

## RESEARCH ARTICLE

## Complex pain phenotypes: Suicidal ideation and attempt through latent multimorbidity

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**Data Availability Statement:** Data are owned by the VA and it is not possible to provide de-identified VA health system data of Veterans outside the VA firewall. In this instance it is even more problematic

## Abstract

### Background

Given the relatively high rates of suicidal ideation and attempt among people with chronic pain, there is a need to understand the underlying factors to target suicide prevention efforts. To date, no study has examined the association between pain phenotypes and suicide related behaviors among those with mild traumatic brain injuries.

### Objective

To determine if pain phenotypes were independently associated with suicidal ideation / attempt or if comorbidities within the pain phenotypes account for the association between pain phenotypes and suicide related behaviors.

### Methods

This is a longitudinal retrospective cohort study of suicide ideation/attempts among pain phenotypes previously derived using general mixture latent variable models of the joint distribution of repeated measures of pain scores and pain medications/treatment. We used national VA inpatient, outpatient, and pharmacy data files for Post-9/11 Veterans with mild traumatic injury who entered VA care between fiscal years (FY) 2007 and 2009. We considered a counterfactual causal modeling framework to assess the extent that the pain phenotypes during years 1–5 of VA care were predictive of suicide ideation/attempt during years 6–8 of VA care conditioned on covariates being balanced between pain phenotypes.

as data include information on substance use disorder, suicidal ideation and suicide attempt. This is based on the VA Research and Development Committee, VA Salt Lake City (Caroline.phinney@va.gov) restrictions. These data are available to interested parties who complete the requirements to access the data behind the VA firewall.

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## Results

Without adjustment, pain phenotypes were significant predictors of suicide related behaviors. When we used propensity scores to balance the comorbidities present in the pain phenotypes, the pain phenotypes were no longer significantly associated with suicide related behaviors.

## Conclusion

These findings suggest that suicide ideation/attempt is associated with pain trajectories primarily through latent multimorbidity. Therefore, it is critical to identify and manage comorbidities (e.g., depression, post-traumatic stress disorder) to prevent tragic outcomes associated with suicide related behaviors throughout the course of chronic pain and mild traumatic brain injury management.

## Introduction

Mild traumatic injury (mTBI) is a signature injury of war in Iraq and Afghanistan Veterans [1, 2]. Although, the mechanism is unknown, mTBI is associated with up to a two-fold increased risk of suicide [3]. Following mTBI, musculoskeletal and headache pain is commonly reported. Pain is a factor that may interact with mTBI to increase the risk of suicide.

Some individuals with chronic pain consider suicide as an option to eliminate suffering and burden to others when pharmacological, medical, and surgical therapies are exhausted [4–9]. Suicidal ideation, attempts and completion are two to three times more likely in those with chronic pain than in those without pain [10–13]. The intersection between longitudinal patterns of pain, mTBI and suicide presents clear challenges to the patients and providers. However, prior research examining longitudinal patterns of pain trajectories, multifaceted treatment, and subsequent adverse outcomes such as suicidal ideation and attempt (suicide-related behavior; SRB) are limited among patients with mTBI [14].

Our prior work identified pain trajectory phenotypes in Post-9/11 Veterans with mTBI using latent trajectory models. We found that four pain trajectory phenotypes (complex low impact, stable pain; complex low impact, worsening pain; complex moderate impact, worsening pain; complex high impact, stable pain) characterized by different patterns of longitudinal pain trajectories and complex, multidimensional longitudinal treatment regimens including medications with dual indications for use (e.g., antidepressants, anticonvulsants) [15]. Because prior research in Post-9/11 Veterans has also found that chronic pain frequently occurs with mTBI, post-traumatic stress disorder (PTSD), and depression [16, 17], our examination includes not only the pain trajectory phenotypes (hereafter pain phenotypes), but also comorbid conditions that may be reflected in the complex treatment regimens reflected in the pain phenotypes. These comorbid conditions account for the mental pain and suffering that can contribute to suicide risk via defeatist thoughts and emotions that color future expectations and threaten a positive future [18].

Different components of complex pain may have additive effects on suicide ideation and attempt including medications, high pain scores, and accumulated non-cancer pain conditions [5, 19–23]. Complex comorbidity may add to the impact of these components of complex pain on SRB [24–26], or they may account for the relationship between pain phenotypes and SRB among Veterans with mTBI [3, 27–33]. We sought to determine if these pain phenotypes in

mTBI were independently associated with SRB, or if the complexity of polymorbidity that may be a latent component of the pain phenotypes accounts for the association between pain phenotypes and SRB.

## Materials and methods

### Study cohort

The study sample and methods for development of pain phenotypes are described previously [15]. This study's analytic sample included those who entered VA care October 1, 2007 through September 30, 2009, who were diagnosed with mild TBI (mTBI), and who had at least three years of care during the first 5 years after entering VA care [34]. The University of Texas Health Science Center at San Antonio, the University of Utah, and the Bedford VHA Hospital institutional review boards approved the study, with a waiver of informed consent.

### Measures and data sources

**Primary outcome: Suicide related behavior.** We used ICD9-CM codes used in prior studies of SRB to identify suicide ideation (V6284) and attempt (E950, E952, E953, E954, E955, E956, E957, E958, E959) in national VA inpatient and outpatient data in years 6–8 of VA care [35]. Due to small numbers of documented attempts, we examined three SRB categories: suicidal ideation without attempt, suicide attempt regardless of suicide ideation, and no SRB. We also examined the combined outcome of any SRB vs. no SRB.

**Primary independent variable: Pain phenotype.** As described in previous work by Song, et al. [15], pain phenotypes were derived from general mixture latent variable models based on repeated measures of pain scores and pain medications or other pain treatments (e.g., complex pain clinic, physical therapy) during years 1–5 of VA care. These models identified four pain phenotypes: 'low impact-stable,' 'low impact- worsening,' 'moderate impact-worsening,' and 'high impact-stable.'

**Covariates.** We included age, sex, race/ethnicity, education, and military characteristics from the Operation Enduring Freedom/Operation Iraqi Freedom/ Operation New Dawn Roster file through December 2014, and percent service-connected disability from Veteran's Service Network data. Age was classified as 18–29, 30–39, 40–49 and greater than or equal to 50 years. Sex was classified as male and female based on data reported from the Department of Defense presented at the time of entry to military service. Race/ethnicity was defined as Black, White, Hispanic, or other based on available numbers in each racial/ethnic group. Education was the education level at the time of leaving military service classified as high school or less and some post-high school education and higher. Military characteristics included branch of service (Army, Marine Corps, Navy/Coast Guard, and Air Force), component of service (Active Duty, National Guard/Reserve), military rank (enlisted, officer/warrant officer), and deployment history (single deployment, multiple deployments). Service-connected disability is awarded in 10% increments and was classified as 0–20%, 30–50%, 60–80%, and 90–100%.

We identified diagnosed health conditions hypothesized to be reflected in the pain phenotypes and associated with SRB [5, 10, 24–26, 36]. S1 Table provides ICD9-CM diagnosis codes used; the algorithm required two or more diagnoses at least 7 days apart in outpatient data or at least once in inpatient data during the period of pain trajectory class analysis (years 1–5 of VA care) [37, 38]. Conditions included as covariates were back/neck pain, other musculoskeletal pain, headache, posttraumatic stress disorder (PTSD), depression, anxiety, substance use disorder, insomnia, attention impairment (proxy for potential impulsiveness), and cognitive dysfunction.

## Statistical analysis

Descriptive statistics for each pain phenotype were calculated. Chi-square tests were used to compare categorical variables between pain phenotypes.

We considered a counterfactual causal modeling framework [39, 40] to assess the extent that the pain phenotypes during years 1–5 of VA care were predictive of SRB during years 6–8 of VA care should covariates be balanced between pain phenotypes. The propensity scores of pain phenotypes were calculated, and the inverse propensity scores were incorporated as weights in the SRB model to minimize observed confounding for assessing the association of pain phenotype with SRB. To obtain robust estimates of propensity scores associated with pain phenotypes, we used generalized boosted multinomial regression modeling implemented by the *twang* package in R [41]. To examine the extent to which comorbidities contribute to differential SRB by pain phenotype, we considered two propensity score models with nested sets of predictors. Set 1 (long set) predictors were age, sex, race/ethnicity, education, military rank, multiple deployments, service-connected disability, prior SRB, and diagnosed health conditions that include headache, pain, anxiety, depression, PTSD, insomnia, substance use disorder, attention impairment and cognitive dysfunction. Set 2 (short set) predictors were a subset of Set 1 covariates excluding comorbid health conditions. Propensity score models were evaluated in terms of covariate balance between pain phenotypes using standardized bias—a standardized bias below the threshold 0.25 was deemed as covariate balance [42].

For SRB, we considered models for both a dichotomous and a trichotomous outcome. For any SRB or none, we conducted three separate logistic regression models to estimate the effects of pain phenotypes in SRB conditioned on varying degrees of adjustment of confounding associated with covariates, including (1) all covariates (long set) as predictors and inverse propensity score weights (IPSW) predicted by all covariates; (2) the short list of covariates (that excludes comorbid health conditions) as predictors and IPSW predicted by the short list of covariates; and (3) none. For the trichotomous SRB outcome (any attempt, ideation only, or no SRB), three multinomial logistic regression analyses were conducted with adjustments (1)–(3) as described above.

In each adjusted model of SRB, we included all predictors in the propensity score model (short or long set) as predictors along with the inverse propensity score weights adjustment so that the estimates associated with pain phenotypes have the ‘double-robustness’ property, i.e., the estimator is consistent either the propensity score model or the outcome model is correctly specified [43]. Under the four assumptions of consistency, exchangeability, positivity, and no misspecification of both outcome and propensity score models, the IPSW estimates of ORs associated with pain phenotypes based on adjustment (1) are interpreted as the effects of pain phenotypes conditioned on the counterfactual all covariates being balanced among phenotypes [44]. Similarly, the IPSW adjusted OR estimates based on the adjustment (2) are interpreted as the effects of pain phenotype on SRB should the partial set of covariates be balanced among pain phenotypes. Comparing estimates associated with pain phenotypes between these two IPSW adjustments will allow us to assess the extent to which the comorbid health conditions jointly attributed to the differential SRB risks between pain phenotypes.

## Results

All 10,717 Veterans with mTBI had complex pain and multiple pain treatment modalities. Proportions of Veterans by phenotype were: ‘low impact-stable’ 33.8%, ‘low impact-worsening’ 19.1%, ‘moderate impact-worsening’ 33.2%, and ‘high impact-stable’ 18.7%. The ‘high impact-stable’ phenotype had the highest prevalence of SRB followed by the ‘low impact-worsening’ phenotype. [Table 1](#) shows that pain phenotype was associated with well-known SRB

Table 1. Demographic and clinical characteristics by complex pain phenotype.

Characteristics	Complex pain phenotype, N = 10717								P value
	Low impact, stable		Low impact, worsening		Moderate impact, worsening		High impact, stable		
	n = 3454 (33.8%)		n = 1955 (19.1%)		n = 3393 (33.2%)		n = 1915 (18.7%)		
Age: ≤29	2479	72%	1289	66%	2136	63%	1088	57%	< .001
30–39	548	16%	429	22%	700	21%	517	27%	
40–49	342	10%	190	10%	469	14%	269	14%	
50+	85	2%	47	2%	88	3%	41	2%	
Sex: Male	3226	93%	1828	94%	3184	94%	1779	93%	.61
Female	228	7%	127	6%	209	6%	136	7%	
Race: Black	437	13%	204	10%	530	16%	199	10%	< .001
White	2430	70%	1400	72%	2274	67%	1393	73%	
Hispanic	433	13%	263	13%	446	13%	236	12%	
Other	154	4%	88	5%	143	4%	87	5%	
Education: High school or less	3055	88%	1684	86%	3004	89%	1679	88%	.04
Some college plus	399	12%	271	14%	389	11%	236	12%	
Rank: Enlisted	3346	97%	1891	97%	3322	98%	1872	98%	.01
Officer/Warrant	108	3%	64	3%	71	2%	43	2%	
Service Branch: Army	2237	65%	1407	72%	2431	72%	1443	75%	< .001
Air Force	130	4%	68	3%	138	4%	86	4%	
Navy/Coast Guard	240	7%	141	7%	245	7%	133	7%	
Marines	847	25%	339	17%	579	17%	253	13%	
Component: Active	2484	72%	1363	70%	2423	71%	1340	70%	.24
Reserve/National Guard	970	28%	592	30%	970	29%	575	30%	
Multiple Deployments	1905	55%	976	50%	1627	48%	824	43%	< .001
Service Connected Disability: 0–20%	646	19%	187	10%	380	11%	163	9%	< .001
30–50%	670	19%	192	10%	373	11%	73	4%	
60–80%	1400	41%	763	39%	1326	39%	556	29%	
90–100%	738	21%	813	42%	1314	39%	1123	59%	
Suicidal Ideation/Attempt, Y1-5: none	3262	94%	1679	86%	3108	92%	1573	82%	< .001
Suicide Attempt	28	1%	30	2%	29	1%	38	2%	
Suicidal Ideation	145	4%	208	11%	214	6%	229	12%	
Suicidal Ideation + Suicide Attempt	19	1%	38	2%	42	1%	75	4%	
Comorbidities, Y1-5 <sup>a</sup>									
Headache	1327	38%	1071	55%	1968	58%	1337	70%	< .001
Back/neck pain	1700	49%	1298	66%	2776	82%	1746	91%	< .001
Other musculoskeletal pain	1507	44%	1126	58%	2343	69%	1628	85%	< .001
Anxiety	993	29%	882	45%	1107	33%	867	45%	< .001
Depression	1608	47%	1386	71%	2025	60%	1477	77%	< .001
Post-traumatic stress disorder	2534	73%	1820	93%	2846	84%	1821	95%	< .001
Insomnia	645	19%	800	41%	812	24%	784	41%	< .001
Substance use disorder	1071	31%	767	39%	1126	33%	874	46%	< .001
Attention impairment	185	5%	174	9%	225	7%	194	10%	< .001
Cognitive dysfunction	126	4%	110	6%	173	5%	132	7%	< .001

<sup>a</sup> Additional comorbidity variables in the long model

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predictors: younger age, race/ethnicity, education, rank, service branch, multiple deployments, service-connected disability, pain and mental health conditions, and prior suicidal ideation

and attempts. The propensity score model for pain phenotypes predicted by the long set of covariates achieved balances of all covariates between pain phenotypes (standardized biases associated covariates all fell below the 0.25 threshold), but the propensity score model predicted by the short set of covariates did not necessarily balance the health covariates. See [S2 Table](#) for binomial logistic regression results and [S3](#) and [S4](#) Tables for the multinomial logistic regression results.

### Modeling any SRB as a dichotomous outcome

Overall, 95% veterans had no SRB and 5% veterans had SRB ([Table 2](#)). In the unadjusted binomial logistic regression, ‘low impact-worsening’ pain, ‘moderate impact-worsening’ and ‘high impact-stable’ pain phenotypes were all associated with increased SRB compared to the ‘low impact-stable’ pain phenotype ([Fig 1](#)). After adjusting for demographics and prior SRB among pain phenotypes (IPSW estimates of the effects of pain phenotypes derived from the propensity scores predicted by the short set of covariates), the ‘low impact-worsening’ and ‘high impact-stable’ pain phenotypes remained significantly associated with increased risk of SRB. The magnitudes of the odds ratios associated with pain phenotypes were attenuated compared to those in the unadjusted model. After balancing diagnosed health conditions between pain phenotypes (IPSW estimates of the effects of pain phenotypes derived from the propensity scores predicted by the long set of covariates), pain phenotypes were no longer associated with SRB risk.

### Modeling no SRB, suicidal ideation, and suicidal attempt as a trichotomous outcome

For the trichotomous outcome of no SRB, suicidal ideation only, and suicide attempt contained 9751, 390, and 93 veterans, respectively ([Table 2](#)).

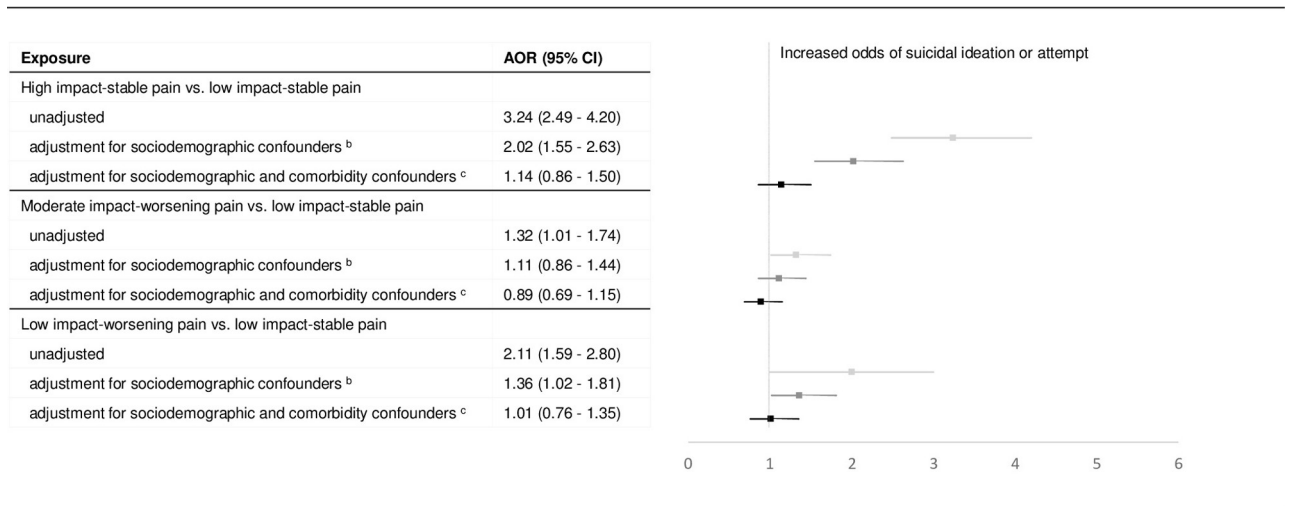
In unadjusted multinomial logistic regression models, the ‘low impact-stable’ pain phenotype had significantly lower odds of suicidal ideation compared to other pain phenotypes ([Fig 2](#)). The ‘low impact-stable’ pain phenotype had significantly lower odds of suicide attempt-only compared to the ‘high impact-stable’ pain. After adjusting for demographic covariates and prior SRB among pain phenotypes (IPSW estimates of the effects of pain phenotypes derived from the propensity scores predicted by the short set of covariates), the ‘high impact-stable’ pain and ‘low impact-worsening’ phenotypes remained associated with increased risk for suicidal ideation but with a lesser magnitude compared to the unadjusted model. The ‘moderate impact-worsening’ pain phenotype was no longer associated with the risk of suicide ideation conditioned on balanced demographic covariates, while the effects of high impact and low impact

**Table 2. Dichotomous and trichotomous analysis suicidal ideation and/or attempt by complex pain phenotype.**

	Complex pain phenotype, No. (%)							
	Low impact, stable		Low impact, worsening		Moderate impact, worsening		High impact, stable	
<b>Outcome by analysis</b>	<b>n = 3454 (33.8%)</b>		<b>n = 1955 (19.1%)</b>		<b>n = 3393 (33.2%)</b>		<b>n = 1915 (18.7%)</b>	
No suicidal ideation/attempt, n = 9751(95.3%)	3360	97.3%	1846	94.4%	3272	96.4%	1756	91.7%
Dichotomous analysis								
Suicidal ideation/attempt, n = 483 (5%)	94	2.7%	109	5.6%	121	3.6%	159	8.3%
Trichotomous analysis								
Suicidal ideation, n = 390 (3.8%)	74	2.1%	92	4.7%	99	2.9%	125	6.5%
Suicidal attempt, n = 90 (0.9%)	20	0.6%	17	0.9%	22	0.7%	34	1.8%

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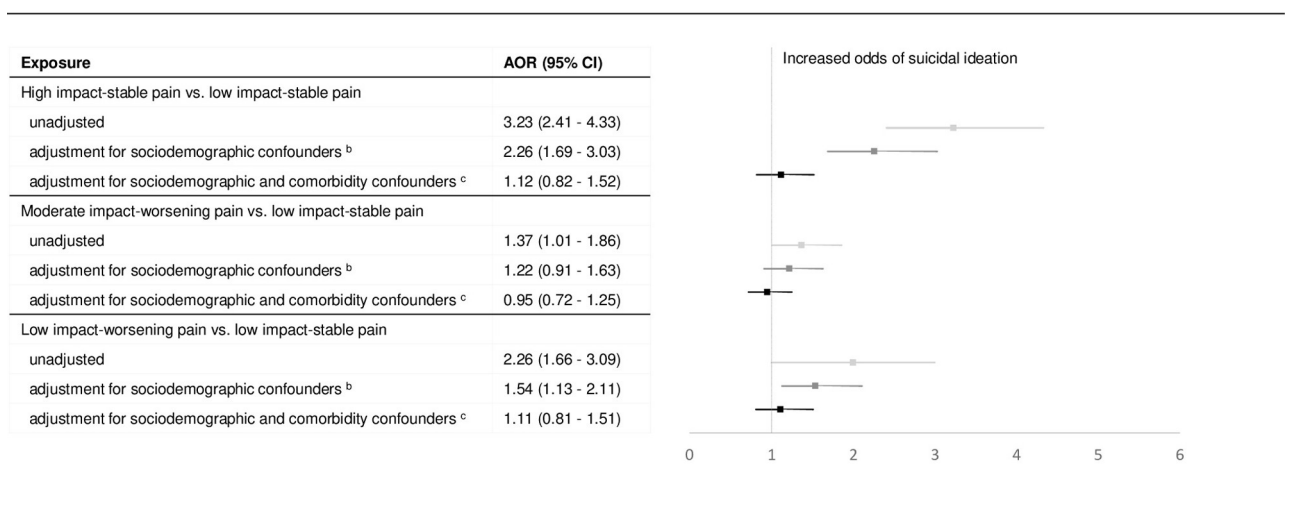
**Fig 1. Effects of pain phenotypes on suicidal ideation or attempt<sup>a</sup>.** <sup>a</sup> Forest plot of odds ratios and 95% confidence intervals associated with pain phenotypes derived from logistic regression analyses: unadjusted, adjusting away confounding associated with short set of covariates using IPSW, and adjusting away confounding associated with long set of covariates using IPSW. <sup>b</sup> The short set covariates includes sociodemographic characteristics (excludes comorbid health conditions) as predictors. <sup>c</sup> The long set covariates includes all covariates sociodemographic characteristics and comorbidities.

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worsening remained significant but with reduced magnitudes. Pain phenotype was no longer associated with increased risk of suicide attempt in either adjusted models (Fig 3).

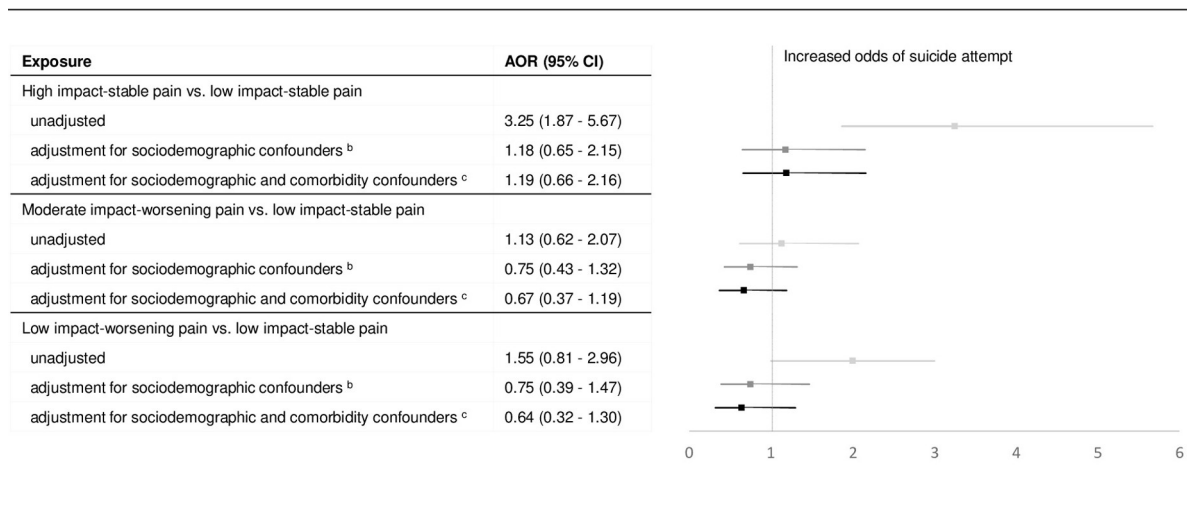
### Discussion

To understand the relatively high-risk of SRB in those with complex chronic pain, we examined the association of pain complexity, comorbidities, and suicide. Without adjustment, our



**Fig 2. Effects of pain phenotypes on suicidal ideation.** <sup>a</sup> Forest plot with odds ratio and 95% confidence intervals of the pain phenotypes with low impact-stable pain as reference from the multinomial logistic regression models. The figure shows the effect sizes with and without weights and using the long and short set of covariates for suicidal ideation. <sup>b</sup> The short set covariates includes sociodemographic characteristics (excludes comorbid health conditions) as predictors. <sup>c</sup> The long set covariates includes all covariates—sociodemographic characteristics and comorbidities.

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**Fig 3. Effects of pain phenotypes on suicide attempt.** <sup>a</sup> Forest plot with odds ratio and 95% confidence intervals of the pain phenotypes with low impact-stable pain as reference from the multinomial logistic regression models. The figure shows the effect sizes with and without weights and using the long and short set of covariates for suicide attempt. <sup>b</sup> The short set covariates includes sociodemographic characteristics (excludes comorbid health conditions) as predictors. <sup>c</sup> The long set covariates includes all covariates—sociodemographic characteristics and comorbidities.

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previously identified pain phenotypes were significant predictors of SRB. However, this assessment did not account for the unobserved presence of comorbidities in this population. Therefore, we utilized propensity scores to balance the comorbidities present in the pain phenotypes, pain intensity and treatment trajectories and found they were no longer significantly associated with SRB. This indicates that comorbidities were a significant factor associating chronic pain with SRB. This further indicates that assessing, treating, and managing comorbid conditions in people living with pain is important to address risk for SRB.

Veterans in the high impact-stable phenotype were most likely to report suicidal ideation and/or attempt suicide. Individuals in this phenotype had the highest rates of PTSD, depression, SUD, and past suicide attempts. Veterans in the low impact-worsening phenotype were the next most likely to endorse SRB and had the second highest rates of PTSD, depression, SUD, and past suicide attempts. Our findings align with prior research on suicide risk in a military polytrauma sample which found that depression and PTSD were significantly associated with suicidal ideation and violent impulses in veterans with chronic pain [36]. Management of these comorbidities may have the most impact on suicide mitigation.

Veterans in the ‘high impact-stable’ and ‘low-impact worsening’ phenotypes had the highest rates of previous suicide attempts and SRB after phenotype development. This finding is consistent with the vast majority of studies that find the best predictor of suicide is prior SRB and that those prior SRB are also associated with comorbidities such as TBI, depression, SUD, and PTSD, all of which are common in Post-9/11 Veterans [35]. Similar to other studies [29, 45, 46], these data suggest that while pain is an important risk factor for suicidal ideation and attempts, psychological comorbidities play a larger role in the development and/or maintenance of suicidal ideation and attempts than pain alone [45]. While the management of chronic pain is paramount within a treatment program, this study highlights the need to add focus to potentially modifiable psychological comorbidities that can drive suicidal ideation and attempts.

The length of the suicidal process may vary among those with chronic pain and mTBI. Individuals with chronic pain alone may have a gradual progression towards suicidal behavior.



Suicide may be deliberative and carefully planned, developed, ruminated, and then systematically carried out. In contrast, those with mTBI may have sudden suicidal behaviors which appear hastily decided-upon with little or no planning. Increased impulsivity associated with frontal lobe damages in those with mTBI may contribute to the sudden emergence of suicide [47]. Therefore, depending on whether mTBI is present, tailored interventions are warranted. With the presence of chronic suicidality, long term mental health and medical treatment are indicated. Impulsivity that leads to suicidal behaviors may seem more difficult to treat; however, due to increased utilization of healthcare by Veterans with mTBI there are ample opportunities to screen for suicide and intervene. Fortunately, there are numerous clinical interventions shown to significantly decrease suicidal behavior [48].

Both mTBI and pain are associated with mental health conditions and physical disabilities leading to difficulty in activities of daily living. These side effects of chronic pain and suicide-related behaviors are hidden disabilities among Veterans with mTBI. Given the high rates of suicide in this population, ongoing monitoring for psychological complications and distress are needed to prevent fatal suicide events. Veterans with mTBI and pain have increased healthcare encounters; thus, multiple opportunities are present to engage patients and caregivers in screening and prevention. Increased screening for suicide within this population is necessary and recommended.

Research related to suicide among patients living with a history of mTBI living with pain is limited. There is insufficient evidence to guide suicide management among those with mTBI and complex comorbid conditions. Among patients with mTBI, the traumatic brain injury is a long-term risk factor for suicide. The current VA/DoD clinical practice guidelines recommend a comprehensive treatment plan by addressing all physical conditions and mental health symptoms simultaneously [49].

## Limitations

Known SRB events were limited to the ICD-codes documented in VA electronic medical records. These SRB data were limited compared to other SRB databases: the VA Suicide Prevention Applications Network (SPAN) [50] and the Joint Department of Defense (DoD)—Department of Veterans Affairs (VA) Suicide Data Repository (SDR) [51–53]. Thus our findings should be interpreted with cautions, including potential biases due to measurement errors (e.g., under detection of non-fatal and fatal suicide attempts, or timing of suicide events) or unmeasured confounding (e.g., factors that influenced both SRB and SRB predictors). Since we did not have access to the VA SPAN and the DoD/VA SDR databases, nor information regarding factors underlying the SRB reporting attrition, we are unable to assess the magnitudes nor directions of these potential biases. However, these biases could be limited as our results were consistent with known suicide predictors in the current literature. Nevertheless, future studies would benefit from combining data from SPAN, SDR and DoD/VA medical records and examining conditional probabilities of factors associated with the highest mortality.

While derived from a national sample, these findings cannot be extrapolated to all patients and should be used with caution due to the possibility of unmeasured confounding. For the purpose of inferring practical intervention to mitigate the sources underlying differential SRB risk associated with pain phenotypes, we chose clinical covariates in the propensity score model that could be modified during clinical care such as mental health conditions that can be treated.

Another limitation is related to the reporting and documentation of suicide attempts and ideations in the patients' medical records. The numbers captured in this study may be lower than the actual number of suicide ideations and attempts that occur among Veterans with mTBI and pain due to reporting and documenting errors. Additionally, our numbers may be

underrepresented because not all Veterans who experience SRB seek treatment at the VA or seek treatment at all due to stigma [54, 55]. It is possible that the rate of suicidal behavior is actually higher than what we found among individuals with TBI because those not seeking treatment may be at higher suicide risk.

## Conclusion

These data expand on the existing knowledge about the impact of pain intensity, suicidal ideation and attempts, and complex patterns of comorbidities. These findings highlight the need for interdisciplinary care as the effect of the phenotypes disappeared when comorbidities were balanced. Assessing and treating both physical and mental health comorbidities are critical to improving outcomes and mitigating risk for suicide-related behavior.

## Supporting information

**S1 Table. ICD-9-CM diagnostic code definitions among Post-9/11 Veterans.**

(DOCX)

**S2 Table. Binomial logistic regression by complex pain phenotype for suicidal ideation or attempt.**

(DOCX)

**S3 Table. Multinomial logistic regression by complex pain phenotype for suicidal ideation.**

(DOCX)

**S4 Table. Multinomial logistic regression by complex pain phenotype for suicide attempt.**

(DOCX)

**S5 Table. Binomial logistic regression by complex pain phenotype for suicidal ideation or attempt.** Adjusted odds ratios and 95% confidence intervals associated with pain phenotypes derived from logistic regression analyses: unadjusted, adjusting away confounding associated with sociodemographic, military characteristics, mental health (minus prior suicide-related behavior) covariates using IPSW.

(DOCX)

**S6 Table. Multinomial logistic regression by complex pain phenotype for suicidal ideation and attempt.** Adjusted odds ratios and 95% confidence intervals associated with pain phenotypes derived from logistic regression analyses: unadjusted, adjusting away confounding associated with sociodemographic, military characteristics, mental health (minus prior suicide-related behavior) covariates using IPSW.

(DOCX)

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