Respiratory Health Among U.S. Veterans Across Age and Over Time

ROBERT BOZICK AND ROLAND NEIL

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Published by the RAND Corporation, Santa Monica, Calif.

Library of Congress Cataloging-in-Publication Data is available for this publication.

ISBN: 978-1-9774-1359-8

Cover photo: Sergey Nivens/Adobe Stock.

About This Report

This report presents findings from two nationally representative surveys of health and well-being that include samples of veterans and their civilian peers. With these data, we compare respiratory health outcomes observed for these two populations who were of prime age for military service during different periods of national conflict: the Korean War, the Vietnam War, Operation Desert Shield/Storm, and the Global War on Terror. This report will be of interest to policymakers, advocacy groups, and health care providers who support the health and well-being of U.S. veterans. Additionally, this report will be of interest to researchers interested in the social determinants of respiratory health.

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Funding

Funding for this publication was made possible by a generous gift from Daniel J. Epstein through the Epstein Family Foundation, which established the RAND Epstein Family Veterans Policy Research Institute in 2021.

Acknowledgments

We thank Carrie Farmer, Jessica Phillips, Rajeev Ramchand, Heather Salazar, Megan Schuler, and Hayley B. Gershengorn for their helpful suggestions, guidance, and support. We also thank Javier Rojas Aguilera for his assistance in cleaning the data.

Summary

Many veterans and their advocates are concerned that military service may cause impaired respiratory function resulting from occupational exposures to environmental hazards (e.g., Agent Orange in the Vietnam War, burn pits in the Global War on Terror) or infectious diseases (e.g., pneumonia) that are associated with close living quarters in harsh environments. Such exposures occurring in young adulthood, when soldiers are in their peak years of strength, mobility, and overall good health, may not have immediately discernible effects on lung health; some symptoms (e.g., shortness of breath, wheezing) may emerge in the immediate months or years after separation from the military, and diagnosable conditions (e.g., lung cancer, chronic bronchitis) may not manifest until decades later in life.

Health care providers serving veteran populations must consider both the unique combat circumstances surrounding the time of veterans' service and the age-graded nature of health conditions that might result from military service.

To characterize lung health across a broad age range of veterans, the authors analyzed data from two nationally representative surveys of health and well-being that include samples of veterans and their civilian peers. With these data, the authors compare respiratory health outcomes observed for the veteran and civilian populations who were of prime age for military service during different periods of national conflict: the Korean War, the Vietnam War, Operation Desert Shield/Storm, and the Global War on Terror.

Key Findings

- Veterans and civilians have similar respiratory health profiles during their 20s and 30s, and key symptoms are generally not present at these younger ages.
- At older ages, veterans have worse respiratory health profiles than civilians. For instance, veterans over the age of 60 have higher rates of chronic obstructive pulmonary disease, lung cancer, functional limitations caused by poor lung health, and activity limitations caused by poor lung health than same-aged civilians do.
- Veterans who served during periods of peace had a similar prevalence of respiratory disease diagnoses and symptoms as veterans who served during wartime.
- Cigarette smoking may be a major reason why veterans have poor respiratory health. Differences in adult smoking behaviors are estimated to account for 20 percent to 25 percent of the differences in respiratory health outcomes between veterans and civilians. Overall differences in smoking behaviors—including differences prior to enlistment—are estimated to account for at least half of veteran–civilian disparities in respiratory outcomes.

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Respiratory Health Among U.S. Veterans Across Age and Over Time

Honoring the contributions and sacrifices of U.S. veterans demands a long-term health care approach that responds to veterans' evolving needs as they separate from the military, reintegrate into civilian life, and progress toward their retirement years. For such approaches to be successful, health care providers serving veteran populations must consider both the unique combat circumstances surrounding the time of their service and the age-graded nature of health conditions that might result from military service.

In terms of combat circumstances, exposure to deleterious environmental conditions has varied across periods of active combat. For example, many service members fighting in the Vietnam War were exposed to Agent Orange, and many service members fighting in Iraq and Afghanistan as part of the Global War on Terror were exposed to burn pits. Agent Orange is a carcinogenic chemical herbicide that was used by the U.S. military in Vietnam to defoliate the jungles where the North Vietnamese forces and their allies were stationed. Burn pits were the primary means through which troops disposed of waste in Iraq and Afghanistan. Often accelerated by the use of jet fuel, burn pits exposed troops to toxic fumes. Variation in environmental exposures across conflict eras might yield differences in the type and severity of health outcomes that result from military service. Additionally, if toxic exposures during wartime affect the long-term respiratory health of veterans, then we hypothesize that enlistment during periods of active combat would be linked to different health outcomes than enlistment during periods of relative peace.

In terms of the age-graded nature of health conditions, military service is typically undertaken during young adulthood, when soldiers are in their peak years of strength, mobility, and overall good health. Environmental exposures during this period of the life course may not have immediately discernible effects on lung health; some symptoms (e.g., shortness of breath, wheezing) may emerge in the immediate months or years after separation from the military, and diagnosable conditions (e.g., lung cancer, chronic bronchitis) may not manifest until decades later in life. Therefore, it is imperative to characterize lung health across a broad age range of veterans.

Background and Motivation for the Current Study

Our study is motivated by concerns among veterans and their advocates that military service may cause impaired respiratory function resulting from occupational exposures to airborne environmental hazards (e.g., toxic chemicals, smoke, dust, other particulate matter) or infectious diseases (e.g., pneumonia) that are associated with close living quarters in harsh environments. To date, findings from research aiming to determine the association of military service with respiratory health are inconsistent; some studies have found negative correlations between deployment and lung health, and other studies have found null or even positive correlations.[1] Most of these studies examine as outcomes both symptoms of potential respiratory diseases and actual diagnoses. Some of the most informative research is based on the recent wars in Iraq and Afghanistan. Analyses of records of service members fighting in the Global War on Terror maintained by the Defense Manpower Data Center show increased rates of respiratory diseases following combat.[2] In contrast, data from the Millennium Cohort Study, a longitudinal study that includes direct surveys of soldiers pre- and postcombat exposure, find an increase in respiratory disease symptoms but not actual diagnoses.[3] One potential explanation for the discrepant findings across these studies is that the Millennium Cohort Study had data on soldiers' cigarette-smoking behavior, which allowed the researchers to control for this critical health risk when estimating the relationship between deployment and respiratory outcomes. Such behavioral data are not included in service member records, and, as a result, analyses of these records may over- or understate the role that military service plays in shaping lung health.

Our study compares the prevalence of six respiratory disease diagnoses and symptoms for veterans and civilians at different ages (see the text box for a description of the outcomes compared in our study). We take a population health approach that builds off and extends prior research in several ways. First, our study includes large, nationally representative, population-based samples of both veterans and civilians. Using data on civilians as a comparison group, we can characterize respiratory health outcomes that might be expected had veterans not joined the military. Second, our study extends prior work, which largely focused on veterans of Iraq and Afghanistan, by additionally including veterans from Operation Desert Shield/Storm, the Vietnam War, and the Korean War, as well as veterans who served during interim periods of peace. Inclusion of veterans from earlier conflicts allows us to assess long-term lung impairments that emerge in later life and to provide potential insights regarding what might be expected for veterans of the Global War on Terror as they age, recognizing that the environmental exposures of each war vary substantially in their

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1 Sean M. Parsel, Charles A. Riley, and Edward D. McCoul, "Combat Zone Exposure and Respiratory Tract Disease," *International Forum of Allergy and Rhinology*, Vol. 8, No. 8, August 2018; Michael J. Falvo, Omowunmi Y. Osinubi, Anays M. Sotolongo, and Drew A. Helmer, "Airborne Hazards Exposure and Respiratory Health of Iraq and Afghanistan Veterans," *Epidemiologic Reviews*, Vol. 37, No. 1, 2015; James McLean, Danielle Anderson, Gregory Capra, and Charles A. Riley, "The Potential Effects of Burn Pit Exposure on the Respiratory Tract: A Systematic Review," *Military Medicine*, Vol. 186, No. 7–8, 2021.

2 Joseph H. Abraham, Samar F. DeBakey, Lawrence Reid, Joey Zhou, and Coleen P. Baird, "Does Deployment to Iraq and Afghanistan Affect Respiratory Health of US Military Personnel?" *Journal of Occupational and Environmental Medicine*, Vol. 54, No. 6, 2012.

3 Besa Smith, Charlene A. Wong, Tyler C. Smith, Edward J. Boyko, and Gary D. Gackstetter, "Newly Reported Respiratory Symptoms and Conditions Among Military Personnel Deployed to Iraq and Afghanistan: A Prospective Population-Based Study," *American Journal of Epidemiology*, Vol. 170, No. 11, December 2009.

Outcomes

We examine six outcomes that measure both respiratory disease *diagnoses* and respiratory disease *symptoms*. The latter are particularly relevant for health care policy planning for Global War on Terror veterans because these symptoms may reflect early signs of long-term health complications that may not fully emerge until later in life.

Respiratory Disease Diagnoses

- **Chronic obstructive pulmonary disease (COPD)**, which refers to a group of diseases that cause airflow blockage, is measured in the National Health Interview Survey (NHIS) by self-reported diagnoses of COPD made by a doctor or health professional. Emphysema, one of the diseases that compose COPD, is self-reported in the NHIS separately. We include emphysema diagnoses as part of the broader measure of COPD diagnoses.
- **Lung cancer** is measured in the NHIS by self-reported diagnoses of lung cancer made by a doctor or health professional.

Respiratory Disease Symptoms

- **Functional limitations** because of poor lung health are measured in the NHIS by sample members indicating that a lung or breathing problem causes them to have difficulty with at least one of 12 basic functions, such as walking up ten steps without resting or carrying something as heavy as ten pounds.
- **Activity limitations** because of poor lung health are measured in the NHIS by sample members indicating that a lung or breathing problem causes them to have difficulty or need assistance with at least one of seven types of activities, including their personal care, work, and routine needs.
- **FEV (forced expiratory volume) ratio** is a measure of lung function that is determined by a spirometry test administered as part of the National Health and Nutrition Examination Survey (NHANES) medical exam. In this test, the sample member breathes into a device called a spirometer, which measures airflow from the respiratory system. The spirometer records the maximum amount of air in mL/kg that the examinee can possibly exhale from their lungs after a full, deeply inhaled breath. The spirometer also records the total amount of air that can be forcibly exhaled in one second in mL/kg. The former is referred to as forced vital capacity (FVC), and the latter is referred to as forced expiratory volume in one second (FEV1). The FEV ratio is calculated as the ratio of these two values: FEV1 over FVC. The ratio can be interpreted as the percentage of air in the lungs that can be expelled in one second, with higher values indicating better lung function.
- **Wheezing** is measured in the NHANES from a question that asked sample members, “In the past 12 months, have you had wheezing or whistling in your chest?”

nature and intensity (e.g., Agent Orange, burn pits). Lastly, our study separately incorporates measures of cigarette smoking behaviors during adulthood and prior to enlistment. This is important because cigarette smoking is a leading cause of poor lung health, and rates of cigarette smoking increase during deployment.[4] Therefore, measuring cigarette smoking behaviors at different life stages is essential for understanding the relationship between military service and respiratory health.

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4 Office of the Surgeon General and Office on Smoking and Health, *The Health Consequences of Smoking: A Report of the Surgeon General*, Centers for Disease Control and Prevention, 2004; Besa Smith, Margaret A. K. Ryan, Deborah L. Wingard, Thomas L. Patterson, Donald J. Slymen, and Caroline A. Macera, “Cigarette Smoking and Military Deployment: A Prospective Evaluation,” *American Journal of Preventative Medicine*, Vol. 35, No. 6, December 2008.

Study Populations

Our analysis is based on samples of veterans and civilians from two different data sets developed and maintained by the Centers for Disease Control and Prevention's (CDC's) NHIS and the NHANES.[5]

The NHIS is a nationally representative, cross-sectional household survey that systematically collects self-reported indicators of health conditions from approximately 30,000 households each year. Each annual wave is based on a new sample of households. The head of the household provides a household roster from which one adult and one child are randomly sampled. We analyzed data on adults from seven waves of NHIS data collection spanning 2012 to 2018. In each wave, adult sample members were asked whether they had ever served in the U.S. armed forces, reserves, or National Guard. If they responded affirmatively, they were then asked during which periods they served: the Korean War (1950–1055), peacetime 1955–1964, the Vietnam War (1964–1975), peacetime 1975–1990, Operation Desert Shield/Storm (1990–1991), the Gulf War Stabilization Period spanning 1991–2001,[6] or the Global War on Terror (2001–2021). We classified veterans who served across periods of both war and peace as having served during war. In instances in which the veterans served in multiple military conflicts, we classified them with respect to the first conflict in which they served. We restricted analyses to those less than 85 years old because age is top-coded at 85, and we excluded the 3 percent of observations that have any missing data. This yielded n = 19,717 veterans and n = 191,433 civilians in the NHIS.

The NHANES is a nationally representative, cross-sectional survey conducted on an annual basis from repeated, independent samples of approximately 5,000 Americans. The survey includes a questionnaire about the respondents' health and an in-person medical examination. Although the NHANES samples are considerably smaller, they allow for a direct assessment of possible respiratory disease symptoms that may not be captured in the NHIS, which measures only diagnoses. An analysis that considers only diagnoses may obscure patterns for sample members who lack regular medical care or medical insurance. We analyzed six years of the NHANES spanning 2007 to 2012, when the National Center for Health Statistics included a respiratory health module as part of data collection. This module was discontinued after 2012. Similar to the NHIS, sample members were asked whether they had ever served in the U.S. armed forces, reserves, or National Guard. However, they were not asked about the period during which they served. Therefore, the NHANES is limited with respect to analyzing health outcomes that are linked to specific conflicts. To provide

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[5] CDC, "NHIS Data, Questionnaires and Related Documentation," webpage, April 6, 2023; CDC, "NHANES Questionnaires, Datasets, and Related Documentation," webpage, undated.

[6] Following Operation Desert Shield/Storm, the United States was still technically at war because neither Congress nor the President had issued an official proclamation ending that period of conflict. We distinguish between the years of central conflict as part of Operation Desert Shield/Storm and the years that preceded the Global War on Terror as the Gulf War Stabilization Period.

an approximation, we used their date of birth to construct birth cohorts by decade: 1930–1939 (Korean War–era veterans), 1940–1949 (oldest Vietnam War–era veterans), 1950–1959 (youngest Vietnam War–era veterans), 1960–1969 (oldest Operation Desert Shield/Storm–era veterans), 1970–1979 (youngest Operation Desert Shield/Storm–era veterans), and 1980–1989 (Global War on Terror–era veterans). However, we caution that these are simply approximations because these cohorts include many veterans who were never deployed overseas and veterans who served during the interim periods of peace. We analyzed data on adults aged 20 to 79, because these are the ages for which our key measures are collected. Excluding the 1 percent of observations with missing data in the NHANES, we had n = 1,667 veterans and n = 14,699 civilians for the analysis of self-reported survey data, and we had n = 1,356 veterans and n = 11,959 civilians for the analysis of in-person medical examination data. The sample size differences between the NHANES study components were because of sample members agreeing to participate in the in-person medical examination at lower rates than the self-administered survey.

One challenge in comparing veterans and civilians is that they are different across key sociodemographic characteristics: Veterans are disproportionately male and tend to attain higher levels of education than their civilian peers.[7] Beyond sociodemographic differences, enlistment in the military requires meeting predefined health and physical fitness standards. Of relevance here is that asthma, one of the most common respiratory ailments, is a disqualifying condition if symptoms persist into adolescence. Consequently, those who enlist in the armed forces have better respiratory health at younger ages than the general population. However, this initial health advantage may be offset because, as discussed earlier, veterans exhibit higher rates of cigarette smoking (even before enlistment) than their civilian peers. Therefore, comparing respiratory health outcomes for civilians and veterans risks attributing potential differences to military service that are actually because of sociodemographic and pre-enlistment health characteristics. To address this, we used a method known as inverse probability of treatment weighting (IPTW), which essentially applies a balancing weight so that the civilian sample mirrors the veteran sample in terms of age, sex, race, ethnicity, nativity, educational attainment, asthma, and cigarette smoking prior to enlistment. We used logistic regression to estimate these weights.

Table 1 shows the distribution of our key sociodemographic characteristics and health measures for veterans in the second column and civilians without the application of our weight in the third column. For example, we see that in both the NHIS and the NHANES, about 43 percent of veterans were smokers before the age of 19, as compared with about a quarter of civilians. In the fourth column, we show the distribution of our key sociodemographic characteristics and health measures for civilians with the application of our balancing weight. The differences between veterans and civilians was largely attenuated when weighting the civilians. For instance, we see that about 43 percent of the weighted civilian popula-

[7] Ernesto F. L. Amaral, Michael S. Pollard, Joshua Mendelsohn, and Matthew Cefalu, "Current and Future Demographics of the Veteran Population, 2014–2024," *Population Review*, Vol. 57, No. 1, 2018.

TABLE 1

Distribution of Covariates for Veterans and Civilians Before and After Weighting

Characteristic	Veterans	Civilians	Civilians (Weighted)
NHIS sample			
Age	60.3	47.3	60.3
Female (%)	9.4	59.6	9.4
Race (%)			
White	81.4	76.8	81.8
Black	13.2	13.6	13.0
Native	1.0	1.1	0.9
Asian	2.2	6.2	2.0
Redacted	0.2	0.3	0.2
Multiple	2.0	2.1	2.0
Hispanic (%)	6.1	16.2	5.8
U.S. born (%)	95.6	81.2	95.6
Regular smoker prior to age 19 (%)	43.7	25.3	43.6
Lifetime asthma diagnosis (%)	9.9	13.6	10.0
High school graduate (%)	89.8	83.2	90.0
NHANES sample			
Age	58.9	46.2	57.9
Female (%)	6.4	56.0	6.9
Race/ethnicity (%)			
White	56.0	40.2	55.7
Black	27.4	21.6	28.4
Hispanic	13.4	28.5	12.6
Other	3.2	9.6	3.3
U.S. born (%)	93.3	68.6	93.0
Regular smoker prior to age 19 (%)	42.5	28.4	42.2
Asthma diagnosis prior to age 19 (%)	5.4	8.2	5.9

Table 1—Continued

Characteristic	Veterans	Civilians	Civilians (Weighted)
Education (%)			
Less than 9th grade	2.8	12.3	2.9
9th–11th grade	11.2	16.6	11.2
High school graduate	26.1	22.4	24.7
Some college	38.1	27.1	39.1
College degree	21.8	21.6	22.1

tion were smokers, the same as veterans. So that we can make the best "apples-to-apples" comparisons between veterans and civilians, all of the findings from the analyses produced in this report were based on the weighted sample of civilians. We did not use the same set of weights in all analyses; rather, we used weights that were tailored for the specific comparisons made in each section of the analysis. See the appendix for technical details on the measures and methods used, including diagnostics of the balancing weights that were estimated.

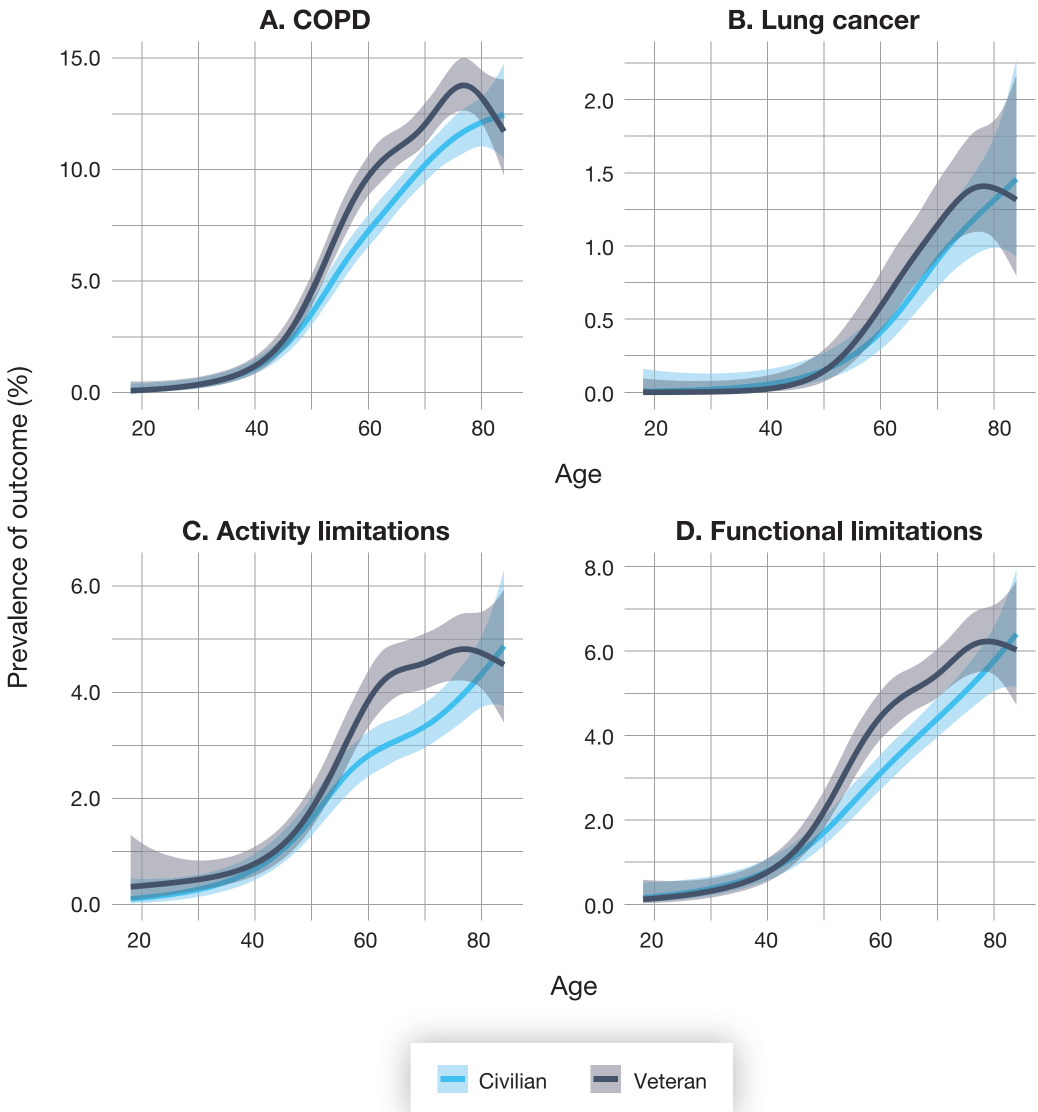
Overall Differences Between Veterans and Civilians

Figure 1 presents the age-specific prevalence of respiratory disease diagnoses and symptoms. This figure draws on NHIS data and compares veterans with similar (i.e., weighted) civilians. Veterans are shown in the dark blue trend lines and civilians in the light blue trend lines, with the shaded areas representing 95-percent confidence intervals. Across all four outcomes, the prevalence of the outcomes was comparable for both veterans and civilians during young adulthood. We observed an increasing prevalence with age, with a steady increase in diagnoses starting around age 30. At older ages, veterans exhibited higher rates of diagnosed lung diseases than their civilian peers. For example, at age 30, 0.4 percent of veterans and 0.4 percent of civilians had been diagnosed with COPD. By age 60, 9.8 percent of veterans and 7.2 percent of civilians had been diagnosed with COPD. Similar patterns were observed for lung cancer. This was true not only of diagnosed lung diseases but also of symptoms of lung diseases. For example, at age 30, 0.3 percent of veterans and 0.4 percent of civilians were limited in performing such basic functional activities as climbing stairs because of lung health. By age 60, these rates for veterans and civilians were 4.6 percent and 3.1 percent, respectively.

Because the respiratory health outcomes in Figure 1 do not emerge until later in life for veterans and civilians alike, Figure 2 draws on NHANES data to examine two further outcomes—FEV ratio and wheezing—which are respiratory health symptoms that may serve as early warning signs of lung diseases. For both symptoms, the patterns for veterans and civilians was nearly identical across adulthood, suggesting that these particular respiratory health

FIGURE 1

Comparisons of Age-Graded Course of Respiratory Health Outcomes Between Veterans and Similar Civilians, NHIS



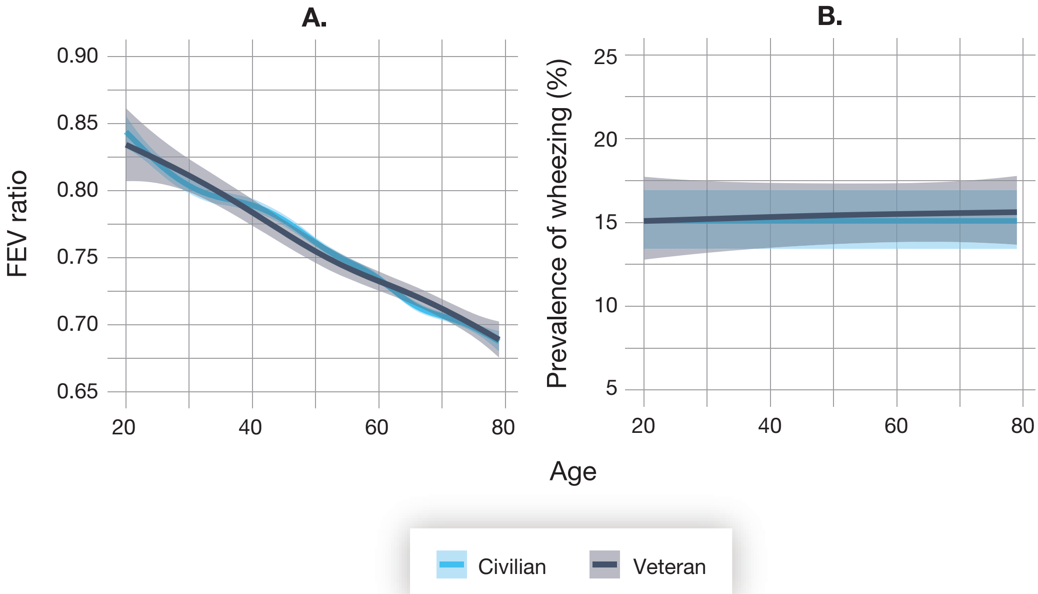
SOURCE: CDC, 2023.

NOTE: *N* = 211,150. To improve comparability of civilians and veterans, we conducted exact matching on age and IPTW to balance civilians and veterans on additional covariates (see the appendix for details). Shading around the trend lines indicates 95-percent confidence intervals.

symptoms are not associated with military service. Lung function, as measured by the FEV ratio, declined over time for both veterans and civilians at very similar rates. The prevalence of wheezing was very similar for veterans and civilians and was generally stable across age.

FIGURE 2

Comparisons of Age-Graded Course of Respiratory Health Outcomes Between Veterans and Similar Civilians, NHANES



SOURCE: CDC, undated.

NOTE: N = 13,315 for FEV ratio analysis and N = 16,366 for wheezing analysis. To improve comparability of civilians and veterans, we used IPTW to balance civilians and veterans on multiple covariates (see the appendix for details). Shading around the trend lines indicates 95-percent confidence intervals.

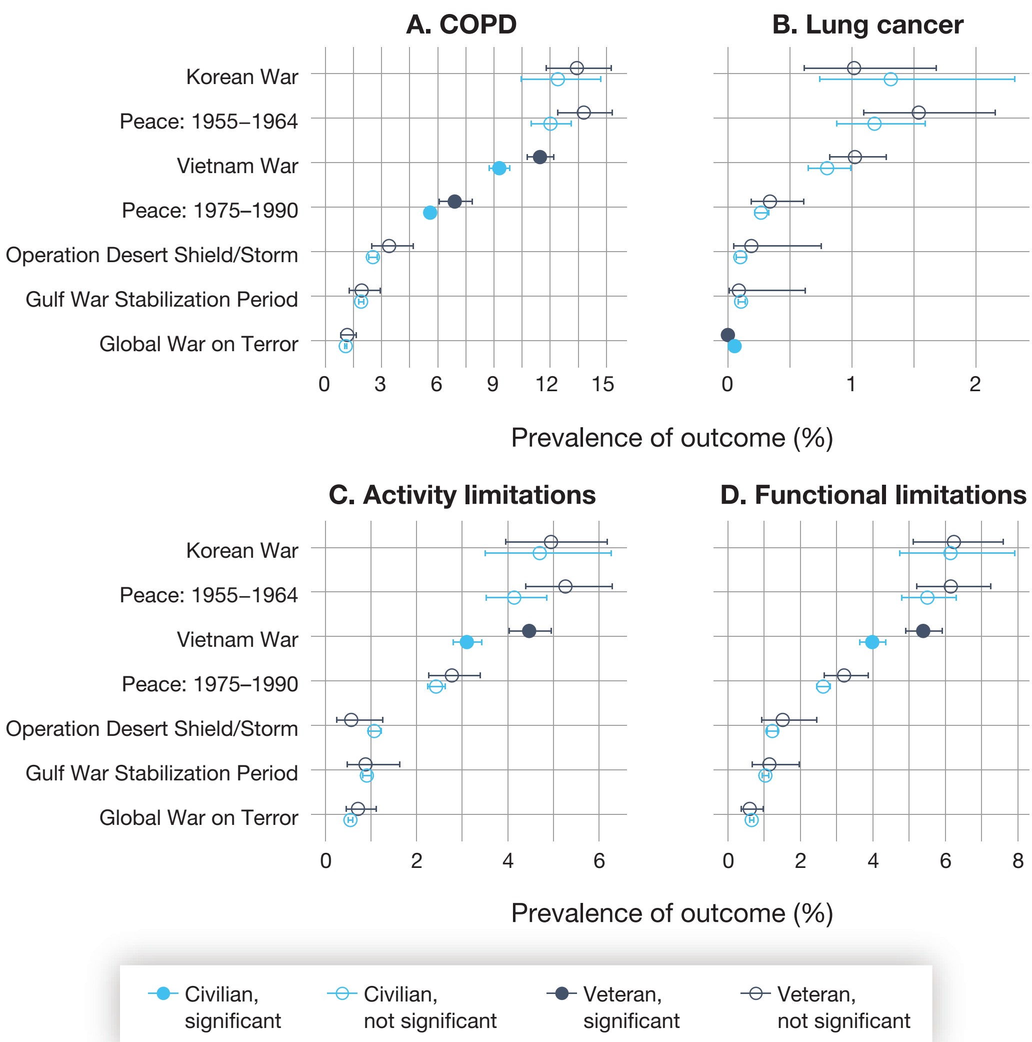
Considered together, lung health symptoms did not vary meaningfully across veterans and civilians in earlier adulthood. For example, when veterans are 35 years old, they exhibited virtually the same degree of functional and activity limitations because of poor lung health, had the same level of lung function, and experienced wheezing at rates comparable with their civilian peers.

Differences Between Veterans and Civilians Across Periods of War and Peace

Next, we examined whether specific military conflicts produce distinct patterns of respiratory health. To do so, we compared rates of respiratory disease diagnoses and symptoms for veterans who served during specific military service eras with rates among their civilian peers who were weighted to be of the same age when these wars took place and who were as similar as possible to veterans in terms of age, sex, race, ethnicity, nativity, education, asthma diagnoses, and regular smoking during youth. More information on this weighting process is included in the accompanying appendix. Additionally, to gauge how much of the veteran–civilian differences are because of exposure to conflict, we also compared veterans and their weighted civilian peers during periods of peacetime. Figure 3 shows the results for outcomes examined with NHIS data, and Figure 4 shows the results for outcomes examined with NHANES data. As with the previous figures, the dark blue data points are for veterans and the light blue data points are for civilians, with bars representing 95-percent confidence

FIGURE 3

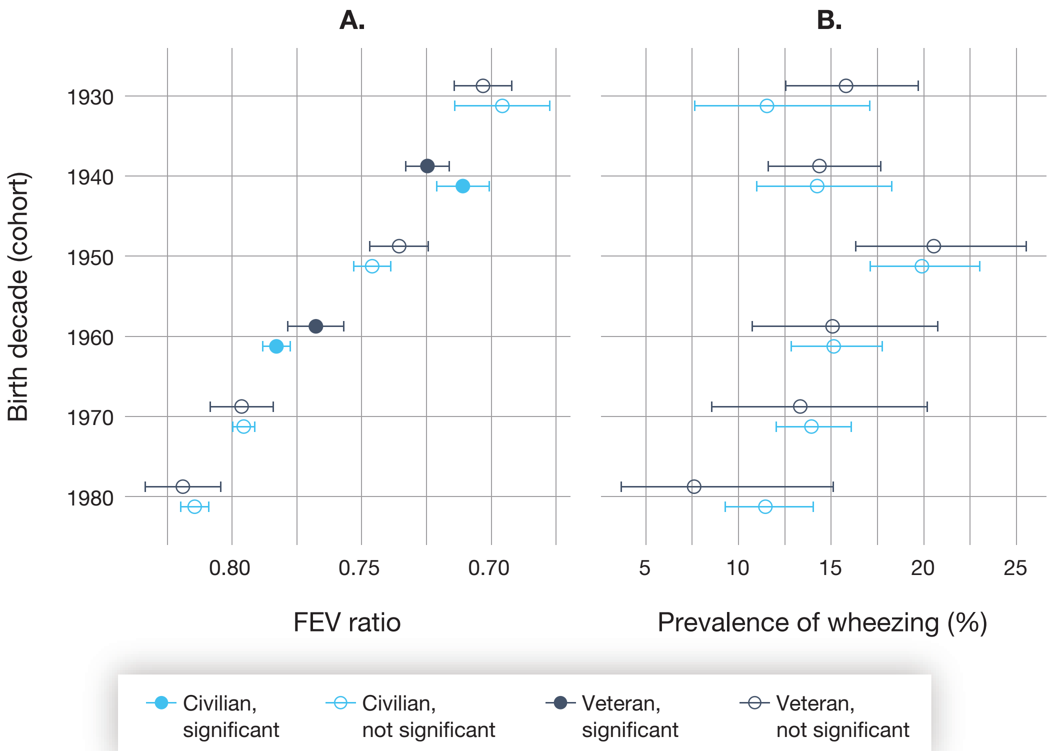
Comparisons of Respiratory Health Outcomes Between Veterans and Similar Civilians of the Same Era, NHIS



SOURCE: CDC, 2023.

NOTE: *N* = 211,150. To improve comparability of civilians and veterans, we used IPTW within each era to balance civilians and veterans on multiple covariates; the comparison set of civilians was restricted to have the same age range as veterans of a given era (see the appendix for details). Error bars around the point estimates indicate 95-percent confidence intervals.

FIGURE 4
Comparisons of Respiratory Health Outcomes Between Veterans and Similar Civilians Born in the Same Decade, NHANES



SOURCE: CDC, undated.
NOTE: *N* = 13,315 for FEV ratio analysis and *N* = 16,366 for wheezing analysis. Weighting is carried out by exact matching on birth cohort and balancing all covariates within birth cohorts to make civilians resemble veterans using IPTW. Error bars around the point estimates indicate 95-percent confidence intervals. Birth cohorts approximate different military conflicts as follows 1930s = Korean War–era veterans, 1940s = oldest Vietnam War–era veterans, 1950s = youngest Vietnam War–era veterans, 1960s = oldest Operation Desert Shield/Storm–era veterans, 1970s = youngest Operation Desert Shield/Storm–era veterans, and 1980s = Global War on Terror–era veterans.

intervals. Circles that have an outline with no shading indicate that differences between veterans and civilians for a specific war or period of peace are not statistically significant ($p \geq 0.05$). Conversely, circles with shading indicate that differences between veterans and civilians for a specific war or period of peace are statistically significant ($p < 0.05$). Recall that for FEV ratio and wheezing, both of which are taken from the NHANES, we can approximate military conflict participation only indirectly through birth cohorts, as we did in Figure 4.

In regard to both respiratory disease diagnoses and symptoms, participation in the Vietnam War appeared to be particularly salient. Vietnam War–era veterans had significantly higher rates of COPD, functional limitations, and activity limitations than their civilian peers. For example, 11.5 percent of Vietnam War–era veterans were diagnosed with COPD compared with 9.3 percent of their civilian peers. However, compared with civilians of the same age, veterans born in the 1940s, which includes a large number of those who served in Vietnam, had slightly better lung functioning as expressed in the FEV ratio. This difference, which is less than one-fifth of a standard deviation, is substantively small: When breathing into a spirometer, Vietnam War–era veterans could exhale 72.5 percent of their total lung capacity in one second compared with their civilian peers, who could exhale 71.1 percent of their total lung capacity in one second.

With respect to more-recent conflicts, we did not find evidence that veterans who served during the eras of Operation Desert Shield/Storm or the Global War on Terror had significantly higher rates of respiratory disease diagnoses than their civilian peers did. As observed in the previous section, differences between veterans and civilians may not be evident until at least age 50. Most Global War on Terror–era veterans were in their 20s and 30s at the time of the NHIS and NHANES data collection, so the implications of combat exposure for their long-term health is unknown. However, across respiratory disease symptoms, which may portend later respiratory disease diagnoses, veterans from the Global War on Terror era were comparable with their civilian peers.

Importantly, veterans who served during peacetime exhibited some signs of poor lung health compared with civilians who came of age during the same period. For example, veterans who served during the period of peace following the Vietnam War had higher rates of COPD than similar civilians did (7.8 percent and 5.9 percent, respectively). That we observed poor lung health even among those who served during peacetime suggests that direct participation in a war may not be the sole explanation for the veteran–civilian differences observed in the aggregate. It indicates that, as people age, disparities in respiratory health compared with civilians may emerge for wartime and peacetime veterans alike. If so, the pronounced differences for Vietnam War–era veterans may reflect their advanced age. We investigate this issue in the next section by making comparisons that hold age constant across wartime and peacetime veterans in an analysis designed to isolate the role of wartime military service.

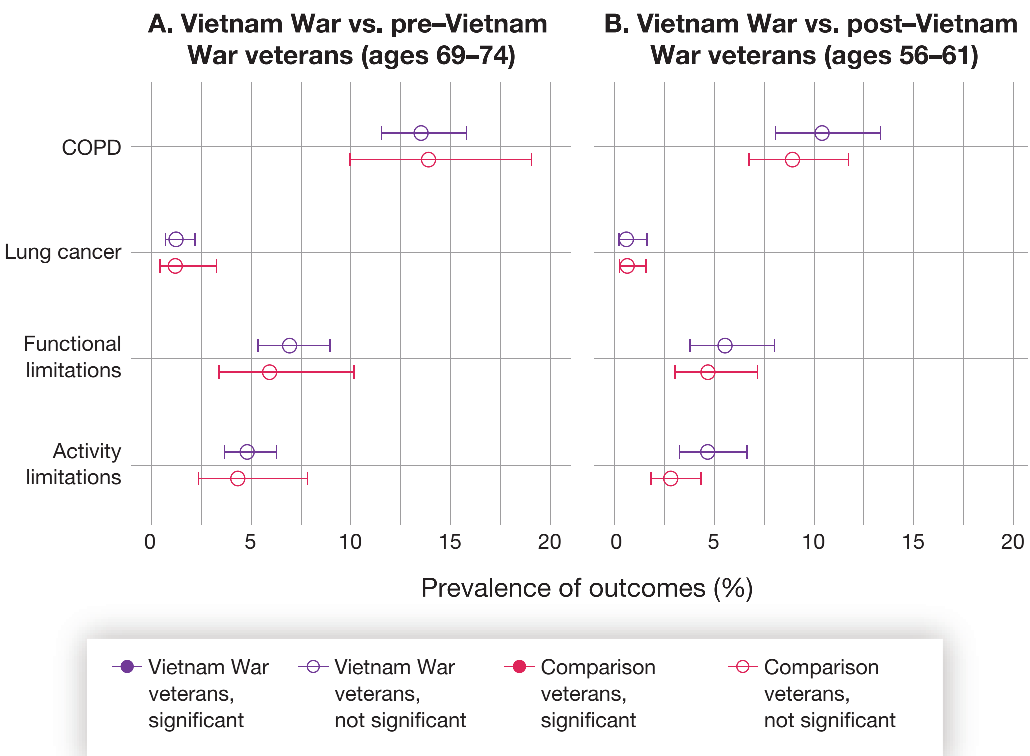
The Role of Military Service During Wartime: A Closer Look at the Vietnam War

To explore whether service during wartime is the reason that veterans exhibit elevated risk for worse respiratory health outcomes, we compared the outcomes of Vietnam War veterans with veterans who served during the peacetime periods that preceded and followed the Vietnam War. To isolate the role of combat from age, we compared Vietnam War veterans with same-age veterans who served during either of the adjacent peacetime periods, using weighting to adjust for differences between these groups. We focused solely on the Vietnam War because it permits comparisons of veterans at older ages, when respiratory diseases become more common, and it has observable periods of peace before and after. Because we are specifically interested in the Vietnam War, we limited our analysis to the four outcomes contained in the NHIS because we were unable to directly measure service during wartime in the NHANES. Even though Vietnam War and peacetime veterans within this age group were very similar to each other in terms of sociodemographics, asthma, and regular smoking during youth, we made them even more comparable by using the same weighting method as we used in the civilian–veteran comparisons. More information on this weighting process is included in the appendix. The findings are shown in Figure 5.

The layout and interpretation of this figure are similar to the ones in the previous section, except that, here, Vietnam War veterans are in purple and their same-age, veteran peers who served during peacetime are in red. The left panel shows the results comparing wartime veterans with those who served right before the Vietnam War, with outcomes measured between the ages of 69 and 74. The right panel shows the results comparing wartime veterans with those who served right after the Vietnam War, with outcomes measured between the ages of 56 and 61. For both panels, the prevalence of the outcomes was very similar between Vietnam

FIGURE 5

Comparisons of Respiratory Health Outcomes Between Vietnam War Veterans and Same-Aged Veterans of the Adjacent Peacetime Periods



SOURCE: CDC, 2023.

NOTE: *N* = 10,145 for the Vietnam War versus post–Vietnam War veteran comparison and *N* = 8,289 for the Vietnam War versus pre–Vietnam War veteran comparison. Weighting is carried out by balancing all covariates across veteran service cohorts using IPTW. Error bars around the point estimates indicate 95-percent confidence intervals. All of the veteran service cohort comparisons are statistically insignificant ($p > 0.05$).

War and peacetime veterans. Furthermore, none of these comparisons yielded statistically significant differences. Because we did not find consistently elevated risk of worse respiratory health outcomes among combat versus peacetime veterans, these findings suggest that such elevated risk among Vietnam War veterans was not strictly because of toxic exposures during combat.

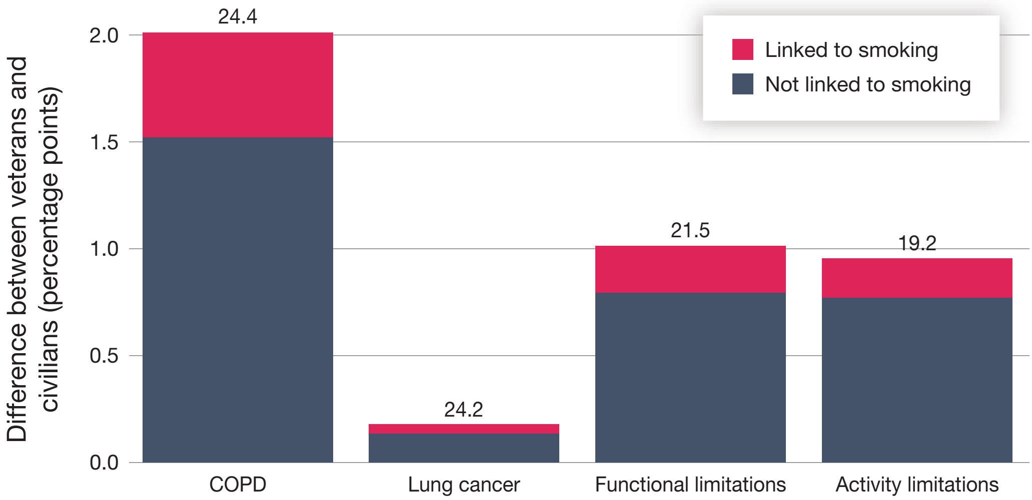
A Possible Explanation for Poor Respiratory Health of Veterans: Cigarette Smoking

One strength of the NHIS and the NHANES is that they collect retrospective information about cigarette smoking during youth, and we used this data to weight the civilian sample so that they have similar regular smoking profiles during youth as their veteran peers. However, smoking is a behavior that can be adopted at any age, and, as discussed earlier, deployment is associated with higher rates of smoking. Higher rates of smoking in adulthood among veterans compared with civilians is a potential explanation for the differences we observe in respiratory health. We explored this issue from two angles. First, following the analytic approach of the analyses presented so far, we used mediation analyses to estimate the extent to which disparities in respiratory health outcomes between veterans and civilians reflected differences in smoking during adulthood after adjusting for smoking behaviors that occurred at or before the time of enlistment. This estimated the contribution of adult smoking to the veteran–civilian disparities shown previously. Second, we used decomposition analyses to estimate the extent to which disparities in respiratory health outcomes between veterans and civilians reflected overall differences in regular smoking, regardless of when that smoking started. This was a departure from all previous analyses in that it did not weight civilians to resemble veterans, including in terms of regular smoking during youth. Instead, it examined the extent to which overall civilian–veteran lung health differences reflected overall differences in regular smoking. More information on the methods used for the mediation and decomposition analyses is included in the accompanying appendix. We restricted these analyses to sample members who were at least age 50, the age at which veteran–civilian disparities emerge.

Figure 6 presents findings from the mediation analyses used to estimate the extent to which disparities in respiratory health outcomes between veterans and civilians reflected differences in smoking during adulthood. Specifically, it shows the percentage-point difference for veterans and civilians in the prevalence of the four respiratory health outcomes included in NHIS: COPD, lung cancer, functional limitations, and activity limitations. The positive value of each bar indicates that, as seen in the earlier analyses, veteran outcomes are worse than those of comparable civilians for all four outcomes. However, these disparities did not seem to be exclusively driven by differences in adult smoking behaviors between veterans and civilians. In the figure, this can be seen by the fact that the red portion of the bars—the dif-

FIGURE 6

Extent to Which Respiratory Health Outcome Differences Between Veterans and Similar Civilians Are Attributable to Smoking in Adulthood



SOURCE: CDC, 2023.

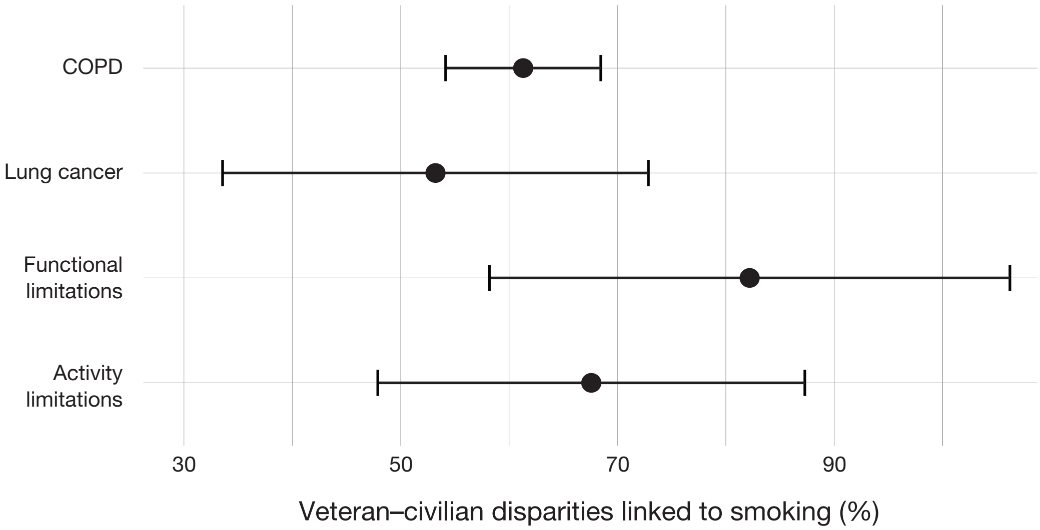
NOTE: *N* = 102,841. Analysis is restricted to sample members who were aged 50 or older. Adult smoking is the hypothesized mediator; mediation analysis is carried out using weighting. IPTW is used to make civilians comparable with veterans on multiple variables, including smoking prior to age 19. See the appendix for details. The percentages above the bars in this plot reflect the percentage of the veteran–civilian disparities that are estimated to be attributable to regular smoking during adulthood.

ferences attributable to adult smoking behaviors—are about 20 percent to 25 percent of the overall veteran–civilian differences.

Importantly, the results in Figure 6 estimate the disparities driven by adult smoking after controlling for differences in smoking behaviors that began before or at the time of enlistment. These estimates provide suggestive evidence about the extent to which the earlier analyses of veterans and civilians reflect the greater prevalence of smoking among veterans during adulthood. However, another distinct question is also of interest: To what extent are overall veteran–civilian respiratory health disparities driven by smoking altogether, regardless of when the smoking behaviors began? Figure 7 presents estimates that provide insight on this second question. Specifically, the figure shows the results of decomposition analyses that estimated the relationship between smoking and respiratory health outcomes and then presents estimates of how disparities would look if the prevalence of regular smoking were lowered for veterans to the level observed in the civilian population. Although the exact answer varies by outcome, overall, our findings suggest that *more than half of the disparities were attributable to cigarette smoking*, some much more so. These estimates suggest that smoking was a major driver—perhaps the leading driver—of respiratory health disparities between veterans and civilians.

FIGURE 7

Extent to Which Overall Disparities in Veteran and Civilian Lung Health Are Attributable to Differences in Smoking Behaviors



SOURCE: CDC, 2023.

NOTE: *N* = 102,841. Analysis is restricted to sample members who were aged 50 or older. This analysis does not weight civilians to be similar to veterans; it estimates how disparities in respiratory health outcomes would change if the prevalence of regular smokers was lowered among veterans to civilian levels. Error bars around the point estimates indicate 95-percent confidence intervals.

Conclusion

Our study contributes to the growing body of research on the relationship between military service and respiratory health. We find that veterans and civilians—who were weighted to resemble veterans in terms of sociodemographic characteristics, regular smoking during youth, and asthma—had similar respiratory health profiles during their 20s and 30s, with key symptoms by and large not present at these younger ages. However, the respiratory health profiles of veterans and civilians diverged with age, such that by age 60, veterans had higher rates of COPD, lung cancer, functional limitations because of poor lung health, and activity limitations because of poor lung health when compared with their civilian peers. Our findings complement existing studies that use service member records maintained by the Defense Manpower Data Center or survey data from the Millennium Cohort Study. Much of this research is motivated by concerns about exposure to toxic chemicals and fumes, such as Agent Orange during the Vietnam War and burn pits during the Global War on Terror. Findings from our study question whether such exposures are the central explanations for the poor lung health of veterans in our samples. Veterans who served during periods of peace, who were highly unlikely to have been exposed to Agent Orange or to burn pits, resembled veterans who served during wartime with respect to lung health. This does not prove that exposure to Agent Orange or to burn pits is benign. However, it raises broader questions regarding which other factors may be contributing to veteran–civilian differences in lung health. Some possible candidate explanations include exposure to toxins and dust during basic training, cumulative levels of stress associated with military service, and adverse occupational environments that are typical of jobs taken by veterans.[8] Although our data do not equip us to evaluate these explanations comprehensively, we do find evidence that cigarette smoking likely plays a large role in explaining veteran–civilian disparities.

Our results suggest that smoking differences between veterans and civilians across the course of life (both prior to age 19 and during adulthood) accounted for more than half of the observed disparities in lung cancer and COPD and account for even greater proportions of the disparities in activity and functional limitations. Notably, veterans were more likely to have smoked prior to age 19 (i.e., likely before they joined the military) compared with civilians; when controlling for these baseline differences, we found that higher rates of smoking among veterans during adulthood accounted for approximately 20 percent to 25 percent of the observed disparities in respiratory health outcomes among veterans. This suggests that although the military is rightfully taking steps to reduce toxic exposures and to provide needed benefits to veterans who were exposed, a broader focus on smoking prevention and cessation may have a more pronounced effect in terms of the overall health of the veteran population.

Despite the many strengths of our study—including large, nationally representative samples of both civilians and veterans from multiple periods of war and peace with pre-enlistment data on cigarette smoking and lung health—our findings should be considered in light of their limitations. First, although we were able to identify the wars in which members of our veteran sample served, we lack data on where they were stationed, and so the extent to which they were directly exposed to toxins is unknown. Consequently, we cannot ascertain how much toxic smoke and fumes in war contexts directly contribute to the poor respiratory health of veterans. Second, enlisting in the military is a nonrandom life choice that may be confounded with other factors. While we were able to measure and adjust for sociodemographic characteristics, pre-enlistment cigarette smoking, and asthma via IPTW, there might be other unmeasured factors that differentiate veterans from civilians and contribute to poor lung health. Third, the smoking analysis should be interpreted as exploratory because, in addition to concerns with unmeasured confounders, our binary measures of smoking used are crude and do not fully capture the level of cigarettes smoked (i.e., dosage) nor the duration of smoking over the lifespan. Lastly, poor lung health can cause death, particularly when it manifests as lung cancer. As a result, our findings are subject to survivorship bias, because those who die from severe lung diseases are not observed in our data. This may be why we observe small civilian–veteran lung cancer disparities. It also suggests value in prospective study designs that do not share this limitation.

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[8] Margaret D. Whitley and Eric Apaydin, *How Working Conditions in Civilian Jobs Can Affect Veterans' Health and Well-Being: Veterans' Issues in Focus*, RAND Corporation, PE-A1363-12, April 2024.

In closing, as policymakers, veterans' advocates, and health care providers grapple with the challenges faced by veterans from the Global War on Terror as they reintegrate into civilian life and enter midlife, respiratory health should remain a top health concern. Findings from our report underscore the need to monitor respiratory diseases and symptoms for this unique population. Future research on this topic should attempt to quantify the different contributors to the poor lung health of veterans to strengthen the empirical foundation for effective preventive and treatment strategies.

Appendix

Further Details on the Independent and Mediator Variables

Detailed descriptions of the independent and mediator variables in the NHIS and the NHANES are shown in Table A.1.

Methods for Age-Specific Comparisons of Veterans and Civilians in Figures 1 and 2

Two steps were used to generate the results shown in Figure 1. First, IPTW was used. With this approach, inverse probabilities of military service were estimated for civilians with logistic regression to make their covariate distribution resemble that of veterans. IPTW was conducted separately for every age, meaning that the analysis exactly matches on age and then balances the covariates within age. This approach, made possible by the very large NHIS sample, balances the joint distribution of age and the other covariates for veterans and civilians. These variables were balanced on sex, race, ethnicity, nativity, education, asthma, and youth smoking. The resulting balance was excellent: As was shown in Table 1, most covariates were nearly identical after balancing. The largest imbalance, for the percentage that were White, was only a 0.4-percentage-point difference (81.4 percent versus 81.8 percent). Second, generalized additive models were used to generate curves relating age to the outcomes. For each binary outcome, logistic regression was used to estimate cubic regression splines, separately for veterans and the weighted civilians, using the weights from the IPTW step.

The method used to produce Figure 2, which uses NHANES data, was similar. However, the NHANES sample is too small for the exact age-matching approach, so age was instead added as another variable to balance on with IPTW. The resulting balance for the sample used to examine wheezing, shown in Table 1, was still excellent. The civilian sample was on average one year older, and the largest difference in the binary variables was the 1.4-percentage-point–lower rate of high school graduation among weighted civilians compared with veterans (24.7 percent versus 26.1 percent). For the IPTW conducted using NHANES data for the FEV ratio analysis, the balance was similar: In that case the age difference was 0.9 years, and the largest difference in binary variables was a 1.3-percentage-point–lower rate of high school graduation rate among weighted civilians compared with veterans (24.4 percent versus 25.7 percent). None of the differences were substantively large.

TABLE A.1

Source and Construction of Variables

Measure	NHIS	NHANES
Veteran	Binary variable indicating whether respondent served in military	Binary variable indicating whether respondent served in military
Age	Age in integer years	Age in integer years
Service cohort	Factor variable indicating the earliest war period that veterans served in; if none, the earliest period of peace they served in	Factor variable indicating decade of birth
Female	Binary variable indicating whether respondent is female	Binary variable indicating whether respondent is female
Race/ethnicity	Race is a factor variable with six categories (White, Black, Native, Asian, redacted, multiple); Hispanic ethnicity is a separate binary variable	Factor variable with four levels (White, Black, Hispanic, other)
Nativity	Binary variable indicating whether respondent was born in the United States	Binary variable indicating whether respondent was born in the United States
Education	Binary variable indicating whether respondent graduated from high school	Factor variable with five levels (<9th grade, 9th–11th grade, high school graduate, some college, college degree)
Asthma	Binary variable indicating whether respondent has ever been told they have asthma by a health care professional	Binary variable indicating whether respondent was told that they have asthma by a health care professional before the age of 19
Youth smoker	Binary variable indicating whether respondents report that they have smoked at least 100 cigarettes and started regularly smoking before the age of 19	Binary variable indicating whether respondents report that they have smoked at least 100 cigarettes and started regularly smoking before the age of 19
Adult smoker (used in mediation analysis only)	Binary variable indicating whether respondents report that they were regular smokers (having smoked more than 100 cigarettes) past the age of 21	N/A
Ever smoker (used in decomposition analysis only)	Used in decomposition analysis; binary variable indicating whether respondent has ever smoked more than 100 cigarettes	N/A

NOTE: For details on the outcome variables, see the main text.

Methods for Cohort-Specific Comparisons of Veterans and Civilians in Figures 3 and 4

To produce Figure 3, IPTW was carried out separately for each period of service. First, to improve comparability, the set of comparison civilians for a given period of service was restricted to those who were within the age range of the veterans of that period of service.

Then, inverse probabilities of military service for those civilians were estimated with logistic regression to make their covariate distribution resemble that of veterans. These variables were balanced on age, sex, race, ethnicity, nativity, education, asthma, and youth smoking. To enhance age balance across civilians and veterans, age was treated as a factor variable. This contrasts with the previous step in which age was treated as a continuous variable because age-related patterns were the focus rather than a control variable. The resulting balance for each period was excellent: Across all the periods of service and covariates, the largest difference was the 1.5-percentage-point difference in high school graduation (79.2 percent of Korean War veterans graduated versus 77.7 percent of weighted civilians). To calculate standard errors and *p*-values, a weighted logistic regression model was fit for each combination of period of service and outcome.

The methods used to produce Figure 4 were similar. One difference was that the NHANES analysis conducts IPTW within birth decades rather than periods of service. Therefore, the relevant set of comparison civilians was simply those civilians born in the same decade as a given set of veterans. The other difference was that age was treated as a continuous variable instead of a factor, owing to the NHANES's smaller sample size. Aside from those differences, the steps taken to construct Figure 4 were the same as Figure 3. In general, the resulting balance was excellent. However, for the wheezing comparison, among those born in the 1930s, 77.7 percent of weighted civilians were White compared with 73.1 percent of veterans. This was by far the largest difference, and only three other covariates (1930s cohort education and 1940s cohort youth smoking and race) differed by more than 1 percentage point. Across the comparisons, average age differed by up to about two months. For the FEV ratio comparison, the same was true, except that for the 1930s cohort, the White difference between civilians and veterans was 4 percentage points, and for the 1930s cohort, youth smoking also differed by just over 1 percentage point.

Methods for Comparisons of Vietnam War Veterans with Other Veterans in Figure 5

Figure 5 contains comparisons of Vietnam War veterans with adjacent peacetime service veteran cohorts. To compare Vietnam War veterans with those who served in the peacetime preceding the war, we dropped peacetime veterans who were born after 1943 and Vietnam War veterans who were born before 1944. Then, we restricted comparisons to those who were observed during the same age range as the remaining veterans (69 to 74). This two-step procedure led to two veteran groups who were the same age but who were from different birth cohorts and served in different periods. Then, IPTW was used to make these two groups of veterans resemble each other (akin to an average treatment effect), again with the weights estimated with logistic regression. These variables were balanced on age (as a factor variable), sex, race, ethnicity, nativity, education, asthma, and youth smoking. Youth smoking differed by 2.3 percentage points after balancing, with most other covariates being nearly identical across the veteran groups. To calculate standard errors and *p*-values, a weighted logistic regression model was fit for each outcome.

The procedure for comparing Vietnam War veterans with postwar veterans was the same, except, in that case, Vietnam War veterans who were born after 1956 were excluded and peacetime veterans born before 1957 were excluded, which made the age range for this comparison 56 to 61 years old. Again, only youth smoking differed by more than 2 percentage points (it differed by 2.4 percentage points), with most other covariates being nearly identical across the veteran groups.

Methods for Mediation Analysis in Figure 6

To produce the mediation results shown in Figure 6, we used the weighting method advanced by Huber (2014).[1] This approach estimated natural direct and indirect effects with inverse probability weights; the primary difference from the earlier analyses is that it estimated the inverse of treatment probability given the mediator, in addition to potential confounders. We used this method on the NHIS respondents who were age 50 and older to estimate the extent to which the veteran–civilian disparities observed among older respondents in the earlier analyses reflected elevated rates of adult smoking among veterans. In this analysis, as in previous veteran–civilian comparisons, the "treatment" variable was veteran status, and we used balancing weights to make civilians resemble veterans. (To use language common in weighting, we estimated an average treatment effect on the treated.) The mediator was a binary measure of adult smoking, specifically whether respondents were regular smokers past the age of 21. The controls were age (measured as a factor), sex, youth smoking, race, ethnicity, nativity, asthma, and education. Standard errors were calculated via bootstrapping.

Methods for Decomposition Analysis in Figure 7

The results in Figure 7 were based on a method that Lundberg (2022) introduced to estimate the extent to which disparities between two groups would be reduced under a hypothetical intervention.[2] We applied this approach in our analysis with smoking as our "intervention" or "treatment." Specifically, we applied this method to NHIS respondents who were age 50 and older to estimate how disparities in respiratory health outcomes between veterans and civilians would look if veterans smoked at the same levels as civilians and to compare that with the observed disparities. Unlike previous analyses, this approach did not entail balanc-

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[1] Martin Huber, "Identifying Causal Mechanisms (Primarily) Based on Inverse Probability Weighting," *Journal of Applied Econometrics*, Vol. 29, No. 6, September/October 2014.

[2] Ian Lundberg, "The Gap-Closing Estimand: A Causal Approach to Study Interventions That Close Disparities Across Social Categories," *Sociological Methods and Research*, Vol. 53, No. 2, 2022.

ing civilians to look like veterans. Rather, it used doubly robust estimation to isolate the effect of a treatment variable—in this case whether respondents were ever regular smokers—and estimate how group (in our case, veteran–civilian) disparities would change if that treatment variable had a different distribution across groups. More specifically, we used IPTW in a treatment model to adjust for differences between smokers and nonsmokers, balancing on sex, age, race, ethnicity, nativity, asthma, education, and veteran status. Separately for each outcome, an outcome model was also fit—specifically a logistic regression model that adjusts for sex, age, race, ethnicity, nativity, asthma, education, and the interaction of veteran status with regular smoking (i.e., the treatment variable in this analysis). Using the resulting estimate, a counterfactual veteran–civilian disparity was calculated, stochastically setting the level of smoking among veterans to the observed level among civilians. This number was divided by the observed disparity to estimate the percentage that disparities would shrink if veterans smoked at level comparable with civilians. Standard errors were calculated via bootstrapping.

Abbreviations

CDC	Centers for Disease Control and Prevention
COPD	chronic obstructive pulmonary disease
FEV	forced expiratory volume
IPTW	inverse probability of treatment weighting
NHANES	National Health and Nutrition Examination Survey
NHIS	National Health Interview Survey

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Many veterans and their advocates are concerned that military service may cause impaired respiratory function resulting from occupational exposures to environmental hazards (e.g., Agent Orange in the Vietnam War, burn pits in the Global War on Terror) or infectious diseases (e.g., pneumonia). Such exposures occurring in service members' young adulthoods may not have immediately discernible effects on lung health; some symptoms may emerge in the immediate months or years after separation from the military, and diagnosable conditions may not manifest until decades later. Health care providers serving veteran populations must consider both the unique combat circumstances surrounding the time of veterans' service and the age-graded nature of health conditions that might result from military service.

To characterize lung health across a broad age range of veterans, the authors analyzed data from two nationally representative surveys of health and well-being that include samples of veterans and their civilian peers. With these data, the authors compared respiratory health outcomes observed for the veteran and civilian populations who were of prime age for military service during different periods of national conflict: the Korean War, the Vietnam War, Operation Desert Shield/Storm, and the Global War on Terror.

The authors estimated that differences in smoking behaviors—including differences prior to enlistment—account for at least half of the veteran–civilian disparities in respiratory outcomes. This suggests the need for military-based and post-transition smoking cessation efforts and further research into other factors that might contribute to these veteran and civilian disparities, such as environmental exposures during military service.

$16.50

ISBN-10 1-9774-1359-5
ISBN-13 978-1-9774-1359-8

51650

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RR-A1363-13