Associations Among Environmental Exposures and Physical and Psychiatric Symptoms in a Care-Seeking Sample of U.S. Military Veterans

Jessica L. Morse, PhD[*,†]; *Dean T. Acheson, PhD*[†,‡]; *Erin Almklov, PhD*[*,‡]; *James O.E. Pittman, PhD, LCSW*[*,†,‡]; *Ariel J. Lang, PhD, MPH*[†,‡,§]; *Laurie Lindamer, PhD*[*,†,‡]

ABSTRACT

Introduction:
Recent research and policy (e.g., the Sergeant First Class (SFC) Heath Robinson Honoring our Promise to Address Comprehensive Toxics (PACT) Act) have highlighted the potential health consequences of toxic environmental exposures. The purpose of the current study was to assess the self-reported prevalence of such exposures among a sample of U.S. military veterans seeking care at a Veterans Affairs facility and to examine associations between exposures and physical and psychiatric symptoms.

Materials and Methods:
Participants were 4,647 newly enrolling post-9/11 veterans at the VA San Diego Healthcare System who completed standard clinical screening processes between January 2015 and April 2019. Electronic health screening data, including demographic information, military history, environmental exposures, and physical and psychiatric symptoms, were assessed. *t*-Tests for continuous variables and chi-square tests for categorical variables were used to compare exposed to unexposed veterans on demographic and military characteristics as well as physical and psychiatric symptoms.

Results:
A total of 2,028 veterans (43.6%) reported exposure to environmental toxins during their military service. Analyses revealed a disproportionate burden of exposure on older, male, educated, combat veterans as well as Asian and Native American veterans. Exposure to any type of environmental toxin was associated with more physical symptoms, particularly pain, fatigue, and insomnia, as well as psychiatric symptoms, including moderate depressive symptomology, mild to moderate anxiety, and scores approaching the threshold for likely post-traumatic stress disorder and alcohol misuse.

Conclusions:
The high prevalence and detrimental health correlates of environmental exposures underscore the importance of implementing screening for exposures and providing healthcare services that address the multisystemic nature of exposure-related illness.

INTRODUCTION

Recent research and policy (e.g., the PACT Act) have highlighted the potential health consequences of environmental exposures, particularly among veterans exposed to chemical, biological, and nerve agents as well as hazardous particulate matter from burn pits, jet fuel fumes, pesticides, and more during their military service.[1] While the Vietnam and Gulf Wars highlighted the detrimental effects of toxins (e.g., Agent Orange) and other environmental exposures, a deeper understanding of the associations between environmental exposures and subsequent physical and psychiatric symptoms in post-9/11 veterans is critical to comprehending the impact of exposures to address the needs of veterans seeking healthcare services.[2]

Historically, environmental exposures have been associated with more physical symptoms, which contribute to poorer functioning and greater disability.[3] Research on the effects of environmental exposures in post-9/11 veterans aligns with that of previous generations, as studies have found greater severity of physical symptoms and heightened prevalence of rare and multisystemic diseases among veterans of Iraq, Afghanistan, or both.[4–6] Additionally, there appear to be an increased incidence of respiratory conditions and reduced physical fitness following Operation Enduring Freedom/Operation Iraqi Freedom/Operation New Dawn deployment, which may be partially attributable to unhealthy levels of airborne hazards, such as burn pit products.[5]

Emerging evidence also suggests that environmental exposures can contribute to the development of psychiatric symptoms with results of some studies associating exposures with

[*]VA San Diego Healthcare System, San Diego, CA 92161, USA
[†]Department of Psychiatry, University of California, San Diego, La Jolla, CA 92037, USA
[‡]VA Center of Excellence for Stress and Mental Health, San Diego, CA 92161, USA
[§]Herbert Wertheim School of Public Health and Human Longevity Science, University of California, San Diego, La Jolla, CA 92037, USA

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mood and perceptual abnormalities as well as changes in behavior and cognition.[7] The mechanisms by which psychiatric symptoms are linked to environmental exposures are not fully understood. Previous research indicates that psychiatric symptoms may develop in the aftermath of toxic exposure due to the psychological stress of the exposing event and physical responses to the stress of the exposing event.[8] One study found that simply believing one was exposed to environmental harm was associated with more somatic and psychiatric symptoms, especially for participants prone to somatization.[9] It is also possible that certain environmental exposures precipitate neurological or physiological changes which contribute to heightened psychiatric symptoms.[7] Regardless of mechanism, restoring wellness among exposed veterans depends on understanding the frequency, intensity, and types of psychiatric symptoms associated with environmental exposures.

This study assesses the prevalence of various types of self-reported environmental exposures and examines the associations between environmental exposures and physical and psychiatric symptoms in a care-seeking sample of U.S. military veterans to inform the healthcare needs of exposed veterans. We hypothesized that exposed veterans would significantly report more physical and psychiatric symptoms than unexposed veterans and that this pattern would hold across most types of exposures.

METHODS

Participants

Participants were 4,647 newly enrolling post-9/11 veterans at the VA San Diego Healthcare System who completed standard clinical screening processes between January 2015 and April 2019. More than 80% of participants had prior service in the Navy or Marines, thus our sample is not representative of the general population of veterans. Data were collected using the VA eScreening program. eScreening is a web-based electronic screening platform that is used to collect self-reported health and demographic information from the veterans. eScreening was developed by the VA Center of Excellence for Stress and Mental Health at the VA San Diego Healthcare System with support from the VA Innovations Ecosystem.

Study procedures were approved by the Institutional Review Board of VA San Diego Healthcare System. Informed consent was not obtained as the study involved analyzing deidentified data collected for clinical purposes. The principles outlined in the Declaration of Helsinki were followed.

Measures

Participants completed self-report measures assessing environmental exposures, physical symptoms, and psychiatric symptoms. Participants also reported their age, race, sex, education, military branch, and combat status.

Environmental Exposures

Participants were asked if they believed they may have been exposed to or encountered any of the following while deployed: chemical agents, biological agents, jet propellant 8 (JP8) or other fuels, asbestos, nerve gas, radiological agents, sand/dust or particulate matter, depleted uranium, industrial pollution, exhaust fumes, paints, animal/insect bites, smoke from burn pits, pesticides, or other. The response choice was yes/no.

Physical Symptoms

The Patient Health Questionnaire-15 was used to screen for somatic symptoms during the past month, including stomach pain, back pain, arm/leg/joint pain, headaches, chest pain, dizziness, fainting spells, heart pounding/racing, shortness of breath, pain with sex, constipation, nausea, fatigue, and insomnia.[10] Each item is scored on a 3-point scale such that higher scores indicate greater somatic symptom severity. Studies suggest strong internal consistency among primary care patients.[10]

Psychiatric Symptoms

The Patient Health Questionnaire 9-Item Depression Module was used to assess depressive symptoms during the past 2-week period.[11] Items are rated on a 4-point scale and summed, with higher scores indicating greater severity. Research supports the PHQ-9 as a reliable and valid measure of depression.[11]

The Generalized Anxiety Disorder 7 scale (GAD-7) was used to assess anxiety symptoms during the past 2-week period.[12] The GAD-7 consists of 7 items rated on a 4-point scale and summed, wherein higher scores are associated with greater levels of anxiety. The GAD-7 has good internal consistency ($\alpha = 0.92$) and validity.[12]

The post-traumatic stress disorder (PTSD) Checklist—Civilian Version (PCL-C) was used to screen for PTSD symptoms.[13] The PTSD Checklist—Civilian Version includes 17 items scored on a 5-point scale and summed with higher scores indicating greater severity of PTSD symptoms. The PTSD Checklist—Civilian Version was used due to its high internal consistency in military populations.[13]

The Insomnia Severity Index was used to assess insomnia symptoms during the past two weeks.[14] The Insomnia Severity Index includes 7 items scored on a 4-point scale and summed, with higher scores indicating more severe insomnia. The Insomnia Severity Index is a reliable and valid instrument with studies supporting detection of insomnia and high internal consistency in community and clinical samples.[14]

The 3-item Alcohol Use Disorders Identification Test-Consumption was used to assess alcohol use.[15] This commonly utilized screening measure for alcohol use is administered throughout the VA Healthcare System and studies support its validity, sensitivity, and specificity in predicting alcohol misuse.[16]

The Patient-Reported Outcomes Measurement Information System pain intensity and interference scales were used to assess pain intensity and pain interference (i.e., consequences of pain on relevant aspects of one's life).[17,18] Pain intensity was assessed by totaling scores on 3 intensity items and interference was assessed by totaling scores on 6 interference items. Studies support the clinical validity and reliability of these Patient-Reported Outcomes Measurement Information System questionnaires.[19,20]

Data Analysis

Chi-squared tests and *t*-tests were conducted using SPSSv28. Chi-squared tests were used to compare participants by exposure status (unexposed versus exposed) on categorical variables, including sex, race, education, military branch, combat status, and physical symptoms. T-tests were conducted to compare participants by exposure status on continuous variables, including age and psychiatric symptoms. T-tests were also conducted to compare mean number of exposures by sex, race, combat status, and military branch.

RESULTS

Data were collected from a total of 4,647 veterans, of whom 43.6% endorsed at least one exposure. Of those veterans, 52.9% endorsed exposure to sand/dust or particulate matter, 50.6% to exhaust fumes, 41.7% to JP8 or other fuels, 40.1% to smoke from burn pits, 34.4% to paints, 26.2% to asbestos, 25.3% to industrial pollution, 21.9% to animal/insect bites, 11.7% to chemical agents, 11.5% to pesticides, 10.3% to radiological agents, 5.8% to depleted uranium, 4.2% to biological agents, and 1.3% to nerve agents. The mean number of exposures was 3.47 (SD = 3.06).

The average age of the sample was 36-years old (SD = 8.9), and participants endorsing any exposure were significantly older (M = 38 years, SD = 8.8) than those unexposed (M = 34 years, SD = 9.0). Most participants were male (78%), and *t*-tests revealed that male participants reported significantly more exposures than female participants ($M_{males} = 4.95$, $SD_{males} = 2.98$; $M_{females} = 3.50$, $SD_{females} = 2.64$). A majority of participants were White (59%; see Table I for sample demographic characteristics). Chi-squared analyses revealed that disproportionately fewer White participants endorsed exposures (55% of the exposed group but 61% of the unexposed group), whereas disproportionately more Native Americans (5% of the exposed group versus 3% of the unexposed) and Asians (17% of the exposed group versus 14% of the unexposed group) endorsed exposures. Combat status was also significantly associated with exposure (59% of the exposed group versus 41% of the unexposed group) such that participants who experienced combat reported significantly more exposures (M = 5.2, SD = 3.64) than non-combat veterans (M = 3.64, SD = 2.51). Additionally, current level of education was significantly associated with exposure such that receiving education beyond high school was associated with exposure (83% of the exposed group versus 77% of the unexposed group). Branch of service was not significantly associated with exposure status; however, as noted earlier, more than 80% of participants served in the Navy or Marines. Type of exposure is likely influenced by service branch, as sailors may be more likely to be exposed to exhaust, JP8, or other fuels compared to soldiers, who may be more likely to be exposed to smoke from burn pits or bites.

TABLE I. Demographic Characteristics of the Sample ($N = 4,696$)

Exposed (%)	43.6
Male (%)*	78
Mean age*	36 (8.8)
White (%)*	59
African American (%)	17
Native American (%)*	4
Pacific Islander (%)	2
Asian (%)*	15
Other (%)	3
Combat ()*	49
High school education or less (%)*	21
Army (%)	13
Air Force (%)	4
Coast Guard (%)	1
Marines (%)	30
National Guard (%)	1
Navy (%)	51

Across all types of physical symptoms, exposed participants reported higher intensity of symptoms than unexposed participants. Chi-squared analyses comparing exposed to unexposed participants on physical symptoms revealed that the exposed participants endorsed experiencing all physical symptoms more frequently than non-exposed participants, and this held true across all types of exposure with effect sizes in the small to medium range. The four symptoms most strongly endorsed (e.g., "a lot") by exposed participants were arm/leg/joint pain (62%), back pain (56%), insomnia (56%), and fatigue (43%). These same four symptoms were also the most strongly endorsed by unexposed participants, but at lower rates (see Table II). Although all types of exposures were associated with significantly higher endorsement of physical symptoms, results suggest that participants exposed to biological and nerve agents reported the highest frequency of most physical symptoms, particularly various forms of pain (χ^2 range: 11.33-16.95, Cramer's V range: 0.08-0.11) as well as fatigue ($\chi^2 = 12.16$; Cramer's V = 0.08), and insomnia ($\chi^2 = 6.51$; Cramer's V = 0.06). Chi-squared analyses also revealed that more exposures were significantly associated with higher frequency of each physical symptom.

t-Tests comparing exposed to unexposed participants on measures of psychiatric symptoms revealed exposed participants endorsed significantly more symptoms of depression, anxiety, PTSD, and more alcohol use than unexposed participants, and these differences ranged from moderate to

TABLE II. Physical and Psychiatric Symptoms Associated with Exposure Status

All exposures	Unexposed			Exposed			
Physical symptoms	**None (%)**	**A little (%)**	**A lot (%)**	**None (%)**	**A little (%)**	**A lot (%)**	**Cramer's *V***
Stomach pain*	69	24	8	53	34	13	0.16
Back pain*	23	37	40	12	32	56	0.18
Arm/leg/joint pain*	19	37	45	9	29	62	0.19
Headaches*	42	37	21	24	44	33%	0.20
Chest pain*	79	18	3	65	29	6	0.16
Dizziness*	74	21	5	56	34	10	0.18
Fainting spells*	96	4	1	90	8	1	0.12
Heart pound/race*	67	25	8	45	39	16	0.22
Shortness of breath*	74	21	5	56	34	10	0.20
Sex pain*	82	11	7	68	19	14	0.18
Constipation*	68	21	11	54	27	19	0.16
Nausea*	66	23	12	48	33	19	0.18
Fatigue*	34	39	27	19	38	43	0.20
Insomnia*	28	37	36	12	32	56	0.23
Psychiatric symptoms	Mean score (SD; SEM)						Cohen's *d*
Depression*	7.34 (6.93; 0.14)			10.80 (7.43; 0.17)			0.48
General anxiety*	6.50 (6.50; 0.13)			9.51 (6.86; 0.16)			0.45
Post-traumatic stress*	32.13 (17.82; 0.45)			43.55 (20.65; 0.57)			0.59
Pain intensity*	7.94 (2.95; 0.06)			9.17 (2.72; 0.06)			0.44
Pain interference*	15.15 (7.03; 0.14)			18.69 (7.01; 0.16)			0.51
Insomnia*	10.74 (7.66; 0.15)			14.98 (7.62; 0.17)			0.56
Alcohol use*	3.20 (2.55; 0.05)			3.47 (2.81; 0.07)			0.10

*$P < .05$.

large effect sizes (see Table II). Endorsement of any exposure was associated with moderate depressive symptomology, mild to moderate anxiety, and scores approaching the threshold for likely PTSD and alcohol misuse. As with physical symptoms, participants exposed to biological and nerve agents had the highest scores on all measures of psychiatric symptoms except alcohol use. In line with the chi-squared results, *t*-tests revealed exposed participants reported significantly higher pain intensity and pain interference as well as more insomnia symptoms than unexposed participants (see Table II).

DISCUSSION

The primary purpose of this study was to explore the prevalence of environmental exposures and differences in physical and psychiatric symptoms by exposure status. Of the 4,647 care-seeking U.S. military veterans nearly half reported exposure to environmental toxins during their military service. Analyses revealed a disproportionate burden of exposure on older, male, educated, combat-exposed veterans as well as Asian and Native American veterans. Exposure to any environmental toxin was associated with more frequent physical symptoms, including pain (e.g., stomach, back, arm/leg/joint, chest, and pain with sex), headaches, dizziness, heart pounding, shortness of breath, constipation, nausea, and fatigue. Exposure to any environmental toxins was also associated with more severe psychiatric symptoms, including depressive, anxiety, post-traumatic stress, and insomnia symptoms as well as alcohol misuse. Biological and nerve agents emerged as the most detrimental in terms of symptom burden, and symptoms of pain, fatigue, and insomnia emerged as most common across exposure types.

Overall, our findings are consistent with the previous studies of environmental exposures in Gulf War era veterans as well as emerging research on post-9/11 veterans.[3–6] As the VA implements the PACT Act, which supports benefits and care for veterans exposed during military service and promotes research into the mechanisms of exposure-induced disability, results of the current study inform our understanding of physical and psychiatric correlates of exposure.[1] Accordingly, the high prevalence and detrimental health and psychiatric correlates of exposures underscore the importance of screening for exposures and potential symptoms and connecting exposed veterans with appropriate multidisciplinary healthcare. One innovative aspect of this study was the use of a novel electronic screening program (eScreening), which may have implications for PACT Act implementation. eScreening enables veterans to directly provide mental and physical health information through a portal that communicates with the electronic medical records system. Veterans rate eScreening as more accessible and satisfactory than paper screening, and rate of connection to VA services is faster with VA eScreening compared to paper screening.[21] As more veterans are screened for exposure, there will likely be a need for large-scale multidisciplinary care. Polytrauma System of Care

clinics, designed as integrated rehabilitation programs, may serve as a useful model for addressing the multidisciplinary healthcare needs of exposed veterans, as they incorporate interdisciplinary evaluation, development of comprehensive plans of care, case management, treatment, psychosocial support, and patient and family education.[22]

The association between exposure and physical and psychiatric symptoms is poorly understood at present but is likely complex as veterans exposed to an environmental toxin may have had pre-existing symptoms or conditions that heightened susceptibility to exposure-related harm, or veterans with health conditions may have heightened somatic awareness that leads them to scan their past for potential exposures in an effort to explain symptoms.[8,9] Most likely, interactions between psychological and biological processes determine veterans' response to exposure; however, regardless of the underlying mechanisms, exposed veterans experiencing symptoms likely may become another population of multisymptom illness (e.g., Gulf War Syndrome, post-concussive syndrome), who will benefit from integrated assessment and intervention.

Limitations of the current study include self-reporting via screening tools, which introduces bias and may not reflect eventual diagnoses[5,7]; purely statistical analysis of associations, which ignores the medical plausibility of exposure-symptom pairs; the cross-sectional design, which precludes interpretations related to causality; and the composition of our sample, which limits generalizability of results. Veterans in the sample were seeking care in Southern California and were predominately veterans of the U.S. Marine Corps and Navy, and thus results may differ from non-help-seeking individuals and veterans in other geographical regions and for other branches of service. Similarly, results related to associations between exposure status and other demographic characteristics, particularly Native American race and educational attainment, should be interpreted with caution due to the low number of Native American participants and the unique educational trajectories of enlisted military personnel, who tend to complete advanced education post-service. Additionally, a small proportion of the sample endorsed exposure to biological and nerve agents, and thus caution is warranted in generalizing results related to these exposures. Future research should address these limitations to improve internal and external validities. Prospective, longitudinal investigations with objective measures of toxic exposures and physical and mental health symptoms, while costly to execute, would help clarify these complex relationships. Future researchers may also seek to clarify if particular symptoms are uniquely associated with different types of exposures or if exposures tend to result in multisymptom illness, as this could inform screening and treatment of exposure-related illnesses.

Despite those limitations, the large sample size and comprehensive screening of exposures in this study provide important information regarding the extent of self-reported exposures and physical and mental health symptoms of veterans seeking care. This study addresses gaps in the literature by exploring the prevalence and correlates of different types of environmental exposures reported by post-9/11, care-seeking U.S. military veterans. Results of this study inform our understanding of the burden of symptoms experienced by those exposed, highlighting the potential multisystemic illness associated with exposure as well as the healthcare needs of this population.

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CLINICAL TRIAL REGISTRATION

Not applicable.

INSTITUTIONAL REVIEW BOARD (HUMAN SUBJECTS)

All study procedures were approved by the Institutional Review Boards of VA San Diego Healthcare System.

INSTITUTIONAL ANIMAL CARE AND USE COMMITTEE (IACUC)

Not applicable.

INDIVIDUAL AUTHOR CONTRIBUTION STATEMENT

J.L.M. contributed to interpretation of results and writing of the original draft. D.T.A. and E.A. contributed to data collection and analyses, interpretation of results, and editing. J.O.E.P. contributed to conceptualization and design, data collection, interpretation of results, and editing. A.J.L. and L.L. contributed to conceptualization and design and editing. All authors read and approved the final manuscript.

INSTITUTIONAL CLEARANCE

Not applicable.

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CONFLICT OF INTEREST STATEMENT

None declared.

DATA AVAILABILITY

The data that support the findings of this study are available on request from the corresponding author.

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