

BRIEF REPORT

Work Disability, Early Retirement, and Loss of a Loved One in the World Trade Center Health Registry Cohort

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ABSTRACT

Background: Existing research on the economic outcomes of 9/11 remains limited and has primarily focused on early retirement. Little is known about the prevalence of work disability and loss of a loved one and whether they are associated with survey attrition.

Methods: The World Trade Center Health Registry (WTCHR) is a closed longitudinal cohort that recruited more than 71,000 participants at baseline (2003–2004). Bivariate analyses were conducted to compare the distribution of 9/11 exposure and sociodemographic factors for (1) work disability, (2) early retirement, and (3) loss of a loved one. Separate Poisson models were constructed to predict survey attrition.

Results: Both those who were work-disabled and early-retired were more likely to be older, male, a rescue/recovery worker, and have greater 9/11 exposure. In addition, work disability was associated with lower income and educational attainment, and PTSD diagnosis. Loss of a loved one was associated with PTSD diagnosis and some measures of 9/11. Work disability was associated with higher and early retirement was associated with lower risk survey attrition at wave 4. Loss of a loved one was not associated with survey attrition.

Conclusion: Early retirement, work disability, and loss of a loved one can have major impacts on an individual's economic wellbeing and are potentially qualifying events for social programs, such as Social Security Administration (SSA) benefits. Future research is needed to overcome the limitations of self-reported data in order to understand how timely receipt of SSA benefits can lead to better health trajectories among disaster- and trauma-exposed populations.

The economic impact of the 9/11 World Trade Center disaster is an emerging area of research. For example, the mechanisms that lead to adverse economic outcomes, such as exiting the workforce in the form of disability, early retirement, or changes in earnings from the loss of family members, remain understudied. Moreover, it is unknown whether these types of workforce exits influence epidemiologic survey participation

due to health limitations, financial stress, or disengagement from the workforce, thereby leading to nonresponse bias and limiting the accuracy of research findings on these populations.

Many of those exposed to the events of September 11, including rescue and recovery workers and survivors, have experienced chronic physical and mental health conditions including lower respiratory symptoms, asthma, cancer, PTSD, anxiety, and

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depression [1–7], which may accelerate exit from the workforce and consequently negatively affect household earnings. Many families may have also lost their primary earner on 9/11. Early retirement, work disability, and loss of a loved one also have implications for the broader public social safety net, including Social Security Disability Insurance (SSDI) and retirement and survivorship benefits.

Work disability, defined by SSDI as being unable to work at a substantially gainful activity level because of a medical condition (Social Security Administration) [8], is a key pathway through which disaster-related illness and injury may lead to diminished labor force participation, though it should be noted that some people choose to work despite severe physical or mental limitations, and others, such as undocumented immigrants, may not have access to SSDI. Limited evidence suggests those exposed to the events of September 11 may have greater risk of work disability. For example, a study of FDNY firefighters found an increase of retirements from accidental disability in the seven years after the terrorist attack [9]. However, far less is known about work disability among survivors, volunteers, or other uniformed workers. Given that several conditions linked to 9/11, depending on severity, may be eligible for social security disability, it is essential to understand whether work disability claims are higher in this cohort compared to the general population and whether onset of benefit receipt is earlier and benefit duration is longer.

Early retirement is another important area of focus, particularly for older adults who may leave the workforce prematurely due to health decline following 9/11 exposure. Although early retirement is an option within the Social Security system, individuals who retire before full retirement age receive reduced monthly benefits, which may have long-term consequences for economic security [10]. Early retirement decision-making processes are heterogeneous. Those with a higher income or the accessibility to an employer-provided pension, such as uniformed workers, may have a greater ability to retire early compared to those of more modest means. However, previous work in the 9/11 exposed population found those with poorer health retire earlier [11]. In the general population, findings have been mixed but generally suggest those who are healthier and of higher SES work to later ages [12–14]. In addition, several WTCHR studies have found increased rates of early retirement in this cohort and substantial income loss post-retirement [9, 11, 15]. However, these studies define early retirement as before age 60, not before the age of full social security retirement benefits (between 65 and 67 depending on birth cohort) and also did not examine how early retirement affected survey attrition. Studying patterns of early retirement in the 9/11-exposed population can illuminate how disaster-related health burdens intersect with retirement decision-making.

Loss of a loved one, particularly widowhood, is often associated with a loss of income and economic security [16, 17]. Although a few studies have examined grief in the 9/11 population [18–20], to date no study to our knowledge has systematically examined survivorship benefits among the surviving spouses and children of the almost 3000 people who died on 9/11. Thus, there is limited insight into how these benefits may have contributed to enhanced financial

security and positive health and developmental outcomes for these spouses and children.

Finally, little is known about whether work disability, early retirement, or loss of a loved one on 9/11 are associated with attrition in longitudinal studies. In a study of WTCHR enrollees, Yu et al. found that wave 3 non-participants were younger, more likely to be male, non-White, and more likely to have PTSD [21], but did not examine work disability, early retirement, or loss of a loved one on 9/11. Similar socio-demographic findings have been found for survey attrition for other cohorts not exposed to 9/11 [22–25]. Fully understanding these survey attrition patterns is critical because disproportionate loss to follow-up can bias estimates of aging, disability, and socioeconomic trajectories, ultimately undermining the validity and policy relevance of longitudinal research findings.

This study will add to the 9/11 literature in two ways: first, by documenting prevalence and risk factors for work disability, early retirement, and loss of a loved one, which are each life events that have complex effects on economic well-being and health trajectories and also qualify an enrollee for social safety programs. Secondly, this work examines patterns of attrition among each of these groups in order to determine whether survey participation is differential longitudinally.

The specific aims are as follows: (1) To determine the prevalence of self-reported work disability, early retirement, and loss of a loved one on 9/11; (2) To describe sociodemographic, health, and 9/11 exposure patterns in the distribution of work disability, early retirement, and loss of a loved one on 9/11; and (3) To determine whether work disability, early retirement, or loss of a loved one on 9/11 predicts survey attrition.

1 | Methods

1.1 | Study Population

World Trade Center Health Registry: WTCHR is a closed cohort designed to study the health effects of 9/11. More than 71,000 enrollees were recruited at baseline (2003–2004) and five additional survey waves have been completed, with a sixth underway. In addition, several sub-studies, such as those described below, have been conducted. The study population falls into four categories, which are not mutually exclusive: (1) more than 43,000 building occupants and passers-by in Lower Manhattan south of Chambers St. (which includes 4000 survivors of the collapsed WTC Towers), (2) close to 15,000 who lived south of Canal Street in Lower Manhattan, (3) approximately 3200 children and staff in schools (pre K-12) south of Canal Street, and (4) about 31,000 rescue, recovery and cleanup workers and volunteers at either the WTC site, the Staten Island recovery operation site, or on the barges that carried debris between these two sites. Survey data include detailed measures of physical and mental health, functional limitations, health care utilization, employment and retirement history, and socioeconomic characteristics. WTCHR study methods are described in more detail elsewhere [26, 27].

Wave 2 Pediatric/Adolescent Surveys: The 2030 minors who were included in the baseline WTCHR and who were under 18 on April 1, 2007, were sent Pediatric/Adolescent surveys rather

than the Adult survey. Parents and guardians were asked to fill out the survey for children under the age of 13, and a separate set of questions were given to older children 13–17 ($n = 1073$) to answer themselves. The final response rate for all Pediatric Surveys was 50%.

9/11 Health and Employment Survey (HES): HES was designed to provide an in-depth analysis of retirement and disability and surveyed a subsample of WTCHR enrollees ($n = 14,887$) in 2017 and 2018. Specifically, HES asked whether enrollees received social security disability (or another type of disability), whether they were retired, and if so, when they retired. The HES study participants were pulled from two groups among the sample pool of English-speaking enrollees below age 75 (as of 2017) who responded to both wave 1 and wave 2: (1) reported retirement or unemployment due to disability/health on Waves 2–4, and (2) an equivalent number of not-yet retired age-matched enrollees randomly drawn from the remaining sample pool. Full survey methods have been described in more detail elsewhere [11].

1.2 | Exposures

1.2.1 | Work Disability

Work disability was defined as “yes” for all respondents who answered “Unable to work because of disability” when asked about employment status in survey wave 2 (2006–2008). This question also allowed enrollees to choose other options such as whether they were on maternity/paternity leave or were a homemaker. We chose this measure because the wave 2 survey was sent to the full cohort of 71,423 enrollees. HES, described above, was sent only to a smaller sample of the WTCHR cohort and the wave 1 survey did not include this question. This allowed us to examine whether work disability predicted attrition in the full cohort.

1.2.2 | Early Retirement

Wave 2 asked for employment status and offered “retired,” but did not ask retired respondents for their retirement date. We therefore excluded all enrollees who were above normal retirement age (NRA) for social security retirement benefits for the analysis of early retirement only. For people born between 1943 and 1954, the NRA is 66, and it gradually increases for those born in later years. For anyone born in 1960 or later, the full retirement age is 67. Although individuals can begin receiving benefits as early as age 62, doing so results in permanently reduced monthly payments. We then considered anyone who was already retired in wave 2 to be early retired.

1.2.3 | Survivorship (Loss of a Loved One)

The wave 2 Pediatric/Adolescent and Adult surveys asked whether a respondent knew anyone who died on 9/11 and, if so, what the person's relationship was to the respondent. All enrollees who answered spouse, parent, or guardian, were considered to be “yes” for loss of a loved one. Enrollees who did not know anyone who died on 9/11 or responded with another relationship to the deceased (e.g., friend) were categorized as “no.” Due to a small number of respondents who lost a loved one, we combined loss of spouse, parent, or guardian into one measure.

1.3 | Outcomes

Our primary outcome of interest was wave 4 (2015–2016) non-response. We chose wave 4 because wave 5 was only sent to enrollees who participated in wave 2 and wave 3 or 4. We considered everyone who did not respond to wave 4 as “yes” even if they responded to other surveys (e.g., those who dropped in and out of survey waves). Because individual-level mortality data was not available, those who died during the follow-up period were considered lost to follow up.

1.4 | Covariates

All covariates were self-reported on WTCHR wave 1 unless noted below. Age was measured as age on 9/11. Race/ethnicity was categorized as White (Non-Hispanic), Black (Non-Hispanic), Hispanic or Latino, Asian, and Multi-racial/Other. Gender was categorized as male or female. Income was measured as a categorical variable, which was collapsed into the following mutually exclusive categories: <\$25,000, \$25,000– <\$50,000, \$50,000– <\$75,000, \$75,000– <\$150,000, $\geq$ \$150,000. PTSD was measured via a 9/11-specific modified version of the PTSD Checklist (PCL). To maintain consistency with a previous analysis of this cohort, the PCL was summed and a score of ≥ 44 was considered probable PTSD; all scores < 44 were classified as no PTSD. All enrollees who did not answer all 17 PCL questions were excluded. Lower respiratory symptoms were considered “yes” if an enrollee responded affirmatively to any of the following: wheezing, shortness of breath, persistent cough, or throat or sinus irritation. Educational attainment was measured as a categorical variable and collapsed into the following four categories: less than high school, high school only, some college, or at least a bachelor's degree. Injury was categorized as a “yes” if a respondent indicated any of the following injuries on 9/11: cut, eye irritation, sprain, burn, broken bone, or concussion. If a respondent answered no to all or was missing information on injury, he or she was considered uninjured. Rescue/recovery worker status was categorized as “yes” if an enrollee was a rescue, recovery, or cleanup worker at World Trade Center site, Staten Island, or barge sites, and “no” otherwise.

September 11 exposure was measured in two ways. First, based on an exposure scale created by Boscarino and Adams, [28] and described in detail elsewhere. In brief, the exposure scale is based on a sum of positive responses to 12 questions about traumatic experiences on 9/11 or immediately after (e.g., being in the North or South tower, having to evacuate home residence, and job loss) in waves 1 and 2. In addition, we adjusted for dust intensity, which was determined using responses to the waves 1 and 2 surveys.

1.5 | Statistical Analysis

All enrollees missing data were excluded from the analytic sample (see Figure 1). Bivariate analyses were conducted either using the χ^2 test to compare the distribution of 9/11 exposure and sociodemographic factors among those who were or were not work disabled, retired early, or who did not lose a loved one (aims 1 and 2). For aim 3, we constructed Poisson models with robust standard errors to account for the fact the outcome (wave 4 attrition) had a high prevalence. All models

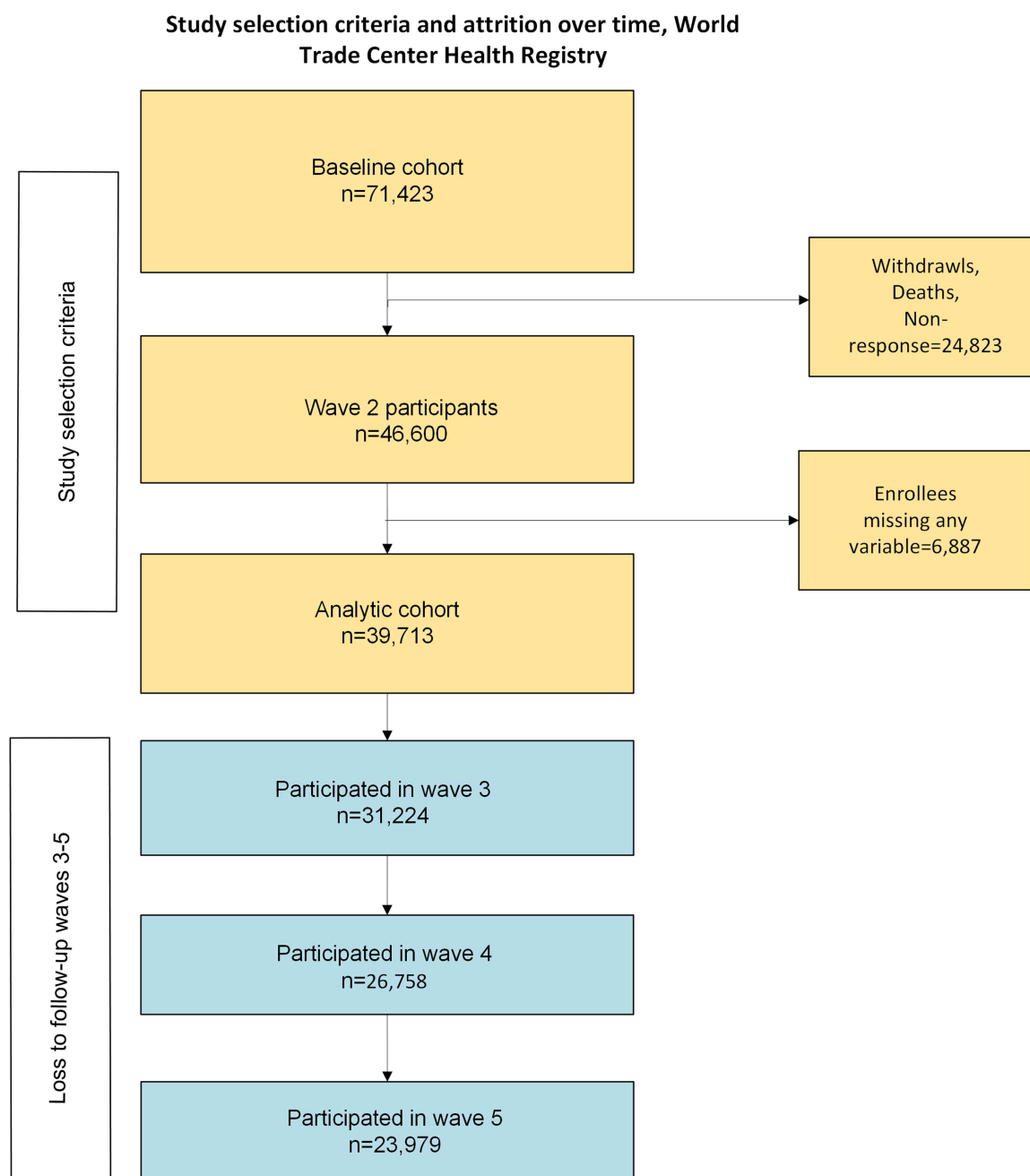


FIGURE 1 | Flow chart describing study sample selection of the World Trade Center Registry (WTCHR) cohort and survey attrition by wave. [Color figure can be viewed at [wileyonlinelibrary.com](https://onlinelibrary.wiley.com/doi/10.1002/ajim.70069)]

were fully adjusted with all confounders (variables that are a common cause of both exposure and outcome) chosen a priori based on previous literature. All analyses were completed in Posit (formerly RStudio) version 2025.05.0.

1.6 | Sensitivity Analyses

Several sensitivity analyses were conducted. First, survey attrition at wave 3 was examined to determine whether timing affected loss to follow up patterns (e.g., to determine whether lower mortality during the shorter follow-up time would affect the overall results). We also examined early retirement and disability in the HES sub-study because it had more robust data on SSDI benefit receipt and also date of retirement. Specifically, we considered enrollees to be

work disabled if they answered yes to the question “Have you ever received social security disability benefits?” The early retirement variable was calculated by comparing month/year (as exact date wasn’t available) of retirement to month/date of NRA. If month wasn’t available, we assumed the individual retired in December to take full advantage of benefits. Anyone missing year of retirement was excluded. We examined the relationship between HES data and wave 5 (2020–2021) attrition because HES was conducted after wave 4.

1.7 | Ethics Review

This study was reviewed and approved by the Institutional Review Board (IRB) of the New York City Department of Health

and Mental Hygiene (NYC DOHMH). All procedures were conducted in accordance with the ethical standards of the NYC DOHMH IRB. Informed consent was obtained from all participants.

2 | Results

The final analytic sample consisted of 39,713 enrollees of which 24,646 were male and 15,067 were female. Non-Hispanic Whites made up 70% of the sample, followed by Hispanics

(12%), non-Hispanic Blacks (10%), Asians (5%), and multi-racial/other (3%). Just over 4% were work-disabled, 8% had retired early as of wave 2, and less than 1% had lost a spouse, parent, or guardian on 9/11. Those who participated in wave 4 were older, more likely to be non-Hispanic White, have higher income and educational attainment, less likely to have PTSD, scored higher on the 9/11 exposure scale, and more likely to be a rescue/recovery worker. Participation in wave 4 was associated with being work-disabled, but not losing a spouse, parent, or guardian on 9/11. Those who retired early were less likely to attrit in wave 4 (Table 1).

TABLE 1 | Characteristics of the World Trade Center Registry (WTCHR) cohort stratified by wave 4 participation.

		Participated no	Participated yes	<i>p</i>
Work disability	No	12,269 (94.7)	25,678 (96.0)	< 0.001
	Yes	686 (5.3)	1080 (4.0)	
Early retirement	No	11,323 (94.1)	23,144 (91.2)	< 0.001
	Yes	715 (5.9)	2236 (8.8)	
Spouse, parent, or guardian lost on 9/11	No	12,936 (99.9)	26,720 (99.9)	1
	Yes	19 (0.1)	38 (0.1)	
Age on 9/11	Mean (SD)	40.6 (12.3)	42.2 (10.9)	< 0.001
Gender	Male	8006 (61.8)	16,640 (62.2)	0.461
	Female	4949 (38.2)	10,118 (37.8)	
Race/ethnicity	White (Non-Hispanic)	8295 (64.0)	19,523 (73.0)	< 0.001
	Black (Non-Hispanic)	1720 (13.3)	2431 (9.1)	
	Hispanic or Latino	1779 (13.7)	2892 (10.8)	
	Asian (Non-Hispanic)	787 (6.1)	1231 (4.6)	
	Multi-racial/Other	374 (2.9)	681 (2.5)	
Income	<\$25,000	1440 (11.1)	1958 (7.3)	< 0.001
	\$25,000– < \$50,000	2921 (22.5)	4824 (18.0)	
	\$50,000– < \$75,000	2720 (21.0)	5934 (22.2)	
	\$75,000– < \$150,000	4317 (33.3)	10534 (39.4)	
	≥\$150,000	1557 (12.0)	3508 (13.1)	
Educational attainment	At least Bachelor	6352 (49.0)	14,602 (54.6)	< 0.001
	Some college	3271 (25.3)	6767 (25.3)	
	High school only	2658 (20.5)	4696 (17.5)	
	Less than high school	674 (5.2)	693 (2.6)	
PTSD	No	10,755 (83.0)	23,015 (86.0)	< 0.001
	Yes	2200 (17.0)	3743 (14.0)	
Lower respiratory symptoms	No	3629 (28.0)	7464 (27.9)	0.815
	Yes	9326 (72.0)	19,294 (72.1)	
9/11 exposure scale	Less than 3	6380 (49.2)	12,591 (47.1)	< 0.001
	3 or more	6575 (50.8)	14,167 (52.9)	
Dust intensity	None	6257 (48.3)	12,915 (48.3)	0.151
	Some	2874 (22.2)	5742 (21.5)	
	Intense	3824 (29.5)	8101 (30.3)	
Any injury on 9/11	No	7804 (60.2)	15,936 (59.6)	0.197
	Yes	5151 (39.8)	10,822 (40.4)	
Rescue/recovery worker	No	6902 (53.3)	13,670 (51.1)	< 0.001
	Yes	6053 (46.7)	13,088 (48.9)	

Those who were work disabled in wave 2 were more likely to be older, male, have PTSD, suffer from lower respiratory symptoms, sustain an injury on 9/11, and be a rescue/recovery worker. Non-Hispanic Whites and Asians were less likely to be work disabled, while Non-Hispanic Blacks, Hispanics, and multi-racial/other enrollees were more like to be work disabled. Those of higher income and educational attainment were less likely to be work disabled. Finally, higher 9/11 exposure and dust cloud intensity were associated with being work disabled (Table 2).

Similar to work disability, those who retired early were more likely to be older (49.6 vs. 39.4), male, to suffer from lower respiratory symptoms, to have greater 9/11 exposure on some measures, to be injured in 9/11, and to be a rescue/recovery worker. However, some patterns differed from work disability. For example, neither PTSD nor dust exposure was associated with early retirement. Additionally, income and educational attainment demonstrated an inverse U-shaped association with

early retirement, with both the well-educated and those of higher income and also those of lower educational attainment and income less likely to retire early. Those of middle income and educational attainment were more likely to retire early. Finally, Non-Hispanic Whites were more likely to retire early while Hispanics and Asians were less likely (Table 3).

Survivorship (defined as those who lost a spouse, parent, or guardian on 9/11) was associated with PTSD, greater score on the 9/11 exposure scale, exposure to some or intense dust, and having an injury on 9/11 (Table 4).

In the final adjusted model, those who were work disabled had 1.16 (95% CI: 1.08, 1.23) times the risk of not completing wave 4. Those who were early retired were less likely to attrit in wave 4 (RR: 0.74 [95% CI: 0.69, 0.79]). There was no statistically significant association between losing a parent, spouse, or guardian and being lost to follow-up in wave 4 (Table 5).

In a sensitivity analysis, we calculated the odds of attrition for wave 3 and found substantively similar results with the

TABLE 2 | Characteristics of the World Trade Center Registry (WTCHR) cohort stratified by wave 2 work disability status.

		Work disabled no	Work disabled yes	<i>p</i>
Age on 9/11	Mean (SD)	41.5 (11.4)	46.0 (9.2)	< 0.001
Gender	Male	23,491 (61.9)	1155 (65.4)	0.003
	Female	14,456 (38.1)	611 (34.6)	
Race/ethnicity	White (Non-Hispanic)	26,692 (70.3)	1126 (63.8)	< 0.001
	Black (Non-Hispanic)	3934 (10.4)	217 (12.3)	
	Hispanic or Latino	4372 (11.5)	299 (16.9)	
	Asian	1968 (5.2)	50 (2.8)	
	Multi-racial/Other	981 (2.6)	74 (4.2)	
Income	<\$25,000	2993 (7.9)	405 (22.9)	< 0.001
	\$25,000– < \$50,000	7384 (19.5)	361 (20.4)	
	\$50,000– < \$75,000	8291 (21.8)	363 (20.6)	
	\$75,000– < \$150,000	14,319 (37.7)	532 (30.1)	
	≥ \$150,000	4960 (13.1)	105 (5.9)	
Educational attainment	At least Bachelor	20,405 (53.8)	549 (31.1)	< 0.001
	Some college	9507 (25.1)	531 (30.1)	
	High school only	6843 (18.0)	511 (28.9)	
	Less than high school	1192 (3.1)	175 (9.9)	
PTSD	No	32,821 (86.5)	949 (53.7)	< 0.001
	Yes	5126 (13.5)	817 (46.3)	
Lower respiratory symptoms	No	10,930 (28.8)	163 (9.2)	< 0.001
	Yes	27,017 (71.2)	1603 (90.8)	
9/11 exposure scale	Less than 3	18,502 (48.8)	469 (26.6)	< 0.001
	3 or more	19,445 (51.2)	1297 (73.4)	
Dust intensity	None	18,503 (48.8)	669 (37.9)	< 0.001
	Some	8254 (21.8)	362 (20.5)	
	Intense	11,190 (29.5)	735 (41.6)	
Any injury on 9/11	No	23,062 (60.8)	678 (38.4)	< 0.001
	Yes	14,885 (39.2)	1088 (61.6)	
Rescue/recovery worker	No	19,804 (52.2)	768 (43.5)	< 0.001
	Yes	18,143 (47.8)	998 (56.5)	

TABLE 3 | Characteristics of the World Trade Center Registry (WTCR) cohort stratified by wave 2 early retirement status.

		Early retired no	Early retired yes	<i>p</i>
Age on 9/11	Mean (SD)	39.4 (9.7)	49.6 (7.3)	< 0.001
Gender	Male	21,071 (61.1)	2202 (74.6)	< 0.001
	Female	13,396 (38.9)	749 (25.4)	
Race/ethnicity	White (Non-Hispanic)	23,975 (69.6)	2227 (75.5)	< 0.001
	Black (Non-Hispanic)	3642 (10.6)	300 (10.2)	
	Hispanic or Latino	4206 (12.2)	286 (9.7)	
	Asian	1726 (5.0)	69 (2.3)	
	Multi-racial/Other	918 (2.7)	69 (2.3)	
Income	<\$25,000	2751 (8.0)	134 (4.5)	< 0.001
	\$25,000– < \$50,000	6739 (19.6)	358 (12.1)	
	\$50,000– < \$75,000	7513 (21.8)	726 (24.6)	
	\$75,000– < \$150,000	12,920 (37.5)	1403 (47.5)	
	≥ \$150,000	4544 (13.2)	330 (11.2)	
Educational attainment	At least Bachelor	18,798 (54.5)	1076 (36.5)	< 0.001
	Some college	8585 (24.9)	989 (33.5)	
	High school only	6059 (17.6)	783 (26.5)	
	Less than high school	1025 (3.0)	103 (3.5)	
PTSD	No	29,252 (84.9)	2502 (84.8)	0.923
	Yes	5215 (15.1)	449 (15.2)	
Lower respiratory symptoms	No	9726 (28.2)	671 (22.7)	< 0.001
	Yes	24,741 (71.8)	2280 (77.3)	
9/11 exposure scale	Less than 3	16,243 (47.1)	1175 (39.8)	< 0.001
	3 or more	18,224 (52.9)	1776 (60.2)	
Dust intensity	None	16,463 (47.8)	1383 (46.9)	0.081
	Some	7546 (21.9)	616 (20.9)	
	Intense	10,458 (30.3)	952 (32.3)	
Any injury on 9/11	No	20,582 (59.7)	1580 (53.5)	< 0.001
	Yes	13,885 (40.3)	1371 (46.5)	
Rescue/recovery worker	No	18,255 (53.0)	896 (30.4)	< 0.001
	Yes	16,212 (47.0)	2055 (69.6)	

exception of early retirement, which was no longer statistically significant but in the same direction (protective) in the fully adjusted model. In a second sensitivity analysis, we calculated the odds of attrition in wave 5 among the HES cohort only and found substantively similar results with the exception of early retirement, which is no longer statistically significant but in the same direction (protective) in the crude and fully adjusted models (Appendices 1–3).

3 | Discussion

This study found a prevalence of 4% for work disability at 5–7 years after the 9/11 disaster. In the full US population in 2007, which was in the middle of wave 2 WTCR data collection, approximately 3.5% of Americans were receiving SSI/SSDI disability benefits [29]. It is important to note that this study's definition of work disability is based on WTCR wave survey data that records whether an enrollee was working, and if not,

whether disability was the reason. Specifically, it did not ask whether an enrollee was collecting SSI/SSDI benefits. A self-reported measure of not working due to disability may not be an exact proxy for collecting SSI/SSDI or ultimately being truly work disabled for a few reasons. First, as noted above, certain groups, such as undocumented workers and those without a sufficient work history, are not eligible for social security payments. Therefore, these particularly vulnerable workers may continue to work despite severe physical or mental limitations. In addition, due to a cumbersome and error-prone application process [30], denial rate is high, with only 21% of initial claim applicants awarded benefits on average between 2010 and 2019 [31]. Our results may therefore be an underestimate of true work disability.

The HES data did ask whether an enrollee was collecting SSI/SSDI disability benefits and in that survey, just under 14% of respondents answered yes. Although the HES oversampled retirees and individuals receiving disability benefits and therefore cannot be used to estimate population prevalence, it

TABLE 4 | Characteristics of the World Trade Center Registry (WTCR) cohort stratified by loss of loved one on 9/11 measured on wave 2.

		Spouse, parent, or guardian lost on 9/11 no	Spouse, parent, or guardian lost on 9/11 yes	<i>p</i>
Age on 9/11	Mean (SD)	41.7 (11.4)	42.8 (11.2)	0.445
Gender	Male	24,613 (62.1)	33 (57.9)	0.609
	Female	15,043 (37.9)	24 (42.1)	
Race/ethnicity	White (Non-Hispanic)	27,786 (70.1)	32 (56.1)	0.086
	Black (Non-Hispanic)	4144 (10.4)	7 (12.3)	
	Hispanic or Latino	4662 (11.8)	9 (15.8)	
	Asian	2013 (5.1)	5 (8.8)	
	Multi-racial/Other	1051 (2.7)	4 (7.0)	
Income	<\$25,000	3392 (8.6)	6 (10.5)	0.072
	\$25,000– < \$50,000	7738 (19.5)	7 (12.3)	
	\$50,000– < \$75,000	8645 (21.8)	9 (15.8)	
	\$75,000– < \$150,00	14,820 (37.4)	31 (54.4)	
	≥ \$150,000	5061 (12.8)	4 (7.0)	
Educational attainment	At least Bachelor	20,919 (52.8)	35 (61.4)	0.543
	Some college	10,025 (25.3)	13 (22.8)	
	High school only	7347 (18.5)	7 (12.3)	
	Less than high school	1365 (3.4)	2 (3.5)	
PTSD	No	33,734 (85.1)	36 (63.2)	< 0.001
	Yes	5922 (14.9)	21 (36.8)	
Lower respiratory symptoms	No	11,084 (28.0)	9 (15.8)	0.058
	Yes	28,572 (72.0)	48 (84.2)	
9/11 exposure scale	Less than 3	18,961 (47.8)	10 (17.5)	< 0.001
	3 or more	20,695 (52.2)	47 (82.5)	
Dust intensity	None	19,154 (48.3)	18 (31.6)	0.034
	Some	8598 (21.7)	18 (31.6)	
	Intense	11,904 (30.0)	21 (36.8)	
Any injury on 9/11	No	23,719 (59.8)	21 (36.8)	0.001
	Yes	15,937 (40.2)	36 (63.2)	
Rescue/recovery worker	No	20,541 (51.8)	31 (54.4)	0.796
	Yes	19,115 (48.2)	26 (45.6)	

provides important contextual information for describing and comparing the characteristics of work-disabled individuals and retirees within the WTCR cohort. More research is needed to understand the true prevalence of work disability in the WTCR cohort.

In addition, we found older age, male sex, Black or Hispanic race, PTSD diagnosis, lower education, and lower income to be associated with greater likelihood of disability. Previous research has found similar demographic patterns in disability claiming [32–39]. Lack of health care access, systemic racism and discrimination, and substandard housing may lead to poorer health in racial minorities and those of low SES [40–43], and ultimately higher work disability claiming. In addition, lower income people often work in jobs that require greater

physical labor, have less flexibility for leave for things such as doctor's appointments, and may expose them to more hazardous conditions [44, 45]. Historically, men have been more likely to claim work disability because they had higher labor participation rates, but there is evidence the gender gap may be narrowing [46].

Approximately 60% of males and 57% of females among WTCR enrollees were retired at age 62. In contrast, 33.5% of males and 36.8% of females claimed social security benefits at age 62 in the U.S. general population in 2007 [47]. However, it is important to note that the WTCR did not specifically ask about whether an enrollee was collecting social security retirement benefits, but only asked respondents who were working whether they were retired. It is therefore important to

TABLE 5 | Risk of attrition from waves 2 to 4 in the World Trade Center (WTCHR) cohort ($n = 39,713$).

	Model 1 Unadjusted				Model 2 Adjusted ^a			
	<i>n</i>	RR	95% CI	<i>p</i> -value	<i>n</i>	RR	95% CI	<i>p</i> -value
Work disability								
No	37,947	ref	ref		37,947	ref	ref	
Yes	1766	1.2	1.13, 1.28	< 0.001	1766	1.16	1.08, 1.23	< 0.001
Early retirement								
No	34,467	ref	ref		34,467	ref	ref	
Yes	2951	0.74	0.69, 0.79	< 0.001	2951	0.88	0.83, 0.95	< 0.001
Spouse, parent, or guardian lost on 9/11 ^b								
No	39,656	ref	ref		39,656	ref	ref	
Yes	57	1.02	0.71, 1.47	0.91	57	1.04	0.72, 1.50	0.83

Note: All models estimated separately for each exposure (six models in total).

^aAdjusted for age on 9/11, sex, race/ethnicity, income, educational attainment, lower respiratory symptoms, PTSD, 9/11 exposure scale, dusty intensity, any injury on 9/11, and rescue/recovery worker status.

^bSpouse, parent, or guardian model not adjusted for 9/11 exposure scale because this variable included loss of close friend or family member.

be cautious when making comparisons to our data and social security early retirement in the general population because an enrollee may indicate he or she is retired but may not yet have claimed social security and are instead reliant on a pension or other savings. Many rescue and recovery workers may be eligible for employer-sponsored retirement benefits at earlier ages than other workers due to the nature of their work. For example, members of FDNY are eligible for a full pension after 22 years of service.

In addition, we found early retirement was associated with older age, male sex, greater 9/11 exposure (on some measures), and being a rescue/recovery worker. Our findings confirm previous work on this topic. For example, Yu et al. found that volunteer responders with multiple chronic health conditions were nearly twice as likely to experience early retirement or health-related job loss than volunteers without chronic conditions. This relationship was stronger among volunteers with comorbid PTSD [11, 15]. Early retirement may be more common among those with chronic health conditions because those enrollees may find it difficult to find or maintain full-time work. Individuals in poor health may exit the labor force through early retirement rather than SSDI, in part because qualifying for disability benefits requires meeting strict medical and work-history criteria and involves a lengthy and uncertain adjudication process. As a result, some individuals with substantial work limitations may appear in retirement pathways despite underlying health-related disablement that would not be captured by SSDI receipt alone.

Finally, this is the first study, to our knowledge, to systematically examine loss of a loved one on 9/11. We found markers of severity of 9/11 exposure (e.g., PTSD, injury, dust intensity) were associated with a greater chance of losing a loved one. This may be due to a few factors. First, it is possible that those who lived, went to school, or worked physically closer to the WTC site were both more likely to have a spouse or parent who worked in one of the towers. In addition, those unable to find their loved one immediately after the attack may have stayed in the area longer and were therefore more exposed to dust and potentially traumatic events following the disaster. We did not find a relationship between age, race/ethnicity, gender, income,

education, lower respiratory symptoms, or being a rescue/recovery worker and loss of a loved one. However, the total number of respondents who lost a spouse or parent/guardian was relatively small ($n = 59$), so statistically significant differences may not have been detected.

In our third aim, we analyzed attrition patterns by work disability, early retirement, and loss of a loved one. In both unadjusted and adjusted models, work disability was associated with greater attrition, early retirement was associated with lower attrition, and loss of a loved one was not associated with attrition. Given poor health is associated with survey non-response [22–25], it is unsurprising work disability is associated with greater loss to follow up. Early retirement sometimes occurs due to poor health, which should suggest higher attrition, but may also be associated with greater amounts of free time and fewer responsibilities, which may explain why it predicted lower loss to follow-up in this study. In addition, at least a portion of those who retire early may have better access to pensions and other forms of supplementary income compared to those who work up to and beyond normal retirement age. Loss of a loved one on 9/11 may not have been associated with attrition for a few reasons. First, as stated above, the overall number of enrollees who lost someone on 9/11 is relatively small. Second, 9/11 occurred 14 years before the start of wave 4 so any effect on attrition may have lessened over time.

3.1 | Strengths and Limitations

This analysis has a few important strengths. First, a longitudinal study design allows for an understanding of whether survey attrition is differential by work disability, early retirement, and loss of a loved one, particularly in a trauma-exposed cohort. Next, the WTCHR has a rich set of covariates that include sociodemographic information and health outcomes. Finally, it is the only study, to our knowledge, to systematically examine work disability in the survivor population, and is also the first to estimate prevalence of and whether WTCHR survey attrition varies by work disability and loss of a loved one on 9/11.

A few limitations should be noted. First, all data are self-reported, and only the HES data asked about social security benefit receipt for disability and year of retirement (which is needed in order to determine whether an enrollee retired early). Misreporting of disability and employment status is a well-known problem in epidemiologic research and is thought to occur due to overreporting disability to justify non-employment [48–52]. The WTCHR does not ask about work disability directly but rather (if applicable) whether a respondent is not working due to disability (wave 2) or health (waves 2–5). It is not known how well these questions correlate to actual SSDI claims. HES did ask enrollees whether they received SSA disability, but these responses have not been validated against administrative data. Several papers have examined whether self-reported work disability data in the Current Population Survey (CPS) and the Survey of Income and Program Participation (SIPP) accurately reflects OASDI benefit records and found them to either over- or underestimate benefits depending on the survey and year [53–55].

In addition, the 2008 economic crisis took place during data collection and may have influenced both work disability and early retirement decisions. However, our results were robust in a sensitivity analysis of HES data, which was collected several years after the crisis ended. Finally, those who died during the study period were considered lost to follow-up. However, in a sensitivity analysis of losses to follow up between waves 2 and 3, a shorter time period with less risk of mortality, we found similar results.

4 | Conclusion

This study suggests work disability and early retirement are more prevalent in the WTCHR population and connects each to higher levels of 9/11 exposure. It is also the first to systematically examine work disability in the survivor population and also the first to estimate prevalence of loss of a loved one in the WTCHR cohort. Future research is needed to overcome the limitations of self-reported data in order to understand how survey participation is inhibited or promoted from resulting SSA benefits. This work will aid in understanding how timely receipt of SSA benefits can lead to better health trajectories among disaster- and trauma-exposed populations.

Author Contributions

JB, JM, and MD participated in the conception or design of the work. JB, JM, and MD participated in the acquisition, analysis, or interpretation of data for the work. JB, JM, and MD participated in the drafting the work or revising it critically for important intellectual content. JM participated in the final approval of the version to be published; and JB, JM, and MD participated in the agreement 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.

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Ethics Statement

This study was reviewed and approved by the Institutional Review Board (IRB) of the New York City Department of Health and Mental Hygiene (NYC DOHMH). All procedures were conducted in accordance with the ethical standards of the NYC DOHMH IRB. Informed consent was obtained from all participants.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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Appendix 1

Characteristics of the World Trade Center Registry (WTCHR) Cohort Stratified by Wave 3 Participation

		Participated no	Participated yes	p
Work disability	No	8004 (94.3)	29,943 (95.9)	< 0.001
	Yes	485 (5.7)	1281 (4.1)	
Spouse, parent, or guardian lost on 9/11	No	8478 (99.9)	31,178 (99.9)	0.825
	Yes	11 (0.1)	46 (0.1)	
Early retirement	No	7463 (94.1)	27,004 (91.6)	< 0.001
	Yes	468 (5.9)	2483 (8.4)	
Age on 9/11	Mean (SD)	39.9 (12.2)	42.2 (11.1)	< 0.001
Gender	Male	5175 (61.0)	19,471 (62.4)	0.019
	Female	3314 (39.0)	11,753 (37.6)	
Race/ethnicity	White (Non-Hispanic)	5345 (63.0)	22,473 (72.0)	< 0.001
	Black (Non-Hispanic)	1131 (13.3)	3020 (9.7)	
	Hispanic or Latino	1234 (14.5)	3437 (11.0)	
	Asian (Non-Hispanic)	530 (6.2)	1488 (4.8)	
	Multi-racial/Other	249 (2.9)	806 (2.6)	
Income	<\$25,000	990 (11.7)	2408 (7.7)	< 0.001
	\$25,000– < \$50,000	1945 (22.9)	5800 (18.6)	
	\$50,000– < \$75,000	1787 (21.1)	6867 (22.0)	
	\$75,000– < \$150,000	2741 (32.3)	12,110 (38.8)	

(Continues)

		Participated no	Participated yes	p
Educational attainment	≥ \$150,000	1026 (12.1)	4039 (12.9)	< 0.001
	At least Bachelor	4143 (48.8)	16,811 (53.8)	
	Some college	2162 (25.5)	7876 (25.2)	
	High school only	1742 (20.5)	5612 (18.0)	
	Less than high school	442 (5.2)	925 (3.0)	
PTSD	No	7026 (82.8)	26,744 (85.7)	< 0.001
	Yes	1463 (17.2)	4480 (14.3)	
Lower respiratory symptoms	No	2359 (27.8)	8734 (28.0)	0.749
	Yes	6130 (72.2)	22,490 (72.0)	
9/11 exposure scale	Less than 3	4154 (48.9)	14,817 (47.5)	0.016
	3 or more	4335 (51.1)	16,407 (52.5)	
Dust intensity	None	4146 (48.8)	15,026 (48.1)	0.46
	Some	1834 (21.6)	6781 (21.7)	
	Intense	2509 (29.5)	9417 (30.2)	
Any injury on 9/11	No	5096 (60.0)	18,644 (59.7)	0.602
	Yes	3393 (40.0)	12,580 (40.3)	
Rescue/recovery worker	No	4567 (53.8)	16,005 (51.3)	< 0.001
	Yes	3922 (46.2)	15,219 (48.7)	

Appendix 2

Risk of Attrition From Waves 2 to 3 in the World Trade Center Registry (WTCHR) Cohort (*n* = 39,713)

	Model 1 unadjusted				Model 2 adjusted*			
	<i>n</i>	RR	95% CI	<i>p</i> -value	<i>n</i>	RR	95% CI	<i>p</i> -value
Work disability								
No	37,947	—	—		37,947	—	—	
Yes	1766	1.3	1.20, 1.41	< 0.001	1766	1.39	1.24, 1.55	< 0.001
Early retirement								
No	34467	—	—		34467	—	—	
Yes	2951	0.73	0.67, 0.80	< 0.001	2951	0.94	0.86, 1.03	0.16
Spouse, parent, or guardian lost on 9/11**								
No	39,656	—	—		39,656	—	—	
Yes	57	0.9	0.53, 1.54	0.7	57	0.91	0.45, 1.70	0.8

Adjusted for age on 9/11, sex, race/ethnicity, income, educational attainment, lower respiratory symptoms, PTSD, 9/11 exposure scale, dusty intensity, any injury on 9/11, rescue/recovery worker status **Spouse, parent, or guardian model not adjusted for 9/11 exposure scale because this variable included loss of close friend or family member.

All models estimated separately for each exposure (six models in total).

Appendix 3

Risk of Attrition From Waves 2 to 5 in the Health and Employment Survey (HES) Cohort ($n = 12,558$)

	<i>n</i>	RR	95% CI	<i>p</i> -value	<i>n</i>	RR	95% CI	<i>p</i> -value
Work disability								
No	10,156	—	—		10,156	—	—	
Yes	1634	1.31	1.15, 1.48	< 0.001	1634	1.2	1.02, 1.3	0.026
Early retirement								
not retired	4514	—	—		4514	—	—	
early retirement yes	7004	0.96	0.87, 1.06	0.37	7004	0.97	0.87, 1.09	0.64
early retirement no	1037	1.1	0.93, 1.30	0.28	1037	1.2	1.0, 1.45	0.052

*Adjusted for age on 9/11, sex, race/ethnicity, income, educational attainment, lower respiratory symptoms, PTSD, 9/11 exposure scale, dusty intensity, any injury on 9/11, rescue/recovery worker status.
All models estimated separately for each exposure (four models in total).