Post-traumatic stress disorder and risk of first-time and repeated opioid-related hospitalizations among World Trade Center Health Registry enrollees

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ABSTRACT

In 2021, and average of 220 deaths from opioid-related overdoses occurred daily in the US. Recent evidence suggests there is an association between post-traumatic stress disorder (PTSD) and increased opioid misuse, while little is known about opioid-related hospitalizations. This study used data from the World Trade Center Health Registry (WTCHR), a longitudinal cohort consisting of individuals directly exposed to the September 11th terrorist attacks with a high prevalence of resulting PTSD (3.8–29.6%). We linked WTCHR data to New York State hospitalization data to examine the question: do opioid-related hospitalizations (first time and repeated) differ by PTSD status. In a study sample of 37,968 adults, 145 experienced at least one episode of opioid-related hospitalization and 64 had repeated episodes during the study period. We found that in the 13-years post-9/11, individuals with PTSD had a significantly higher risk of a first-time opioid-related hospitalization (Hazard Ratio: 3.6, 95% CI: 2.7, 5.0) and repeated opioid-related hospitalizations (Hazard Ratio: 3.9, 95% CI: 2.7, 5.8) than those who did not have PTSD. Improved treatment of and increased screenings for PTSD may reduce the likelihood of opioid misuse in this population and consequently overdoses, hospitalizations, and healthcare costs.

1. Introduction

The opioid crisis continues to be a major public health and economic concern in the United States (US). Drug overdose deaths are the leading cause of death by injury nationally (Scholl et al., 2019), a corresponding increase in opioid-related inpatient and emergency department (ED) visits has also been observed (Weiss et al., 2017). While there have been several waves of the overdose crisis, driven by either prescription or illicit substances, the primary substance underlying the crisis since the early 1990s has always been opioids (Jenkins, 2021). In 2017, almost 68% of all drug overdose deaths involved the consumption of an opioid, which represents a 12-percentage point increase in opioid overdose deaths from the previous year (Scholl et al., 2019). Recently, the COVID-19 pandemic further exacerbated this trend (Kiang et al., 2022), the Centers for Disease Control and Prevention (CDC) estimated that 80, 411 of overdose deaths that occurred in 2021 involved an opioid (synthetic or otherwise), a 69% increase from 2017 opioid-involved overdose deaths (Abuse, 2023).

In addition to a major public health burden, the consequences of opioid misuse in the US include a significant economic impact. The CDC estimated that, in 2017, the total national economic burden of opioid use disorder and fatal overdoses at $1021 billion (Luo et al., 2021). Part of this total is an estimated $20 billion specifically attributed to annual healthcare costs (AHRQ, 2018), of which an estimated $11 billion may stem from opioid overdoses (Premier, 2019). ED visits can result from the misuse of prescription opioids or the use of non-prescription opioids such as heroin that lead to non-fatal or fatal overdose and withdrawal. The pathway to an overdose can differ between individuals. For instance, an individual may be prescribed opioids for pain and misuse those prescribed opioids while others may use illicit opioids, such as heroin (Abuse, 2023; Seal et al., 2012a). Both types of misuse can result in an overdose and can result in an subsequent ED visit or hospitalization (Quality, 2019). In line with the ongoing opioid epidemic over the past decade, opioid-related ED and inpatient admissions have increased

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(Weiss et al., 2017).

Recent evidence suggests there is an association between having post-traumatic stress disorder (PTSD) and increased opioid overuse and misuse (Seal et al., 2012a; Shiner et al., 2017; Takemoto et al., 2019). This association may be, in part, explained by the self-medication hypothesis, which posits that individuals with anxiety-related disorders like PTSD can intentionally use substances such as drugs and alcohol to cope with their resulting symptoms (Khantzian, 1997; Leeies et al., 2010a; North et al., 1999). Findings from a recent study of individuals directly exposed to the September 11th, 2001 terrorist attacks, where the prevalence of PTSD is high (3.8% - 29.6%) (Lowell et al., 2018), found that currently experiencing or having past PTSD symptoms were strongly related to self-reported opioid use, over-use, and misuse (Takemoto et al., 2020). Little is known about the association of PTSD with objective and more severe health outcomes like opioid-related hospitalizations.

The purpose of the current investigation was to extend the scope of a prior study on opioid use and PTSD in a World Trade Center-exposed cohort to include information on opioid-related hospitalizations to better understand the full burden of opioid use and misuse on this population, healthcare utilization, and the long-term health consequences of PTSD. This study has two aims: Aim 1) to assess the association of PTSD with the risk of opioid hospitalization and Aim 2) to assess the association of opioid hospitalization risk and PTSD measured repeatedly over the 13 years of follow up after exposure to 9/11. We hypothesized that individuals with 9/11-related PTSD, measured both at baseline and repeatedly over the timespan following exposure to 9/11, would be at an increased risk of first-time and repeated opioid-related hospitalizations. Findings from this study may contribute to the identification of modifiable risk factors for opioid misuse and the associated morbidity and mortality critical to help mitigate the epidemic, improve population health, and decrease healthcare costs.

2. Methods

2.1. Data sources

The World Trade Center Health Registry (WTCHR) is a longitudinal cohort consisting of rescue and recovery workers and lower Manhattan community members ($N = 71,426$) who were directly exposed to the terrorist attacks on September 11th, 2001. Data on demographics and health conditions were drawn from the first three major WTCHR surveys: Wave 1 (W1, 2003–04; $n = 71,426$), Wave 2 (W2, 2006–07; $n = 46,600$), and Wave 3 (W3, 2011–2012; $n = 43,133$). The present study used data collected on the W1, W2, and W3 surveys. Details on WTCHR recruitment, enrollment, and survey administration are described in detail elsewhere (Farfel et al., 2008). The institutional review boards at the Centers for Disease Control and the New York City Department of Health and Mental Hygiene approved the WTCHR study protocol.

The New York State Statewide Planning and Research Cooperative System (SPARCS) was used to source patient-level opioid hospitalization data (New York State Department of Health, 2022). SPARCS is a state-wide administrative database with patient-level information on over 95% of all hospitalizations that occur in non-federal and non-psychiatric hospitals in New York state. Both inpatient stays and emergency department visits are captured. SPARCS data was linked to the WTCHR enrollee data using a deterministic algorithm developed by the WTCHR that matches records between both databases and is based on parts of the first and last names, date of birth, social security number, and zip code. Dates of admission and discharge, and admitting, principal, and secondary diagnosis codes (ICD-9-CM: International Classification of Disease, Ninth Revision, Clinical Modification) were obtained from the SPARCS record.

2.2. Variables

First-time opioid-related hospitalization was defined by the first opioid-related hospitalization, defined through ICD-9-CM codes in any diagnosis code field (admitting, primary, and secondary), that occurred in New York state between the W1 interview date and 10/1/2015. This cut-off point was chosen because, on this date, ICD-9 diagnostic codes were changed to ICD-10 codes. An opioid-related hospitalization was defined as either an inpatient admission or emergency department visit. The ICD-9 codes used in this analysis were selected based on Healthcare Cost and Utilization Project (HCUP) criteria for "opioid-related hospital use" (herein referred to as "opioid-related hospitalizations"). Codes include opioid-related use stemming from illicit opioids such as heroin, illegal use of prescription opioids, and the use of opioids as prescribed (Table 1) (AHRQ 2018; Compton et al., 2016; Healthcare Cost and Utilization Project, 2021). Each type of opioid use is important for understanding and addressing the association between PTSD and opioid-related hospitalizations. For Aim 1, only first-time hospitalizations that occurred during the study period were considered: respondents were censored after their first opioid-related hospitalization in the study period.

Repeated opioid-related hospitalizations were the primary outcome in Aim 2. Individuals remained in the study after their first opioid-related hospitalization and the total number of opioid-related hospitalizations occurring among each enrollee was enumerated. Inpatient admissions that occurred within 24 h of an emergency department admission were considered as a single event. As enrollees admitted to a hospital were not at risk for re-hospitalization until discharge, the time during a hospitalization stay was excluded from the accumulation of person-time.

Our primary exposure was time-varying probable 9/11-related PTSD (hereafter, "PTSD") measured at W1, W2, and W3. PTSD, an anxiety disorder that is triggered by a traumatic, perceived life-threatening event, was measured using the PTSD Checklist (PCL-17) with questions that were queried specifically to 9/11. The PCL is a self-reported 17-symptom scale corresponding to DSM-IV criteria with five response options for each symptom ($1 = $ not at all, $2 = $ a little bit, $3 = $ moderately, $4 = $ quite a bit, or $5 = $ extremely). Corresponding to DSM-IV criteria, PCL responses were summed (scores can range from 17 – 85) and a cutoff score of ≥ 50 was used to indicate probable 9/11-related PTSD at W1 (internal consistency=0.94–0.97, sensitivity=0.78–0.82, specificity=0.83–0.86) (Weathers, 1993). We used a counting method to allow for a variance in PTSD status. Subjects could either have a yes, no, or "missing" PTSD status at each wave. We assumed that PTSD status remained constant during the time-periods between waves, for which we do not have data. Subjects with a missing PTSD status had their PTSD status from the subsequent wave carried over as a stand-in for their missing status. Subjects with a missing PTSD status at W1 were excluded from the study.

Covariates included age at W1 (years: 15–30; 31–40; 41–50; 50+)

Table 1

International Classification of Disease, Ninth Revision, Clinical Modification (ICD-9-CM) codes used to define opioid-related hospitalizations.

304.00 – 304.02	Opioid type dependence (unspecified; continuous; episodic)
304.70 – 304.72	Combinations of opioid type drug with any other drug dependence (unspecified; continuous; episodic)
305.50 – 305.52	Opioid abuse (unspecified; continuous; episodic)
965.00 – 965.02, 965.09	Poisoning by opium (alkaloids), unspecified; heroin; methadone; other opiates and related narcotics
970.1	Poisoning by opiate antagonists
E850.0 – E850.2	Accidental poisoning by heroin; methadone; other opiates and related narcotics
E935.0 – E935.2	Heroin, methadone, other opiates, and related narcotics causing adverse effects in therapeutic use
E940.1	Opiate antagonists causing adverse effects in therapeutic use

race/ethnicity (non-Hispanic White; Hispanic/Latino, Black/Indigenous/Person of Color (BIPOC)), gender (male, female), education level at W1 (high school/GED or less, some college, college degree, graduate degree), number of injuries on 9/11 (0, 1, 2+), pre-9/11 mental health diagnosis of depression, anxiety or PTSD (yes/no), and number of pre-9/11 chronic physical conditions defined as cancer, asthma, hypertension, angina, heart attack, stroke, and/or diabetes (0, 1, 2+).

2.3. Analytic sample

Of the 71,426 enrollees in the WTCHR, we first excluded enrollees who were deceased at the W1 interview date and had the health survey completed by proxy ($n = 161$). Next, enrollees who reported never living in New York state or who had missing address information were also excluded ($n = 16,179$). Then, enrollees who had an opioid-related hospitalization before their W1 interview date were excluded ($n = 114$). Enrollees under 18, or whose age was unknown, at the W1 interview were further excluded ($n = 2489$). Finally, enrollees with an incomplete W1 PCL ($n = 2174$) were excluded, resulting in a final analytic sample of 37,968.

2.4. Statistical analysis

We first described the demographic characteristics of the analytic sample overall and stratified by PTSD status as measured at W1. We used Cox proportional hazards regression to estimate the hazard ratios (HR) and 95% confidence interval (CI) estimating the risk of an opioid hospitalization in those with PTSD vs. without, adjusted for covariates. For Aim 1, person-time was calculated for each respondent beginning at Wave 1 interview date (range: 9/5/2003 – 11/20/2004). Individuals contributed person-time until they were censored by the first of the following events: an opioid-related hospitalization occurred, the respondent withdrew from the WTCHR, the respondent died, or follow-up ended (October 1st, 2015). For Aim 2, individuals contributed person-time until they were censored by the first of the following events: the respondent withdrew from the WTCHR, the respondent died, or the end of follow-up (October 1st, 2015). If a hospitalization occurred, subjects re-entered the risk set on the day after their hospitalization discharge date. The Andersen-Gill counting process model, an extension of the Cox Proportional Hazards Model that allows for repeated failure events (Andersen and Gill, 1982), was used to calculate hazard ratios for repeated opioid-related hospitalization. The Andersen-Gill model is designed to handle correlated data in which each individual can experience multiple events over time, as opposed to censoring the individual following the event. One assumption of the Anderson-Gill model is the independence of events incurred by an individual, thus for our aim focused on repeat hospitalizations, each repeat event was considered to be an independent event. Lastly, we also compared the participants excluded from our study sample compared to the included on basic demographics characteristics (age, gender, race, education). All analyses were performed on SAS Enterprise Guide, v9.4 (SAS Institute, Cary, NC).

3. Results

Table 2 describes the baseline demographic characteristics of 37,968 participants, the largest proportions of whom were men (60%), non-Hispanic White (65%), and aged 41 to 50 years (32%). The overall prevalence of 9/11-related PTSD was 10% at Wave 1; enrollees with PTSD were more likely to be women, Hispanic/Latino, have depression/anxiety at baseline, and sustain 2 or more injuries on 9/11. The prevalence of PTSD was highest among those who experienced one (26%) and those with two or more opioid-related hospitalizations (31%), as compared to those who had no hospitalizations (10%).

Between 2003–2015, 209 enrollees experienced a first-time opioid-related hospitalization. Examining only first-time hospitalizations, a

Table 2

Characteristics of 37,968 New York state residents exposed to the World Trade Center disaster by post-traumatic stress disorder status at baseline.

Characteristic, N (%)	Overall* ($n = 37,968$)	PTSD at Wave 1	
		No** ($n = 34,118$)	Yes** ($n = 3850$)
Age (years)			
18–30	4604 (12.1)	4275 (92.9)	329 (7.1)
31–40	10,498 (27.7)	9562 (91.1)	936 (8.9)
41–50	12,151 (32.0)	10,760 (88.6)	1391 (11.4)
50+	10,715 (28.2)	9521 (88.9)	1194 (11.1)
Gender			
Male	22,753 (59.9)	20,881 (91.8)	1872 (8.2)
Female	15,215 (40.1)	13,237 (87.0)	1978 (13.0)
Race/Ethnicity			
Non-Hispanic, White	24,648 (64.9)	22,913 (93.0)	1735 (7.0)
Non-Hispanic, Other race*	8240 (21.7)	7163 (86.9)	1077 (13.1)
Hispanic/Latino, Any race	5080 (13.4)	4042 (79.6)	1038 (20.4)
Education			
High school or less	8830 (23.3)	7434 (84.2)	1396 (15.8)
Some College	9622 (25.3)	8542 (88.8)	1080 (11.2)
College Graduate	12,008 (31.6)	11,080 (92.3)	928 (7.7)
Postgraduate Degree	7339 (19.3)	6921 (94.3)	418 (5.7)
Missing Education	169 (0.4)	141 (83.4)	28 (16.6)
Depression or Anxiety symptoms			
No	17,724 (46.7)	17,452 (98.5)	272 (1.5)
Yes	20,244 (53.3)	16,666 (82.3)	3578 (17.7)
Number of Chronic Conditions, pre-9/11			
None	31,265 (82.3)	28,131 (90.0)	3134 (10.0)
1	5652 (14.9)	5068 (89.7)	584 (10.3)
2+	1051 (2.8)	919 (87.4)	132 (12.6)
Number of Injuries sustained on 9/11			
None	32,521 (85.7)	29,879 (91.9)	2642 (8.1)
1	3977 (10.5)	3225 (81.1)	752 (18.9)
2+	1470 (3.9)	1014 (69.0)	456 (31.0)
Opioid-Related Hospitalization during follow-up			
None	37,759 (99.4)	33,966 (90.0)	3793 (10.0)
1	145 (0.4)	108 (74.5)	37 (25.5)
2+	64 (0.2)	44 (68.8)	20 (31.3)

*Column percent; **Row percent.
Abbreviations: M: missing; Other: Black/Indigenous/Person of Color (BIPOC), Multi-racial, Other, Unknown; PTSD: Post Traumatic Stress Disorder.

total of 37,968 enrollees contributed a total of 430,203 person-years. In unadjusted models, an individual with PTSD was at more than four times the risk of an opioid-related hospitalization compared to an enrollee without PTSD. In adjusted models, the association was only mildly attenuated, individuals with PTSD were at significantly increased risk of an opioid-related hospitalization (HR: 3.6, 95% CI: 2.7, 5.0) (Table 3). In analyses of repeated opioid-related hospitalizations, 209 enrollees experienced an average of 1.9 hospitalizations (range 1–19), resulting in a total of 379 hospitalizations between 2003 and 2015. PTSD was associated with a nearly four-fold increased risk of repeated opioid-

Table 3

Hazard ratio (HR) of first-time and repeated opioid-related hospitalization by time-varying PTSD among World Trade Center Health Registry enrollees, 2003–2015.

	First-hospitalization		Repeated Hospitalizations	
Opioid-related hospitalization, N / total N	209 / 37,968		379 / 37,968	
Total person-years at risk	430,203		431,192	
Time-varying PTSD	HR (95% CI)		HR (95% CI)	
Unadjusted	4.4	(3.3, 5.8)	5.5	(3.8, 7.6)
Adjusted*	3.6	(2.7, 5.0)	3.9	(2.7, 5.8)

*Model adjusted for age, gender, race/ethnicity, education, pre-9/11 chronic conditions, depression/anxiety at W1, number of injuries on 9/11.
Abbreviations: N, number; PTSD, post-traumatic stress disorder; CI: confidence interval.

related hospitalizations (HR: 3.9, 95% CI: 2.7, 5.8) (Table 3).

When comparing the demographics of excluded participants to those included in the analytic sample, excluded participants were relatively similar in the distribution of sex and age. Excluded participants were slightly more likely to have a high school education or less and be of *Other* race (Supplementary Table).

4. Discussion

We examined the association between time-varying 9/11-related PTSD and opioid-related hospitalizations among a diverse population exposed to the WTC attacks in 2001. In this analysis of 37,968 individuals, we found that the prevalence of opioid-related hospitalizations was the highest among those with a history of PTSD and the risk of an opioid-related hospitalization was more than triple for individuals with PTSD compared to those without. When we further analyzed the risk of repeated opioid-related hospitalizations, the risk of a repeated opioid-related hospitalization was nearly four-fold greater among individuals with PTSD. Our finding is salient as it suggests that PTSD is associated with a level of opioid use that may greatly increases the risk of one or more hospitalizations, which have serious societal and economic implications. These findings also align with the well-established association of mental health disorders and subsequent detrimental impacts on substance use and misuse, we extend this existing body of literature by considering repeated hospitalizations, a severe and objectively measured consequence of substance use/misuse. These findings support the need for a renewed focus on interdisciplinary approaches that focus on both physical and mental health. It should be noted, however, that although our findings are robust, opioid-hospitalizations were ultimately a rare outcome in our study. In our sample, the risk of opioid hospitalization was *relatively* higher among those with PTSD compared to those without, however there is only a 1-percentage point difference in the crude risk of opioid hospitalizations between either group.

While there is a robust body of evidence supporting the link between PTSD and an increased risk of opioid use and misuse, including our prior study on self-reported use and misuse (Takemoto et al., 2019), there are few published papers reporting on hospitalization-related outcomes making it difficult to compare to current literature. However, the findings of our study align with a recently published paper on the risk of non-fatal overdose among people who use drugs. A Canadian based population study found that among people who use drugs in Canada, a provisional PTSD diagnosis nearly doubled the risk of non-fatal overdose (Lee et al., 2020). Findings are also similar to that of the association with PTSD and alcohol-related hospitalizations in the same World Trade Center exposed population, although the risk of opioid-related hospitalizations was stronger than that of alcohol-related hospitalizations (Takemoto et al., 2021). Disparate populations and health outcomes make it difficult to compare directly, however, both studies provide evidence that PTSD may increase the risk of subsequent substance use and misuse, which extends to the more severe outcomes of overdose and hospitalization.

Several potential mechanisms exist that might put those with PTSD at a greater risk of opioid-related hospitalizations. For instance, it could be that individuals with PTSD who use opioids end up doing so with greater intensity or in riskier ways than those without PTSD. One study, on a group of HIV patients who were prescribed opioids for chronic pain, found that among those who developed opioid use disorder (OUD), those with PTSD exhibited more intense or hazardous behaviors around opioid use (Bhatraju et al., 2021). A second study reported that, among veterans prescribed opioids, those with PTSD were more likely to engage in higher-risk opioid use and that the duration of their opioid prescription was significantly longer compared to those without PTSD (Seal et al., 2012b). With the available data, we were unable to determine if individuals in this study had opioids prescribed to them or were using illicit opioids and whether or not the hospitalization was related to

prescription or illicit opioid use. Future studies on opioid-related hospitalizations should include information on prescription status to better understand the contribution of opioid prescribing, potential misuse of prescribed opioids, and illicit opioid use.

Another mechanism that can explain the comorbidity of opioid-related hospitalizations and PTSD found in the present study may, in part, be the self-medication hypothesis. This theory posits that those who experience states of emotional dysregulation as a result of an underlying mental health conditions may use substances as a coping mechanism (Khantzian, 1997). PTSD is characterized by impairments to one's ability to adequately regulate distressing emotions tied to a traumatic event/events specifically in three symptom domains: avoidance of thoughts or situations related to a traumatic event, hyperarousal that can manifest in hypervigilance or being easily startled, and re-experiencing traumatic occurrences by way of intrusive thoughts or repeated flashbacks (Association, 2010; Blanchard et al., 1996; Wilkins et al., 2011). The self-medication hypothesis suggests that individuals with PTSD may be using opioids, prescribed or otherwise, to directly alleviate the symptoms of their PTSD. A large body of research on substance use and misuse supports the finding that self-medication is common among individuals with PTSD (Alexander and Ward, 2018; Hawn et al., 2020; Leeies et al., 2010b). Also, one prior study on the WTC exposed population found that people with PTSD were more likely to intentionally self-medicate with alcohol, providing additional support for this mechanism (Garrey et al., 2020). Other possible mechanisms include a shared neural dysregulation characteristic of both PTSD and OUD and/or common genetic risk factors that simultaneously predispose affected individuals to both PTSD and OUD (María-Ríos and Morrow, 2020). The current study lacks intermediary information on the reasons for which individuals were using or misusing the opioids that led to the hospitalization; future studies should better aim to identify explicit reasons for misuse to elucidate avenues for specific intervention.

4.1. Limitations

This study was subject to several limitations. Firstly, as described earlier, the Anderson-Gill counting model that was used in our analysis relies on the assumption that repeated events are independent of each other. While this assumption simplifies the modeling process and increases the interpretability of our results, we acknowledge that there may be some degree of dependence between subsequent opioid hospitalizations. Future studies on repeated opioid hospitalizations should incorporate models that relax this assumption. The measure used for PTSD, our primary exposure, was self-reported and not derived from a clinical assessment. However, the PCL, which was used to measure PTSD is a validated psychometric tool with high sensitivity, specificity, and internal consistency (Blanchard et al., 1996). Further, there is evidence showing that prevalence measures derived from self-reported data are moderately comparable to those measured using data from administrative records (Alper et al., 2021). Although our outcome variable, opioid-related hospitalizations, was measured objectively using discharge records, opioid events that appear in administrative hospital data only account for individuals that make it to the hospital. Many overdoses are fatal, and individuals never make it to the hospital. Similarly, many overdose victims are revived in the field and refuse transport to the ED (Bergstein et al., 2021). Consequently, this study's findings are only generalizable to overdose victims who survive and are hospitalized as a result. Further, the SPARCS data used for the outcome measure only account for hospitalizations that occurred in New York State, meaning WTCHR participants who experienced opioid-related hospitalizations in other states are not included in the study. Although our dataset is longitudinal, we cannot comment with certainty on the temporality of the PTSD/opioid-related hospitalizations found. We do not know if the onset of the opioid use that led to hospitalization captured in this study preceded 9/11, although we attempted to control for this by excluding individuals with a history of an opioid related

hospitalization prior to 9/11. Finally, we compared the demographic characteristics of individuals who were excluded from this study due to wave non-participation or a non-valid PCL score ($n = 14,515$). BIPOC and Latino/Hispanic respondents and those with lower education levels were more likely to be excluded from the analytic sample (Supplementary Table). This suggests the possibility of selection bias, however, in studies of attrition among the WTCHR cohort, findings suggest that the loss to follow-up that has occurred in the WTCHR cohort has not led to significant bias in the associations between 9/11-related exposures and key health outcomes such as PTSD (Yu et al., 2015). Our generalizability may be limited to more highly educated white populations; future research in this area should focus on more diverse communities, including communities of color.

Conclusion

We found that having 9/11-related PTSD at any point in the 13-years after the WTC disaster may have substantially increased the risk of opioid-related hospitalizations, an outcome that has not yet been considered in published works on the long-term health outcomes of 9/11. This insight contributes to a growing literature that shows individuals with direct exposure to 9/11 continue to be at an increased risk of a roster of serious physical and mental health conditions even thirteen years later (Brackbill et al., 2019). This study also adds robust longitudinal evidence to the existing body of literature on PTSD and the subsequent risk of substance use/misuse, among a large sample of the Registry's population.

Members of a 9/11-exposed population endure a greater burden of both physical and mental health morbidities compared to the general population and are thus potentially at a greater risk of opioid use, misuse, or overdose. The World Trade Center Health Program should improve access to treatment and care for WTCHR enrollees who struggle with substance use. Ultimately, improving access for this population to harm reduction and substance misuse services, counselling, and psychiatric support could prevent future opioid hospitalizations and reduce systemic healthcare costs.

Funding/Support

Role of the funder

The funders had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review or approval of the manuscript; and decision to submit the manuscript for publication.

Ethics approval and consent to participate

The Centers for Disease Control and Prevention and New York City Department of Health and Mental Hygiene Institutional Review Boards approved this study's protocol. Informed consent was obtained from participants at enrollment into World Trade Center Health Registry.

Disclaimer

The raw data used to produce this publication was purchased from or provided by the New York State Department of Health (NYSDOH). However, the calculations, metrics, conclusions derived, and views expressed herein are those of the author(s) and do not reflect the conclusions or views of NYSDOH. NYSDOH, its employees, officers, and agents make no representation, warranty, or guarantee as to the accuracy, completeness, currency, or suitability of the information provided here.

Data availability

World Trade Center Health Registry Data may be made available following review of applications to the Registry from external researchers. SPARCS data may be requested from the New York State Department of Health. The data are not publicly available due to privacy or ethical restriction.

Authors' contributions

SKG and ET initiated the study. SL, SKG, and ET conducted the data analysis. CP coded, provided support, and consulted on SPARCS data. JL coded, provided support, and consulted on person-time data. SKG drafted the manuscript. ET offered advice, and critical comments and edited the draft manuscript. All authors reviewed the draft and approved the final manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.psychres.2023.115462.

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