personal injury, and emotional trauma.

These findings of significant respiratory and mental illness comorbidity are consistent with recent studies of firefighters and other rescue and recovery workers [Niles et al., 2011; Luft et al., 2012]. Niles et al. [2011] found a moderate association between WTC cough syndrome and probable PTSD among exposed NYC firefighters. The causal path models developed by Luft et al. [2012] suggest that, among police as well other responders, associations between exposures and respiratory outcomes were mediated in part by

TABLE IV. Comorbid LRS and PTSD and Mental Health Symptoms and Conditions

		PTSD		LRS and PTSD		LRS and PTSD
	Total number	Number	%	Number	%	vs. PTSD aOR[a,b]
	14,388	1,058	7.4	1,413	9.8	
PTSD symptoms in last 30 days						**$P < 0.001$**[c]
Median PCL score (Q1, Q3)		53 (48, 60)		59 (52,67)		
DSM IV criteria reexperiencing symptoms						
5	942	290	27.4	594	42.0	**2.1 (1.6, 2.8)**
3–4	1,475	420	39.7	524	37.1	**1.5 (1.1, 1.9)**
1–2	3,358	348	32.9	295	20.9	Ref
0	8,613	0	0.0	0	0.0	
Avoidance symptoms						
6–7	1,261	460	43.5	759	53.7	**1.4 (1.1, 1.8)**
5	617	227	21.5	263	18.6	1.1 (0.8, 1.5)
3–4	1,667	371	35.1	391	27.7	Ref
0–2	10,843	0	0.0	0	0.0	
Arousal symptoms						
5	1,645	520	49.1	888	62.8	**1.6 (1.3, 1.9)**
2–4	3,662	538	50.9	525	37.2	Ref (0–4)
0–1	9,081	0	0.0	0	0.0	
Non-specific psychological distress in last 30 days	14,247	1,049	7.4	1,397	9.8	
13–24	1,346	365	34.8	754	54.0	**2.5 (1.8, 3.3)**
8–12	2,176	447	42.6	464	33.2	1.3 (0.95, 1.7)
0–7	10,725	237	22.6	179	12.8	Ref
Mental health diagnoses post-9/11						
PTSD	1,752	347	33.3	673	48.8	**1.5 (1.2, 1.9)**
Depression	2,123	420	41.1	767	56.0	**1.6 (1.3, 1.9)**
Anxiety	1,279	254	24.5	454	33.0	1.2 (0.95, 1.5)
Talked to a mental health professional in last 12 months	2,478	368	34.8	636	45.2	**1.4 (1.1, 1.7)**
Taken medication prescribed for mental or emotional problem	1,409	244	23.1	449	32.0	1.3 (0.99, 1.6)

LRS, lower respiratory symptoms; PTSD, posttraumatic stress disorder; aOR, adjusted odds ratio.

[a]Comorbid LRS and PTSD versus PTSD alone, adjusting for age, gender, race/ethnicity, education, marital status, social support, smoking, method of recruitment, survey mode, intense dust cloud exposure, earliest work period, duration worked at WTC, job loss due to 9/11, fear of being injured or killed, loss of friend or relative, personal injury, and witnessing trauma on 9/11.

[b]Statistically significant values are bolded.

[c]Wilcoxon two-samples test.

PTSD. The current study confirms the associations previously found in responders as well as in survivors [Nair et al., 2012], and documents the intensifying effect of comorbidity on the reporting of respiratory and psychological problems, increased disability, and decreased quality of life.

Numerous risk factors for both LRS and PTSD were documented in this study. Comorbid responders were more likely to be smokers and less likely to be married or living with a partner; they had less education and less social support. They were more likely on 9/11 to have had physical exposures such as being in the dust cloud or bodily injury, and emotional trauma such as losing a job, losing a friend or relative, or personally witnessing traumatic events. However, even when these differences in demographics and exposures were controlled for, comorbidity with PTSD was associated with intensified respiratory symptoms in responders reporting LRS, and comorbidity with LRS was linked to increased reporting of the re-experiencing, avoidance, and arousal components in responders with PTSD. Comorbid responders were also more likely to report having other psychological problems and to report receiving mental health treatment in the 12 months prior to W2. The health burden of comorbid LRS and PTSD was also reflected in greater reporting of poor physical, mental, and overall health.

A strength of Registry studies is the presence of large worker and survivor populations, which permits detailed analysis of subgroups. Compared with results previously reported in survivors [Nair et al., 2012], in the current study, responders were only slightly more likely to report PTSD (17.2% vs. 14.3%), but were considerably more likely to

TABLE V. Comorbidity, Quality of Life, and Unmet Healthcare Needs

All responders	Total	Neither	%	LRS only	%	PTSD only	%	LRS and PTSD	%		
	14,388	9,760	67.8	2,157	15.0	1,058	7.4	1,413	9.8		
Responders answering yes to:	**Total**	**Neither**	**%[a]**	**LRS only**	**%[a]**	**PTSD only**	**%[a]**	**LRS and PTSD**	**%[a]**	**aORs[b,d] LRS and PTSD vs. LRS**	**aORs[c,d] LRS and PTSD vs. PTSD**
Fair or poor general health	2,707	753	7.8	687	32.1	357	34.1	910	65.1	**2.7 (2.3, 3.3)**	**3.7 (3.0, 4.7)**
Poor physical health ≥14 days	2,430	829	8.6	618	28.9	243	23.3	740	53.2	**2.0 (1.7, 2.4)**	**3.6 (2.8, 4.5)**
Poor mental health ≥14 days	2,493	707	7.3	378	17.8	488	46.8	920	65.9	**6.6 (5.4, 8.1)**	**1.7 (1.4, 2.1)**
Days lost to poor health ≥14	1,664	423	4.6	307	14.7	262	25.3	672	48.4	**4.0 (3.3, 5.0)**	**2.3 (1.8, 2.9)**
Did not get needed health care	2,748	1,254	12.9	522	24.4	349	33.2	623	44.6	**2.1 (1.7, 2.5)**	**1.8 (1.5, 2.3)**
Did not get needed mental health counseling[e]	748	162	14.2	78	16.0	186	55.4	322	53.6	**6.0 (4.0, 8.8)**	0.95 (0.7, 1.4)

LRS, lower respiratory symptoms; PTSD, posttraumatic stress disorder; aORs, adjusted odds ratios.

[a]Percentage of responders answering yes of those answering the question.

[b]Quality of life indicators in comorbid responders versus responders with LRS alone, adjusting for age group at 9/11, sex, race/ethnicity, education level, marital status, social support, smoking, recruitment method, survey mode, dust cloud intensity, earliest work period, duration worked at WTC, job loss due to 9/11, fear of being injured or killed, loss of a friend or relative, personal injury, and witnessing trauma on 9/11.

[c]Quality of life indicators in comorbid responders versus responders with PTSD alone, adjusting for age group at 9/11, sex, race/ethnicity, education level, marital status, social support, smoking, recruitment method, survey mode, dust cloud intensity, earliest work period, duration worked at WTC, job loss due to 9/11, fear of being injured or killed, loss of a friend or relative, personal injury, and witnessing trauma on 9/11.

[d]Statistically significant values are bolded.

[e]Among those who had an unmet healthcare need.

report LRS (24.8% vs. 14.9%). Hence, it is not unexpected that responders and survivors with LRS were comorbid with PTSD in similar proportions (39.6% vs. 38.7%), while responders with PTSD were comorbid with LRS in greater proportions than were survivors (57.2% vs. 40.4%).

Factors associated with increased reporting of comorbid LRS and PTSD among responders were strikingly similar among survivors in the Registry [Nair et al., 2012]. Educational level, pre-9/11 diagnosed depression, and lack of social support had similar associations with comorbidity for responders and survivors. Intense exposure to the dust cloud on 9/11 was also associated with comorbidity among both groups. Work exposure measures such as earlier arrival and longer duration of working at the site increased the likelihood of comorbid illness among responders, just as exposure to dust in the workplace or home increased the likelihood of comorbidity in survivors.

The association between comorbidity and intensity of poor respiratory health outcomes noted among survivors by Nair et al. [2012] was even stronger among responders for some exposure and outcome variables. Adjusted odds ratios for responders for seeking care for persistent cough, for reported post-9/11 diagnosis of chronic bronchitis or other obstructive disease, and for inhaler use in the past 30 days were significantly associated with comorbidity among responders but not among survivors. However, the increased reporting of respiratory health problems and increased days lost to poor health among comorbid asthmatic responders were similar to reporting in comorbid asthmatic survivors.

The association between comorbidity and a higher rate of reporting of adverse mental health outcomes including non-specific psychological distress and diagnosed PTSD and depression, previously reported in survivors, was also noted in responders. The association between talking to a mental health professional and comorbidity appeared to be stronger in responders. It may also be that access to sources of mental health care was more of an issue for survivors, since comorbidity was associated with inability to get needed mental health services among survivors [Nair et al., 2012] but not among responders.

The net effect of comorbid LRS and PTSD was reflected in greater reporting of poor physical, mental, and overall health. More than 40% of both responders and survivors who were comorbid for LRS and PTSD experienced significant disability based on reporting greater than 14 days' activity lost to poor health during the 30 days prior to W2 [Nair et al., 2012]. These data clearly demonstrate the continuing heavy burden of comorbid LRS and PTSD across WTC disaster affected groups.

Evidence for concurrence of respiratory symptoms or asthma and psychological illnesses has been presented in veterans and other populations [Wright et al., 1998; Goodwin et al., 2007; O'Toole and Catts, 2008], although the biological mechanisms are not well understood. WTC disaster exposures and experiences provided stimuli to initiate physical and mental illnesses. PTSD may have increased LRS through a compromising effect on the immune response [Boscarino, 2004] or through enhanced perception. LRS, as an ongoing reminder of the physical health effects of the disaster, may have stimulated PTSD symptoms. Together they resulted in a higher reported prevalence and intensification of both illnesses.

A potential limitation of this study is the high proportion of self-identified (69%) compared to list-identified (31%) participants, which raises a concern regarding possible selection bias. However, source of recruitment was not significantly associated with comorbidity. Another limitation is that symptoms and diagnoses were self-reported, with potential for reporting bias. As Nair et al. [2012] pointed out in their study of comorbidity in the survivor population, the Registry lacks objective measures of scope and severity of respiratory symptoms. Nevertheless, in a study of survivors nested within this Registry cohort, Friedman et al. [2011] found a significant association between reported LRS and lower airway dysfunction measured by pulmonary function testing (spirometry and impulse oscillometry). Furthermore, many of the Registry questionnaire-derived physical and mental health outcomes have been consistently found to be associated with a wide variety of 9/11 exposure measures in responder as well as survivor populations [Perrin et al., 2007; Wheeler et al., 2007; Brackbill et al., 2009; Li et al., 2011; Maslow et al., 2012], and the psychological measures used in the current study (PCL and Kessler-6) are well validated.

Because physician diagnosis of respiratory conditions like asthma may be affected by access to care, responders' report of LRS was used as the primary qualification for respiratory illness. Reported physician diagnosis of respiratory disease in subanalyses supplemented and supported associations found in responders with LRS but lacking a respiratory diagnosis.

This study demonstrated the compounding effect of comorbidity on the severity of LRS and PTSD, and on the attendant increased disability and diminished quality of life. These effects remained significant even while controlling for factors noted to affect physical and mental health outcomes. The results are consistent with and expand on those found in prior research on responders and survivors. Taken together, these studies indicate the necessity of examining responders and survivors for both respiratory and mental health illness when either is suspected, coordinating treatment when both are diagnosed, and assuring that mental health needs are fully met. Disaster planning efforts must include preparation for coordinated multidisciplinary clinical activities.

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