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ORIGINAL RESEARCH

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Association of prior military service with olfactory function among older adults

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Abstract

Objective: Olfactory dysfunction (OD) is a condition primarily affecting older adults. Several factors have been implicated in OD, such as age, socioeconomic status, and neurodegenerative disease; however, the effect of military service still requires additional investigation. Here, we aim to determine if there is an association between prior military service and OD among older adults.

Methods: This cross-sectional study included 2268 adults from Round 1 of the National Social Life, Health, and Aging Project. OD was defined as 0–3 odors correctly identified on the 5-item Sniffin' Sticks test. Bivariate analysis was conducted to calculate crude odds ratios (cOR) for the association of prior military service with OD and identify covariates for regression. Associations between prior military service and OD were assessed using logistic regression, and adjusted odds ratios (aOR) were calculated controlling for age, gender, race/ethnicity, education, stroke history, dementia, diabetes, and mental health. All analyses were weighted using survey weights to account for sampling design.

Results: OD was present in 489 adults (21.6%). Among those with OD, the average age was 71.0 ± 7.9 years, whereas the average age in those without OD was 67.0 ± 7.2 years. Among adults with OD, 34.4% reported prior military service, compared to 27.7% of adults without OD (cOR = 1.37; 95% CI: 1.05–1.79). However, after adjusting for covariates, prior military service was not associated with OD (aOR: 1.09; 95% CI: 0.79–1.50). Older age (aOR: 1.07; 95% CI: 1.05–1.09) and worse mental health (aOR: 1.68; 95% CI: 1.14–2.49) were associated with OD.

Conclusion: Prior military service was not associated with OD among older adults after controlling for covariates. More nuanced research is needed to examine

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correlations between OD and specific elements of military service such as duration, toxin exposure, and head trauma.
Level of Evidence: Level 4.

KEYWORDS
anosmia, military, older adults, olfactory dysfunction, veterans

1 | INTRODUCTION

Olfactory dysfunction (OD) is a multifactorial condition that commonly impacts the older adult population.[1] Among civilians, several common risk factors have been identified, including upper respiratory tract illness, neurodegenerative diseases, diabetes, smoking, and low socioeconomic status.[2,3] However, veterans experience a unique set of environmental exposures, with commonly implicated factors, including head trauma, toxins, and blast exposures.[4–6] Despite independent associations between these risk factors and OD, some studies have suggested that there are no long-term associations between military service and OD.[1] Given the myriad possible exposures veterans experience during their service, we aimed to further study the association between prior military service and OD, particularly among older adult veterans who served during the mid-1900s (World War II, Korean War, or Vietnam War), given their unique characteristics of trauma and toxin exposures.

The olfactory receptors located in the nasal epithelium, which is in direct contact with the external environment, are susceptible to environmental toxins. Such toxins can impact these receptors or potentially traverse them and enter into the brain through the olfactory nerves.[4] Several toxins have been implicated in affecting the olfactory system such as lead, chlorine, benzyl acetate, and sulfur dioxide, to name a few, some of which have been used in warfare.[7,8] More specifically, the Vietnam and Korean Wars saw the widespread use of herbicidal and pesticidal agents whose impact on the nasal epithelium has been sparsely studied. However, prior literature has described a modest association between OD and agents such as 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) and 2,4-dichlorophenoxyacetic acid (2,4-D), chemicals used in the herbicides "Agent Orange" and "Agent White."[9,10]

Head trauma resulting in damage to the skull base or leading to intracranial hemorrhage or hematoma is also a known cause of OD.[5] A recent study investigating mild traumatic brain injury (mTBI) in post-9/11 era veterans (Operations Enduring Freedom, Iraqi Freedom, and New Dawn) found no association with objective odor identification dysfunction[11]; however, characteristics of head trauma were much different during the wars of the mid-1900s. Compared to younger veterans of the post-9/11 era who had a higher rate of nonpenetrating or blast-associated TBI, older veterans of World War II, the Korean War, and the Vietnam War were more likely to experience penetrating TBI.[12–15] Thus, the impact on olfaction may be different, especially given evidence showing that the degree of olfactory impairment is linked to the severity of TBI.[6]

Given these considerations, our proposed study aims to better characterize the prevalence of OD among older veterans and further explore the potential association between military service and OD among this population by analyzing a large dataset from the National Social Life, Health, and Aging Project (NSHAP).[16] We believe our study contributes to existing literature on this topic and offers additional evidence from a nationally representative cohort using objective measures of OD.

2 | METHODS

The analysis in this cross-sectional study utilized data from Round 1 of the National Social Life, Health, and Aging Project (NSHAP). Because NSHAP is a de-identified public dataset, this study was determined exempt by the institutional review board.

NSHAP is a nationally representative study that focuses on the health and social aspects of older, community-dwelling Americans. Participants were aged 57–85 years old at the time of the study (born 1920–1948) and resided in a private household. For veterans in this cohort, this age range would likely correspond to military service in World War II, the Korean War, or the Vietnam War. Household sampling in Round 1 of NSHAP was derived from the 2004 Health and Retirement Study, which included both urban and nonurban households.[16,17] The data were collected through face-to-face interviews, biomeasurement via physical specimens such as blood and saliva, and cognitive function testing.[16] For our study, we specifically selected individuals from this dataset who took part in the 5-item Sniffin' Sticks test. The 5-item Sniffin' Sticks odor identification test is a modified version of the original 16-item test, which is a validated tool for evaluating an individual's olfactory function.[18,19] Based on prior literature, we defined olfactory dysfunction (OD) as identifying 0–3 odors correctly, and normal olfactory function as identifying 4–5 odors correctly on the 5-item Sniffin' Sticks test.[18,20] Participant-reported prior active military service was included as the exposure of interest. Additionally, we included data on various characteristics known to potentially affect olfactory function, such as age, gender, race/ethnicity, education, history of stroke, diagnosed dementia or Alzheimer's disease, Parkinson's disease, diabetes, smoking status, self-rated mental health, and usage of nasal medications, drawing upon existing literature.[2,21–26] Any individual with missing outcome, exposure, or covariate data was excluded from the study.

2.1 | Statistical analysis

Baseline characteristics were calculated and stratified by olfactory function groups, and *p*-values were calculated using chi-square or *t*-

TABLE 1 Survey-weighted baseline characteristics and bivariate analysis stratified by olfactory function.

Characteristic	Weighted %		Crude odds ratio (95% CI)
	Normal olfaction ($n = 1779$)	Olfactory dysfunction ($n = 489$)	
Age	p-value ≤.001*		
Years, weighted mean ± SD	67.0 ± 7.2	71.0 ± 7.9	1.07 (1.05–1.09)
Gender	p-value = .003*		
Male	46.5	56.0	Ref
Female	53.5	44.0	0.68 (0.53–0.88)
Race/ethnicity	p-value = .001*		
White	84.6	75.5	Ref
Black	7.2	13.0	2.03 (1.31–3.14)
Hispanic, non-Black	6.0	7.4	1.39 (0.92–2.11)
Other	2.2	4.0	2.05 (1.03–4.11)
Education	p-value ≤.001*		
Some college or greater	61.1	42.5	Ref
High school or less	38.9	57.5	2.13 (1.68–2.70)
Ever had a stroke	p-value = .005*		
No	93.1	88.8	Ref
Yes	6.9	11.2	1.70 (1.17–2.47)
Dementia (including Alzheimer's)	p-value ≤.001*		
No	99.9	98.8	Ref
Yes	0.1	1.2	8.85 (2.09–37.57)
Parkinson's disease	p-value = .485		
No	98.4	97.8	Ref
Yes	1.6	2.2	1.36 (0.57–3.27)
Diabetes	p-value = .231		
No	81.8	79.2	Ref
Yes	18.2	20.8	1.18 (0.90–1.54)
Taking any nasal medications	p-value = .662		
No	98.0	97.5	Ref
Yes	2.0	2.5	1.22 (0.49–3.04)
Self-rated mental health	p-value ≤.001*		
Good/very good/excellent	92.1	84.6	Ref
Poor/fair	7.9	15.4	2.12 (1.53–2.95)
Current smoker	p-value = .810		
No	85.6	85.1	Ref
Yes	14.4	14.9	1.05 (0.73–1.50)
Prior military service	p-value = .022*		
No	72.3	65.6	Ref
Yes	27.7	34.4	1.37 (1.05–1.79)

Abbreviation: SD, standard deviation.
*p <.05.

test, as appropriate. Bivariate analysis was also conducted to determine crude odds ratios (cOR). Covariates that were statistically significant in bivariate analysis, examining associations of covariates with OD as well as military service, were included in a multivariable logistic regression model to determine characteristics associated with OD. Adjusted odds ratios (aOR) and 95% confidence intervals (CI) were calculated. The primary outcome of our study was the association between prior military service and OD, whereas our secondary outcomes were the associations between study covariates and OD.

To account for sampling design, all analyses were weighted using NSHAP-provided survey weights. A p-value of <.05 was used to denote statistical significance for all statistical tests. Statistical analysis

TABLE 2 Survey-weighted and adjusted associations of prior military service and covariates with olfactory dysfunction.

Covariates	Adjusted odds ratio (95% confidence interval)
Prior military service	1.09 (0.79–1.50)
Age (years)	1.07* (1.05–1.09)
Gender, female	0.61* (0.47–0.80)
Race/ethnicity	
White	Ref
Black	2.20* (1.44–3.34)
Hispanic, non-Black	1.26 (0.87–1.83)
Other	2.37* (1.20–4.69)
Education	
Some college or greater	Ref
High school or less	1.73* (1.34–2.24)
Stroke in the last 5 years	1.22 (0.78–1.91)
Dementia, including Alzheimer's	5.13* (1.61–16.40)
Diabetes	1.06 (0.79–1.41)
Self-rated mental health	
Good/very good/ excellent	Ref
Poor/fair	1.68* (1.14–2.49)

*p <.05.

was conducted using R, version 4.1.2 (R Foundation for Statistical Computing, Vienna, Austria).

3 | RESULTS

Round 1 of NSHAP includes a total of 3005 participants. We subsequently identified 2778 individuals who participated in the 5-item Sniffin' Sticks test. Of these, 493 were omitted for missing data on prior military service, 8 were omitted for missing race/ethnicity data, 8 were omitted due to refusal to self-report mental health status, and 1 was omitted due to missing data on cigarette use. The remaining 2268 individuals were included in our study, of whom 489 (21.6%) had OD and 661 (29.1%) had prior military service. Among this population of 2268, the weighted mean age was 67.8 years, 83.0% identified as White, and 51.8% identified as female Weighted percentages for baseline characteristics, stratified by olfactory function, are listed in Table 1. Bivariate analysis revealed that those with OD were more likely to be older (p <.001), male ($p = .003$), non-White ($p = .001$), without a college degree (p <.001), and have a poorer self-rated mental health status (p <.001), and were also more likely to have other comorbidities such as prior stroke ($p = .005$) and dementia (p <.001). Notably, a greater proportion of those with OD reported prior military service ($p = .022$).

The results for the multivariable logistic regression, controlling for covariates that were statistically significant in bivariate analysis, are listed in Table 2. Covariates that were significantly associated with an increased likelihood of OD included older age (aOR: 1.07; 95% CI: 1.05–1.09), Black (aOR: 2.20; 95% CI: 1.44–3.34) and other race (aOR: 2.37; 95% CI: 1.20–4.69) as compared to Whites, less education (aOR: 1.73; 95% CI: 1.34–2.24) for high school or less as compared to having some college of more, diagnosed dementia or Alzheimer's disease (aOR: 5.13; 95% CI: 1.61–16.40), and self-rated poor/fair mental health (aOR: 1.68; 95% CI: 1.14–2.49) as compared to self-rated good/excellent mental health. On the other hand, female gender (aOR: 0.61; 95% CI: 0.47–0.80) was associated with a lower likelihood of OD. Compared to those with no prior military service, prior military service was associated with OD in bivariate analysis (cOR: 1.37; 95% CI: 1.05–1.79); however, this association disappeared after controlling for covariates (aOR: 1.09; 95% CI: 0.79–1.50).

4 | DISCUSSION

In this study, our primary aim was to investigate the relationship between prior military service and the incidence of OD within an older demographic. While military personnel are more likely to be exposed to unique OD risk factors, such as environmental toxins and head trauma,[4,5] our results did not find a significant association between military service and OD among older adults after controlling for covariates. Our findings align with those of Noel et al.,[1] who, using the National Health and Nutrition Examination Survey (NHANES) data, found no significant association between military service and OD. However, compared to NHANES, NSHAP focuses on an older study population of adults 57 and older. Moreover, while Noel et al. only examined associations between military service and self-reported OD, our study investigated this association using objective measures of OD.

Beyond our study's main focus, we also found that age, race, gender, education, dementia, and self-rated mental health were significantly associated with OD after controlling for covariates. Prior research utilizing the NSHAP dataset has underscored a positive association of OD with male gender, older age, and Black race.[27,28] Our study's findings regarding the positive association of OD with dementia and lack of college education in the context of NSHAP data are in line with extensive prior literature investigating these associations.[21,29,30] Additionally, although prior literature has established an association between OD and objective measures of depression,[23,31] our study found a significant association between OD and poorer self-reported mental health, which has not been as thoroughly reported. These insights may provide clinicians additional knowledge on risk factors and warning signs associated with OD and help inform future research on the underlying mechanisms of OD.

Our study has certain limitations. Given its cross-sectional nature, causation could not be established. Numerous factors may have also introduced bias, including the self-reported nature of military service, reliance on secondary data for other covariates, requirement for NSHAP participants to reside in a private household in the context of higher rates of homelessness among veterans,[32] and survivorship bias associated with studying an older population. Moreover, omission of data from individuals who refused to report their prior military service

and those who did not participate in the Sniffin' Sticks test could have introduced nonresponse bias. Another limitation is the lack of detailed information on the nature and extent of military service and exposure to head trauma and environmental toxins, which are helpful to develop a thorough understanding of the relationship between military service and OD. Our dataset's broad categorization of military service unfortunately does not capture the diverse experiences of veterans and potentially oversimplifies the complex relationship between military service and OD.

In conclusion, while military service was not independently associated with an increased risk of OD, we found associations with dementia, education level, and self-rated mental health, as well as with age, race, and gender; however, the latter variables have already been explored in prior studies using NSHAP data.[27,28] Further studies should conduct a more nuanced exploration of the relationship between military service and OD by examining factors such as exposure to head trauma, environmental toxins, and duration of service. Additionally, older veterans such as those included in this study have distinct military exposures and trauma characteristics compared to younger veterans of the post-9/11 era, with the latter having had greater exposure to burn pits and increased rates of non-penetrative and mild TBI.[13,14,33] Thus, future studies should also investigate associations between these exposures and OD among younger veterans as the conclusions in this study are not generalizable to veterans of all ages.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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REFERENCES

1. Noel J, Habib A-RR, Thamboo A, Patel ZM. Variables associated with olfactory disorders in adults: a U.S. population-based analysis. *World J Otorhinolaryngol Head Neck Surg*. 2017;3:9-16.
2. Liu G, Zong G, Doty RL, Sun Q. Prevalence and risk factors of taste and smell impairment in a nationwide representative sample of the US population: a cross-sectional study. *BMJ Open*. 2016;6:e013246.
3. Murphy C, Schubert CR, Cruickshanks KJ, Klein BE, Klein R, Nondahl DM. Prevalence of olfactory impairment in older adults. *JAMA*. 2002;288:2307-2312.
4. Doty RL. Neurotoxic exposure and impairment of the chemical senses of taste and smell. *Handb Clin Neurol*. 2015;131:299-324.
5. Haxel BR, Grant L, Mackay-Sim A. Olfactory dysfunction after head injury. *J Head Trauma Rehabil*. 2008;23:407-413.
6. Schofield PW, Moore TM, Gardner A. Traumatic brain injury and olfaction: a systematic review. *Front Neurol*. 2014;5. doi:10.3389/fneur.2014.00005
7. Upadhyay UD, Holbrook EH. Olfactory loss as a result of toxic exposure. *Otolaryngol Clin North Am*. 2004;37:1185-1207.
8. Ganesan K, Raza SK, Vijayaraghavan R. Chemical warfare agents. *J Pharm Bioallied Sci*. 2010;2:166-178.
9. Shrestha S, Umbach DM, Beane Freeman LE, et al. Occupational pesticide use and self-reported olfactory impairment in United States farmers. *Occup Environ Med*. 2020;2020:oemed-2020-106818.
10. Institute of Medicine (US) Committee on Blue Water Navy Vietnam Veterans and Agent Orange (last). Selected chemicals used during the Vietnam war. *Blue Water Navy Vietnam Veterans and Agent Orange Exposure*. National Academies Press (US); 2011 Accessed June 19, 2024. https://www.ncbi.nlm.nih.gov/books/NBK209597/
11. Rothman DJ, McDonald SD, Walker WC, Feldman G. Olfactory changes after military deployment are associated with emotional distress but not with mild traumatic brain injury history. *Am J Phys Med Rehabil*. 2022;101:423-428.
12. Walker AE, Jablon S. A follow-up of head-injured men of world war II. 1959;16:600-610. doi:10.3171/jns.1959.16.6.0600
13. Guevara AB, Demonet J-F, Polejaeva E, et al. Association between long-term cognitive decline in Vietnam veterans with TBI and caregiver attachment style. *J Head Trauma Rehabil*. 2015;30:E26-E33.
14. French LM. Military traumatic brain injury: an examination of important differences. *Ann N Y Acad Sci*. 2010;1208:38-45.
15. Santiago LA, Oh BC, Dash PK, Holcomb JB, Wade CE. A clinical comparison of penetrating and blunt traumatic brain injuries. *Brain Inj*. 2012;26:107-125.
16. Waite LJ, Laumann EO, Levinson WS, Lindau ST, O'Muircheartaigh CA. National social life, health, and aging project (NSHAP): round 1, [United States], 2005-2006: version 10. 2007. doi:10.3886/ICPSR20541.V10
17. O'Muircheartaigh C, Eckman S, Smith S. Statistical design and estimation for the National Social Life, health, and aging project. *J Gerontol B Psychol Sci Soc Sci*. 2009;64B:i12-i19.
18. Mueller C, Renner B. A new procedure for the short screening of olfactory function using five items from the 'Sniffin' Sticks' identification test kit. *Am J Rhinol*. 2006;20:113-116.
19. Rumeau C, Nguyen DT, Jankowski R. How to assess olfactory performance with the Sniffin' sticks test(®). *Eur Ann Otorhinolaryngol Head Neck Dis*. 2016;133:203-206.
20. Kern DW, Wroblewski KE, Schumm LP, Pinto JM, McClintock MK. Field survey measures of olfaction: the olfactory function field exam (OFFE). *Field Methods*. 2014;26:421-434.
21. Murphy C, Gilmore MM, Seery CS, Salmon DP, Lasker BR. Olfactory thresholds are associated with degree of dementia in Alzheimer's disease. *Neurobiol Aging*. 1990;11:465-469.
22. Kim SJ, Windon MJ, Lin SY. The association between diabetes and olfactory impairment in adults: a systematic review and meta-analysis. *Laryngoscope Investig Otolaryngol*. 2019;4:465-475.
23. Sivam A, Wroblewski KE, Alkorta-Aranburu G, et al. Olfactory dysfunction in older adults is associated with feelings of depression and loneliness. *Chem Senses*. 2016;41:293-299.
24. Wehling E, Naess H, Wollschlaeger D, et al. Olfactory dysfunction in chronic stroke patients. *BMC Neurol*. 2015;15:199.
25. Ross GW, Petrovitch H, Abbott RD, et al. Association of olfactory dysfunction with risk for future Parkinson's disease. *Ann Neurol*. 2008;63:167-173.
26. Siegel JK, Wroblewski KE, McClintock MK, Pinto JM. Olfactory dysfunction persists after smoking cessation and signals increased cardiovascular risk. *Int Forum Allergy Rhinol*. 2019;9:977-985.
27. Pinto JM, Wroblewski KE, Kern DW, Schumm LP, McClintock MK. The rate of age-related olfactory decline among the general population of older U.S. Adults. *J Gerontol A Biol Sci Med Sci*. 2015;70:1435-1441.
28. Pinto JM, Schumm LP, Wroblewski KE, Kern DW, McClintock M. Racial disparities in olfactory loss among older adults in the United States. *J Gerontol A Biol Sci Med Sci*. 2014;69:323-329.
29. Zou Y, Lu D, Liu L, Zhang HH, Zhou YY. Olfactory dysfunction in Alzheimer's disease. *Neuropsychiatr Dis Treat*. 2016;12:869.
30. Heian IT, Helvik A-S, Hummel T, et al. Measured and self-reported olfactory function in voluntary Norwegian adults. *Eur Arch Otorhinolaryngol*. 2022;279:4925-4933.

31. Gopinath B, Anstey KJ, Sue CM, Kifley A, Mitchell P. Olfactory impairment in older adults is associated with depressive symptoms and poorer quality of life scores. *Am J Geriatr Psychiatry*. 2011;19:830-834.
32. Fargo J, Metraux S, Byrne T, Munley E, Montgomery AE, Jones H. Prevalence and risk of homelessness among US veterans. *Prev Chronic Dis*. 2012;9:E45.
33. Woskie SR, Bello A, Rennix C, Jiang L, Trivedi AN, Savitz DA. Burn pit exposure assessment to support a cohort study of US veterans of the wars in Iraq and Afghanistan. *J Occup Environ Med*. 2023;65:449-457.

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