Heart disease among adults exposed to the September 11, 2001 World Trade Center disaster: Results from the World Trade Center Health Registry

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ABSTRACT

Objective. To examine associations between 9/11-related exposures, posttraumatic stress disorder (PTSD), and subsequent development of heart disease (HD).

Methods. We prospectively followed 39,324 WTC Health Registry participants aged ≥ 18 on 9/11 for an average of 2.9 years. HD was defined as self-reported physician-diagnosed angina, heart attack, and/or other HD reported between study enrollment (2003–2004) and a follow-up survey (2006–2008) in enrollees without previous HD. A PTSD Checklist (PCL) score ≥ 44 was considered PTSD. We calculated adjusted hazard ratios (AHR) and 95% confidence intervals (CI) to examine relationships between 9/11-related exposures and HD.

Results. We identified 1162 HD cases (381 women, 781 men). In women, intense dust cloud exposure was significantly associated with HD (AHR 1.28, 95% CI 1.02–1.61). Injury on 9/11 was significantly associated with HD in women (AHR 1.46, 95% CI 1.19–1.79) and in men (AHR 1.33, 95% CI 1.15–1.53). Participants with PTSD at enrollment had an elevated HD risk (AHR 1.68, 95% CI 1.33–2.12 in women, AHR 1.62, 95% CI 1.34–1.96 in men). A dose–response relationship was observed between PCL score and HD risk.

Conclusion. This exploratory study suggests that exposure to the WTC dust cloud, injury on 9/11 and 9/11-related PTSD may be risk factors for HD.

Introduction

During the September 11, 2001 World Trade Center (WTC) terrorist attack, many survivors experienced exposures that could potentially have raised their risk for heart disease (HD). The concentration of airborne particulate matter (PM), which has been linked to increased cardiovascular disease (CVD) morbidity and mortality in other settings (Brook et al., 2010), was extremely high in the dust cloud resulting from the collapse of the WTC towers, and remained elevated in lower Manhattan for weeks thereafter (Thurston et al., 2003). Previous studies have evaluated short-term changes in cardiovascular outcomes after acute elevations in PM concentration, or examined associations between sustained PM exposure and long-term CVD risk (Brook et al., 2010). Whether intense but circumscribed PM exposure such as that resulting from the 9/11 dust cloud also increases long-term HD risk is relatively unexplored.

In addition to inhaled pollutants, 9/11 survivors were exposed to severe psychological stress. Psychological stress resulting from disasters, as well as from daily emotional strain, has been linked to both acute and long-term increases in CVD risk (Armenian et al., 1998; Gullette et al., 1997; Jiang et al., 1996; Nakagawa et al., 2009; Stalnikowicz and Tsafrir, 2002). An association has also been identified between HD mortality and one outcome of severe psychological stress, posttraumatic stress disorder (PTSD), among combat veterans (Ahmadi et al., 2011; Boscarino, 2008; Kubzansky et al., 2007). Because PTSD is one of the most common 9/11-related health problems reported to date (Brackbill et al., 2009; Stellman et al., 2008), it may have contributed substantially to increased HD risk in heavily exposed populations.

Elevations in HD-related hospitalizations were observed in lower Manhattan and neighboring areas within the 2 months following 9/11 (Allegra et al., 2005; Feng et al., 2006; Lin et al., 2010), although cardiac mortality among New York City (NYC) residents was not increased during the month after 9/11 (Chi et al., 2003). These investigations were ecological in nature, limiting inferences about 9/11 exposure and HD risk. A study of cardiac function among police

officers 7–8 years after 9/11 found increased left ventricular dysfunction as well as isolated right ventricular diastolic dysfunction (Croft et al., 2010). In a previous WTCHR study, high levels of exposure were associated with heart disease-related mortality among non-rescue/recovery enrollees [adjusted hazard ratio (AHR) 2.06, 95% CI 1.10–3.86] (Jordan et al., 2011).

We hypothesized that there was a sustained increase in HD risk among 9/11 survivors who were directly exposed to WTC dust and/or psychological stress. We studied non-fatal HD among enrollees in the WTC Health Registry (the Registry), a volunteer registry that prospectively monitors the health of persons exposed to the 9/11 disaster. We sought to determine whether HD was associated with 9/11-related exposures.

Methods

Study population

The Registry's methods were described previously (Farfel et al., 2008). Briefly, potential enrollees were rescue/recovery workers and volunteers; lower Manhattan area residents, workers, school staff and attendees; and commuters and passersby on 9/11. Lists of potentially eligible persons were obtained from lower Manhattan area employers and government agencies (list-identified enrollees), and multilingual media campaigns were used to encourage other potentially eligible persons (self-identified enrollees) to enroll via a website or toll-free telephone number. Between September 2003 and November 2004, 71,434 eligible persons provided verbal informed consent and completed a Wave 1 (W1) computer-assisted (95%) or in-person (5%) enrollment interview on demographics, 9/11-related exposures, and health information. Between November 2006 and January 2008, 46,602 enrollees updated their health information and clarified their 9/11 exposures on a Wave 2 (W2) questionnaire via mail (46%), website (42%), or telephone (12%). The Registry protocol was approved by the Centers for Disease Control and Prevention (CDC) and NYC Department of Health and Mental Hygiene (DOHMH) institutional review boards.

Study outcome

HD was defined as self-reported angina, heart attack, or any other heart condition first diagnosed by a physician between Registry enrollment and the W2 survey. We refer to self-reported, physician-diagnosed HD as HD for the remainder of this manuscript. Because the W2 survey only asked for a year of diagnosis, we assigned a diagnosis date of June 30 of the reported year. For enrollees who reported being diagnosed the same year they completed W1, we assigned a W1 survey date of June 30 of that year and a diagnosis date of December 31 of the same year. For those diagnosed in 2003, we assigned a W1 survey date of September 5, as that was the date the survey officially launched. Person-years were counted from the date of enrollment.

Additional study variables

We categorized enrollees into mutually exclusive, hierarchical eligibility groups based on likelihood of exposure, with rescue/recovery enrollees followed by lower Manhattan residents, lower Manhattan area workers, and passersby on September 11. Data on socio-demographic factors, smoking, and physician-diagnosed hypertension and diabetes were obtained from the W1 questionnaire. Some dust cloud exposure was defined as being caught in the dust cloud on the morning of 9/11 and reporting a geocodable location in lower Manhattan; intense exposure was being caught in the dust cloud on the morning of 9/11 and answering any of the following questions affirmatively: could not see a couple of feet in front of me; had trouble walking or finding my way because the dust was so thick; had to find shelter such as under a car or in a doorway; was covered from head to toe with dust or debris; or could not hear anything (Brackbill et al., 2009). Because injury on 9/11 was associated with both asthma and PTSD in previous studies (Brackbill et al., 2009; Galea et al., 2003), it is thought to be a marker for higher levels of dust cloud and psychological exposures; we therefore explored 9/11-related injury as a potential HD risk factor. Injury was defined as reporting any of the following on 9/11: cut, abrasion, or puncture wound; eye injury or irritation; sprain or strain; burn; broken or dislocated bone; and concussion or head injury.

For rescue/recovery workers, initiation of work was categorized as 9/11 plus work on the dust/debris pile; 9/11 but no pile work; 9/12–9/17; or 9/18–June 2002. Lower Manhattan area residents and workers were asked about the degree of damage to their home or workplace; these measures were categorized as no damage, damage without a heavy layer of dust, or a heavy layer of dust with or without damage.

Posttraumatic stress symptoms were assessed with the PTSD Checklist (PCL), a validated, 17-item, event-specific scale that inquired about symptoms within the 30 preceding days (Blanchard et al., 1996; Ventureyra et al., 2002; Weathers et al., 1993). Question scores ranged from 1 (no symptoms) to 5 (severe), such that total scores ranged from 17 to 85. Responses missing answers to any of the 17 questions were considered invalid. Probable PTSD (referred to as PTSD hereafter) was defined as a score ≥44 (Blanchard et al., 1996).

We used quartiles of the total PCL score but additionally subdivided the upper quartile into three levels in order to distinguish the two commonly used cutoff points for defining PTSD, 44 and 50 (Stellman et al., 2008). The resulting PCL score categories were: 17–19 (20.9% of participants); 20–25 (28.6%); 26–34 (23.7%); 35–43 (13.3%); 44–49 (5.1%); and ≥50 (8.4%).

Inclusion and exclusion criteria

Enrollees aged ≥18 years on 9/11 who completed W2 (n = 46,012) were eligible. We excluded enrollees who were lower Manhattan area school students or staff but did not belong to other eligibility groups due to small numbers (n = 56), those with HD before study enrollment (n = 4719), and those missing data on HD history or year of diagnosis (n = 1913).

Statistical analyses

Person-time began on the date of Registry enrollment and ended at the HD diagnosis date or the W2 survey completion date, whichever was earlier. We stratified analyses on sex given well-established differences between HD risk profiles for men and women. Proportional hazards regression models adjusted for age, race/ethnicity, education, marital status, smoking, history of hypertension, and history of diabetes were used to estimate hazard ratios (HR) and 95% confidence intervals (CI) for HD. We evaluated the impact of adjustment for Registry eligibility group in models including the complete study sample, but no substantial changes in the HRs were observed, so eligibility group was not included in final models. We added PTSD to models with 9/11-related exposure variables to evaluate whether PTSD and 9/11-related exposures were independently associated with HD. There was no evidence that the data violated the proportional hazards assumption. Analyses used SAS version 9.2 (SAS Institute Inc., Cary, North Carolina).

Results

Table 1 shows socio-demographic characteristics, 9/11-related exposures, and physical and mental health conditions present upon enrollment for the 39,324 study participants, who were followed for an average of 2.9 years. Participants were primarily white, aged 25–44 at 9/11, and highly educated. The mean age was 43.9 years [standard deviation (SD) = 11.8] for women and 44.0 years (SD = 10.4) for men. Nearly one-third (29.9% of women and 29.4% of men) reported being heavily exposed to the 9/11 dust cloud. Incurring one or more injuries on 9/11 was reported by 36.6% of women and 38.7% of men. At study enrollment (2003–2004), 16.6% of women and 10.9% of men screened positive for PTSD. Enrollees who did not participate in W2 (n = 20,164) were similar to those who did complete W2 in terms of a history of smoking, hypertension, and diabetes. However, non-participants had higher rates of probable PTSD at W1 (women: 21.5%; men: 15.7%), and were more likely to have been non-Hispanic black, Hispanic or Asian and to be list-identified.

On the W2 survey, 1162 enrollees reported being diagnosed with HD since enrollment. Of these, 125 (10.8%) reported being diagnosed with angina, 140 (12.0%) with a heart attack, 746 (64.2%) with other heart disease, and 151 (13.0%) with more than one of these diagnoses. The HD incidence rate was 859.1/100,000 person-years in women and 1130.4/100,000 person-years in men.

Table 1
Characteristics of the study population. World Trade Center Health Registry participants aged ≥18 on September 11, 2011, New York, 2003–2008.

Characteristic	W2 participants		W2 non-participants	
	Women n = 15,102	Men n = 24,222	Women n = 8160	Men n = 12,004
	%	%	%	%
Age at enrollment (years)				
18–24	3.9	1.6	5.8	3.5
25–44	48.2	52.2	52.8	59.0
45–64	43.8	43.0	35.4	34.1
65+	4.0	3.2	6.1	3.4
Race/ethnicity				
Non-Hispanic white	62.1	76.5	42.8	57.9
Non-Hispanic black	15.5	6.4	21.1	12.4
Hispanic	12.4	10.0	17.8	15.8
Asian	6.3	4.4	12.2	8.4
Other	3.8	2.7	6.2	5.6
Education				
Less than high school	2.2	3.2	7.4	7.9
High school	14.9	19.4	17.7	22.7
Some college	22.3	25.9	23.8	23.6
College graduate	59.9	50.8	47.9	42.8
Employment status				
Full/self employed	84.1	88.9	76.4	83.6
Unemployed	15.6	10.7	21.1	13.7
Marital Status				
Married	43.0	69.7	38.8	58.0
Widowed/divorced/separated	18.9	8.3	20.6	10.7
Never married	29.2	15.6	29.7	20.8
Living with partner	8.0	5.9	7.2	7.4
Eligibility group[a]				
Rescue/recovery worker	26.6	60.6	24.1	53.1
Lower Manhattan area resident	20.6	9.3	26.3	14.6
Lower Manhattan area worker	46.3	26.9	42.4	28.1
Passerby/commuter on 9/11	6.5	3.2	7.2	4.3
Study recruitment source				
List	22.7	28.6	32.4	43.7
Self	77.3	71.4	67.6	56.3
Smoking status				
Never	58.2	55.8	61.8	54.5
Current	14.6	15.1	16.3	20.0
Former	26.6	28.6	19.5	23.0
History of hypertension at enrollment				
Yes	13.9	16.1	15.1	15.2
No	85.9	83.7	84.2	83.9
History of diabetes at enrollment				
Yes	3.4	3.8	4.5	4.4
No	96.4	96.0	94.9	94.9
9/11 dust cloud exposure[b]				
Intense	29.9	29.4	n/a	n/a
Some	16.3	12.2	n/a	n/a
None	50.6	54.5	n/a	n/a
Injured on 9/11[c]				
Yes	36.6	38.7	37.8	37.2
No	63.4	61.3	62.2	62.8
PTSD at enrollment[d]				
Yes	16.6	10.9	21.5	15.7
No	80.6	87.0	71.5	79.0

Rescue/recovery workers/volunteers

	n = 4018	n = 14,675	n = 1967	n = 6370
Time of arrival				
9/11, on pile	2.5	18.8	2.0	13.2
9/11, other WTC site	11.2	14.0	10.8	14.0
9/12–9/17	29.6	42.0	31.4	43.6
9/18–6/2002	52.2	21.9	50.6	26.2

Lower Manhattan area residents

	n = 3104	n = 2260		
Damage to home[b]				
Heavy layer of dust ± damage	16.7	17.0	n/a	n/a
Damage without heavy layer of dust	12.9	12.0	n/a	n/a
No damage	70.3	70.9	n/a	n/a

Table 1 (continued)

Lower Manhattan area workers

	n = 6995	n = 6505		
Damage to workplace[b]				
Heavy layer of dust ± damage	8.9	11.2	n/a	n/a
Damage without heavy layer of dust	15.2	14.9	n/a	n/a
No damage	75.8	73.9	n/a	n/a

Abbreviations: posttraumatic stress disorder (PTSD).
Percents may not sum to 100 due to missing values.
[a] Enrollees were categorized into mutually exclusive, hierarchical eligibility groups based on likelihood of degree of exposure, with rescue/recovery enrollees followed by lower Manhattan residents, lower Manhattan area workers, and passersby on September 11.
[b] Variables required both Wave 1 and Wave 2 data.
[c] Injury was defined as any of the following on 9/11: cut, abrasion, or puncture wound; eye injury or irritation; sprain or strain; burn; broken or dislocated bone; concussion or head injury.
[d] PTSD was defined as a PCL score ≥44.

Table 2 shows associations between HD and socio-demographic factors and previous medical history. Smoking was positively associated with HD risk among men but not women. Among both sexes, a history of hypertension or diabetes was associated with an elevated HD risk.

9/11 dust exposure and heart disease

We examined relationships between 9/11-related dust exposures, including several specific to individual Registry eligibility groups, and HD in multivariable models (Table 3). Accounting for other factors, intense dust cloud exposure was associated with HD among women (AHR 1.28, 95% CI 1.02–1.61), but the association did not reach statistical significance among men (AHR 1.14, 95% CI 0.97–1.34). Male rescue/recovery workers who worked on the pile on 9/11 had a higher HD risk compared to those who arrived on 9/18 or later (AHR 1.39, 95% CI 1.04–1.86). Among female rescue/recovery workers, the association between working on the pile on 9/11 and HD was not statistically significant, although working on another WTC site on 9/11 and arrival between 9/12 and 9/17 were each significantly associated with an elevated HD risk (AHR 1.94, 95% CI 1.10–3.42 and AHR 1.76, 95% CI 1.11–2.77, respectively). The association between heavy dust in the home and HD was significant among male but not female lower Manhattan area residents (AHR 2.05, 95% CI 1.15–3.67, AHR 1.23, 95% CI 0.63–2.42, respectively). Similarly, encountering a heavy layer of dust upon return to a lower Manhattan area workplace was associated with an elevated HD risk among men but not women (AHR 1.55, 95% CI 1.03–2.31, AHR 1.35, 95% CI 0.85–2.14, respectively).

Injury, psychological stress, and heart disease

We evaluated associations between injury on 9/11, psychological stress (PTSD as measured by the 9/11-specific PCL score), and subsequent HD. Table 4 shows adjusted hazard ratios for HD in relation to 9/11 dust cloud exposure, injury, and PTSD separately (Models 1, 2, and 3, respectively). Injury on 9/11 and PTSD at enrollment were both significantly associated with subsequent HD in men and women, with hazard ratios ranging from 1.33 to 1.68. Whereas intense dust cloud exposure by itself was a significant predictor of HD in women (Model 1: AHR 1.28, 95%CI 1.02–1.61) and nearly so in men (AHR 1.14, 95% CI 0.97–1.34), it was attenuated when PTSD was also included (Model 4) and not significant in either sex. However, injury and PTSD considered jointly (Model 5) were significant predictors of HD in both women and men, suggesting that they may be independent risk factors for HD. In these models, PTSD at

Table 2

Associations between socio-demographic and biologic factors and self-reported physician-diagnosed heart disease.[a] World Trade Center Health Registry participants aged ≥18 on September 11, 2001 (n = 39,324), New York, 2003–2008.

	Women				Men			
	No. with HD[b]	Person-time (years)	AHR[c]	95% CI	No. with HD[b]	Person-time (years)	AHR[c]	95% CI
Age on 9/11 (years)			1.03	1.02–1.04			1.05	1.04–1.05
Race/ethnicity								
Non-Hispanic white	204	27,496	Ref		561	52,745	Ref	
Non-Hispanic black	82	6862	1.30	0.99–1.71	51	4544	0.92	0.69–1.24
Hispanic	61	5451	1.39	1.03–1.88	95	6853	1.32	1.05–1.65
Asian	16	2734	0.71	0.42–1.21	41	3065	1.20	0.87–1.66
Other	18	1685	1.20	0.71–2.02	33	1874	1.62	1.13–2.33
Education								
Less than high school	15	966	1.39	0.80–2.44	47	2227	1.41	1.02–1.93
High school	78	6601	1.27	0.96–1.68	164	13,364	1.12	0.93–1.36
Some college	114	9852	1.46	1.14–1.87	224	17,767	1.30	1.09–1.54
College graduate	167	26,538	Ref		342	35,324	Ref	
Marital status								
Married	152	19,101	Ref		582	47,944	Ref	
Widowed/divorced/separated	125	8277	1.32	1.03–1.70	98	5724	1.17	0.94–1.46
Never married	68	12,948	0.81	0.60–1.08	62	10,983	0.67	0.51–0.87
Living with partner	30	3516	1.28	0.86–1.90	36	4087	0.86	0.61–1.21
Smoking status								
Never	220	25,708	Ref		354	38,502	Ref	
Current	52	6458	0.91	0.67–1.24	160	10,468	1.65	1.36–2.00
Former	106	11,822	0.90	0.71–1.15	262	19,751	1.06	0.90–1.25
History of hypertension at enrollment								
Yes	109	6085	1.56	1.22–1.99	203	11,006	1.28	1.08–1.52
No	268	38,053	Ref		573	57,935	Ref	
History of diabetes at enrollment								
Yes	31	1500	1.54	1.05–2.25	72	2614	1.51	1.17–1.94
No	348	42,650	Ref		708	66,378	Ref	

Abbreviations: Heart disease (HD); adjusted hazard ratio (AHR); confidence interval (CI).

[a] Heart disease defined as physician-diagnosed angina, heart attack, or other heart problem first reported on the 2006–2008 Wave 2 survey.

[b] Frequencies may not sum to total due to missing values.

[c] Hazard ratio adjusted for all other variables in the table.

enrollment was represented as a binary (yes/no) variable based on the commonly used cutoff score of 44.

Fig. 1 shows the relationship between PTSD and HD with an alternative representation of PTSD that uses a six-category grouping of PCL scores. In this model, the AHR increases monotonically with the PCL score and is significantly above 1.0 for scores as low as 26–34.

Sensitivity analysis of primary outcome

Using an alternate definition of HD restricted to incident angina and/or heart attack, we found similar associations with both 9/11-related exposures and PTSD (data not shown).

Discussion

The WTC disaster produced a unique combination of physical and psychological exposures that may have impacted survivors' risk for chronic HD. In this exploratory study, we investigated relationships between exposure to air pollution and psychological stress on 9/11 and new-onset HD. We found that, two to six years following the disaster, measures of dust cloud exposure, injury and PTSD were each associated with an elevated risk of non-fatal self-reported physician-diagnosed HD. With a few exceptions, findings were similar among men and women.

Prospective studies of US veterans have found that PTSD is independently associated with both coronary atherosclerosis and an elevated risk of all-cause and HD-related mortality (Ahmadi et al.,

2011; Boscarino, 2008; Kubzansky et al., 2007). Our results add to the more limited body of work on PTSD and HD risk among civilian populations. Although the exact mechanisms for the association between PTSD and HD remain undefined, it has been proposed that psychological stress may accelerate atherosclerosis via excess sympathetic nervous system activation (Rozanski et al., 1999). PTSD may also contribute to HD risk though the disorder's association with health behaviors that are known cardiovascular risk factors, including smoking (Beckham et al., 1997; Breslau et al., 2003).

We found that HD risk increased steadily with PCL score. This is consistent with the observation of a dose–response relationship between the level of PTSD symptoms and the risk of medically confirmed coronary HD in a prospective study of US military veterans (Kubzansky et al., 2007). In keeping with a growing body of evidence that "subthreshold" posttraumatic stress symptoms can result in deleterious effects on general functional status (Grubaugh et al., 2005; Jakupcak et al., 2011; Marshall et al., 2001), we also found that a significant association between posttraumatic stress symptoms and HD risk was present at PCL scores substantially below the commonly used PCL score cutoff of 44. These results suggest that further investigation of the relationship between PTSD and HD should consider subthreshold symptoms as a potential risk factor. PTSD attenuates the association between dust cloud and HD in women, suggesting that PTSD could be explored as a mediator of exposures experienced on 9/11 in future studies.

Our results must be interpreted with caution. Our HD definition was a composite of angina, heart attack, and/or other HD (constituting the majority of cases), so the exact nature of the reported heart

Table 3
Associations between measures of 9/11-related dust exposure and self-reported physician-diagnosed heart disease.[a,b] World Trade Center Health Registry participants aged ≥18 on September 11, 2011 (n = 39,324), New York, 2003–2008.

Exposure	Women				Men			
	No. with HD[c]	Person-time (years)	AHR	95% CI	No. with HD[c]	Person-time (years)	AHR	95% CI
All enrollees								
9/11 dust cloud exposure								
Intense	141	13,357	1.28	1.02–1.61	243	20,371	1.14	0.97–1.34
Some	48	7247	0.83	0.60–1.14	90	8500	1.00	0.79–1.25
None	171	22,237	Ref		412	37,511	Ref	
Rescue/recovery workers								
Time of arrival								
9/11, on pile	4	292	2.25	0.79–6.40	87	7452	1.39	1.04–1.86
911, other WTC site	19	1298	1.94	1.10–3.42	71	5846	1.21	0.89–1.63
9/12–9/17	39	3404	1.76	1.11–2.77	216	17,420	1.24	0.98–1.56
9/18–6/2002	44	6186	Ref		112	9293	Ref	
Area residents								
Damage to home								
Heavy layer of dust ± damage	12	1543	1.23	0.63–2.42	18	1152	2.05	1.15–3.67
Damage without heavy layer of dust	13	1213	1.69	0.87–3.25	7	841	1.09	0.48–2.48
None	34	6369	Ref		39	4666	Ref	
Area workers								
Damage to workplace								
Heavy layer of dust ± damage	21	1822	1.35	0.85–2.14	31	2075	1.55	1.03–2.31
Damage without heavy layer of dust	31	3178	1.23	0.83–1.82	29	2864	1.12	0.75–1.69
None	128	15,501	Ref		124	13,792	Ref	

Abbreviations: Heart disease (HD); adjusted hazard ratio (AHR); confidence interval (CI).
[a] Heart disease defined as physician-diagnosed angina, heart attack, or other heart problem first reported on the 2006–2008 Wave 2 survey.
[b] Models were adjusted for age, race/ethnicity, education, marital status, smoking, hypertension, and diabetes.
[c] Frequencies may not sum to total due to missing values.

problems is unknown. We found similar associations between HD and both 9/11-related exposures and PTSD when we used an alternate definition of HD restricted to incident angina and/or heart attack. Nonetheless, clarification of the types of HD experienced by enrollees is needed. Because HD was self-reported, our findings require substantiation with more objectively defined end-points, such as medically confirmed HD. Previous studies of the validity of self-reported HD suggest that respondents tend to over-report individual HD events; however, when different cardiovascular events are combined into clinically relevant groups, such as the composite used in our study, self-report more closely matches medical records (Barr et al., 2009, Joshi and Turnbill, 2009).

We relied on self-reported 9/11-related exposures because objective measures of these exposures are not available for our cohort. We assumed that PTSD identified at the time of Registry enrollment resulted from 9/11 exposure. Although we could not definitively determine what proportion of PTSD cases were due to other traumatic experiences, results of the W2 survey indicate that only a small proportion of those screening positive for PTSD had also been diagnosed with PTSD before 9/11 (data not shown), suggesting that PTSD identified at W1 is likely to have been 9/11-related. A further limitation was our lack of information on important CVD risk factors, including dyslipidemia, family history, and depression. We may have had insufficient follow-up time to detect an association between smoking and HD among women, who tend to develop HD later in life compared to men. Additionally, our assignment of event dates was imprecise, and the relatively short duration of follow-up restricted our ability to perform detailed sub-group analyses.

Another important limitation is loss to follow-up between the W1 and W2 surveys. How this loss to follow-up may have impacted our results is unknown. However, W2 non-participants did not differ from participants regarding several key HD risk factors, including smoking, hypertension, and diabetes, suggesting that our results are likely to be representative of those for the full cohort.

Finally, because this study began two years after 9/11, we could not evaluate associations between 9/11 exposure and immediate HD risk. In-depth studies of HD among Registry enrollees and among members of other WTC cohorts will be needed to further elucidate the potential association between 9/11-related exposures and HD.

Conclusion

This study provided an opportunity to prospectively explore the relative importance of physical and psychological exposures for HD risk in a large and diverse cohort of 9/11 survivors. With the exception of smoking among women, our results reflected established HD risk factors such as hypertension and diabetes, substantiating our findings on 9/11-related exposures. We found evidence that 9/11-related exposures were associated with an elevated HD risk several years after the disaster. These results have important implications for HD risk factor screening among persons who were directly exposed to the 9/11 disaster, as they indicate that the intensity of dust exposure, injury incurred on 9/11, and the severity of PTSD should be considered in addition to the classic HD risk factors in this population.

Funding

Table 4

Evaluation of PTSD and 9/11-related dust cloud exposure as independent risk factors for self-reported physician-diagnosed heart disease.[a,b] World Trade Center Health Registry participants aged ≥18 on September 11, 2001 (n = 39,324), New York, 2003–2008.

Exposure(s) added to model	Women				Men			
	No. with HD[c]	Person-time (years)	AHR	95% CI	No. with HD[c]	Person-time (years)	AHR	95% CI
Model 1								
9/11 dust cloud exposure								
Intense	141	13,357	1.28	1.02–1.61	243	20,371	1.14	0.97–1.34
Some	48	7247	0.83	0.60–1.14	90	8500	1.00	0.79–1.25
None	171	22,237	Ref		412	37,511	Ref	
Model 2								
Injured on 9/11[d]								
Yes	186	16,298	1.46	1.19–1.79	348	26,551	1.33	1.15–1.53
No	195	27,928	Ref		433	42,529	Ref	
Model 3								
PTSD at enrollment[e]								
Yes	107	7317	1.68	1.33–2.12	137	7491	1.62	1.34–1.96
No	260	35,688	Ref		624	60,166	Ref	
Model 4								
9/11 dust cloud exposure								
Intense	136	13,002	1.17	0.92–1.48	238	19,902	1.09	0.93–1.29
Some	47	7078	0.80	0.58–1.11	89	8307	1.00	0.80–1.26
None	165	21,610	Ref		400	36,816	Ref	
PTSD at enrollment[e]								
Yes	101	7062	1.62	1.26–2.07	126	7061	1.56	1.27–1.91
No	247	34,628	Ref		601	57,965	Ref	
Model 5								
Injured on 9/11[d]								
Yes	179	15,750	1.35	1.09–1.68	344	25,964	1.29	1.12–1.50
No	188	27,253	Ref		417	41,693	Ref	
PTSD at enrollment[e]								
Yes	107	7317	1.54	1.21–1.97	137	7491	1.50	1.24–1.83
No	260	35,686	Ref		624	60,166	Ref	

Abbreviations: Heart disease (HD); adjusted hazard ratio (AHR); confidence interval (CI); posttraumatic stress disorder (PTSD).

[a] HD was defined as physician-diagnosed angina, heart attack, or other heart problem first reported on the 2006–2008 Wave 2 survey.

[b] Models were also adjusted for age, race/ethnicity, education, marital status, smoking, hypertension, and diabetes.

[c] Frequencies may not sum to total due to missing values.

[d] Injury was defined as any of the following on 9/11: cut, abrasion, or puncture wound; eye injury or irritation; sprain or strain; burn; broken or dislocated bone; concussion or head injury.

[e] PTSD was defined as a PCL score ≥44.

analysis, data interpretation, or writing of the report. NYC DOHMH participated in study design and development, data collection, and review of the manuscript.
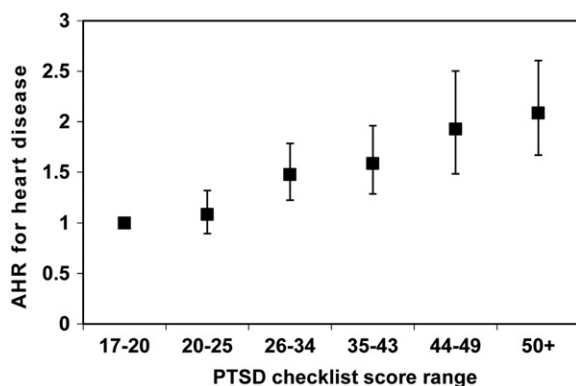
Fig. 1. Adjusted hazard ratios (AHR) for self-reported physician-diagnosed heart disease according to posttraumatic stress disorder (PTSD) checklist score for World Trade Center Health Registry participants aged ≥18 on September 11, 2011 (n = 39,324), New York, 2003–2008. Heart disease was defined as physician-diagnosed angina, heart attack, or other heart problem first reported on the 2006–2007 Wave 2 survey. Hazard ratios were adjusted for age, race/ethnicity, education, marital status, smoking, hypertension, and diabetes. Error bars represent 95% confidence intervals.

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