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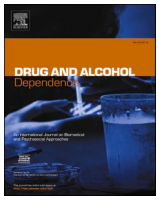

Short communication

Longitudinal study of smoking cessation among World Trade Center Health Registry enrollees, 2003–2021

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ABSTRACT

Background: Individuals with post-traumatic stress disorder (PTSD) are more likely to smoke and less likely to quit smoking than people without the condition. Building upon previous research, we examined associations between probable PTSD and smoking cessation among World Trade Center Health Registry (WTCHR) enrollees, who have a relatively high prevalence of PTSD.

Methods: We used five waves of survey data (2003–2021) from the WTCHR, a closed cohort of 9/11-exposed individuals, to examine longitudinal associations between probable PTSD and subsequent smoking cessation among enrollees who reported current smoking. Probable PTSD was assessed with the PTSD Checklist for DSM-IV (PCL-S). The outcome of smoking cessation was also assessed via survey responses at the subsequent wave. Multivariable-adjusted risk ratios (RRs) and 95 % confidence intervals (95 % CI) were estimated with generalized estimating equations.

Results: Overall, 31.3 % of enrollees quit smoking by the subsequent survey wave. Differences by probable PTSD status were observed, and in multivariable adjusted models, enrollees with probable PTSD were 8 % less likely to quit smoking compared to enrollees without probable PTSD (RR=0.92, 95 % CI: 0.87, 0.97).

Conclusion: Although various smoking cessation programs have been implemented among the WTC-exposed population, differences in cessation by PTSD status persist. Additional efforts to promote cessation among this group should consider mental health conditions.

1. Introduction

Over the past several decades, the use of combustible cigarettes (hereafter referred to as "smoking") in the United States has declined overall (Cornelius et al., 2021) but remains elevated for persons living with PTSD (Kearns et al., 2018; Pericot-Valverde et al., 2018). Compared to people without PTSD, those with PTSD are more likely to smoke, more likely to smoke more cigarettes, and are less likely to quit smoking (Pericot-Valverde et al., 2018). General population data show that PTSD and traumatic exposure are each associated with current smoking and greater smoking intensity (Estey et al., 2021). Individuals with PTSD who smoke have more frequent quit attempts than those without PTSD (Budenz et al., 2021), but are less likely to achieve smoking cessation, due to a higher likelihood of resuming smoking (Kearns et al., 2018; Zvolensky et al., 2008).

After the World Trade Center (WTC) attack on September 11th, 2001 (9/11), the World Trade Center Health Registry (WTCHR) was established as a collaboration between New York City Department of Health (DOH) and the Centers for Disease Control and Prevention (CDC); the World Trade Center Health Program (WTCHP) has provided 9/11-related healthcare for survivors and rescue/recovery workers. Community members and responders enrolled in the WTCHR have a persistently high prevalence of PTSD (Sisti et al., 2025). Previous studies of WTC-exposed individuals report that those with PTSD are more likely to smoke (Vlahov, 2002; Zvolensky et al., 2015), though overall smoking prevalence in the exposed population has decreased in the years since the disaster (Welch et al., 2015).

Among the WTC-exposed population, PTSD is comorbid with several physical health conditions including asthma and GERD (Li et al., 2011), whose symptoms may be exacerbated or worsened by cigarette smoking. It is therefore imperative to promote targeted smoking cessation efforts in the WTC-exposed population. The WTCHR previously examined data from 2003 to 2012 and found that odds of quitting were 25–39 % lower among people who smoke with probable PTSD compared to those

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without PTSD (Welch et al., 2015). With eight additional years of follow-up, we build upon that previous work to examine the association between probable PTSD and subsequent smoking cessation among WTCHR enrollees who currently smoke.

2. Methods

2.1. Population

The WTCHR is a closed, longitudinal cohort established to study the effects of WTC exposure on the health of rescue/recovery workers and community members who lived, worked, went to school or who were passersby in Lower Manhattan on 9/11. Enrollment was completed in 2003–2004 when 71,423 enrollees responded to an initial survey (Wave 1); to date, four additional surveys have been conducted (Wave 2: 2007–2008; Wave 3: 2011–2012; Wave 4: 2015–2016; Wave 5: 2020–2021). Surveys query respondents' 9/11 exposures; physical and mental health diagnoses and symptoms; and health risk factors, including smoking. In all surveys, respondents indicated whether they currently smoked cigarettes every day, some days, or not at all. At Waves 1, 4 and 5, enrollees also reported whether they had smoked ≥ 100 cigarettes in their lifetime ("Have you smoked at least 100 cigarettes in your entire life? (A pack is about 20 cigarettes.)"). If yes, follow-up questions included, "Do you now smoke cigarettes every day, some days, or not at all?" and "How many cigarettes on average do you smoke per day?" When lifetime smoking was available, we defined current smoking as having smoked ≥ 100 lifetime cigarettes and currently smoking some days or every day. Waves 2 and 3 did not include the lifetime smoking survey item; enrollees were considered to currently smoke in these waves if they reported smoking some days or every day. The current analysis includes enrollees who reported currently smoking in any of Waves 1–4 and who were ≥ 18 years old on 9/11/2001.

2.2. Measures

Exposure: Probable PTSD was assessed at Waves 1–4 using the 17-item stressor-specific PTSD Checklist (PCL-S), corresponding to DSM-IV criteria. The PCL-S assessed prior 30-day symptoms of PTSD specific to enrollees' 9/11 experiences using a 5-point scale for each item. Enrollees with scores of ≥ 44 were considered to have probable PTSD (Ruggiero et al., 2003).

Outcome: The outcome was smoking cessation at the subsequent survey wave (Waves 2–5), defined as an enrollee reporting that they did not currently smoke cigarettes at all.

Covariates: Enrollees' sex and race/ethnicity were assessed at Wave 1. Time-varying sociodemographic characteristics were assessed at Waves 1–4, including age, marital status, and employment. Household income and educational attainment were assessed at Waves 1 and 4; for these variables, Wave 1 values were used for Wave 2 and 3. Physician-diagnosed health conditions were self-reported at Waves 1–4; we created dichotomous indicators for whether enrollees self-reported any respiratory condition, cardiovascular disease, cancer, or diabetes. Smoking intensity at Waves 1–4 was categorized as: nondaily; daily, 1–9 cigarettes/day; or daily, ≥ 10 cigarettes/day.

2.3. Analysis

Enrollees were included in analyses if they had data from at least two consecutive survey waves. Enrollees' data from consecutive survey waves were analyzed as a single exposure-outcome pair, with probable PTSD and covariates assessed at the earlier of the two waves (baseline), and cessation status assessed at the later (follow-up) wave. Enrollees could contribute up to four observations (i.e., Waves 1 and 2, Waves 2 and 3, Waves 3 and 4, Waves 4 and 5) to analyses.

To account for within-enrollee correlation between observations, we estimated risk ratios (RRs) and 95 % confidence intervals (95 % CI) for associations of probable PTSD and smoking cessation using generalized estimating equations with a log link and binomial distribution. Adjustment for self-reported health conditions did not change results and these covariates were not retained in final models. To assess whether specific PTSD symptom clusters were differentially related to smoking cessation, we conducted secondary analyses examining associations between DSM-IV symptom clusters (avoidance, re-experiencing, and arousal) and cessation, separately, in multivariable-adjusted models. Data on some potential confounders, including lifetime diagnosis of depression, alcohol use, and past 12-month check-up, were first assessed in Wave 2. We conducted sensitivity analyses restricted to baseline waves 2–4 and assessed whether adjustment for these variables impacted results. Complete case analysis was performed, as missingness for covariates was < 5 %, except household income (6.7 %).

3. Results

Of 68,041 enrollees aged ≥ 18 years on 9/11, there were 12,941 enrollees (19.0 %) who indicated currently smoking on at least one of Waves 1–4. Of those, 12,705 enrollees had PCL-S scores at baseline, and 8289 had valid smoking data at the subsequent wave and were included in analyses. The number of unique enrollees who contributed to 1 paired wave of data was 4149; 2258 contributed 2 paired waves, 1010 contributed 3 paired waves, and 872 contributed 4 paired waves, totaling 15,183 observations.

The proportion of enrollees who reported currently smoking decreased from 16.1 % at Wave 1 to 6.6 % at Wave 5. Among those who reported currently smoking in Waves 1–4, 31.3 % reported not smoking in the subsequent wave (Table 1). Differences in cessation by sociodemographic characteristics were observed. Among those who graduated from college, 37.5 % reported not smoking at the follow-up wave, compared to 26.3 % of those who graduated from high school or less. Approximately one-third of non-Hispanic White and non-Hispanic Asian reported not smoking at follow-up wave (32.3 % and 33.3 %, respectively), compared to 26.0 % of non-Hispanic Black enrollees. Smoking intensity was inversely associated with cessation; rates of cessation were 42.5 % among those who reported non-daily smoking, and 22.5 % among those who smoked ≥ 10 cigarettes/day.

Among enrollees with probable PTSD at the baseline wave, 27.8 % were people who did not smoke at the subsequent wave, compared to 32.6 % of those without probable PTSD. In unadjusted models, those with probable PTSD were 14 % less likely to quit smoking than those without probable PTSD (RR=0.86, 95 % CI: 0.82, 0.91). After multivariable adjustment, this association persisted, though the magnitude was attenuated (RR=0.92, 95 % CI: 0.87, 0.97). In secondary analyses restricted to baseline waves 2–4 and adjusted for diagnosed depression, past 12-month check-up, and alcohol use, RRs were nearly identical to those from the full sample (RR=0.91, 95 % CI: 0.85, 0.98). Each DSM-IV PTSD symptom cluster was associated with lower likelihood of cessation, and associations were similar across clusters (e.g., $RR_{avoidance}$=0.93, 95 % CI: 0.89, 0.98; $RR_{arousal}$=0.94, 95 % CI: 0.90, 0.99; $RR_{re\text{-}experiencing}$=0.94, 95 % CI: 0.90, 0.98).

4. Discussion

In longitudinal data from the WTCHR collected over more than 15 years, probable PTSD was associated with lower likelihood of smoking cessation, consistent with previous research from the WTCHR (Welch et al., 2015) and from other populations (Budenz et al., 2021; Kelly et al., 2016). The magnitude of association observed in our study appeared smaller than those previously reported among WTCHR enrollees (Welch et al., 2015), which may be at least partially explained by methodological differences. For example, the previous analysis cross-sectionally examined probable PTSD and smoking status, making it difficult to determine temporality or to rule out the possibility of reverse causation. Additionally, the previous analysis reported odds

Table 1
Characteristics of World Trade Center enrollees* who report currently smoking cigarettes at baseline wave (Waves 1–4) by cessation status at follow-up wave (Waves 2–5).

Smoking status, follow-up wave	Current	Former
	N = 10,426 (68.7)	N = 4757 (31.3)
Sex		
Male	6438 (67.9)	3044 (32.1)
Female	3988 (70.0)	1713 (30.0)
Race/ethnicity		
Non-Hispanic White	7268 (67.7)	3472 (32.3)
Non-Hispanic Black	1065 (74.0)	374 (26.0)
Hispanic	1319 (69.5)	579 (30.5)
Non-Hispanic Asian	381 (66.7)	190 (33.3)
Non-Hispanic Other	393 (73.5)	142 (26.5)
Age category		
<40 years	2672 (64.6)	1465 (35.4)
40–49 years	3491 (70.4)	1466 (29.6)
50–59 years	3033 (71.1)	1233 (28.9)
≥ 60 years	1230 (67.5)	593 (32.5)
Household income category		
<$50,000	3365 (72.8)	1259 (27.2)
$50,000-< $75,000	2259 (69.3)	1003 (30.7)
$75,000-< $150,000	3299 (66.5)	1665 (33.5)
≥ $150,000	816 (61.7)	506 (38.3)
Educational attainment category		
High school or less	3455 (73.7)	1221 (26.3)
Some college	3291 (71.1)	1335 (28.9)
College graduate	3624 (62.5)	2176 (37.5)
Employed		
Yes	8214 (68.2)	3831 (31.8)
No	2170 (70.4)	912 (29.6)
Marital status		
Married	6061 (67.3)	2949 (32.7)
Not married	4307 (70.7)	1784 (29.3)
Smoking intensity		
Non-daily	3505 (57.5)	2587 (42.5)
Daily, < 10 cig/d	1229 (70.7)	509 (29.3)
Daily, ≥ 10 cig/d	5648 (77.5)	1641 (22.5)
Diagnosed respiratory condition		
No	7940 (68.8)	3602 (31.2)
Yes	2373 (68.2)	1108 (31.8)
Diagnosed cardiovascular condition		
No	9230 (68.6)	4227 (31.4)
Yes	1061 (69.4)	468 (30.6)
Missing	135	62
Diagnosed diabetes		
No	9595 (68.7)	4377 (31.3)
Yes	739 (69.7)	322 (30.3)
Missing	92	58
Diagnosed cancer		
No	9678 (68.7)	4417 (31.3)
Yes	700 (68.9)	316 (31.1)
Baseline survey wave		
Wave 1	4750 (72.3)	1824 (27.7)
Wave 2	2866 (65.5)	1509 (34.5)
Wave 3	1837 (69.1)	823 (30.9)
Wave 4	973 (61.8)	601 (38.2)
Probable PTSD (PCL-S ≥44)		
No	7552 (67.4)	3649 (32.6)
Yes	2874 (72.2)	1108 (27.8)

* Not unique enrollees; each enrollee may be represented up to four times.

ratios, which may overestimate risk ratios when the outcome is not rare.

The relationship between PTSD and smoking has not been fully elucidated, and several mechanisms may underlie this association. Individuals with PTSD are more likely than those without to report negative affect, and those with PTSD who smoke may expect that smoking will relieve negative affect (Calhoun et al., 2011), or that cessation will exacerbate it (Kearns et al., 2018). Individuals with PTSD may also have an elevated fear of anxiety, or anxiety sensitivity (Vujanovic et al., 2008), and may have heightened concern about withdrawal symptoms and their ability to tolerate these symptoms (Kelly et al., 2016). Mahaffrey et al. (2016) found that associations of

Table 2
Risk ratios (RRs) and 95 % confidence intervals (95 % CI) for association of probable PTSD (PCL-S score ≥44) with subsequent smoking cessation, among WTCHR enrollees who report currently smoking cigarettes.

	PCL-S score	N*	N*, quit	%, quit	RR	95 % CI
Unadjusted	< 44	11,201	3649	33 %	1.00	ref.
	≥ 44	3982	1108	28 %	**0.86**	**(0.82, 0.91)**
Multivariable-adjusted[a]	< 44	10,344	3353	32 %	1.00	ref.
	≥ 44	3701	1042	28 %	**0.92**	**(0.87, 0.97)**

*Not unique enrollees; each enrollee may be represented up to four times.
[a]Adjusted for age, sex, race/ethnicity, employment status, household income, educational attainment, smoking intensity, marital status, survey wave

PTSD symptoms with nicotine dependence and perceived barriers to cessation were each mediated partly by negative affect reduction motives, and Cook et al. (2014) reported that anxiety sensitivity was a mediator of associations between PTSD symptoms and negative beliefs about the consequences of quitting.

PTSD is a heterogeneous condition characterized by distinct symptom clusters. A study in the general population (Greenberg et al., 2011) found that PTSD symptom clusters were differentially associated with lifetime smoking, nicotine dependence, and cigarettes per day. In a previous study of WTC police responders, hyperarousal only was inversely associated with smoking cessation (Zvolensky et al., 2015). In contrast, our study did not find evidence that the association between PTSD symptoms and cessation varied by symptom cluster.

Our results suggest that cessation efforts among trauma-exposed populations should include assessment and treatment of mental health symptoms. Data from US veterans suggests that individuals who experience clinically meaningful PTSD symptom improvement are more likely to quit smoking than those without symptom improvement (Salas et al., 2022). Also among US veterans, an integrated approach to smoking cessation that included PTSD treatment was approximately twice as effective as standard cessation approaches in achieving long-term abstinence (McFall et al., 2005). While a sizeable portion of the literature on PTSD and smoking has focused on veteran populations (Kearns et al., 2018), our analysis broadens this evidence base to include disaster responders and survivors, which may have implications for post-disaster surveillance and intervention.

The proportion of WTCHR enrollees who currently smoke (6.6 %) is lower than the general population (11.5 %) (Cornelius et al., 2021). This may be due, in part, to previous cessation efforts that provided access to nicotine replacement therapy to enrollees who reported currently smoking. However, we observed bivariate disparities in smoking cessation by race/ethnicity similar to those in the general population, which may be attributable to systemic inequities including disproportionate advertising of tobacco products to Black communities (Cornelius et al., 2021), highlighting the need for equitable delivery of future cessation programs.

Limitations of this analysis should be noted. First, loss to follow-up between survey waves may have resulted in bias if attrition was differentially related to PTSD and smoking cessation. Additionally, our measures of smoking status were self-reported, and because our measure of current smoking did not specify a time period (e.g., past 30- day use), misclassification of our outcome is possible. We also lacked data on potentially important smoking-related variables, including nicotine dependence, quit intentions and attempts, and use of other tobacco or nicotine-containing products. As wave surveys were conducted every 3–4 years, we were not able to detect transitions in smoking status that occurred between waves.

5. Conclusion

Despite decreases in smoking prevalence, likelihood of smoking cessation was lower among WTC-exposed individuals with probable PTSD, demonstrating the need for integrated, evidence-based tobacco control interventions for this population, with a particular focus on addressing health inequities and improving cessation among persons living with mental health conditions such as PTSD.

CRediT authorship contribution statement

Cone James E.: Writing – review & editing, Writing – original draft, Supervision, Methodology, Conceptualization. **Laura Sirbu:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **Julia S. Sisti:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Formal analysis, Conceptualization.

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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.

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