






PTSD symptoms, depressive symptoms, and subjective cognitive concerns in WTC-exposed and non-WTC-exposed firefighters

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Abstract

Background: Firefighting has been associated with posttraumatic stress disorder (PTSD) and other mental health conditions. We previously found that among Fire Department of the City of New York (FDNY) responders to the World Trade Center (WTC) disaster, higher-intensity WTC-exposure predicted PTSD symptoms, depressive symptoms, and subjective cognitive concerns. The present study aims to compare these symptoms in the FDNY WTC-exposed cohort versus a comparison cohort of non-FDNY, non-WTC-exposed firefighters.

Methods: The study population included WTC-exposed male firefighters from FDNY ($N = 8466$) and non-WTC-exposed male firefighters from Chicago ($N = 1195$), Philadelphia ($N = 770$), and San Francisco ($N = 650$) fire departments who were employed on 9/11/2001 and completed a health questionnaire between 3/1/2018 and 12/31/2020. Current PTSD symptoms, depressive symptoms, and subjective cognitive concerns were assessed via validated screening instruments. Multivariable linear regression analyses stratified by fire department estimated the impact of covariates on each outcome.

Results: Adjusted mean PTSD symptom scores ranged from 23.5 ± 0.6 in Chicago firefighters to 25.8 ± 0.2 in FDNY, and adjusted mean depressive symptom scores ranged from 7.3 ± 0.5 in Chicago to 9.4 ± 0.6 in Philadelphia. WTC-exposure was associated with fewer subjective cognitive concerns ($\beta = -0.69 \pm 0.05$, $p < .001$) after controlling for covariates. Across cohorts, older age was associated with more cognitive concerns, but fewer PTSD and depressive symptoms.

Conclusions: WTC-exposed firefighters had fewer cognitive concerns compared with non-WTC-exposed firefighters. We were unable to estimate associations between WTC exposure and PTSD symptoms or depressive symptoms due to variability between non-WTC-exposed cohorts. Longitudinal follow-up is needed to

Alexandra K. Mueller and Ankura Singh contributed equally to this study.

assess PTSD, depressive, and cognitive symptom trajectories in firefighter populations as they age.

KEYWORDS

cognitive decline, depression, firefighters, PTSD, World Trade Center

1 | INTRODUCTION

Occupational exposures related to firefighting have been shown to have negative impacts on both the physical and the mental health of firefighters.¹⁻⁴ Posttraumatic stress disorder (PTSD) and depression are among the most studied mental health conditions; in firefighters, they are often associated with potentially traumatic events (PTEs) from repeated occupational stressors like dangerous situations, unpredictable conditions, and witnessing injury and emotional distress,⁵⁻⁹ and from acute traumatic experiences like a terrorist attack, manmade or natural disasters, or witnessing a death.¹⁰⁻¹⁵ One systematic review found that the severity and duration of a disaster exposure are directly related to the development of PTSD and depression in cross-national samples, suggesting that exposure to severe acute traumatic events may outweigh protections gained from career experience and/or resiliency training.¹⁶

Until recently, cognitive function in firefighters was understudied, despite firefighters' exposure to common occupational stressors like smoke and sleep deprivation, which have been shown to have detrimental impacts on cognitive performance.^{17,18} Other studies reported that thermal stress among those that work in hot environments may also lead to cognitive deficits.^{19,20} Additionally, traumatic brain injury may be related to an increased risk of reporting subjective memory impairment,²¹ as well as PTSD and depression.^{22,23}

Studies of World Trade Center (WTC)-exposed rescue/recovery workers have found that those most exposed to the WTC disaster were at increased risk of developing PTSD symptoms and depressive symptoms.^{15,24-27} In recent studies, we found that WTC exposure, PTSD symptoms, and depressive symptoms were associated with subjective cognitive concerns in Fire Department of the City of New York (FDNY) rescue/recovery workers,¹² with PTSD and depressive symptoms acting as mediators of the association between WTC exposure and cognitive concerns.²⁸ In a cohort of non-FDNY WTC responders, duration of WTC exposure and PTSD symptom severity were risk factors for reduced cognitive function.^{29,30} Another study of WTC-exposed individuals found that the risk of experiencing confusion or memory loss, analogs for cognitive function, increased along with participants' number of other mental health conditions.³¹

While studies of WTC-exposed rescue/recovery workers have found associations between WTC exposure and the above mental health conditions, investigators have not previously had access to a comparison population consisting of non-WTC-exposed rescue/recovery workers. The current study was undertaken to compare levels of PTSD symptoms, depressive symptoms, and subjective cognitive concerns in WTC-exposed FDNY firefighters versus in non-WTC-exposed firefighters from the Chicago, Philadelphia, and San

Francisco fire departments who completed a health questionnaire for the Career Firefighter Health Study (CFHS).³² We also sought to identify demographic, lifestyle, and other characteristics associated with each of these mental health conditions in the firefighter cohorts.

2 | METHODS

2.1 | Study population

Male WTC-exposed FDNY and non-WTC-exposed Chicago Fire Department (CFD), Philadelphia Fire Department (PFD), and San Francisco Fire Department (SFFD) firefighters who were actively employed by their fire department on 9/11/2001, completed a self-administered health questionnaire with mental health screening measures, and provided written informed consent were included in this study. FDNY firefighters who performed rescue/recovery work at the WTC site any time between 9/11/2001 and 7/25/2002 were considered WTC-exposed. Of the 10,003 male firefighters in the FDNY source population, 1537 firefighters were excluded because their last routine health monitoring examination at FDNY was before 3/1/2018, the date the subjective cognitive assessment was added to FDNY's self-administered health monitoring questionnaire. The final FDNY population included 8466 firefighters.

The original CFHS source population consisted of 29,992 professional firefighters from CFD, PFD, and SFFD whose information was originally obtained by the National Institute for Occupational Safety and Health (NIOSH) from the fire department rosters.³³ There were 8813 male CFHS members who were actively employed on 9/11/2001; by 12/31/2020, 2866 had completed the CFHS self-administered health survey, a questionnaire similar to FDNY's health questionnaire.³² Of these individuals, 251 respondents reported some type of participation in the WTC rescue/recovery effort between 9/11/2001 and 7/25/2002, and were excluded from the current study. The final non-WTC-exposed firefighter population for analyses included 2615 firefighters.

This study was approved by the Albert Einstein College of Medicine Institutional Review Board.

2.2 | Demographic and lifestyle information

FDNY participants' dates of birth and race/ethnicity were available via the FDNY employee database, and WTC exposure level, defined by arrival time at the WTC site, was self-reported on the first

post-9/11 health monitoring questionnaire.³⁴ Non-WTC-exposed firefighters provided their race/ethnicity information via the CFHS health questionnaire; their dates of birth and employment were available from the fire department roster data. Through the FDNY and CFHS health questionnaires, all participants also reported education level, smoking status (current, former, or never smoker), current alcohol use/binge drinking frequency, and whether they sought treatment for a mental health condition in the past year. FDNY participants' most recent questionnaire data were used.

2.3 | Health-related quality of life

The FDNY and CFHS questionnaires also contained the 12-item Short-Form Health Survey (SF-12), which measured participants' health-related quality of life.³⁵ Each participant received two composite scores when completing the SF-12: the Physical Component Summary (PCS) and Mental Component Summary (MCS) scales, as detailed in previous studies.^{36,37} Scores of 50 on the SF-12 PCS and MCS represent the average self-rated physical and mental health-related quality of life, respectively, in the US general population. Lower scores correspond to worse health-related quality of life.

2.4 | PTSD, depression, and subjective cognition assessment

Previously validated mental health screening instruments were included in both the FDNY and CFHS health questionnaires. We used the 17-item PTSD Checklist Specific (PCL-S) to measure PTSD symptoms.³⁸⁻⁴⁰ The Life Events Checklist, which assessed participants' most traumatic experiences, was included in the health questionnaires along with the PCL-S.⁴¹ In the FDNY questionnaire, WTC exposure was added to the list of options. Both FDNY and CFHS participants identified their index trauma before completing the PCL-S by indicating which experience from the Life Events Checklist was most traumatic to them. The 20-item Center for Epidemiologic Studies Depression Scale (CES-D)⁴² and 14-item Cognitive Function Instrument (CFI)⁴³⁻⁴⁵ assessed depressive symptoms and subjective cognitive concerns, respectively, as described in our previous studies.^{12,28} CFI items measured whether participants felt that they had experienced cognitive and/or functional decline over the past year. Participants were asked if certain cognitive and functional abilities had declined compared to 1 year ago and received one point for every "yes" answer, half a point for every "maybe", and zero points for every "no." For each mental health screening instrument, higher scores corresponded to greater symptoms. A positive screen for probable PTSD was defined as having PCL-S score ≥ 44 ³⁹; for probable depression, it was CES-D score ≥ 16 ⁴²; and for subjective cognitive change, we used a cutoff of CFI score ≥ 2 .¹² Hereafter, we refer to these outcomes as PTSD, depression, and subjective cognitive change, respectively.

2.5 | Statistical analyses

We used proportions (%), means (\pm SD), and medians (IQR), as appropriate, to describe demographic and other characteristics of the FDNY, CFD, PFD, and SFFD groups. Multivariable linear regression models stratified by fire department examined which variables, if any, were similarly associated with PCL-S, CES-D, and CFI scores in each department. The covariates were selected based on their previously established associations with PTSD, depression, and/or cognitive function.⁴⁶⁻⁴⁹ The models included age at questionnaire completion, race/ethnicity, education level, smoking status, current excess alcohol use, and other mental health symptom scores as covariates; CES-D score was not included as a covariate in models predicting PCL-S score, and vice versa, due to the collinearity of these two variables (Pearson correlation $r = .83$; $p < .001$). Covariate data were centered at the mean values for the study population (59 years of age; PCL-S score of 25; CES-D score of 8; CFI score of 2) or the reference values (white race; high school or some college education; never smoker; moderate alcohol use without binge drinking).

We then estimated associations between WTC exposure, assessed as a binary variable (yes/no), and mental health symptom scores using multivariable linear regression analyses: first controlling only for demographic characteristics and subsequently controlling for all potential confounders stated above. In a sensitivity analysis, we ran multivariable logistic regression models using a positive mental health screening result, as defined by the above cutoff scores, as the outcome. We again fit two models estimating the associations with WTC exposure, one controlling for demographics only, and the second controlling for all of the previously identified covariates.

Data analyses were performed using SAS version 9.4 (SAS Institute Inc.). We reported two-sided p values, considered statistically significant when $p < .05$.

3 | RESULTS

Characteristics of the 8466 FDNY, 1195 CFD, 770 PFD, and 650 SFFD male firefighters in the final study population are displayed in Table 1. Members of the source population who were excluded from the study were similar in age to the study population, but were more likely to be retired/deceased (data not shown). Among those included, WTC-exposed FDNY firefighters were younger, on average, and more likely to be white than those in the non-WTC-exposed firefighter cohorts. The FDNY group also had greater proportions of individuals with a bachelor's (or higher) degree and never smokers than the CFD and PFD groups; FDNY and SFFD participants were similar in education level and smoking status. The average physical health-related quality of life scores were lower (worse) for WTC-exposed firefighters than for non-WTC-exposed firefighters, while the average mental health-related quality of life scores were similar.

TABLE 1 Selected population characteristics

	WTC-exposed FDNY	Non-WTC-exposed		
		CFD	PFD	SFFD
<i>n</i>	8466	1195	770	650
Age at exam (SD)	58.34 (7.44)	61.28 (8.41)	63.81 (8.93)	62.01 (8.82)
Race (%)				
Non-Hispanic White	8002 (94.52)	894 (74.81)	606 (78.70)	397 (61.08)
Non-Hispanic Black	182 (2.15)	107 (8.95)	111 (14.42)	44 (6.77)
Hispanic	257 (3.04)	140 (11.72)	24 (3.12)	84 (12.92)
Other race ^a	25 (0.3)	54 (4.52)	29 (3.77)	125 (19.23)
Education (%)				
High school or some college	4638 (54.78)	710 (59.41)	553 (71.82)	280 (43.08)
Associates or RN	1108 (13.09)	181 (15.15)	96 (12.47)	132 (20.31)
Bachelor's degree or higher	2720 (32.13)	304 (25.44)	121 (15.71)	238 (36.62)
Smoking status (%)				
Never	5707 (67.42)	702 (58.74)	349 (45.32)	427 (65.69)
Former	2560 (30.24)	408 (34.14)	354 (45.97)	203 (31.23)
Current	198 (2.34)	85 (7.11)	67 (8.70)	20 (3.08)
HR QoL (SF-12) (SD)				
PCS score	46.51 (10.19)	49.72 (8.58)	48.09 (9.51)	49.38 (9.37)
MCS score	52.80 (9.50)	52.94 (8.64)	51.37 (9.64)	52.31 (8.58)
PCL-S score (SD)	24.98 (10.82)	24.50 (9.38)	27.05 (11.19)	24.68 (9.00)
CES-D score (SD)	8.45 (9.07)	8.48 (8.04)	9.91 (8.99)	8.87 (8.07)
Median CFI score (IQR)	0 (0–2)	1 (0–3.5)	2 (0.5–4.5)	1 (0–3)
Probable PTSD (%)	671 (7.92)	64 (5.36)	68 (8.83)	28 (4.31)
Probable depression (%)	1408 (16.63)	182 (15.23)	168 (21.82)	110 (16.92)
Cognitive concerns ≥ 2 (%)	2296 (27.12)	517 (43.26)	417 (54.16)	271 (41.69)
Sought mental health treatment in past 12 months	902 (10.6)	77 (6.4)	78 (10.1)	41 (6.3)
Excess alcohol use ^b (%)				
No alcohol use	1979 (23.63)	277 (23.18)	183 (23.77)	150 (23.08)
Never	2882 (34.41)	312 (26.11)	254 (32.99)	259 (39.85)
<Monthly	2516 (30.04)	317 (26.53)	165 (21.43)	168 (25.85)
Monthly	688 (8.21)	166 (13.89)	80 (10.39)	47 (7.23)
Weekly or daily	310 (3.70)	123 (10.29)	88 (11.43)	26 (4.00)

Abbreviations: CES-D, Center for Epidemiologic Studies Depression Scale; CFD, Chicago Fire Department; CFI, Cognitive Function Instrument; FDNY, Fire Department of the City of New York; HR QoL (SF-12), Health-Related Quality of Life Short Form 12; MCS, mental component summary; PCL-S, PTSD Checklist Specific; PCS, physical component summary; PFD, Philadelphia Fire Department; SFFD, San Francisco Fire Department; WTC, World Trade Center.

^aIncludes Asian, Pacific Islander, Hawaiian, Native American, and other/unknown race.

^bDefined using participant responses to the question "In the past 12 months, how often have you had six or more drinks on one occasion?"

Table 1 also shows the crude mental health symptom scores in each of the firefighter cohorts. Average PCL-S and CES-D scores were similar in FDNY, CFD, and SFFD participants, but higher (worse) in those from PFD. The non-WTC-exposed firefighter cohorts all had higher (worse) median CFI scores than the FDNY group.

3.1 | PTSD symptoms in each firefighter cohort

All participants selected traumatic life events they had experienced, if any, on the Life Events Checklist before completing the PCL-S. Among WTC-exposed firefighters who reported experiencing at least one traumatic event, 79.0% indicated that WTC exposure was their most traumatic experience, or index trauma. The second most common index trauma among WTC-exposed firefighters was the non-WTC-related unexpected death of a relative, close friend, or coworker (10.2%). This was also the most common index trauma among non-WTC-exposed firefighters (43.1%), followed by 25.6% reporting a severe accident, injury, or illness.

Table 2 shows variables associated with PTSD symptoms when using multivariable linear regression analyses stratified by department. In each of the cohorts, after adjusting for other covariates, higher CFI scores corresponded to higher PCL-S scores, and older age was associated with lower PCL-S scores. Also shown in Table 2 are the model intercepts, or adjusted mean PCL-S scores, for an average member of the study population by fire department. Frequent binge drinking and abstaining from alcohol use were both associated with a higher PCL-S score in FDNY, compared with moderate alcohol use/no binge drinking. The same associations were not seen in the other firefighter cohorts (CFD, PFD, SFFD).

3.2 | Depressive symptoms in each firefighter cohort

In stratified analyses in which depressive symptoms were the outcome (Table 3), as with PTSD, we observed that increased CFI scores were consistently associated with greater CES-D scores, while older age was linked to lower CES-D scores. Smoking was

TABLE 2 Multivariable regression models with PTSD symptom scores as the outcome in male firefighters, by fire department

Variable	WTC-exposed firefighters		Non-WTC-exposed firefighters					
	FDNY $\beta \pm SE$	<i>p</i>	CFD $\beta \pm SE$	<i>p</i>	PFD $\beta \pm SE$	<i>p</i>	SFFD $\beta \pm SE$	<i>p</i>
Intercept	25.84±0.19	<.001	23.45±0.56	<.001	25.68±0.77	<.001	24.81±0.73	<.001
CFI score	2.93±0.04	<.001	1.99±0.09	<.001	2.30±0.12	<.001	1.78±0.12	<.001
Age at exam	-0.05±0.01	<.001	-0.12±0.03	<.001	-0.23±0.04	<.001	-0.14±0.04	<.001
Race/ethnicity								
Non-Hispanic Black versus Non-Hispanic White	0.75±0.60	.215	1.33±0.81	.099	-0.69±0.94	.461	-1.69±1.24	.176
Hispanic versus Non-Hispanic White	-0.53±0.51	.297	-1.15±0.71	.104	1.15±1.91	.545	0.27±0.96	.782
Other race ^a versus Non-Hispanic White	1.41±1.60	.380	2.37±1.10	.032	1.07±1.73	.538	0.09±0.85	.913
Education level								
Associates degree versus HS/some college	0.17±0.27	.530	1.22±0.65	.061	0.15±1.00	.878	-1.26±0.82	.124
Bachelor's degree versus HS/some college	-0.11±0.20	.566	0.60±0.54	.266	-0.29±0.92	.750	0.15±0.70	.830
Smoking status								
Former versus never	0.10±0.20	.625	0.78±0.51	.123	-0.12±0.72	.870	-0.08±0.71	.911
Current versus never	0.90±0.58	.123	0.81±0.91	.372	-1.12±1.22	.360	2.06±1.78	.249
Excess alcohol use ^b								
No alcohol use versus never	1.09±0.23	<.001	0.90±0.65	.166	2.33±0.88	.008	0.51±0.81	.528
<Monthly versus never	0.44±0.22	.047	-0.11±0.63	.861	-0.10±0.92	.911	0.47±0.79	.555
Monthly versus never	1.85±0.34	<.001	-0.80±0.76	.296	1.18±1.17	.313	-0.45±1.25	.720
Weekly/daily versus never	3.17±0.48	<.001	1.46±0.85	.086	1.60±1.14	.163	0.07±1.62	.968

Abbreviations: CFD, Chicago Fire Department; CFI, Cognitive Function Instrument; FDNY, Fire Department of the City of New York; PFD, Philadelphia Fire Department; PTSD, posttraumatic stress disorder; SFFD, San Francisco Fire Department; WTC, World Trade Center.

^aIncludes Asian, Pacific Islander, Hawaiian, Native American, and other/unknown race.

^bDefined using participant responses to the question "In the past 12 months, how often have you had six or more drinks on one occasion?"

TABLE 3 Multivariable regression models with depressive symptom scores as the outcome in male firefighters, by fire department

Variable	WTC-exposed firefighters		Non-WTC-exposed firefighters					
	FDNY $\beta \pm SE$	<i>p</i>	CFD $\beta \pm SE$	<i>p</i>	PFD $\beta \pm SE$	<i>p</i>	SFFD $\beta \pm SE$	<i>p</i>
Intercept	9.05±0.16	<.001	7.32±0.47	<.001	9.38±0.59	<.001	8.42±0.65	<.001
CFI score	2.41±0.03	<.001	1.79±0.08	<.001	1.98±0.09	<.001	1.67±0.10	<.001
Age at exam	-0.02±0.01	.040	-0.10±0.02	<.001	-0.18±0.03	<.001	-0.07±0.03	.031
Race/ethnicity								
Non-Hispanic Black versus Non-Hispanic White	-0.14±0.51	.778	0.08±0.67	.902	-1.68±0.72	.021	-1.18±1.10	.282
Hispanic versus Non-Hispanic White	-0.51±0.43	.240	-0.16±0.59	.788	-1.24±1.47	.401	0.58±0.85	.496
Other race ^a versus Non-Hispanic White	0.90±1.36	.509	0.94±0.92	.308	2.22±1.33	.097	0.67±0.75	.370
Education level								
Associates degree versus HS/some college	-0.03±0.23	.889	0.33±0.54	.546	0.22±0.77	.776	0.74±0.72	.302
Bachelor's degree versus HS/some college	-0.14±0.17	.390	0.26±0.45	.565	-0.19±0.71	.791	0.18±0.62	.768
Smoking status								
Former versus never	0.29±0.17	.078	0.91±0.42	.033	0.08±0.55	.884	0.17±0.62	.788
Current versus never	1.43±0.49	.004	2.24±0.76	.003	0.47±0.94	.616	2.46±1.57	.119
Excess alcohol use ^b								
No alcohol use versus never	1.09±0.20	<.001	1.50±0.54	.006	1.13±0.67	.096	0.12±0.71	.868
<Monthly versus never	0.53±0.19	.004	-0.22±0.53	.683	-1.34±0.71	.059	-0.53±0.69	.444
Monthly versus never	1.54±0.29	<.001	0.35±0.64	.581	-0.54±0.91	.552	0.16±1.11	.887
Weekly/daily versus never	2.84±0.41	<.001	0.87±0.71	.220	-0.02±0.88	.981	0.28±1.43	.844

Abbreviations: CFD, Chicago Fire Department; CFI, Cognitive Function Instrument; FDNY, Fire Department of the City of New York; PFD, Philadelphia Fire Department; SFFD, San Francisco Fire Department; WTC, World Trade Center.

^aIncludes Asian, Pacific Islander, Hawaiian, Native American, and other/unknown race.

^bDefined using participant responses to the question "In the past 12 months, how often have you had six or more drinks on one occasion?"

associated with higher CES-D scores in FDNY and CFD firefighters, but not in the other firefighter cohorts. We also observed that in FDNY, but not the other firefighter cohorts, frequent binge drinking and abstaining from alcohol use were both associated with higher CES-D scores, compared with moderate alcohol use/no binge drinking.

3.3 | Subjective cognitive concerns in each firefighter cohort

When assessing factors associated with subjective cognitive concerns, we found associations between older age and greater CFI scores in the firefighter cohorts (Table 4), in addition to observing the same associations of PCL-S and CES-D scores with CFI scores stated above. The WTC-exposed FDNY cohort had a lower adjusted mean CFI score, when controlling for covariates, than the other firefighter cohorts. Binge drinking was also associated with modestly elevated CFI scores in FDNY, CFD and PFD cohorts, but not SFFD.

3.4 | WTC exposure and mental health symptoms

Because adjusted mean PCL-S and CES-D scores and their associated variables varied in the three non-WTC-exposed firefighter cohorts, we determined it was inappropriate to combine the three cohorts as a reference category to estimate associations between WTC exposure and PCL-S score or WTC exposure and CES-D score. We were able to do so, however, when assessing the association between WTC exposure and CFI score. We observed that WTC-exposed firefighters had a significantly lower CFI score ($\beta = -0.76 \pm 0.06$, $p < .001$) than non-WTC-exposed firefighters in a multivariable linear regression model controlling for age, race, and education level (Table 5). An analysis that controlled for smoking status, excess alcohol use, and CES-D score in addition to the demographic variables showed similar results ($\beta = -0.69 \pm 0.05$, $p < .001$).

Sensitivity analyses examined associations between WTC exposure and subjective cognitive change (CFI score ≥ 2) in multivariable logistic regression models. WTC-exposed firefighters had significantly lower odds of subjective cognitive change when controlling only for demographics (odds ratio [OR] = 0.49, 95% confidence

TABLE 4 Multivariable regression models with subjective cognitive concerns as the outcome in male firefighters, by fire department

Variable	WTC-exposed firefighters		Non-WTC-exposed firefighters					
	FDNY $\beta \pm SE$	<i>p</i>	CFD $\beta \pm SE$	<i>p</i>	PFD $\beta \pm SE$	<i>p</i>	SFFD $\beta \pm SE$	<i>p</i>
Intercept	1.35±0.04	<.001	1.81±0.15	<.001	2.04±0.19	<.001	1.88±0.21	<.001
CES-D score	0.18±0.002	<.001	0.18±0.01	<.001	0.20±0.01	<.001	0.17±0.01	<.001
Age at exam	0.01±0.003	<.001	0.03±0.01	<.001	0.05±0.01	<.001	0.02±0.01	.158
Race/ethnicity								
Non-Hispanic Black versus Non-Hispanic White	0.22±0.14	.107	-0.09±0.21	.680	0.01±0.23	.962	0.21±0.35	.558
Hispanic versus Non-Hispanic White	0.30±0.12	.009	0.06±0.19	.761	0.43±0.46	.354	-0.19±0.27	.480
Other race ^a versus Non-Hispanic White	0.06±0.37	.875	0.42±0.29	.148	-0.17±0.42	.687	0.06±0.24	.787
Education level								
Associates degree versus HS/some college	0.01±0.06	.817	-0.02±0.17	.894	-0.19±0.24	.432	0.01±0.23	.982
Bachelor's degree versus HS/some college	-0.13±0.04	.004	-0.02±0.14	.916	0.22±0.22	.335	-0.23±0.20	.246
Smoking status								
Former versus never	0.02±0.04	.684	0.14±0.13	.288	-0.09±0.17	.624	0.26±0.20	.202
Current versus never	-0.05±0.13	.685	0.09±0.24	.694	-0.06±0.30	.832	-0.55±0.51	.280
Excess alcohol use ^b								
No alcohol use versus never	0.19±0.05	.001	0.24±0.17	.158	-0.02±0.21	.924	0.34±0.23	.140
<Monthly versus never	0.01±0.05	.853	0.09±0.17	.603	0.49±0.22	.030	0.06±0.22	.798
Monthly versus never	0.04±0.08	.594	0.16±0.20	.436	0.34±0.28	.235	0.04±0.35	.905
Weekly/daily versus never	0.32±0.11	.004	0.48±0.22	.032	0.48±0.28	.081	0.44±0.46	.344

Abbreviations: CFD, Chicago Fire Department; CFI, Cognitive Function Instrument; FDNY, Fire Department of the City of New York; PFD, Philadelphia Fire Department; SFFD, San Francisco Fire Department; WTC, World Trade Center.

^aIncludes Asian, Pacific Islander, Hawaiian, Native American, and other/unknown race.

^bDefined using participant responses to the question "In the past 12 months, how often have you had six or more drinks on one occasion?"

interval [CI] = 0.45–0.54), as well as when controlling for demographics, smoking status, excess alcohol use, and positive depression screening (OR = 0.44, 95% CI = 0.40–0.50).

4 | DISCUSSION

This study is unique as it is the first to look at mental health outcomes in WTC-exposed firefighters compared with these outcomes in a similar, non-WTC-exposed, firefighter occupational cohort. Specifically, we examined PTSD symptoms, depressive symptoms, and subjective cognitive concerns in WTC-exposed FDNY firefighters compared with non-WTC-exposed firefighters. In the study population of over 10,000 firefighters, WTC exposure was associated with fewer cognitive concerns after controlling for demographics, smoking, excess alcohol use, and PTSD symptom scores. WTC-exposed firefighters had a 56% lower odds of subjective cognitive change in the last year, defined as a score ≥ 2 on the CFI compared with non-WTC-exposed firefighters.

In multivariable-adjusted analyses that assessed each firefighter subpopulation separately, we found that an average member of the WTC-exposed FDNY firefighter cohort had adjusted mean PTSD and depressive symptom scores of 25.8 ± 0.2 and 9.1 ± 0.2 , respectively. In the non-WTC-exposed firefighter subpopulations, adjusted mean PTSD symptom scores ranged from 23.5 ± 0.6 to 25.7 ± 0.8 , and adjusted mean depressive symptom scores ranged from 7.3 ± 0.5 to 9.4 ± 0.6 . When evaluating PTSD symptoms and depressive symptoms in the WTC-exposed and non-WTC-exposed cohorts, we determined it was inappropriate to perform analyses in which the three non-WTC-exposed firefighter cohorts were combined, due to their varied levels of PTSD and depressive symptoms.

To date, the literature about risk factors for PTSD in firefighters is mixed. Much of the research suggests that repeated exposure to stress increases the risk of developing stress-related diseases.^{50–52} However, there is also evidence to support the idea that professional or career firefighters have greater resilience to stress-related diseases due to better training and experience compared to volunteers.^{51,52} Our data show that PTSD and depressive symptom scores

TABLE 5 Multivariable regression models assessing the association between WTC exposure and CFI scores in male firefighters

Variable	CFI score		CFI score	
	$\beta \pm SE$	<i>p</i>	$\beta \pm SE$	<i>p</i>
Intercept	2.44±0.08	<.001	2.03±0.07	<.001
WTC exposure	-0.76±0.06	<.001	-0.69±0.05	<.001
Age at exam	0.02±0.003	<.001	0.02±0.002	<.001
Race/ethnicity				
Non-Hispanic Black versus non-Hispanic White	0.06±0.12	.628	0.11±0.09	.255
Hispanic versus non-Hispanic White	0.14±0.11	.224	0.12±0.09	.185
Other race ^a versus non-Hispanic White	0.43±0.17	.012	0.06±0.13	.648
Education level				
Some college versus HS	-0.15±0.07	.029	-0.02±0.05	.716
Associates degree versus HS	-0.13±0.09	.148	-0.02±0.07	.787
Bachelor's degree versus HS	-0.42±0.07	<.001	-0.13±0.06	.022
CES-D score			0.18±0.002	<.001
Smoking status				
Former versus never			0.05±0.04	.202
Current versus never			-0.05±0.10	.654
Excess alcohol use ^b				
No alcohol use versus never			0.19±0.05	<.001
<Monthly versus never			0.04±0.05	.398
Monthly versus never			0.07±0.07	.314
Weekly/daily versus never			0.37±0.09	<.001

Abbreviations: CES-D, Center for Epidemiologic Studies Depression Scale; CFI, Cognitive Function Instrument; WTC, World Trade Center.

^aIncludes Asian, Pacific Islander, Hawaiian, Native American, and other/unknown race.

^bDefined using participant responses to the question "In the past 12 months, how often have you had six or more drinks on one occasion?"

in each cohort were, on average, well below published screening thresholds for probable PTSD and depression.^{39,42} As all cohorts were comprised entirely of professional firefighters, we expect that training experiences were similar across cohorts. Instead, the severity of the WTC trauma may have played a larger role. Amir et al.⁵³ examined the association between severity of trauma exposure (battlefield experience, civilian terrorism, and work or traffic accidents) and PTSD symptoms and found that the more severe the trauma

exposure, the more severe the PTSD symptoms. A 2019 study by Pozza et al.⁵⁴ found that victims of terrorist attacks had significantly greater general PTSD severity compared with those who had experienced other PTEs. In prior screening studies, we and others have found that greater WTC exposure is associated with an increased risk of PTSD and depression.^{12,15,24,25,27} Of the WTC-exposed group, 79% reported that the WTC disaster was their most traumatic experience. Among non-WTC-exposed firefighters, the most traumatic experience was the unexpected death of a relative, close friend, or coworker (43%).

We found PTSD and depressive symptom scores to be highly correlated. Comorbidity of mental health outcomes is not uncommon. O'Donnell et al.⁵⁵ found that psychopathology following trauma exposure was better explained through a generalized traumatic stress factor that included both PTSD and depression as opposed to each individually. Both conditions are also often associated with other mental health concerns, like alcohol use disorders^{15,56-58}; accordingly, we controlled for alcohol use in the analyses. PTSD and depression have also been linked to reduced cognitive functioning in WTC-exposed individuals, as well as in other populations.^{46,47,49,59}

We previously observed associations of PTSD and depressive symptoms with subjective cognitive change, and found that PTSD and depressive symptoms mediate the association between WTC exposure and subjective cognitive concerns. In the current analysis, we found fewer subjective cognitive concerns among WTC-exposed firefighters compared with the nonexposed firefighters. While this difference was statistically significant, the WTC-exposed group reported, on average, only one less cognitive symptom out of a 14-item instrument. It is also important to note that in our prior studies, we used internal comparisons by WTC exposure intensity, and observed an exposure-response gradient where cognitive complaints increased in those most highly exposed. Clouston et al.²⁹ compared non-FDNY WTC-exposed responders' performance on an objective cognitive battery with age-matched published normative data from clinical trials, and found that WTC responders' cognitive function was worse than expected. The current study used an external comparison group that is occupationally similar, which is important given the ubiquity of firefighting-related health concerns.¹⁻⁴ It is possible the differences in perceived cognitive decline between the WTC-exposed and nonexposed groups may include uncontrolled residual confounding (such as traumatic brain injuries) or cultural differences. Future studies investigating cognition in these cohorts will need an objective cognitive assessment to confirm any differences in cognitive function between the two groups.

We found that older age was associated with worse self-assessed cognitive function, but better PTSD and depression outcomes. This is supported through the literature, as it is widely accepted that cognitive function tends to decline over time, often referred to as age-related cognitive decline.⁶⁰⁻⁶² More interestingly, PTSD symptom severity has also been reported to improve over time. Yehuda et al.⁶³ conducted a 10-year longitudinal study of PTSD in Holocaust survivors and found that symptom severity declined between the two time points. Posttraumatic growth is the positive

psychological change that can occur after a traumatic event.⁶⁴ While there is limited research examining long-term trajectory of post-traumatic growth, a 2020 study of WTC-exposed individuals found that it was present 15 years after the WTC disaster.⁶⁴ Bluvstein et al.⁶⁵ found that posttraumatic stress symptoms were positively associated with posttraumatic growth. This suggests that posttraumatic growth can follow posttraumatic stress and improve over time, a finding supported by our work. Prior work has shown that increased social support among the elderly is associated with improved cognitive function.⁶⁶⁻⁶⁹ Further, Stanley et al.⁷⁰ found that greater perceived organizational support attenuated PTSD symptom severity in US firefighters. These findings support continued access to mental health services, which may improve PTSD symptoms and cognitive function over time.

We note that WTC-exposed FDNY firefighters may have greater access to mental health treatment, via the WTC Health Program, than the other three firefighter cohorts. It is possible that treatment for PTSD and/or depression reduced cognitive concerns,^{71,72} as well as PTSD and depressive symptoms, within the FDNY cohort; however, we observed that FDNY and the three non-WTC-exposed firefighter cohorts had similar proportions of mental health treatment-seeking patients (10.6%, 6.4%, 10.1%, and 6.3% in FDNY, CFD, PFD, and SFFD, respectively).

Another limitation of this study was our use of screening instruments as opposed to diagnoses; the results are therefore only generalizable for symptoms of PTSD, depression, and cognitive decline, not diagnoses. However, these screening instruments measure the same outcome for each cohort and do not depend on availability of mental health services for diagnosis. The PCL and CES-D have been validated in WTC-exposed firefighters, as well as in other populations.^{38,40,42,73,74} The CFI was validated in older adults who were determined to be free of clinical dementia or impairment at baseline^{43,45}; in these populations, higher baseline CFI scores predicted dementia and worse performance on an objective cognitive measure.^{43,75,76} Future studies are planned that will assess cognitive function among firefighters using an objective cognitive assessment, as the CFI is not yet validated in this cohort.

Further limitations of this study include the potential for selection bias, as 85% of the WTC-exposed FDNY source population and 30% of the CFHS source population were included in the final sample, the exclusion of women due to low numbers in the cohorts, and uncontrolled confounding, particularly surrounding cultural differences in self-reporting potentially stigmatic symptoms. Use of an objective cognitive measure could be useful in addressing the latter concern. However, the surveys were self-administered for all participants, the response method was similar for all firefighters, and our analyses controlled for demographic variables that could potentially affect response variation. Finally, we observed that PTSD and depressive symptom scores were highly correlated in our study population, and were therefore not included in the multivariable models simultaneously.

In conclusion, 20 years after the attacks on September 11, 2001, 8% of WTC-exposed firefighters had probable PTSD and 17% had

probable depression. While we estimated adjusted mean PTSD and depressive symptom scores in the WTC-exposed and non-WTC-exposed firefighter cohorts, we were unable to test for associations between WTC exposure and PTSD symptoms or depressive symptoms due to differences between the non-WTC-exposed cohorts. We did find, however, that WTC-exposed firefighters had fewer cognitive concerns compared with non-WTC-exposed firefighters. Longitudinal follow-up is needed to further assess PTSD, depressive, and cognitive symptom trajectories in firefighter populations as they age. Comparing cohorts in this manner allows for a better understanding of the lasting effect of the exposure to the WTC disaster and adds to the growing body of research surrounding occupational hazards and mental health.

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CONFLICT OF INTERESTS

The authors declare that there are no conflict of interests.

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Steven Markowitz declares that he has no conflict of interest in the review and publication decision regarding this article.

AUTHOR CONTRIBUTIONS

Rachel Zeig-Owens, Mayris P. Webber, Charles B. Hall, and David J. Prezant participated in the conception, design of the work and the acquisition or methodology of the funding for the work. Alexandra K. Mueller and Ankura Singh participated in data curation. Alexandra K. Mueller, Ankura Singh, Charles B. Hall, and Rachel Zeig-Owens conducted analyses and interpretation of data for the work. All authors participated in drafting the work or revising it critically for important intellectual content. All authors provided the final approval of the version to be published. Rachel Zeig-Owens agrees to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

DATA AVAILABILITY STATEMENT

Data may be obtained from a third party and are not publicly available. Reasonable request for deidentified data will be considered by

the investigators and by the National Institute for Occupational Safety and Health.

ETHICS APPROVAL AND INFORMED CONSENT

This study was approved by Institutional Review Board (IRB) at Albert Einstein College of Medicine, Participants provided informed consent.

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