Health Conditions as Mediators of the Association Between World Trade Center Exposure and Health-Related Quality of Life in Firefighters and EMS Workers

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Objective: Studies have reported reduced health-related quality of life (HrQoL) in rescue/recovery workers for years postdisaster. Few have examined specific postdisaster physical and mental health conditions as mediators of the association between exposure to disaster and HrQoL. **Methods:** We used the Short Form-12 to measure HrQoL in 7190 male World Trade Center (WTC)-exposed first responders. Potential mediators included physician diagnoses obtained from medical records and mental health conditions obtained from questionnaires. **Results:** Among moderately and highly WTC-exposed workers, health conditions fully mediated the observed relationship between WTC-exposure and physical health functioning of HrQoL, and substantially mediated the association between WTC-exposure and mental health functioning. **Conclusions:** Because WTC-related health conditions explain the relationship between WTC-exposure and HrQoL, medical monitoring with treatment of affected populations is necessary to mitigate the adverse effects of WTC-exposure on HrQoL.

Exposure to disasters is associated with reduced health-related quality of life (HrQoL),[1–3] a concept that broadly refers to an individual's everyday functioning and well-being.[4]

Understanding the mechanisms through which this exposure affects HrQoL may help inform the selection and organization of postdisaster interventions. For example, if exposure to disaster adversely impacts HrQoL, independent of other factors, then intervening programs and policies may focus on stress reduction strategies (eg, coping mechanisms, benefits counseling, desensitization). On the contrary, if exposure to disaster primarily affects HrQoL through specific health condition(s), then treatment of those condition(s) would be the priority, with other interventions (eg, stress reduction) occurring as necessary.

HrQoL among workers who performed rescue/recovery activities at the World Trade Center (WTC) site on and after September 11, 2001 (9/11) is poorly understood, despite evidence that both physical (eg, asthma, obstructive airways disease, chronic rhinosinusitis, and gastroesophageal reflux disease [GERD])[5–9] and mental health conditions (eg, posttraumatic stress disorder [PTSD], depression, generalized anxiety disorder (GAD), panic syndrome, and harmful alcohol use),[9,10] associated with the disaster, have persisted for years. Among the few studies that assessed HrQoL in WTC-exposed individuals, Adams and Boscarino[3] reported that WTC-exposure was associated with poorer physical and mental health functioning of HrQoL in New York City adult residents 1 year after the attacks. Similarly, another study conducted 1 year after 9/11 found that quality of life was inversely related to mental health symptoms in a convenience community sample of WTC-exposed adults.[11] Furthermore, our earlier research showed that WTC-exposed firefighters with aerodigestive conditions had impaired physical and mental health functioning of HrQoL.[12] Although previous research found that diminished quality of life is associated with WTC-exposure[3] and with WTC-related health conditions,[11,12] it remains unclear whether it is the exposure to the disaster or subsequent disaster-related health conditions that are mainly responsible for lower HrQoL years later.

Given our access to information on multiple health conditions from the FDNY electronic medical records database, including dates of diagnoses, and from self-administered health questionnaires completed during routine medical monitoring exams, we evaluated HrQoL among WTC-exposed FDNY firefighters and emergency medical service (EMS) workers and assessed health conditions as mediators of the association between WTC-exposure intensity and HrQoL. We hypothesized that specific WTC-related chronic health conditions—chronic rhinosinusitis, GERD, respiratory conditions, musculoskeletal conditions, PTSD, depression, GAD, panic syndrome, and harmful alcohol use—are the primary mediators of the WTC-exposure–HrQoL association.

METHODS

Study Population

Participants eligible for analyses were FDNY members who were active (ie, not retired) on 9/11 and consented to research ($n = 12{,}206$), male ($n = 11{,}715$), arrived on the WTC disaster site between the morning of 9/11 and September 24, 2001 ($n = 11{,}153$), had no evidence of diminished pre-9/11 health ($n = 7532$), and no evidence of a chronic, non-WTC-related health condition diagnosed post-9/11, resulting in a final study population of 7190. We defined individuals with diminished pre-9/11 health status as those who either had evidence of any of the conditions of interest before 9/11 or who had two or more episodes of medical and/or light duty leave that lasted for at least 30 days in the 2 years pre-9/11.

Data Sources

The FDNY World Trade Center Health Program (FDNY WTCHP) schedules monitoring evaluations every 12 to 18 months for active and WTC-exposed retired FDNY members and provides separate treatment care, as necessary. Before 9/11, routine monitoring evaluations were scheduled every 18 to 24 months for active FDNY members to assess fitness for duty. FDNY's electronic medical database, implemented since 1996, contains physician diagnoses recorded from monitoring or treatment evaluations. Since

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2001, monitoring visits also included self-administered health questionnaires; separate mental health questionnaires were added in 2005. We used questionnaire data to describe HrQoL and mental health conditions described below. We obtained additional characteristics (race, sex, and age) from the FDNY employee database.

Predictor: WTC-Exposure

Intensity of WTC-exposure was obtained from participants' first post-9/11 questionnaire, based on their initial arrival time to the disaster site. Participants who arrived on the morning of 9/11 were the most intensely exposed (high exposure group). Those who arrived in the afternoon of 9/11 or on September 12, 2001 were categorized as the moderate exposure group, and those who arrived between September 13, 2001 and September 24, 2001 as the low exposure group.

Outcome: HrQoL

We used the Short Form-12 (SF-12) survey[13] to assess HrQoL. Derived from the Medical Outcomes Study Short Form-36 survey,[14] the SF-12 is a generic measure of health status that contains 12 questions on eight domains: General Health, Physical Functioning, Mental Health, Vitality, Social Functioning, Role-Physical, Role-Emotional, and Bodily Pain. These domains were used to construct two composite scores: Physical Component Summary (PCS) and Mental Component Summary (MCS). PCS and MCS scores were calculated using norm-based methods based on the 1998 US population; scores were transformed to have a mean of 50 and a SD of 10.[15] Scores of 50 correspond to the average of the general US population; when restricted to the US male population, the average PCS score is 50.60 and the average MCS score is 50.38. Lower scores indicate poorer HrQoL. We analyzed participants' most recent SF-12 examination taken between 2008, the year the instrument was first included in the self-administered questionnaire, and the end of the study period, September 10, 2014.

Potential Mediators: Health Conditions

We reviewed participants' medical records for the following post-9/11 physical health conditions: chronic rhinosinusitis, GERD, asthma, chronic bronchitis, chronic obstructive pulmonary diseases/emphysema (COPD/emphysema), interstitial lung diseases (ILD), and musculoskeletal conditions. Participants can have more than one condition.

Participants were classified as having lower respiratory conditions if they met the criteria for asthma, chronic bronchitis, COPD/emphysema, or ILD. To be classified as post-9/11 cases of asthma, COPD/emphysema, chronic rhinosinusitis, or GERD, participants were required to have at least two documented diagnoses of the respective condition at least 30 days apart on separate physician visits. Chronic bronchitis required two diagnoses within 1 year and at least one additional diagnosis in the following 3 years. An ILD case was defined as having two diagnoses (pneumonitis, asbestosis lung, pulmonary fibrosis, sarcoidosis) at least 30 days apart. We did not include cases where the first diagnosis date for a physical health condition occurred after the SF-12 examination date.

Participants who were categorized as having a musculoskeletal condition had either a physician-confirmed post-9/11 diagnosis of an autoimmune-related musculoskeletal condition (eg, rheumatoid arthritis, psoriatic arthritis, or polymyositis) that occurred before their SF-12 date or were considered to have a traumatic musculoskeletal condition related to work at the WTC disaster site.

We included results from mental health screening questionnaires, taken between 2005 and the end of the study period, September 10, 2014, to describe symptoms consistent with PTSD, depression, harmful alcohol use, GAD, and panic syndrome. Mental health symptoms assessed after participants' HrQoL assessment were not included in the analyses.

PTSD was assessed using the PTSD Checklist-Civilian Version 17 (PCL-17),[16] a 17-item survey corresponding to the Diagnostic and Statistical Manual of Mental Disorders Fourth Edition (DSM-IV) diagnostic criteria for PTSD. The PCL-17 inquires about symptoms in the past month related to a traumatic event. Participants with scores 44 or more on the PCL-17[17] were categorized as having probable PTSD.

The 20-item Centers for Epidemiologic Studies Depression Scale (CES-D)[18] was used to evaluate depression. The FDNY version inquires about symptom presence in the past month. Scores 16 or more on the CES-D were used to categorize participants as having probable depression.

Harmful alcohol use was assessed using the Alcohol Use Disorder Identification Test (AUDIT),[19] a 10-item survey that inquires about alcohol behaviors during the past year. Participants with scores 8 or more on the AUDIT were categorized as having probable harmful alcohol use.

We evaluated GAD using the GAD 7 item survey (GAD-7)[20] that corresponds to the DSM-IV diagnostic criteria for GAD. The GAD-7 inquires about symptoms of anxiety (eg, not being able to stop or control worrying) in the preceding 2 weeks. In the FDNY version, we inquired about symptoms in the past month. We used a cutoff 10 or more in the GAD-7 to indicate GAD.

The panic module in the Patient Health Questionnaire (PHQ)[21] was used to assess panic syndrome. We categorized participants as having panic syndrome if they answered affirmatively to the first four questions (ie, having an anxiety attack in the last 4 weeks, having a history of anxiety attacks, having anxiety attacks that happen suddenly, and being worried about having another anxiety attack) and to having four or more somatic symptoms of panic attacks (eg, shortness of breath).

Statistical Analyses

Figure 1 shows a model schematic of our statistical analyses. We conducted several regression analyses to test the hypothesis that selected health conditions mediate the association between WTC-exposure and HrQoL in both the SF-12 PCS and MCS domains. Specifically, we assessed the following criteria: (1) the association

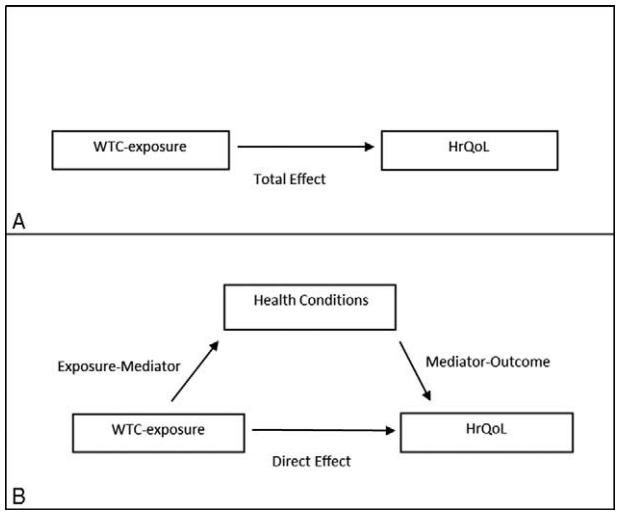

FIGURE 1. Model schematic of assessing health conditions as mediators in the association between WTC-exposure and HrQoL. HrQoL, health-related quality of life; WTC, World Trade Center

between WTC-exposure and HrQoL, not controlling for possible mediators was significant; this is the Total Effect of WTC-exposure on HrQoL (Fig. 1; Panel A); (2) WTC-exposure is significantly associated with health conditions (Panel B); (3) health conditions are significantly associated with HrQoL (Panel B); (4) the relationship between WTC-exposure and HrQoL was attenuated when health conditions were included in the statistical models; this is the Direct Effect of WTC-exposure on HrQoL (Panel B). All regression models used the low WTC-exposure group as the reference category and were adjusted for age at the time of the SF-12 survey, with age groups corresponding to available norms for the SF-12 (25 to 44 years old; 45 to 54 years old; and 55+ years old). If all four criteria are met, the data support the hypothesis that health conditions mediate the association between WTC-exposure and HrQoL.[22–24] We further estimated the proportion of the effect mediated by health conditions using the following formula: 1-([*Direct Effect*]/[*Total Effect*]).[23]

As a sensitivity analysis, we stratified by work assignment on 9/11 (firefighter or EMS) and assessed health conditions as potential mediators in the WTC-exposure and HrQoL association among firefighters and EMS workers, separately. A P value <0.05 is considered statistically significant. All analyses were performed using SAS, version 9.4 (SAS Institute, Cary, NC).

RESULTS

Table 1 shows the distribution of SF-12 PCS and MCS scores by demographic and other characteristics. The majority of the participants were white (87.6%), worked as firefighters at the time of 9/11 (84.4%), and between ages 45 and 54 years old at the time of their SF-12 survey (42.9%). Approximately 16.4% reported arriving at the WTC site in the morning of 9/11; most (68.7%) reported arriving at the site anytime from the afternoon of September 11, 2001 to September 12, 2001. The most prevalent physical health condition is chronic rhinosinusitis (26.6%), followed by GERD (24.3%). Approximately 33.6% of participants screened positive for depression at any time. Approximately 23% of participants have at least one comorbid physical and mental health condition. Participants with any mental health condition have SF-12 PCS and MCS scores that are lower than both the FDNY disease-free and the US general male population, indicating lower HrQoL. In contrast, participants with only physical health conditions tended to only have PCS scores that were below those of the FDNY disease-free and the US general male population. The average time interval between WTC-exposure and participants' most recent SF-12 assessment was 12 years.

In linear regression analyses, WTC-exposure was significantly associated with both physical health and mental health functioning of HrQoL (Tables 2 and 3). In exposure-mediator analyses, WTC-exposure was a significant predictor of health conditions (data not shown), and in mediators-outcome analyses, health conditions were significantly associated with HrQoL in both physical health and mental health aspects of HrQoL (data not shown).

We examined the effects of health conditions as mediators of the associations between WTC-exposure and SF-12 PCS, and

TABLE 1. Study Participants' Demographic and Other Characteristics by HrQoL Scores

Characteristic	No.	%	Physical Component Summary (SD)[a]	Mental Component Summary (SD)[b]
Total	7,190	100.0	50.1 (9.4)	52.5 (8.7)
WTC-exposure (initial arrival)				
High exposure group: morning of 9/11/2001	1,181	16.4	49.4 (9.9)	50.9 (9.8)
Moderate exposure group: afternoon of 9/11/2001 to 9/12/2001	4,936	68.7	50.1 (9.4)	52.7 (8.5)
Low exposure group: 9/13/2001 to 9/24/2001	1,073	14.9	50.9 (8.6)	53.3 (8.0)
Class on 9/11				
Firefighters	6,065	84.4	49.9 (9.5)	52.6 (8.7)
EMS workers	1,125	15.7	51.4 (8.3)	52.2 (8.8)
Race				
White	6,296	87.6	50.0 (9.5)	52.5 (8.7)
African American	351	4.9	51.0 (8.4)	52.7 (9.2)
Hispanic	495	6.9	51.2 (8.6)	52.7 (8.7)
Asian or Native American	48	0.7	50.2 (8.5)	53.7 (6.6)
Age at the time of HrQoL measurement				
25–44 yrs old	2,011	28.0	52.5 (7.8)	52.8 (8.2)
45–54 yrs old	3,087	42.9	50.3 (9.2)	52.2 (8.8)
55+ yrs old	2,092	29.1	47.6 (10.2)	52.7 (8.9)
Health conditions				
Disease-free[c]	2,592	36.1	53.8 (6.0)	56.0 (4.0)
Chronic rhinosinusitis	1,914	26.6	46.3 (10.7)	51.1 (10.0)
GERD	1,750	24.3	45.5 (10.8)	50.2 (10.6)
Lower respiratory conditions	1,455	20.2	43.0 (11.1)	49.7 (11.1)
Musculoskeletal conditions	59	0.8	42.8 (10.7)	49.7 (11.3)
PTSD[d]	1,101	15.3	43.4 (11.3)	41.7 (11.7)
Depression[e]	2,419	33.6	46.4 (10.9)	45.9 (10.8)
Harmful alcohol use[f]	1,654	23.0	48.2 (10.1)	48.8 (10.5)
Generalized anxiety disorder[g]	963	13.4	43.8 (11.4)	40.6 (11.4)
Panic syndrome[h]	323	4.5	40.0 (11.2)	37.6 (11.2)

EMS, emergency medical service; GERD, gastroesophageal reflux disease; HrQoL, health-related quality of life; PTSD, posttraumatic stress disorder; WTC, World Trade Center. Percentages may not sum to 100 because of rounding.

[a,b]SF-12 PCS and MCS scores are unadjusted for age.

[c]Participants categorized as disease-free do not have any of the below conditions.

[d,e,f,g,h]Mental health symptoms, assessed by screening questionnaires, at any time between 2005 and the end of the study period, September 10, 2014.

TABLE 2. HrQoL Physical Health Domain: Health Conditions Posited as Mediators of the Association Between WTC-Exposure and Physical Component Scores

	Total Effect		Model 1 Mental Health Conditions as Mediators			Model 2 Physical Health Conditions as Mediators			Model 3 All Conditions as Mediators		
Parameter	**Estimate (95% CI)**	***P***	**Estimate (95% CI)**	***P***	**% Mediated**	**Estimate (95% CI)**	***P***	**% Mediated**	**Estimate (95% CI)**	***P***	**% Mediated**
Intercept	51.10	<0.001	52.62	<0.001		53.10	<0.001		53.80	<0.001	
WTC-exposure											
High exposure group: morning of 9/11/2001	−1.61 (−2.36, −0.85)	<0.001	−0.24 (−0.96, 0.47)	0.502	85	−0.31 (−1.00, 0.39)	0.388	81	0.42 (−0.26, 1.09)	0.225	∼100
Moderate exposure group: afternoon of 9/11/2001 to 9/12/2001	−0.82 (−1.43, −0.22)	0.008	−0.49 (−1.06, 0.08)	0.090	40	−0.10 (−0.65, 0.45)	0.719	88	0.00 (−0.53, 0.53)	0.999	∼100
Low exposure group: between 9/13/2001 and 9/24/2001	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Health conditions											
PTSD			−3.84 (−4.61, −3.08)	<0.001					−2.64 (−3.37, −1.92)	<0.001	
Depression			−2.46 (−2.99, −1.93)	<0.001					−1.81 (−2.30, −1.31)	<0.001	
Generalized anxiety disorder			−1.35 (−2.14, −0.57)	0.001					−1.07 (−1.81, −0.33)	0.005	
Panic syndrome			−5.50 (−6.58, −4.43)	<0.001					−3.80 (−4.82, −2.78)	<0.001	
Harmful alcohol use			−0.27 (−0.77, 0.22)	0.279					−0.19 (−0.65, 0.28)	0.428	
Chronic rhinosinusitis						−1.57 (−2.07, −1.07)	<0.001		−1.33 (−1.81, −0.85)	<0.001	
GERD						−2.78 (−3.29, −2.27)	<0.001		−1.96 (−2.46, −1.47)	<0.001	
Lower respiratory conditions						−6.92 (−7.46, −6.39)	<0.001		−5.83 (−6.35, −5.31)	<0.001	
Musculoskeletal conditions						−4.66 (−6.81, −2.50)	<0.001		−3.72 (−5.80, −1.64)	0.0001	

CI, confidence interval; GERD, gastroesophageal reflux disease; HrQoL, health-related quality of life; PTSD, posttraumatic stress disorder; WTC, World Trade Center. All models are adjusted for age at the time of HrQoL measurement (reference category = 45 to 54 years old).

TABLE 3. HrQoL Mental Health Domain: Health Conditions Posited as Mediators of the Association Between WTC-Exposure and Mental Component Scores

	Total Effect		Model 1 Mental Health Conditions as Mediators			Model 2 Physical Health Conditions as Mediators			Model 3 All Conditions as Mediators		
Parameter	**Estimate (95% CI)**	***P***	**Estimate (95% CI)**	***P***	**% Mediated**	**Estimate (95% CI)**	***P***	**% Mediated**	**Estimate (95% CI)**	***P***	**% Mediated**
Intercept	53.00	<0.001	55.96	<0.001		53.88	<0.001		55.92	<0.001	
WTC-exposure											
High exposure group: morning of 9/11/2001	−2.44 (−3.16, −1.73)	<0.001	−0.19 (−0.73, 0.36)	0.505	92	−1.91 (−2.61, −1.20)	<0.001	22	−0.22 (−0.77, 0.33)	0.437	91
Moderate exposure group: afternoon of 9/11/2001 to 9/12/2001	−0.62 (−1.19, −0.05)	0.032	−0.04 (−0.47, 0.40)	0.864	94	−0.33 (−0.89, 0.24)	0.254	48	−0.06 (−0.50, 0.37)	0.786	90
Low exposure group: between 9/13/2001 and 9/24/2001	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Health conditions											
PTSD			−4.17 (−4.76, −3.58)	<0.001					−4.18 (−4.77, −3.59)	<0.001	
Depression			−5.31 (−5.72, −4.91)	<0.001					−5.32 (−5.73, −4.92)	<0.001	
Generalized anxiety disorder			−5.67 (−6.27, −5.07)	<0.001					−5.68 (−6.28, −5.08)	<0.001	
Panic syndrome			−5.07 (−5.90, −4.25)	<0.001					−5.11 (−5.94, −4.28)	<0.001	
Harmful alcohol use			−1.14 (−1.52, −0.77)	<0.001					−1.14 (−1.52, −0.76)	<0.001	
Chronic rhinosinusitis						−0.12 (−0.63, 0.39)	0.638		0.45 (0.06, 0.85)	0.024	
GERD						−2.16 (−2.67, −1.64)	<0.001		−0.21 (−0.62, 0.19)	0.302	
Lower respiratory conditions						−2.62 (−3.16, −2.08)	<0.001		−0.01 (−0.44, 0.42)	0.966	
Musculoskeletal conditions						−1.60 (−3.78, 0.59)	0.153		0.49 (−1.20, 2.18)	0.569	

CI, confidence interval; EMS, emergency medical service; GERD, gastroesophageal reflux disease; HrQoL, health-related quality of life; PTSD, posttraumatic stress disorder; WTC, World Trade Center. All models are adjusted for age at the time of HrQoL measurement (reference category = 45 to 54 years old).

WTC-exposure and SF-12 MCS scores in Tables 2 and 3, respectively. As shown in Table 2, SF-12 PCS scores were significantly different between high and low exposure groups and between moderate and low exposure groups. The inclusions of mental and physical health conditions separately in models 1 and 2, and together in model 3, attenuated the WTC-exposure–HrQoL association such that WTC-exposure was no longer significantly associated with SF-12 PCS scores (Table 2). Among those who were highly exposed to WTC, mental health conditions explained 85% of the association between WTC-exposure and SF-12 PCS scores, whereas physical health conditions explained 81% of the association. Among the moderate exposure group, mental health conditions accounted for 40% of the association between WTC-exposure and SF-12 PCS scores, whereas physical health conditions accounted for 88% of the association. All health conditions together fully accounted for the WTC-exposure–SF-12 PCS relationship.

In addition, SF-12 MCS scores were different between high and low exposure groups and between moderate and low exposure groups (Table 3). After controlling for mental health conditions in model 1, WTC-exposure no longer remained significantly related to SF-12 MCS scores. After adding physical health conditions in model 2, the moderate exposure group no longer remained significant, whereas the high exposure group remained significantly associated with SF-12 MCS scores. Among those who were highly exposed, mental health conditions explained 92% of the WTC-exposure–SF-12 MCS association, whereas physical health conditions explained 22% of the association. Furthermore, among those who were moderately exposed, mental health conditions accounted for 94% of the WTC-exposure–SF-12 MCS association, whereas physical health conditions accounted for 48% of the association. The health conditions collectively accounted for a substantial proportion of the WTC-exposure–SF-12 MCS association (high exposure group: 91%; moderate exposure group: 90%).

We repeated analyses for firefighters and EMS workers, separately. Similar to results shown in Tables 2 and 3, all health conditions together accounted for nearly all of WTC-exposure–HrQoL association, for both SF-12 PCS and MCS scores, in both firefighters and EMS workers (data not shown).

DISCUSSION

Building upon prior research that reported associations between WTC-exposure and HrQoL,[3] between WTC-exposure and various adverse health outcomes,[6,9,10,25–28] and between health outcomes and diminished HrQoL,[11,12] we confirmed hypothesized mediators through which WTC-exposure affected HrQoL in FDNY firefighters and EMS workers who worked at the WTC disaster site.

Participants with any adverse health condition had impaired HrQoL. This finding is in keeping with the non-WTC literature on HrQoL in relation to depression,[29,30] PTSD,[30,31] ILD,[32] and GERD.[33] Focusing on a responder cohort, we found impaired HrQoL years after working at the WTC site. Poor HrQoL reported by FDNY responders, on average 12 years after 9/11, was consistent with work by Slottje et al[2] who showed that firefighters and police officers exposed to an aircraft crash disaster had reduced HrQoL 8 years postevent. In the current analysis, chronic health conditions such as rhinosinusitis and asthma, PTSD and depression, affected HrQoL more than a decade after 9/11. In contrast to previous studies that assessed quality of life in the acute aftermath of disaster,[3,11] we showed that impaired physical and mental health functioning of HrQoL may be a long-term health consequence of WTC-exposure.

More importantly, we now demonstrate an apparent causal pathway in which WTC-exposure impacts HrQoL. We showed that years later WTC-exposure does not independently affect HrQoL and instead affects HrQoL through a group of health conditions. Identifying health conditions that mediated the association between WTC-exposure and HrQoL helps confirm the need for medical monitoring and treatment of these conditions to mitigate the deleterious effects of WTC-exposure on HrQoL. The health conditions posited as mediators in the current study have been commonly reported among WTC-exposed individuals. In particular, respiratory conditions are strongly linked to lower physical functioning of HrQoL.[32] Exposure to the WTC dust cloud and respirable materials are associated with lung function decline[34] and the development or exacerbation of respiratory illnesses.[35,36] In addition, we found that mental health symptoms such as PTSD, depression, and panic syndrome are associated with impairments in both the physical and mental health domains of HrQoL, similar to findings in previous non-WTC disaster research.[31,37,38]

One of the strengths of this study is our use of the SF-12, a standardized instrument that is validated in the general US population to assess HrQoL. In addition, we used FDNY's electronic medical records system and health questionnaires to analyze multiple health conditions. More importantly, we had information on dates of physician diagnoses for physical health conditions. Participants were only included in the case definitions for chronic rhinosinusitis, GERD, lower respiratory, or musculoskeletal conditions if date of their first diagnosis of the respective condition occurred after 9/11, but preceded their SF-12 examination date. Because mediation analyses posit causal relationships, the temporal order of WTC-exposure followed by physical health diagnoses followed by HrQoL assessment enabled us to establish stronger causal inferences in the association between WTC-exposure and physical health conditions, and between physical health conditions and HrQoL.

Our study also had some limitations. The SF-12 instrument is validated in the general US population and not in a responder cohort. Because our study population is primarily composed of healthy workers, the SF-12 may have a floor effect, particularly in the physical health domain. The SF-12 inquires about functional difficulties in everyday physical activities (eg, climbing flights of stairs), which most of our participants are able to meet, despite one or more health conditions. Furthermore, the SF-12 is a generic measure of HrQoL, and thus may not be sensitive enough to detect HrQoL impairments associated with a particular health condition. For the current study, however, the use of a generic measure allowed us to meaningfully analyze multiple health conditions, which would not otherwise have been possible.

Also, we do not have a comparable WTC-unexposed population; thus we used the low WTC-exposure group as the reference group in all statistical models. In contrast to physical health conditions for which physician diagnoses were available both before and after 9/11, information on mental health conditions was only available starting 2005 when some screening instruments were added to FDNY's health questionnaires. Therefore, we were unable to be sure of the temporal sequence of symptom onset in relation to WTC-exposure. Furthermore, despite assessing mental health conditions using screening tools and not physician diagnoses, we used validated instruments, some of which (PCL-17 and GAD-7) correspond well with the DSM-IV diagnostic criteria. Finally, we evaluated health conditions as mediators of the association between WTC-exposure and HrQoL that was assessed years later; thus, we do not know if health conditions are also mediators of the relationship between WTC-exposure and HrQoL assessed immediately after the disaster.

CONCLUSIONS

We confirmed the hypothesis that health conditions mediate the association between WTC-exposure and HrQoL and are the primary reason for lower HrQoL years later. Reduced HrQoL is associated with various health conditions among FDNY responders who participated in the rescue/recovery effort at the WTC site. Mental health symptoms associated with WTC or other disasters

may warrant increased clinical attention because they are likely associated with both decreased physical and mental health functioning of HrQoL. Our findings suggest that treatment of exposure-related physical and mental health conditions postdisaster must be a priority if we expect to mitigate the effects of that exposure on HrQoL.

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