Sinusitis and rhinitis among US veterans deployed to Southwest Asia and Afghanistan after September 11, 2001

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Background: Post-9/11 veterans were exposed to environmental and occupational pollutants during deployment.
Objective: Our aim was to determine associations between deployment-related exposures and sinusitis and rhinitis.
Methods: Between April 2018 and March 2020, veterans with land-based deployment after 9/11 who were living within 25 miles of 6 Department of Veteran Affairs medical centers were randomly chosen by using a Defense Manpower Data Center roster. Participants completed interviewer-administered questionnaires, which included a 32-item deployment exposure battery and self-report of rhinitis and health professional–diagnosed sinusitis. Exposure categories included burn pit smoke, combustion engine exhaust/ground dust, other open combustion sources, toxicants, and military job-related VGDF. Each item was scored on the basis of frequency and duration of exposure; ordinal scores were summed and scaled to 100 within each category. Odds ratios (ORs) were estimated using logistic regression for sinusitis and rhinitis separately. ORs were scaled per 20-point exposure score.
Results: Among the 1960 participants, the incidences of sinusitis and rhinitis with onset during deployment were 2.1% and 3.6%, respectively; the incidences of postdeployment onset were 5.1% and 5.6%, respectively. Toxicant exposure consisted mainly of "applying pesticide, insecticide, or repellent to your own skin or to your own clothing" and was associated with rhinitis with onset during deployment (OR = 1.50 [95% CI = 1.31-1.84]) and onset after deployment (OR = 1.21 [95% CI = 0.93-1.50]). There were no associations with burn pit smoke or other exposure categories.
Conclusion: Veterans with deployment exposures to toxicants were at increased risk of rhinitis, particularly during deployment. The clinical evaluation of postdeployment veterans should address rhinitis as a deployment-related condition. (J Allergy Clin Immunol Global 2025;4:100367.)

***Key words:** Sinusitis, chronic rhinosinusitis, rhinitis, environmental exposure, occupational exposure, veterans, military*

US veterans with land-based deployment to Afghanistan and Southwest Asia experienced potentially harmful inhalational exposures.[1,2] Potential service-related pollutants include burn pit combustion byproducts, engine exhaust, petroleum smoke and fumes, oil fires, mechanically generated dust, occupational exposures from a range of military duties, and selected toxicants, such as insect repellents and pesticides. In addition, the ambient regional environment in Southwest Asia is characterized by periodic dust storms that can suspend particular matter (PM) for extended periods of time and transport biologic. materials such as pollen and fungal spores.[3-5]

Ambient air quality is particularly relevant to chronic sinusitis and rhinitis. Multiple observational studies and meta-analyses have demonstrated an association between air pollution and the

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Abbreviations used

DEET:	*N,N*-Diethyl-*meta*-toluamide
OEF:	Operation Enduring Freedom
OIF:	Operation Iraqi Freedom
OR:	Odds ratio
PM:	Particulate matter
VA:	US Department of Veterans Affairs
VGDF:	Vapors, gas, dust, or fumes

development and progression of chronic sinusitis and rhinitis,[6-9] and *in vitro* and animal studies have demonstrated the upregulation of inflammatory pathways in the presence of PM.[10-13] With regard to dust storms in particular, research on upper respiratory tract conditions is limited,[4] but the studies do suggest an association between PM and the transport of pollen and fungal spores and sinonasal disease.[4,14-18] Conversely, occupational rhinitis has been well studied, with positive associations for various workplace exposures in, for example, the manufacturing, service, and agricultural sectors.[19-21] To our knowledge, studies of exposure-related rhinitis or sinusitis have not been performed in military populations deployed in Afghanistan and Southwest Asia, which constitute a group with potentially intense occupational and environmental exposures.[22-24]

Allergic rhinitis affects 10% to 30% of US adults, and nonallergic inflammatory rhinitis affects 17% to 52% of US adults, with up to 24% of them experiencing a combination of the 2 conditions.[25,26] The symptoms of rhinitis are often trivialized by patients, and many patients go undiagnosed and undertreated.[25] Sinusitis, of either allergic or nonallergic origin, affects 11% to 12% of US adults.[27,28] Rhinitis and sinusitis are highly burdensome to the quality of life of those who experience the diseases, leading to disturbed sleep, daytime somnolence and fatigue, depression, decreased sense of smell, and chronic cough.[25,27] Health care spending on sinusitis has been estimated at $10 billion to $13 billion per year,[27] spending on rhinitis has been estimated at estimated at $2 billion to $5 billion per year,[29]and both negatively affect worker productivity.[29,30]

The goal of our study was to characterize the environmental and military occupational risk factors for sinusitis and rhinitis among a formerly deployed military population that was recruited independently of medical complaints or symptoms. The results of this analysis were, in part, previously published in abstract form.[31]

METHODS

Overview

We utilized interim survey data from the Veterans Affairs Cooperative Studies Program 595, Pulmonary Health and Deployment to Southwest Asia and Afghanistan (ClinicalTrials.gov identifier NCT02825654), also known as Service and Health Among Deployed Veterans (SHADE). We used a structured questionnaire to evaluate deployment-related military occupational and environmental exposures and upper respiratory tract conditions. We assessed clinical characteristics of sinusitis and rhinitis and the associations between exposure categories and sinusitis or rhinitis with onset during or after deployment.

Study recruitment

Participants were randomly selected by using Defense Manpower Data Center deployment roster records if they met the following study eligibility criteria: was separated from active duty US military service; served between October 2001 and February 2017; had 1 or more deployments during that period to at least 1 of 7 countries (Afghanistan, Kyrgyzstan, Iraq, Kuwait, Qatar, United Arab Emirates, or Djibouti); and was a member of a service branch that had land-based deployments (Air Force, Army, or Marine Corps). We also required that at the time of recruitment potential, study participants reside within 25 miles of the US Department of Veteran Affairs (VA) medical center that was a study testing site (Atlanta, Ga; Boston, Mass; Houston, Tex; Minneapolis, Minn; San Diego, Calif; or Seattle, Wash).

The study sites conducted recruitment of eligible persons through a combination of postal mail and telephone outreach. We used LexisNexus to update address and telephone contact information from the Defense Manpower Data Center. Study visits were conducted between April 2018 to March 2020, at which point recruitment was paused because of the coronavirus disease 2019 (COVID-19) pandemic. All participants completed an in-person, interviewer-administered structured questionnaire that included demographic, smoking-related, and health-based items; military service–related characteristics (including service branch and dates and locations of deployments), and a multiple-item battery on deployment-related exposure (see Exposure Assessment and Scoring later). The study protocol was approved by the VA Central Institutional Review Board, and all participants provided informed consent.

Exposure assessment and scoring

The detailed methodology for exposure assessment and scoring can be found in Garshick et al.[32] The exposure questionnaire, which was designed for this study, elicited responses regarding 32 possible deployment-related occupational or environmental exposures that veterans may have experienced during their service. Using *a priori* groupings and a confirmatory factor analysis, we grouped exposures into 5 categories of "heavy" exposure as follows: burn pit smoke; engine exhaust/ground dust; other open combustion sources; toxicants (including pesticides, insect repellents, and chemical warfare agents); and military job–related vapors, gas, dust, or fumes (VGDF). For each exposure-related question, an affirmative response indicating heavy exposure was elicited only if the veteran experienced sustained or direct exposure in close proximity, which is to say exposure that the study participant could clearly sense at the time (eg, through effects on the eyes, throat, or breathing). For any affirmative responses, participants were asked the number of months with exposure and the estimated number of days in a typical month in which that exposure occurred.

We dichotomized self-reported exposures as no exposure versus any reported frequency and categorized missing item responses as having no exposure. Intensity was quantified on the basis of frequency of occurrences expressed in person days of exposure. The median number of exposure days were calculated among those with exposure for each individual question, generating a 3-level ordinal score for each item as follows: 0, no exposure; 1, moderate exposure (defined by a frequency less than or equal to median for that item); and 2, heavy exposure (exposure exceeding the median frequency). We assigned a score of 1 to any positive response for which the frequency was not otherwise quantified. Within each of the 5 exposure categories, we summed the respondent ordinal scores (0, 1, or 2) for each question (reduced in number from 32 to 28 after the confirmatory factor analysis) and scaled to 100 to standardize the scores among categories (as there were different numbers of questions in each category).[32] Of note, among the 1962 participants who completed the exposure questionnaire, exposure to any toxicant was reported by 926 participants (47.2%). There were 3 questions in the toxicants category, of which "applying pesticide, insecticide, or repellent to your skin or to your own clothing" had the most affirmative responses (42.8% for a median duration of 2.8 months), followed by "other pesticide, insecticide, or repellent application or handling" (6.6% for a median duration of 6.0 months) and "exposure to chemical warfare agents" (5.1% for a median duration of 0.23 months) (see Table E1 in the Online Repository at www.jaci-global.org). Civilian workplace exposure to VGDF was defined as at least 1 year spent in a participant's primary full- or part-time civilian job with report of regular exposure to VDGF.

Outcome assessment

The health component of the survey included assessment of sinusitis and rhinitis using items based on the 2008 Genetic Epidemiology of Chronic Obstructive Pulmonary Disease (COPDGene) questionnaire and 2005-2006 National Health and Nutrition Examination Survey (NHANES) allergy questionnaire.[33,34] We defined sinusitis as an affirmative response to the question "Has a doctor or other health professional ever told you that you had sinusitis?" and rhinitis as an affirmative response to the question "Have you ever had hay fever, meaning allergy involving the nose and/or eyes?" If there was missing information, the response was assumed to be negative (n = 12 for sinusitis and n = 25 for rhinitis). We defined predeployment incident illness as an illness for which the age at onset was less than the age at first deployment (both considered as whole numbers [integers]). If precise age at onset was not reported, we used a multiple-choice follow-up question in which the respondent was prompted to choose "kindergarten age or younger," "elementary school age," "middle school or high school age," or "as an adult, but before any active duty military service." We defined incident illness during deployment as an illness for which the age at onset was equal to or greater than age at first deployment and less than or equal than age at the end of last deployment. We defined incident illness after deployment as an illness for which the age at onset was greater than the age at the end of last deployment. If age was not reported, we used the response from a multiple-choice follow-up question in which the respondent was prompted to choose "during or between active duty military service times" and "after all active duty military service."

Statistical analyses

All analyses were conducted in R, version 4.3.0.[35] For descriptive characteristics, we used standard summary measures, including means and SDs for continuous normally distributed variables and medians and interquartile ranges for continuous nonnormally distributed variables, respectively. We used generalized linear models with a logit link to estimate the associations of all 5 exposure categories included in the same model for each of the 2 outcomes (sinusitis or rhinitis). We implemented additional separate models for rhinitis with onset during versus after deployment (excluding rhinitis after or during deployment from the respective models). Those who reported predeployment sinusitis or rhinitis were excluded from the models, as they would not have been eligible to develop new incident sinusitis or rhinitis during deployment or after deployment. Models were adjusted for age, sex, race (White non-Hispanic versus others), body mass index category (<25 kg/m^2 [referent], 25-30 kg/m^2, or ≥30 kg/m^2); and cigarette smoking (the 3-level factor never [referent], former, or current). To account for possible correlation among participants who had been recruited from the same study site, we estimated regression parameter CIs using cluster bootstrapping on site, which is the choice that is preferable to generalized estimating equations when the number of clusters is small (eg, 6 study sites), especially in the setting of a binary response.[36] We scaled the estimated odds ratios (ORs) and 95% CIs to a 20-point change in exposure score. The 20-point change effectively represents a one-fifth (quintile) range within a 100-point scaled score.

We performed 3 additional sensitivity analyses as follows: an additional analysis of rhinitis with the toxicant exposure score considered in tertiles; an analysis in which we added an additional covariate to the main model (ie, exposure to civilian job–related VGDF, scored as binary yes or no responses based on the longest-held civilian occupation as an adult older than 18 years and at least 1 year in the job); and an analysis restricted to men only.

RESULTS

Of the 6913 eligible individuals, 2299 (33.3%) agreed to participate and 1967 completed onsite visits. We excluded 5 participants who did not complete the questionnaire protocol and 2 with missing respiratory symptom outcome data. The remaining 1960 veterans were predominantly male (88.5%) and White non-Hispanic (67.9%), with a mean age of 40.7 ± 9.7 years (Table I). Most participants were overweight (41.1%) or obese (44.1%); 54.6% were never smokers. The majority served in the Army (60.4%) and had only 1 deployment (57%). The median time elapsed since last deployment until study interview was 120 months.

Sinusitis and rhinitis prevalence and clinical characteristics

The prevalence of reporting ever having sinusitis among the entire cohort was 15.2% (297 participants), with 2.1% reporting incident sinusitis during deployment and 5.1% reporting with incident sinusitis after deployment (Table II). Among those with postdeployment sinusitis as well as information on age at onset (n = 95), the median number of years between last deployment and postdeployment onset was 5.0 years (interquartile range = 3.0-9.0 years). Approximately 30% of participants with incident sinusitis during or after deployment had experienced their last episode within a year of the study visit compared with 19% of participants with predeployment onset of sinusitis. Similar percentages of participants with sinusitis onset before, during, and after deployment had episodes of sinusitis more than once (75%-85%), had ever received antibiotics for their sinusitis (82%-84%), and had undergone sinus radiographic imaging (31%-36%).

The prevalence of rhinitis among the entire cohort was 28.6% (60 participants), with 3.6% reporting incident rhinitis onset during deployment and 5.6% reporting onset after deployment (Table III). Among those with postdeployment onset of rhinitis and information on age at onset (n = 108), the median number of years between last deployment and postdeployment onset

TABLE I. Participant characteristics (n = 1960)

Characteristic	Value
Age (y)	40.7 (9.7)
Male sex, no. (%)	1734 (88.5)
Race/ethnicity, no. (%)	
White	1331 (67.9)
Black or African American	292 (14.9)
Asian or Pacific Islander	94 (4.8)
American Indian/Alaskan Native	13 (0.7)
Multiracial or other	213 (10.9)
Missing/declined to answer	17 (0.9)
Any Hispanic	282 (14.4)
White Hispanic	150 (7.7)
Black Hispanic	12 (0.6)
Current education level, no. (%)*	
<High school	1 (0.1)
High school/General Educational Development certificate	172 (8.8)
Some college	452 (23.1)
Associate degree	322 (16.4)
Bachelor's degree	618 (31.5)
≥Master's degree	394 (20.1)
Body mass index (kg/m^2), no. (%)	
<25	289 (14.7)
25 to <30	806 (41.1)
≥30	865 (44.1)
Cigarette smoking, no. (%)	
Never	1071 (54.6)
Former	633 (32.3)
Current	256 (13.1)
Civilian job–related VGDF exposure, no. (%)†	594 (30.3)
Military branch, no. (%)	
Army	1183 (60.4)
Air Force	318 (16.2)
Marines	429 (21.9)
Mixed/other	30 (1.5)
Deployment characteristic, median (IQR)	
Duration (mo)	11.7 (7.4-16.1)
Time since last deployment (mo)	120 (89.8-156.7)
Deployments, no. (%)‡	
1	1118 (57.0)
2	573 (29.2)
≥3	262 (13.4)

IQR, Interquartile range.
*Data missing for 1 participant.
†Data missing for 51 participants.
‡Data missing for 7 participants.

was 4.0 (interquartile range = 2.0-7.0) years. The number of new cases of rhinitis in which onset occurred after deployment decreased as the years since last deployment progressed (Fig 1). Those with postdeployment onset rhinitis had fewer formal diagnoses from a health care professional than did those in whom onset occurred in other periods relative to deployment, although overall approximately 40% of cases in any period were undiagnosed (Table III). Many participants with rhinitis regardless of onset period still reported having the condition (76%-84%). Similar percentages of participants regardless of period in which onset occurred had used medication for rhinitis in the past year (53%-62%) or had received allergy shots (3%-5%). There was little concurrence between rhinitis and sinusitis onset before deployment and during or after deployment: only 80 (4.1%) and 35 (1.8%) participants responded affirmatively to having both conditions, respectively.

Associations with exposure

The results of the adjusted analyses are shown in Figs 2 and 3 and Table E2 (see the Online Repository at www.jaci-global.org), which present the ORs and 95% CIs associated with each of the 5 exposures per 20-unit increase in exposure category score along with a summary of exposure scores. In the adjusted models, toxicant exposure was positively and significantly associated with rhinitis during or after deployment (OR =1.38 [95% CI = 1.15-1.60]). Burn pit smoke and other open combustion sources were not associated with increased odds of rhinitis onset. Engine exhaust/ground dust and military job–related VGDFs were associated with marginally increased but nonstatistically significant odds of rhinitis. In further analysis, rhinitis onset during deployment was associated with a 50% increase in odds with toxicant exposure (OR = 1.50 [95% CI = 1.31-1.84]), whereas rhinitis onset after deployment was associated with a 21% increase in odds with toxicant exposure (OR = 1.21 [95% CI = 0.93-1.50]) (Table IV). There were no statistically significant associations between the exposure scores with sinusitis, other than a suggestive association with military job–related VGDFs (OR = 1.22 [95% CI = 0.90-1.57]).

In a sensitivity analysis treating toxicant exposure score as an ordinal categoric value, the ORs remained positive and the highest exposure tertile of toxicant score was associated with the highest OR (2.46 [95% CI = 1.52-4.87]) (see Table E3 in the Online Repository at www.jaci-global.org). Adding civilian job–related VGDFs to the regression models did not alter our results substantially (see Table E4 in the Online Repository at www.jaci-global.org). The ORs for female sex were 4.54 (95% CI = 2.66-6.38) and 1.86 (95% CI = 0.76-3.24) for sinusitis and rhinitis during and after deployment, respectively (see Table E2). When we repeated the main analysis excluding females, the results did not change meaningfully (see Table E5 in the Online Repository at www.jaci-global.org).

DISCUSSION

In this analysis of post-9/11 US military veterans with land-based deployment to Afghanistan and Southwest Asia who had been recruited independent of any symptoms, we observed a strong association between select toxicants, predominantly self-exposure to pesticides or insect repellents on skin or clothing, and rhinitis. The odds were greatest for incident rhinitis during deployment, although many participants reported current rhinitis symptoms. Furthermore, although postdeployment onset rhinitis associated with toxicants did not reach statistical significance, incident cases declined steadily since last deployment, suggesting that deployment was a critical exposure event. There was no association for a range of other deployment-related exposures, including burn pits, nor was there an association for sinusitis.

The overall prevalence of sinusitis or rhinitis that we observed in our cohort is similar to that reported for nonmilitary cohorts in the United States: approximately 11% to 12% for sinusitis and 25% for rhinitis.[26,28] Upper respiratory tract conditions, including rhinitis, are of potential concern following military deployment.[22] In a 2014 mail survey of 20,563 Operation Enduring Freedom (OEF)/Operation Iraqi Freedom (OIF) veterans, Barth et al found that deployed veterans were 30% more likely to report sinusitis than nondeployed veterans were.[23] The estimated prevalence was 6.9% in post-2001 deployed veterans, which is similar to the combined prevalence that we observed (ie, 2.1% during

TABLE II. Characteristics of sinusitis based on time of onset in 1960 deployed veterans

Characteristic	Onset before deployment (n = 155 [7.9%])	Onset during deployment(s) (n = 42 [2.1%])	Onset after deployment (n = 100 [5.1%])
Time since last sinusitis incident (y), median (IQR)	6 (1-15)*	1 (0-4)†	2 (0-5)‡
Sinusitis within 1 y of study visit, no. (%)	28 (19.3)*	11 (31.4)†	30 (30.6)‡
Had sinusitis more than once, no. (%)	132 (85.2)	33 (78.6)	75 (75.0)
Sinusitis ever treated with antibiotics, no. (%)	130 (83.9)	35 (83.3)	82 (82.0)
Ever had a sinus x-ray or CT for sinusitis, n (%)	53 (34.2)	13 (31.0)	36 (36.0)

CT, Computed tomography; *IQR*, interquartile range.
*A total of 145 participants with age at last sinusitis incident are reported.
†A total of 35 participants with age at last sinusitis incident are reported.
‡A total of 98 participants with age at last sinusitis incident are reported.

TABLE III. Characteristics of rhinitis based on time of onset in 1960 deployed veterans

Characteristic, no. (%)	Before deployment (n = 381 [19.4%])	During deployment(s) (n = 70 [3.6%])	After deployment (n = 109 [5.6%])
Diagnosed by a doctor or other health professional	240 (63.0)	39 (55.7)	53 (48.6)
Still has rhinitis	290 (76.1)	59 (84.3)	91 (83.5)
Used medication for rhinitis in the past 12 mo	203 (53.3)	44 (62.9)	68 (62.4)
Currently receiving allergy shots	13 (3.4)	4 (5.7)	5 (5.0)

deployment and 5.1% after deployment). According to self-report in another study, veterans with at least 1 exposure during deployment were approximately 80% more likely to report sinusitis.[37] In a 2021 study of veterans with an encounter in the VA Desert Pacific Healthcare Network (based on International Classification of Diseases codes) between 2016 and 2019, Tam et al found that the prevalence of sinonasal disease was greater among OEF/OIF veterans than among non-OEF/OIF veterans.[24]

Close contact with pesticides or insect repellents emerged as the salient risk factor for rhinitis and is consistent with field conditions. Because military personnel are at risk of insect-borne diseases, common preventive measures during deployment include wearing permethrin-treated uniforms and applying insect repellents to exposed skin (this refers mainly to those agents that contain *N,N*-diethyl-*meta*-toluamide [DEET], with alternatives such as picardin or IR3535).[38] The US Environmental Protection Agency has reported thorough safety testing for use of permethrin on clothing from the standpoint of skin absorption; however, US Environmental Protection Agency, and others note that there are no acceptable data on acute inhalation toxicity.[39,40] A 2022 study by Lee et al demonstrated that inhalation of permethrin induces a dose-dependent increase in reactive oxygen species in sinonasal epithelial cells.[41] Per report from 2 of our coauthors (P.C. and C.B.), early in the post-9/11 conflicts uniforms were mainly treated with permethrin by the individual owner. Kits and sprays with concentrations that did not require respiratory protection were provided for this purpose even though military personnel were instructed to avoid contact of permethrin with mucosal surfaces.[42] Higher concentrations of permethrin spray were sometimes used, but only by trained personnel required to wear respiratory protection. Individual application of permethrin was phased out when military departments began utilizing uniforms pretreated by the manufacturer. With regard to insect repellents, the US Centers for Disease Control and Prevention reports that use of DEET on the skin is generally safe but notes that no studies assessing the effects of DEET on the airway after inhalation have been performed; moreover, there have been reports of cough, wheezing, and chest pain, suggesting airway tract entry,[43] and DEET has been demonstrated to induce dose-dependent cytotoxicity in sinonasal epithelial cells.[44] To our knowledge, there are no laboratory studies similarly assessing other insect repellants, and insect repellents have not been reported as a risk factor for rhinitis in the general population.[45,46] Although any broader pesticide use (ie, application to regions surrounding base camps) was typically done by trained contractors, studies have shown that residential exposure to commercial pesticide application within a 2000-m buffer was independently associated with an approximately 2.5-fold increase in the odds of being diagnosed with sinusitis.[47] Although rhinitis was not assessed, these results suggest that there is an association between pesticide exposure and sinonasal symptoms. It is relevant that many of those who reported rhinitis onset during or after deployment rhinitis reported still having such symptoms at the time of their interviews, which is consistent with reports that occupational rhinitis may persist even after separating from the workplace.[48,49] Finally, an additional or alternative explanation of our findings is that those with rhinitis during deployment may have been using repellents as a general protective measure during deployment more so than others did.

We studied self-reported exposures and outcomes, an approach that could lead to misclassification or recall bias. However, our study design used *a priori* exposure groupings spanning a range of potential exposures, and our use of confirmatory factor analysis to reduce heavily collinear exposures minimizes recall bias and reduces the effects of intersubject variability. We also provided a standard definition of heavy exposure to the participant and asked each participant to classify person days of exposure for each exposure-related question. Of note, the patterns of associations differed from those in the 2023 analysis by Garshick et al focusing on lower respiratory tract symptoms in the same cohort,[32] which supports lack of reporting bias. Furthermore, the lack of an association with burn pit smoke, which has been heavily publicized in the media, supports this idea as well. The associations between exposure category and our 2 outcomes also differed, making it unlikely that reporting bias contributes to the associations.

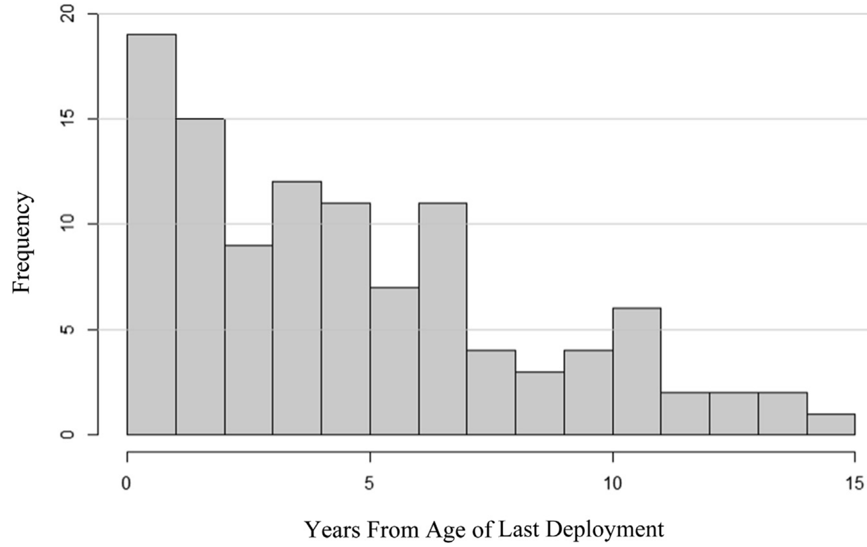
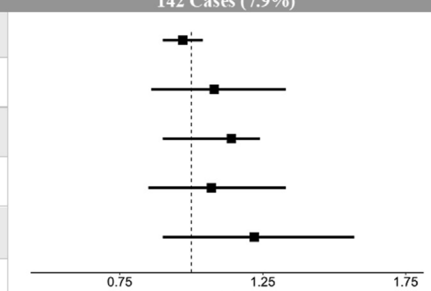


FIG 1. Frequency of postdeployment rhinitis per each successive year after deployment (n = 100).

Exposure Category	Exposure Score Median (IQR)	Sinusitis 142 Cases (7.9%)	OR (95% CI)
Burn pit smoke	25.0 (0.0, 62.5)		0.97 (0.90, 1.04)
Engine exhaust/ground dust	37.5 (18.8, 50.0)		1.08 (0.86, 1.33)
Other open combustion sources	12.5 (0.0, 37.5)		1.14 (0.90, 1.24)
Toxicants	0.0 (0.0, 33.3)		1.07 (0.85, 1.33)
Military Job-Related VGDF	11.1 (0.0, 22.2)		1.22 (0.90, 1.57)



Models adjusted for smoking status (never, former, current), age, race, sex, and body mass index category (<25, 25 - <30, =30).
OR= Odds Ratio. ORs expressed per 20-point score interval.
IQR= Interquartile range. Exposure score scaled to 100.
VGDF = vapors, gas, dust, or fumes

FIG 2. Multivariable associations between exposure categories and sinusitis during and after deployment (n = 1805).

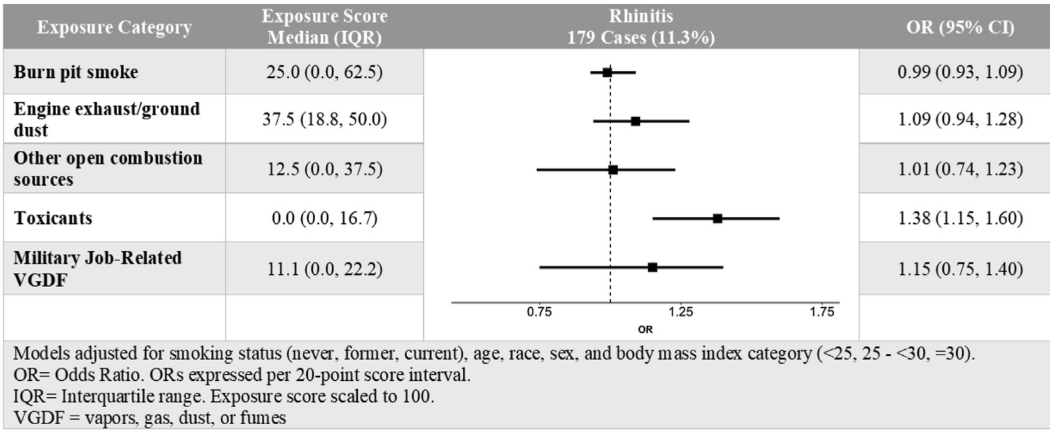
Our definition of rhinitis, unlike the definition used for sinusitis, did not require diagnosis by a health care provider. We took this approach because patients may not report rhinitis symptoms and are thus unlikely to have a formal diagnosis by their health care team. Although we did not ask about nonallergic rhinitis, it is likely that lay persons consider all rhinitis to be "hay fever." Thus, it is likely that the response to the question on rhinitis included participants with nonallergic rhinitis. Importantly, only 1% to 4% reported both sinusitis and rhinitis, suggesting that participants understood the delineation between the 2 diseases.

There are several other potential limitations to this study. Our exposure battery was developed for this study and has not been externally validated in other cohorts of previously deployed veterans. We carried out this analysis using the initial phase of data collection from a larger study in which data collection was suspended during the COVID-19 pandemic; thus, the number of subjects included was not driven by considerations of study size and power. Our participants were recruited at only a select number of centers that may not be generalizable to other regions of the United States. We did not have any questions in the survey that would have allowed us to assess for worsening of predeployment rhinitis or sinusitis after deployment. We did not ask about the use of respiratory protection during deployment. There was no theater-wide requirement or recommendation for the use of respiratory protection, although according to 1 of our coauthors (P.C.), some individuals chose to wear N95 masks or "military respirators" and others were required to do so for specific occupational duties.

Despite these limitations, we believe that our analysis provides important insight into environmental and occupational exposures as contributors to upper respiratory tract disease in veterans during and after deployment. These findings will aid medical practitioners who care for veterans in recognizing the potential exposures that veterans experience during deployment and to screen for diseases that may be related, particularly rhinitis.

DISCLOSURE STATEMENT

Supported by the VA Cooperative Studies Program 595: Pulmonary Health and Deployment to Southwest Asia and



Exposure Category	Exposure Score Median (IQR)	Rhinitis 179 Cases (11.3%)	OR (95% CI)
Burn pit smoke	25.0 (0.0, 62.5)		0.99 (0.93, 1.09)
Engine exhaust/ground dust	37.5 (18.8, 50.0)		1.09 (0.94, 1.28)
Other open combustion sources	12.5 (0.0, 37.5)		1.01 (0.74, 1.23)
Toxicants	0.0 (0.0, 16.7)		1.38 (1.15, 1.60)
Military Job-Related VGDF	11.1 (0.0, 22.2)		1.15 (0.75, 1.40)

Models adjusted for smoking status (never, former, current), age, race, sex, and body mass index category (<25, 25 - <30, =30).
OR= Odds Ratio. ORs expressed per 20-point score interval.
IQR= Interquartile range. Exposure score scaled to 100.
VGDF = vapors, gas, dust, or fumes

FIG 3. Multivariable associations between exposure categories and rhinitis during and after deployment (n = 1579).

TABLE IV. Multivariable associations between exposure categories and rhinitis, stratified by onset during deployment versus after deployment

	Multivariable association			
	Rhinitis during deployment (n = 70 of 1470)		Rhinitis after deployment (n = 109 of 1509)	
Exposure category	OR*	95% CI	OR*	95% CI
Burn pit smoke	1.05	0.89-1.18	0.98	0.92-1.10
Engine exhaust/ground dust	1.21	0.96-1.66	1.02	0.90-1.19
Other open combustion sources	1.05	0.67-1.47	1.03	0.77-1.27
Toxicants	1.50	1.31-1.84	1.21	0.93-1.50
Military job–related VGDF	1.06	0.63-1.45	1.17	0.96-1.44

Models adjusted for smoking status (never, former, or current), age, race, sex, and body mass index category (<25 kg/m^2, 25 to <30 kg/m^2, and ≥ 30 kg/m^2).
*ORs expressed per 20-point score change.

Afghanistan, also known as SHADE (Service and Health Among Deployed Veterans) from the US Department of Veterans Affairs, Office of Research and Development, Clinical Science Research and Development, Cooperative Studies Program. The contents do not represent the views of the US Department of Veterans Affairs or the US Government.

Disclosure of potential conflict of interest: E. S. Wan has served on a scientific advisory board for Verona Pharma, outside the current work. The rest of the authors declare that they have no relevant conflicts of interest.

Data availability statement: The data underlying this article cannot be shared publicly because of privacy restrictions in place related to the study. The data will be shared on reasonable request after obtaining the required permissions and approvals; interested parties should contact the corresponding author.

Clinical implications: Our results suggest that providers caring for veterans should inquire about deployment-related environmental and occupational exposures and upper respiratory tract symptoms and conditions.

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