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Physical health of Post-9/11 U.S. Military veterans in the context of Healthy People 2020 targeted topic areas: Results from the Comparative Health Assessment Interview Research Study

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ABSTRACT

Large-scale epidemiological studies suggest that veterans may have poorer physical health than nonveterans, but this has been largely unexamined in post-9/11 veterans despite research indicating their high levels of disability and healthcare utilization. Additionally, little investigation has been conducted on sex-based differences and interactions by veteran status. Notably, few studies have explored veteran physical health in relation to national health guidelines. Self-reported, weighted data were analyzed on post-9/11 U.S. veterans and nonveterans (n = 19,693; 6,992 women, 12,701 men; 15,160 veterans, 4,533 nonveterans). Prevalence was estimated for 24 physical health conditions classified by Healthy People 2020 targeted topic areas. Associations between physical health outcomes and veteran status were evaluated using bivariable and multivariable analyses. Back/neck pain was most reported by veterans (49.3 %), twice that of nonveterans (22.8 %)($p < 0.001$). Adjusted odds ratios (AORs) for musculoskeletal and hearing disorders, traumatic brain injury, and chronic fatigue syndrome (CFS) were 3–6 times higher in veterans versus nonveterans ($p < 0.001$). Women versus men had the greatest adjusted odds for bladder infections (males:females, AOR = 0.08, 95 % CI:0.04–0.18)($p < 0.001$), and greater odds than men for multiple sclerosis, CFS, cancer, irritable bowel syndrome/colitis, respiratory disease, some musculoskeletal disorders, and vision loss ($p < 0.05$). Cardiovascular-related conditions were most prominent for men ($p < 0.001$). Veteran status by sex interactions were found for obesity ($p < 0.03$; greater for male veterans) and migraine ($p < 0.01$; greater for females). Healthy People 2020 targeted topic areas exclude some important physical health conditions that are associated with being a veteran. National health guidelines for Americans should provide greater consideration of veterans in their design.

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Abbreviations

AOR	Adjusted odds ratio
BMI	Body mass index
CHAI	Comparative Health Assessment Interview Research Study
Chisq	Chi-square
CI	Confidence interval
COPD	Chronic obstructive pulmonary disease
DoD	U.S. Department of Defense
in	Inches
kg	Kilograms
lbs	Pounds
LGBT	Lesbian, Gay, Bisexual, and Transgender
M	Mean
m^2	Meters squared
OEF/OIF/OND	Operation Enduring Freedom/Operation Iraqi Freedom/Operation New Dawn
OR	Odds ratio
Pr	Probability
PTSD	Posttraumatic stress disorder
RR	Relative risk
SE	Standard error
TBI	Traumatic brain injury
USVETS	U.S. Veterans Eligibility Trends and Statistics database
UTI	Urinary tract infection
VA	U.S. Department of Veterans Affairs
VHA	Veterans Health Administration

1. Introduction

The first Surgeon General's report on the health of U.S. citizens was released in 1979 (Ochiai et al., 2021). Four additional reports have been produced since then, with the latest report, Healthy People 2030 now in development (Ochiai et al., 2021; U.S. Department of Health and Human Services, 2022). These reports establish important, measurable benchmarks for Americans' health and well-being (U.S. Department of Health and Human Services, 2010). But despite research demonstrating that veterans may have poorer physical health than nonveterans (Agha et al., 2000; Boersma et al., 2021; Dominick et al., 2006; Hoerster et al., 2012; Kramarow and Pastor, 2012; Lehavot et al., 2012; Schult et al., 2019), the applicability of these national guidelines to veterans' health needs is unclear. Only a few studies have considered Healthy People 2020 objectives in relation to U.S. veterans (Boersma et al., 2022; Harrold et al., 2018; Kautzmann and Lancaster, 2018; Maust et al., 2019).

There are over 3 million veterans who served during Operation Enduring Freedom, Operation Iraqi Freedom, and Operation New Dawn (OEF/OIF/OND) since 2001 (Holder, 2018) and who now comprise an ever-growing proportion of all U.S. veterans (Schaeffer, 2021). Notably, research has indicated that these post-9/11 era veterans have poor physical health (Iverson et al., 2013; McAndrew et al., 2016; Waszak and Holmes, 2017) and high levels of disability (Duggal et al., 2010) and healthcare use (Bilmes, 2021; Duggal et al., 2010). The physical health conditions that have been reported include musculoskeletal disorders (Frayne et al., 2011; Gaffey et al., 2021; Gundlapalli et al., 2020; Haskell et al., 2012; Haskell et al., 2020; Higgins et al., 2017; VHA, 2017), respiratory problems (Barth et al., 2016; Barth et al., 2014), diabetes/other endocrine-based conditions (Boyko et al., 2010; Díaz Santana et al., 2017; Dursa et al., 2016; Gaffey et al., 2021; VHA, 2017), hearing loss (Dursa et al., 2016; Frayne et al., 2011; Oleksiak et al., 2012), migraines (Dursa et al., 2016; Frayne et al., 2011; Reiber et al., 2010), sleep problems (Dursa et al., 2016; Vogt et al., 2020), and brain injury (Hoge et al., 2008; Iverson et al., 2013; Reiber et al., 2010). Obesity (Breland et al., 2017; Gaffey et al., 2021; Haskell et al., 2010; Maguen et al., 2013) and cardiovascular disease risk factors, such as hypertension and dyslipidemia, have also been reported in this population and were found to be of particular concern for veterans with poor mental health status (Breland et al., 2017; Cohen et al., 2009; Frayne et al., 2011; Maguen et al., 2013). Overall, these conditions may make physical activity more challenging (Buis et al., 2011) and limit veterans' ability to maintain optimal health. Many studies were based on subsets of this population, relying on VA healthcare and administrative data for example rather than large-scale epidemiological studies designed to systematically sample the post-9/11 veteran population (i.e., users and nonusers of VA health care).

The type and frequency of physical health problems may vary by sex in post-9/11 veterans. For women, there is evidence that some musculoskeletal conditions (Frayne et al., 2011; Gaffey et al., 2021; Gundlapalli et al., 2020; Haskell et al., 2012; Haskell et al., 2020; Higgins et al., 2017), certain gastrointestinal disorders (Frayne et al., 2011; Gaffey et al., 2021), genitourinary disorders (Frayne et al., 2011), and migraine/headache (Carlson et al., 2013; Gaffey et al., 2021) are particularly prominent. Yet, conditions that are more commonly reported for male veterans such as hypertension and other cardiovascular-related issues are often a more primary focus of research even though women veterans have increasingly experienced these disorders (Danan et al., 2017; Dhruva et al., 2022; Vimalananda et al., 2013; Whitehead et al., 2019).

Veterans' physical health may differ from nonveterans as was shown in numerous studies comparing the general population of veterans to U.S. nonveterans (Agha et al., 2000; Boersma et al., 2021; Dominick et al., 2006; Hinojosa and Hinojosa, 2016; Hoerster et al., 2012; Kramarow and Pastor, 2012; Lehavot et al., 2012). Yet, the comparison of physical health specifically between post-9/11 veterans and nonveterans has not been adequately investigated and is needed to understand the consequences of military service overall on health. Despite the differences that may exist between veterans and nonveterans, or between men and women for that matter, there have been no published analyses that have tested statistical interactions involving veteran status (veterans versus nonveterans), sex, and physical health in this population.

The main aim of this analysis was to examine the association between veteran status and each of 24 physical health conditions by comparing post-9/11 veterans to a demographically similar cohort of nonveterans. We examined differences in physical health conditions first by veteran status, and then by sex. We also tested statistical interactions of veteran status by sex for each physical health outcome. Secondarily, we evaluated these conditions within the context of Healthy People 2020 targeted topic areas.

2. Methods

2.1. Study design

The 2018 Comparative Health Assessment Interview Research Study (CHAI) is a cross-sectional nationwide survey of the health and well-being of post-9/11 veterans that was administered between January and August 2018. CHAI derived the veteran sampling frame from the U.S. Department of Veterans Affairs' (VA) 2015 U.S. Veterans Eligibility Trends and Statistics (USVETS) database. Stratified random sampling was applied to obtain the veteran sample of adults 18 years of age and over (n = 67,500). Women were oversampled. Using address-based sampling, a comparison sample of nonveterans (n = 16,843) with no prior military experience was drawn from the GfK KnowledgePanel®. The GfK panel is a probability-based, nationally representative panel (n = 55,000) of the non-institutionalized U.S. adult population (Ipsos,

2022).

Of the veteran sample (n = 67,500), 38,633 veterans were asked to participate, while 16,843 nonveterans were invited to participate. The latter included active (n = 7,895; regular participants of GfK surveys) and inactive GfK panelists (n = 8,948). The veteran response rate was 39.5 % (n = 15,170 eligible, returned surveys) based primarily on the final disposition of complete and partial interviews, noncontacts, and refusals. Of the 15,170 veterans, four veterans were removed because they could not be categorized into deployment study groups due to missing data on key service and demographic variables. This left 15,166 veterans. For nonveterans, the completion rate for active panelists was 56.5 % (n = 4,458) and 8.4 % for inactive panelists (n = 752). Of these 5,210 nonveterans, 4,654 met qualification criteria (i.e., at least 18 years old with no prior military experience) and comprised 3,971 active and 683 inactive panelists. Qualification rates for active and inactive panelists were 89.1 % and 90.8 % respectively.

CHAI employed a modified Tailored Mixed-Mode Design (Dillman et al., 2014) consisting of a self-administered, web-based mobile device application with a computer-assisted telephone interview option. Data were self-reported. Further details on CHAI methods have been reported elsewhere (Blosnich et al., 2021; Hoffmire et al., 2021; Maguen et al., 2022). Participants provided informed consent prior to survey administration. Study procedures were approved by the VA Central Institutional Review Board.

2.2. Measures

Physical health outcomes. The CHAI questionnaire asked for yes/no responses on chronic physical health conditions using an item based on the 2018 National Health Interview Survey question: "Has a doctor or other healthcare provider ever told you that you had any of the following conditions?" (National Center for Health Statistics, 2018). These conditions included: irritable bowel syndrome/colitis, heart condition or disease, hypertension, high cholesterol, chronic fatigue syndrome, sleep apnea, cirrhosis, hepatitis, chronic obstructive pulmonary disease (COPD)/chronic bronchitis/emphysema, asthma, sinusitis, constrictive bronchiolitis, pulmonary fibrosis, other respiratory diseases, vision or seeing problems/loss, significant hearing loss, arthritis, back/neck pain, fractures/bone or joint injury, missing limbs/amputation, spinal cord injury, traumatic brain injury (TBI), diabetes, migraine, epilepsy/seizures, frequent bladder infections, multiple sclerosis, and cancer. The six respiratory diseases were recoded into a single dichotomous variable called 'respiratory disease,' representing a report of having at least one of the six respiratory conditions or having no respiratory conditions. Respondents who endorsed cancer were provided an open-ended response option to specify the type of cancer. Open-ended responses were recoded as cancer or not based on consensus by three authors (Y.C., A.S., E.L.).

Obesity was derived from body mass index (BMI). BMI was calculated from CHAI questions on height ("How tall are you without shoes?") and weight ("How much do you weigh without shoes? If currently pregnant, please give your usual weight before becoming pregnant") using cut-offs implemented in prior research (height: < 48 in. versus > 84 in.; weight: < 74 lbs. versus > 700 lbs.) (Breland et al., 2017). Obesity was coded dichotomously as any level of obesity (BMI $\geq$ 30 kg/m^2) (Jensen et al., 2014) or no obesity.

In total, 24 CHAI physical health conditions (i.e., irritable bowel syndrome/colitis, heart condition or disease, hypertension, high cholesterol, chronic fatigue syndrome, sleep apnea, cirrhosis, hepatitis, respiratory disease, vision problems/loss, hearing loss, arthritis, back/neck pain, fractures/bone or joint injury, missing limbs/amputation, spinal cord injury, TBI, diabetes, migraine, epilepsy/seizures, bladder infections, multiple sclerosis, cancer, obesity) were examined and classified into 11 health topic areas. Ten of these were based on 20 physical health priority topics derived from the 42 topic areas listed in Healthy People 2020 (Supplementary Table 1) (U.S. Department of Health and Human Services, 2010). These 42 topics, which also covered mental health and other areas, had been deemed most important to the well-being of the broader U.S. population and were earmarked for tracking and monitoring by federal agencies (Ochiai et al., 2021; U.S. Department of Health and Human Services, 2010). In this analysis, the ten Healthy People 2020 physical health topics used were "Arthritis, Osteoporosis, Chronic Back", "Cancer", "Diabetes", "Heart Disease and Stroke", "Nutrition and Weight Status", "Respiratory Diseases", "Sleep Health", "Vision", "Hearing and Other Sensory or Communication Disorders", and "Disability and Health." The eleventh topic, "Other Conditions," was created for conditions not covered by Healthy People topic areas.

Explanatory variables. Veteran status was ascertained by USVETS and a survey screener; for nonveterans, the Gfk KnowledgePanel® and main survey were used. Sociodemographic characteristics included sex, age (years), race/ethnicity (non-Hispanic White, Black, and other race; non-Hispanic, two or more races; Hispanic), education, current marital status, and region (U.S. Census Bureau, 2022).

2.3. Statistical analyses

Descriptive statistics were calculated by veteran status. Categorical associations were evaluated using the design-adjusted Rao-Scott chi-square test (Heeringa et al., 2017). P-values $\leq$ 0.05 were statistically significant, based on two-tailed tests, and adjusted, where applicable, for multiple, pairwise comparisons via the Tukey-Kramer method (Kramer, 1956; SAS Institute, 2017). This approach reduces the Type I error probability to minimize multiplicity (the inflation of Type I error with repeated comparisons) (Streiner and Norman, 2011; SAS Institute, 2017). Of 19,820 records (n = 15,166 veterans; 4,654 nonveterans), 127 were removed by data administrators because there were no veterans under 21 years age (under 21 years: n = 94 nonveterans, n = 0 veterans) and counts were scarce for veterans and nonveterans over 75 years of age (over 75 years: n = 27 nonveterans, n = 6 veterans). This left 19,693 records for analysis (n = 15,160 veterans; 4,533 nonveterans). Missing observations across analytic variables were <1.0 %. Analyses were performed using SAS Enterprise Guide (Version 8.2, SAS Institute, Inc., Cary, NC, USA) for Linux.

Statistics were weighted (except for counts) to account for CHAI's complex sampling design and survey nonresponse. For veterans, weights were calibrated to frame totals on sex and service-based characteristics. For nonveterans, weights reflected the sampling, recruitment, and attrition processes of the GfK KnowledgePanel®, and age, sex, and race/ethnicity distributions for the noninstitutionalized adult civilian population from the Current Population Survey. Nonveteran weights were also post-stratified to the post-9/11 veteran population by age, sex, race/ethnicity, and education to optimize comparisons between cohorts. Thus, estimates from univariate and bivariable analyses involving these weights were partially adjusted via nonveteran-to-veteran standardization weighting. A resampling-based variance estimation approach, employing the (n-1) rescaling bootstrap method, was applied using 200 replicate weights (Kolenikov, 2010; Rao et al., 1992). Weights for the 127 persons who were removed were set to zero.

Prevalence was calculated by veteran status. Contingency table analysis and bivariable logistic regression were used to calculate relative risks (RRs) and odds ratios (ORs) with their respective 95 % confidence intervals (CIs) per physical health outcome. RRs were reported because ORs misestimate effect size as outcomes become more common (>10 %) (Zhang and Yu, 1998). Adjusted odds ratios (AORs) and 95 % CIs were

Table 1
Characteristics of CHAI respondents (n = 19,693), by veteran status.

Characteristic[2]	Veterans (n = 15,160)		Nonveterans[1] (n = 4,533)	
	n	% (SE)	n	% (SE)
Sex				
Males	9,519	82.7 (0.01)	3,182	82.7 (0.02)
Females	5,641	17.3 (0.01)	1,351	17.3 (0.02)
Age, years				
21–24	294	3.3 (0.15)	156	7.2 (0.56)
25–34	4,487	38.0 (0.29)	1,542	35.4 (0.55)
35–44	4,871	32.5 (0.34)	1,465	31.6 (0.01)
45–54	3,162	16.4 (0.27)	765	16.3 (0.01)
55–64	1,893	8.3 (0.18)	468	5.8 (0.26)
65–75	453	1.6 (0.09)	137	3.7 (0.26)
Age, years M (SE)[3]	38.7 (0.04)		38.4 (0.06)	
Men	39.0 (0.05)		38.6 (0.07)	
Women	37.2 (0.09)		37.1 (0.12)	
Race/ethnicity				
White, non-Hispanic (single race)	9,713	66.4 (0.47)	3,152	66.4 (0.03)
Black, non-Hispanic (single race)	2,344	12.7 (0.32)	373	12.7 (0.03)
Other race, non-Hispanic (single race)	534	3.8 (0.20)	245	7.8 (0.24)
2 or more races, non-Hispanic	862	5.7 (0.24)	131	1.8 (0.24)
Hispanic	1,707	11.4 (0.30)	632	11.4 (0.02)
Education, lifetime				
<High School, High School, GED	1,491	12.5 (0.33)	968	12.5 (0.00)
Some college/no degree	3,913	29.1 (0.48)	812	28.9 (0.75)
Associate/technical degree	2,647	17.2 (0.40)	489	17.4 (0.75)
Bachelor's degree	3,951	24.4 (0.43)	1,351	24.4 (0.00)
Graduate degree	3,158	16.8 (0.31)	913	16.8 (0.00)
Marital status, current				
Never married	2,474	19.9 (0.37)	1,380	35.7 (0.84)
Married/domestic partner	9,772	63.4 (0.45)	2,699	55.5 (0.87)
Separated/divorced/widowed	2,877	16.7 (0.36)	447	8.8 (0.50)
Census region, current				
Northeast	1,367	9.7 (0.29)	801	17.6 (0.99)
Midwest	2,764	20.0 (0.42)	1,120	23.6 (1.06)
South	7,601	47.7 (0.53)	1,525	34.5 (1.10)
West	3,356	22.6 (0.40)	1,087	24.3 (1.06)
Other[4]	24	0.12 (0.03)	0	—

Notes: CHAI, Comparative Heath Assessment Interview Research Study; GED, General Education Diploma; M, mean; SE, standard error. All statistics, except raw counts, were weighted.
[1] Nonveteran-to-veteran standardization weighting was applied.
[2] Rao-Scott chi-square tests (design-adjusted) were significant ($p < 0.001$) except for sex and education. "-" – no statistics generated..
[3] Difference in mean age between veterans and nonveterans was significant by Tukey ($p < 0.001$).
[4] Other: Armed Forces (Europe, Middle East, Africa, Canada) (n = 14), Armed Forces (Pacific) (n = 8), Guam (n = 1), and Northern Mariana (n = 1). Proportions based on counts < 30 may not be reliable (Parker et al., 2017).

calculated via multivariable logistic regression. They represented fully-adjusted associations between physical health outcomes and veteran status after controlling for marital status and Census region in addition to variables applied in weighting (i.e., sex, age, race/ethnicity, education). The sociodemographic variables were used in prior large-scale studies of U.S. veteran and nonveteran health (Agha et al., 2000; Higgins et al., 2017; Hoerster et al., 2012; Lehavot et al., 2012). Variables used in weighting were reused in models to help account for distributional differences in cohort characteristics after the application of weights. Cut-offs for multicollinearity were applied (tolerance < 0.40), using unweighted linear regression, to identify linear dependencies among the explanatory variables (Allison, 2012). No linear dependencies were found because tolerances ranged from 0.89 to 0.97. Observations for 'other' regions (e.g., Guam) reported by veterans (n = 24) were not set to missing. The first order interaction of veteran status by sex was tested to examine differential effects by sex for each physical health condition by cohort. Interactions were plotted. Interaction terms were dropped from models when they were not significant (Beck and Bliwise, 2014) and only main effects reported. AORs exceeding 3.0, or <0.33, signified strong associations (Haddock et al., 1998).

3. Results

3.1. Sample characteristics

Most respondents were between 25 and 44 years of age; male; White, non-Hispanic; earned at least an associate/technical degree; were married or had a domestic partner; and residents of the South (Table 1).

3.2. Prevalence of physical health conditions

The conditions having the greatest, significant elevations in prevalence for veterans compared to nonveterans were back/neck pain (49.3 % versus 22.8 %, respectively) ($p < 0.001$), fractures/bone-joint injuries (47.6 % versus 29.2 %) ($p < 0.001$), and any obesity (39.9 % versus 36.6 %) ($p = 0.002$) (Table 2). Prevalence was also higher in veterans for hypertension (27.8 % versus 22.5 %), high cholesterol (26.9 % versus 21.3 %), arthritis (26.2 % versus 10.9 %), sleep apnea (20.8 % versus 9.7 %), migraine (19.1 % versus 10.3 %) ($p < 0.001$), and respiratory disease (23.7 % versus 21.7 %) ($p = 0.02$). In veterans, prevalence fell at or below 10 % for irritable bowel syndrome/colitis (10.2 %), hearing loss (9.9 %), TBI (6.9 %), heart condition (6.6 %), spinal cord injury (5.5

Table 2
Physical health conditions of Post-9/11 U.S. veterans and nonveterans, by Healthy People 2020 targeted topic areas.

Healthy People targeted topic areas, physical health conditions	Veterans (n = 15,160)		Nonveterans (n = 4,533)[2]		Pr > Chisq[1]	Relative Risk (95 % CI)	Odds Ratio (95 % CI)
	n	% (95 % CI)	n	% (95 % CI)			
Arthritis, Osteoporosis, and Chronic Back							
Arthritis	4,711	26.2 (25.3–27.0)	564	10.9 (9.8–12.0)	**<0.001**	**2.40 (2.17–2.66)**	**2.90 (2.58–3.26)**
Back/neck pain	8,027	49.3 (48.4–50.3)	1,100	22.8 (21.1–24.5)	**<0.001**	**2.16 (2.00–2.34)**	**3.30 (2.97–3.67)**
Spinal cord injury	771	5.5 (5.1–5.9)	75	1.8 (1.3–2.2)	**<0.001**	**3.13 (2.32–4.23)**	**3.26 (2.43–4.37)**
Cancer	808	3.6 (3.3–3.9)	157	2.9 (2.4–3.5)	**0.034**	1.23 (0.99–1.54)	1.24 (1.00–1.55)
Diabetes	950	4.8 (4.5–5.2)	325	7.2 (6.3–8.1)	**<0.001**	**0.67 (0.58–0.78)**	**0.66 (0.56–0.77)**
Heart Disease and Stroke							
Hypertension	4,444	27.8 (27.0–28.7)	1,034	22.5 (20.9–24.1)	**<0.001**	**1.24 (1.14–1.34)**	**1.33 (1.20–1.48)**
High cholesterol	4,557	26.9 (26.1–27.8)	993	21.3 (20.0–22.7)	**<0.001**	**1.26 (1.17–1.36)**	**1.36 (1.24–1.49)**
Heart condition	1,171	6.6 (6.2–7.0)	217	4.3 (3.6–5.0)	**<0.001**	**1.54 (1.29–1.84)**	**1.58 (1.32–1.90)**
Nutrition and Weight Status							
Obesity, any[3]	5,972	39.9 (38.9–40.8)	1,693	36.6 (34.8–38.4)	**0.002**	**1.09 (1.03–1.15)**	**1.15 (1.05–1.26)**
BMI M (SE)	28.9 (0.05)	–	28.6 (0.13)	–	0.135	–	
Respiratory Disease[4]	4,204	23.7 (22.9–24.5)	1,049	21.7 (20.2–23.3)	**0.02**	**1.09 (1.01–1.18)**	**1.12 (1.01–1.24)**
Sleep Health							
Sleep apnea	3,186	20.8 (20.0–21.6)	424	9.7 (8.7–10.8)	**<0.001**	**2.13 (1.89–2.41)**	**2.43 (2.12–2.78)**
Vision							
Vision loss	6,248	36.4 (35.5–37.4)	1,627	34.7 (32.9–36.4)	0.080	1.05 (0.99–1.11)	1.08 (0.99–1.18)
Hearing and Other Sensory or Communication Disorders							
Hearing loss	1,548	9.9 (9.3–10.4)	136	2.5 (2.0–3.1)	**<0.001**	**3.93 (3.10–4.98)**	**4.25 (3.36–5.37)**
Disability and Health							
Missing limbs/amputation	106	0.7 (0.5–0.8)	22	0.5 (0.2–0.7)	0.123	1.44 (0.77–2.70)	1.45 (0.84–2.50)
Fractures, bone or joint injury	7,220	47.6 (46.7–48.6)	1,347	29.2 (27.5–30.8)	**<0.001**	**1.63 (1.54–1.74)**	**2.21 (2.02–2.42)**
Other Conditions[5]							
Cirrhosis	62	0.4 (0.3–0.6)	27	0.5 (0.2–0.7)	0.828	0.94 (0.49–1.81)	0.94 (0.54–1.66)
Hepatitis	191	1.1 (0.9–1.3)	66	1.2 (0.8–1.5)	0.813	0.96 (0.67–1.38)	0.96 (0.67–1.37)
Irritable bowel syndrome/colitis	1,746	10.2 (9.5–10.8)	321	6.3 (5.4–7.2)	**<0.001**	**1.63 (1.39–1.90)**	**1.70 (1.44–2.01)**
Multiple sclerosis	72	0.4 (0.3–0.5)	27	0.4 (0.2–0.6)	0.856	0.95 (0.49–1.85)	0.95 (0.53–1.71)
Bladder infections	540	2.0 (1.8–2.2)	65	1.3 (0.9–1.6)	**<0.001**	**1.60 (1.16–2.21)**	**1.62 (1.19–2.20)**
Chronic fatigue syndrome	770	4.3 (3.9–4.7)	62	1.1 (0.7–1.4)	**<0.001**	**3.93 (2.73–5.65)**	**4.06 (2.86–5.75)**
Migraine	3,460	19.1 (18.4–19.8)	552	10.3 (9.3–11.3)	**<0.001**	**1.85 (1.66–2.07)**	**2.06 (1.82–2.32)**
Traumatic brain injury	912	6.9 (6.4–7.5)	61	1.3 (0.9–1.7)	**<0.001**	**5.39 (3.72–7.80)**	**5.72 (4.02–8.12)**
Epilepsy/seizures	231	1.5 (1.2–1.7)	79	1.8 (1.3–2.3)	0.253	0.82 (0.58–1.15)	0.81 (0.58–1.14)

Notes: BMI, body mass index (kilograms/meters squared); CI, confidence interval; M, mean; SE, standard error. All statistics, except for raw counts, were weighted. Bolded relative risks and odds ratios were significant. Based on n = 19,693.
[1] P-value obtained from design-adjusted Rao-Scott chi-square.
[2] Nonveteran-to-veteran standardization weighting was applied.
[3] BMI $\geq$ 30 kg/m^2
[4] Respiratory disease was at least one report of any of the following: chronic obstructive pulmonary disease/chronic bronchitis/emphysema, asthma, sinusitis, constrictive bronchiolitis, pulmonary fibrosis, or other respiratory diseases.
[5] "Other conditions" were those conditions not specifically represented in Healthy People 2020 targeted topic areas.

%), chronic fatigue syndrome (4.3 %), cancer (3.6 %), and bladder infections (2.0 %), but still significantly higher than the prevalence for nonveterans ($p < 0.05$). Diabetes was significantly ($p < 0.001$) lower for veterans than nonveterans (4.8 % versus 7.2 %).

3.3. Bivariable associations between physical health condition and veteran status

Veterans, versus nonveterans, had a statistically significant greater risk ($p < 0.05$) of disease for 16 (67 %) of the 24 physical health conditions (Table 2). Only a significantly lower risk of diabetes ($p < 0.001$) was found for veterans (RR = 0.67, 95 % CI:0.58–0.78). ORs showed similar patterns as RRs regarding their relative magnitude and direction.

3.4. Multivariable associations between physical health condition and veteran status

The estimated odds of arthritis and related musculoskeletal disorders in veterans were nearly 3.5 times the estimated odds for nonveterans after adjusting for sociodemographic characteristics (arthritis, AOR = 3.40, 95 % CI:2.92–3.97; back/neck pain, AOR = 3.36, 95 % CI:2.98–3.79; spinal cord injury, AOR = 3.31, 95 % CI:2.32–4.73) ($p < 0.001$) (Table 3). The odds for hearing loss in veterans were 4.62 times those for nonveterans (AOR = 4.62, 95 % CI:3.50–6.09) ($p < 0.001$). Other conditions strongly and significantly ($p < 0.001$) associated with being a veteran were TBI (AOR = 5.57, 95 % CI:3.82–8.14) and chronic fatigue syndrome (AOR = 3.80, 95 % CI:2.52–5.73). The odds of sleep apnea in veterans were 2.5 times those for nonveterans (AOR = 2.51, 95 % CI:2.15–2.94), in range of the AOR for fractures, bone or joint injuries (AOR = 2.18, 95 % CI:1.96–2.41)($p < 0.001$). Irritable bowel syndrome/colitis (AOR = 1.69, 95 % CI:1.39–2.04) and certain metabolic disorders (hypertension, AOR = 1.33, 95 % CI: 1.18–1.50; high cholesterol, AOR = 1.32, 95 % CI: 1.19–1.46; heart condition, AOR = 1.67, 95 % CI: 1.35–2.06) were significantly ($p < 0.001$) greater for veterans.

3.5. Multivariable associations between physical health condition and sex

Veteran and nonveteran women had odds of bladder infections that were 12.5 times those of men (males:females, AOR = 0.08, 95 % CI:0.04–0.18) ($p < 0.001$) (Table 3). Highly elevated odds for females overall were also found for these conditions: multiple sclerosis (male: females, AOR = 0.36, 95 % CI:0.15–0.86)($p < 0.05$), chronic fatigue syndrome (AOR = 0.42, 95 % CI:0.22–0.81)($p < 0.01$), cancer (AOR = 0.47, 95 %CI:0.31–0.71), irritable bowel syndrome/colitis (AOR = 0.50,

Table 3
Multivariable associations among physical health conditions, veteran status, and sex, by Healthy People 2020 targeted topic areas.

Healthy People 2020 targeted topic areas, physical health conditions	Comparison by Veteran status (Veterans:Nonveterans)	Comparison by Sex (Males:Females)	Interaction (Veteran status by Sex)	
	AOR (95 % CI)		AOR (95 % CI)	P value
Arthritis, Osteoporosis, and Chronic Back				
Arthritis	**3.40 (2.92–3.97)*****	0.69 (0.55–0.87)**	–	0.674
Back/neck pain	**3.36 (2.98–3.79)*****	0.66 (0.54–0.80)***	–	0.086
Spinal cord injury	**3.31 (2.32–4.73)*****	1.60 (0.77–3.33)	–	0.845
Cancer	1.16 (0.89–1.50)	0.47 (0.31–0.71)***	–	0.397
Diabetes	0.62 (0.52–0.74)***	1.07 (0.76–1.51)	–	0.450
Heart Disease and Stroke				
Hypertension	1.33 (1.18–1.50)***	1.70 (1.36–2.13)***	–	0.511
High cholesterol	1.32 (1.19–1.46)***	1.50 (1.25–1.81)***	–	0.643
Heart condition	1.67 (1.35–2.06)***	0.88 (0.60–1.31)	–	0.602
Nutrition and Weight Status				
Obesity, any (BMI $\geq$ 30 kg/m^2)				0.028*[1]
Veterans, Males:Females	–	–	1.30 (1.14–1.47)***	
Nonveterans, Males:Females	–	–	1.04 (0.84–1.29)	
Respiratory Disease[2]	1.08 (0.97–1.21)	0.65 (0.54–0.77)***	–	0.361
Sleep Health				
Sleep apnea	2.51 (2.15–2.94)***	2.02 (1.45–2.79)***	–	0.425
Vision				
Vision loss	1.08 (0.98–1.18)	0.71 (0.60–0.84)***	–	0.604
Hearing and Other Sensory or Communication Disorders				
Hearing loss	**4.62 (3.50–6.09)*****	1.40 (0.87–2.25)	–	0.249
Disability and Health				
Missing limbs/amputation	1.49 (0.79–2.83)	1.49 (0.25–8.77)	–	0.826
Fractures, bone or joint injury	2.18 (1.96–2.41)***	1.25 (1.04–1.51)*	–	0.768
Other Conditions[3]				
Cirrhosis	1.00 (0.52–1.94)	0.38 (0.14–1.03)	–	0.105
Hepatitis	1.14 (0.72–1.81)	0.65 (0.32–1.30)	–	0.093
Irritable bowel syndrome/colitis	1.69 (1.39–2.04)***	0.50 (0.37–0.68)***	–	0.370
Multiple sclerosis	0.97 (0.54–1.75)	0.36 (0.15–0.86)*	–	0.414
Bladder infections	1.52 (0.99–2.31)	**0.08 (0.04–0.18)*****	–	0.908
Chronic fatigue syndrome	**3.80 (2.52–5.73)*****	0.42 (0.22–0.81)**	–	0.187
Migraine				0.011*[4]
Veterans, Males:Females	–	–	0.38 (0.33–0.44)***	
Nonveterans, Males:Females	–	–	0.28 (0.21–0.37)***	
Traumatic brain injury	**5.57 (3.82–8.14)*****	1.29 (0.60–2.77)	–	0.403
Epilepsy/seizures	0.86 (0.59–1.26)	1.24 (0.65–2.40)	–	0.158

Notes: AOR, adjusted odds ratio; BMI, body mass index (kilograms per meters squared); CI, confidence interval. Weighted, fully-adjusted associations between health outcome and veteran status after controlling for age, sex, education, race/ethnicity, Census region, and marital status. Interactions (veteran status by sex) were included when statistically significant. Bolded AORs represented strong associations (Haddock et al., 1998). Based on n = 19,693.
[1] Interaction was significant (p = 0.028). In males, veterans:nonveterans, AOR = 1.16, 95 % CI:1.01–1.34*; In females, veterans: nonveterans, AOR = 0.94, 95 % CI:0.74–1.17.
[2] Respiratory disease was at least one report of the following: chronic obstructive pulmonary disease/chronic bronchitis/emphysema, asthma, sinusitis, constrictive bronchiolitis, pulmonary fibrosis, and other respiratory diseases.
[3] "Other conditions" were those conditions not specifically represented in Healthy People 2020 targeted topic areas.
[4] Interaction was significant (p = 0.011). In males, veterans:nonveterans, AOR = 2.26, 95 % CI:1.77–2.88***; In females, veterans: nonveterans, AOR = 1.63, 95 % CI:1.26–2.11***
"-" – no estimate presented either because there was no significant interaction or no main effect.
*p < 0.05; **p < 0.01; ***p < 0.001.

95 % CI:0.37–0.68), respiratory disease (AOR = 0.65, 95 % CI:0.54–0.77)(p < 0.001), arthritis (AOR = 0.69, 95 % CI:0.55–0.87)(p < 0.01), back/neck pain (AOR = 0.66, 95 % CI:0.54–0.80), and vision loss (AOR = 0.71, 95 % CI:0.60–0.84)(p < 0.001).

Physical health conditions strongly associated with being female fell mainly into "Other Conditions" (Table 3). The Healthy People 2020 topic areas that were represented for women were "Cancer"; "Respiratory Diseases"; "Arthritis, Osteoporosis, and Chronic Back"; and "Vision".

Compared to women, men had significantly greater (p < 0.001) odds of sleep apnea (AOR = 2.02, 95 % CI:1.45–2.79), hypertension (AOR = 1.70, 95 % CI:1.36–2.13), and high cholesterol (AOR = 1.50, 95 % CI:1.25–1.81) (Table 3). Fractures and bone or joint injuries (AOR = 1.25, 95 % CI:1.04–1.51) were also significantly greater (p < 0.05) for men.

The Healthy People topic areas that represented conditions for men were "Sleep Health", "Heart Disease and Stroke", and "Disability and Health" (Table 3).

3.6. Statistical interactions of veteran status by sex for each physical health outcome

Interactions were found for obesity (p < 0.03) and migraine (p < 0.01) (Table 3) (Fig. 1, plots a and b, respectively). For obesity in veterans, the odds for males were 1.3 times those for females (AOR = 1.30, 95 % CI:1.14–1.47)(p < 0.001). For obesity in nonveterans, there was no difference by sex. For migraine in veterans, the odds for women were 2.63 times those for men (males:females, AOR = 0.38, 95 % CI:0.33–0.44) (p < 0.001). In nonveterans, the association was even stronger for women (males:females, AOR = 0.28, 95 % CI:0.21–0.37) (p < 0.001).

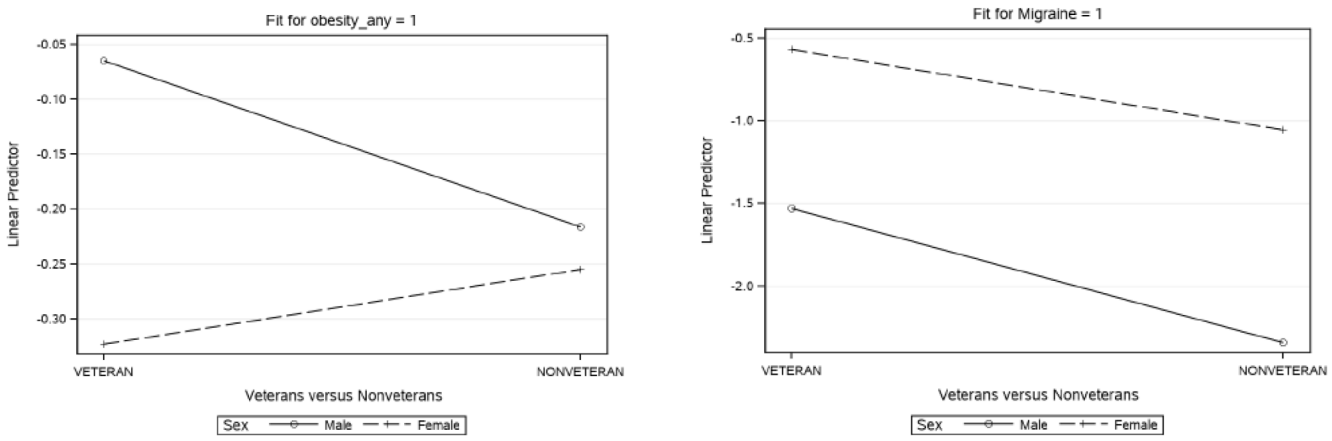

Fig. 1. (a) Interaction of veteran status by sex, obesity (any obesity, Body mass index ≥ 30 kg/m2). (b) Interaction of veteran status by sex, migraine.

4. Discussion

Post-9/11 veterans had poorer physical health than nonveterans. Veterans had greater adjusted odds than nonveterans of most reported physical health conditions. TBI, musculoskeletal disorders, hearing disorders, chronic fatigue syndrome, bone-related injuries, irritable bowel syndrome/colitis, and certain metabolic conditions were foremost. Veteran and nonveteran women, compared to veteran and nonveteran men, had higher adjusted odds of cancer, migraine, and genitourinary, neurologic, gastrointestinal, respiratory, vision, and some musculoskeletal disorders. High blood pressure and cholesterol, bone-related injuries, and sleep apnea were most notable for men. The relationship between physical health condition and sex differed by veteran status for obesity and migraine. Among veterans, obesity was greater for males whereas no difference by sex was found among nonveterans.

We found that musculoskeletal-related problems were highest in veterans – 49.3 % reported back/neck pain. The prevalence for arthritis, back/neck pain, and spinal cord injury in CHAI respondents was 27 % on average, close to 29.3 % reported by post-9/11 VHA healthcare users for any musculoskeletal disorder (Haskell et al., 2020). Musculoskeletal issues have been shown to be important health issues in other studies specific to post-9/11 veterans (Díaz Santana et al., 2017; Frayne et al., 2011; Gundlapalli et al., 2020; Haskell et al., 2012; Higgins et al., 2017), Gulf War veterans (Kang et al., 2000), and U.S. veterans overall (Hoerster et al., 2012; Murphy et al., 2014). These conditions have been associated with greater hospitalization, poor quality of life, adverse mental health (Singh et al., 2005), and long-term disability (Cross et al., 2011).

Musculoskeletal conditions in male veterans have also been associated with poor mental health status. In a study of mostly male Iraq War veterans, arm, leg, or joint pain was twice as high in veterans with PTSD (50.2 %) than in those without PTSD (25.9 %) ($p \ll 0.001$) (Hoge et al., 2007). The odds of these conditions in PTSD-positive veterans were nearly-three times those for veterans without PTSD (OR = 2.89, 95 % CI:2.35–3.57). In another report, musculoskeletal disease in OEF/OIF veterans with PTSD was nearly twice ($p < 0.001$) that of veterans without PTSD (males, AOR = 1.72, 95 % CI:1.64–1.81; females, AOR = 1.79, 95 % CI:1.59–2.02) (Nazarian et al., 2012). Other studies have also reported elevated associations with poor mental health in Vietnam War era (Boscarino et al., 2010; O'Toole and Catts, 2008; Schnurr et al., 2000) and other veterans (Fetzner et al., 2012). One explanation was that poor mental health may alter important preventive health behaviors, such as regular exercise or medical screening (Buckley et al., 2004), which may consequently increase the risk of musculoskeletal injuries. Also, PTSD may exacerbate injury via its association with the inflammatory response (Boscarino, 2004).

CHAI showed that the adjusted odds for arthritis and back/neck pain in women were approximately 1.5 times those for men, similar to other research on women (Dominick et al., 2006; Harrington et al., 2019; Haskell et al., 2012; Higgins et al., 2017; Hinojosa and Hinojosa, 2016; Ziobrowski et al., 2006). Post-9/11 women veterans reported fewer upper extremity, spine, or knee problems, but more hip and ankle/foot problems than men (Haskell et al., 2020). Evidence of associations with mental health was also shown in prior research. OEF/OIF women veterans with PTSD had more musculoskeletal problems than women with no mental health conditions; associations were also higher for women (age-adjusted OR = 1.95, 95 % CI:1.78–2.13) than men (OR = 1.71, 95 % CI:1.65–1.77) (Frayne et al., 2011). In another study, musculoskeletal disease was significantly associated ($p < 0.001$) with PTSD in post-9/11 women veterans (AOR = 1.79, 95 % CI:1.59–2.02) (Nazarian et al., 2012).

Obesity was determined to be one of the mostly frequently diagnosed medical conditions among veterans (VHA, 2017) and has reached epidemic levels (Breland et al., 2017). Obesity prevalence in CHAI veterans was 40 % (95 % CI: 38.9–40.8). Recent estimates were 44 % for post-9/11 veteran VA healthcare users (Breland et al., 2017) and 32.7 % for U.S. veterans using 2011 data (Stefanovics et al., 2018). Obesity prevalence among CHAI nonveterans was 37 %, in range of a 2017–2018 estimate of 40 % for the U.S. population aged 20–39 years (National Institute of Diabetes and Digestive and Kidney Diseases, National Institutes of Health, 2021). As in other studies, we found that obesity was greater in male veterans than female veterans (Barber et al., 2011; Breland et al., 2017, for ages 18–44 years; Gaffey et al., 2021; Haskell et al., 2010; Higgins et al., 2017; Maguen et al., 2013; Nelson, 2006; Rush et al., 2016). Overall, further obesity research is needed in veterans due to associated physical (e.g., arthritis, sleep apnea, diabetes, hypertension) (Rush et al., 2016; Stefanovics et al., 2018) and mental health disorders (e.g., PTSD, depression) (Maguen et al., 2013; Rush et al., 2016; Stefanovics et al., 2018), and increased risk of mortality (Breland et al., 2021; Tsai et al., 2021; Wischik et al., 2019).

Strong associations between obesity and type 2 diabetes have been demonstrated – and their mutual existence has led to the term "diabesity" (Leitner et al., 2017). In our analysis, despite high levels of obesity, diabetes risk was lower for veterans than nonveterans (RR = 0.67, 95 % CI: 0.58–0.78) which persisted after adjusting for covariates (AOR = 0.62, 95 % CI: 0.52–0.74). Several prior studies of U.S. veterans showed no difference in diabetes between veterans and nonveterans (Boersma et al., 2021; Hoerster et al., 2012, Appendix A; Lehavot et al., 2012, Appendix A), whereas other results demonstrated lower associations when female and male veterans were each compared to civilians (Schult et al., 2019). Diabetes prevalence was 6 % on average in veterans aged 35–44 years (mainly Persian Gulf War and OEF/OIF veterans) (Vimalananda et al., 2013), and 6.8 % in post-9/11 veterans enrolled in VHA

health care (Gaffey et al., 2021). Both estimates neared CHAI's estimate for veterans of 4.8 % (95 % CI: 4.5–5.2). One possible reason for a lower prevalence and risk of diabetes in veterans may relate to anthropometrics. Fat distribution, specifically abdominal fat mass, is more highly associated with metabolic disorders like diabetes than obesity (Stefan, 2020). Veterans may have better fat and muscle distribution than nonveterans due to health requirements maintained during service. Also, veterans who presented with diabetes at recruitment may have been denied entry into service (Reiber et al., 2004).

We found that women were 13 times more likely to report bladder infections than men, which was the most prominent difference by sex. Urinary tract infections (UTIs) are one of the most common infections in adult women (Medina and Castillo-Pino, 2019) and deployed female personnel (Defense Department Advisory Committee on Women in the Services, 2008). The estimated prevalence of bladder infections for women veterans in our analysis was 7.9 % (95 % CI:7.0–8.7)(not shown in tables) and ranged between 4.0 and 8.0 % in other women veteran studies (Anger et al., 2008; Cohen et al., 2012; Frayne et al., 2011). Nearly 20 % of deployed women experienced UTIs during deployment (Lowe and Ryan-Wenger, 2003), likely due to deployment conditions such as decreased access to fluid, sanitary bathrooms (Defense Department Advisory Committee on Women in the Services, 2008; Lowe and Ryan-Wenger, 2003; Resnick et al., 2012), and female practitioners (Steele and Yoder, 2013). Associations between UTI and mental health have also been demonstrated in post-9/11 women veterans (Cohen et al., 2012; Frayne et al., 2011).

The adjusted odds for migraine based on CHAI data were 2.5–3.5 times higher in women than men, and veterans were twice as likely to report migraine than nonveterans (19.1 % versus 10.3 %, respectively). Similarly, headache, including migraine, was more prevalent in women (17.6 %) than men (7.4 %) in other post-9/11 veteran research (Frayne et al., 2011). Female veterans had 2.3 times the risk of "migraine headaches" than male veterans in another study (Harrington et al., 2019). Additional research found that post-9/11 veterans had migraine diagnoses that were nearly 3 times higher in women than men (prevalence ratio = 2.66, 95 % CI:2.59–2.73) (Carlson et al., 2013).

Respiratory disease was an important health concern in veteran and nonveteran women based on CHAI results. The National Health and Resilience in Veterans Study results showed that asthma, chronic bronchitis, or COPD were higher in female veterans (15.9 %) than male veterans (10.5 %) (Ziobrowski et al., 2017) similar to other reports where women were found at heightened risk of respiratory disease relative to men (Barth et al., 2016; Harrington et al., 2019; Pugh et al., 2016; Schult et al., 2019; Soltis et al., 2009). Asthma, COPD, and chronic bronchitis were also greater for U.S adult nonveteran women than men (American Lung Association, 2022). Biological differences in lung structure (women have smaller lung size than men) and hormone levels may partially account for differences by sex (Han et al., 2018; Pinkerton et al., 2015), as well as women's changing occupational roles (Meleis et al., 2016). Moreover, lung disease has been increasing among women overall (Pinkerton et al., 2015).

We were able to classify 15 of the 24 CHAI physical health conditions (62.5 %) into Healthy People 2020 topic areas (Supplementary Table 1), but still about a third of these conditions such as TBI, migraine, multiple sclerosis, irritable bowel syndrome/colitis fell under "Other Conditions". Thus, two important areas of physical health for veterans were not covered by Healthy People 2020 topic areas, namely neurological (e.g., TBI, migraine) and gastrointestinal disorders, which were two of the top self-reported conditions among Million Veteran Program enrollees (Harrington et al., 2019). Healthy People 2020 also provided topic areas for certain subgroups of the population, such as adolescents and LGBT and older individuals, but no targeted topic area was provided for veterans. Although health guidance for most of these subgroups may be relevant to veterans, the unique health concerns facing veterans should still be specifically addressed in recommendations intended for the entire U.S. population.

For VA practitioners, clinical practice guidelines have been developed through joint collaborations between the VA and DoD and other organizations (U.S. Department of Veterans Affairs, 2022). These provide standards of care and patient-based educational materials for a limited set of common, chronic physical health conditions such as diabetes, hypertension, obesity, and asthma. Yet, the equivalence of these guidelines to Healthy People 2020 overall is unclear. This is important because not all veterans use VA health care. Veterans may be receiving some or all of their guidance from other federal or privately-based health information sources. Federal guidelines developed external to VA may still be useful for all providers since veterans and nonveterans share some of the same chronic health conditions.

Limitations and strengths should be noted. This was a retrospective, cross-sectional study, so statements about causality are not possible. Self-reported data are subject to biases. To optimize model comparability across a large number of conditions, we controlled for sociodemographic characteristics and did not adjust for other covariates such as other service characteristics, health behaviors (e.g., cigarette use), or mental health status. Mode effects were not assessed. As to strengths, this analysis examined a range of conditions from large, nationally representative samples of post-9/11 veterans and nonveterans. A mixed-mode methodology was implemented to maximize response (Dillman et al., 2014) and survey-specific procedures optimized data analysis to reflect CHAI's complex research design.

In conclusion, Healthy People efforts should consider guidance recommendations that are more greatly tailored to the approximately 19 million U.S. veterans who constitute 10 % of the U.S. adult population (Schaeffer, 2021), and have unique health needs (Olenick et al., 2015; Oster et al., 2017; Waszak and Holmes, 2017) much like other segments of our society. Further development of health improvement initiatives to increase veteran well-being such as VA's weight management program "MOVE!" (Kinsinger et al., 2009) or its Diabetes Prevention Program (Moin et al., 2017) should be encouraged. The connection between physical and mental health is evident, so that an emphasis on an integrated approach to improving the health status of veterans should always remain paramount.

5. Disclaimer

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The U.S. Department of Veterans Affairs supports efforts to provide limited, restricted access to research data under written agreements

consistent with commitments made to protecting subjects' privacy and confidentiality.

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Appendix A. Supplementary data

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