Walden University

College of Health Sciences and Public Policy

This is to certify that the doctoral study by

Brandy Hill

has been found to be complete and satisfactory in all respects,
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Walden University
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Abstract

Cumulative Exposure to Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS)

Impacting Veteran Cancer Diagnosis

by

Brandy Hill

MPH, Purdue Global University, 2019

BS, Kaplan University, 2017

Doctoral Study Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Public Health

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November 2023

Abstract

Based on the ecosocial theory of disease distribution, this study investigated potential links between US military veterans' exposure to PFAS-contaminated water sources and specific health diagnoses from 2005 to 2015. Utilizing a quantitative cross-sectional design, with the NHANES datasets for years 2005-2015, the study examined the associations between prostate cancer, liver damage, thyroid disease diagnoses, and cumulative environmental exposures resulting from permanent change of station assignments during veterans' US Military service. Despite rigorous analytical approaches incorporating tools such as Pearson correlation, Spearman rank correlation, and multiple linear regression, the study did not identify any statistically significant relationship between the specific health conditions and PFAS exposure. However, the study's significance goes beyond primary findings, emphasizing the complex and multi-layered nature of disease distribution, which is influenced by various environmental, societal, and biological determinants. The study underscored the importance of a multi-dimensional approach to health determinants, as suggested by the ecosocial theory. This approach can inspire positive social change through leading policy-makers to consider the intricate interplay between societal constructs, biological predispositions, and environmental exposures when making decisions.

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Dedication

To my husband, four children, and my grandson (Leyland), who traveled my educational journey with me for the past decade. Thank you all for always encouraging, telling me that I was strong, and giving me the space to continue. This is your final degree!

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Chapter 1: Introduction to the Study

Introduction

Individuals can consider the effects of our lived-in environment as a positive or a negative influence on overall personal health. Nearly 12 million individuals around the globe perish each year due to unhealthy lived-in or employment settings (Office of Disease Prevention and Health Promotion, 2020). A lived-in location will be impacted by variances in geographic sizes, environments, biodiversity, ecological assets, culture, lifestyle, and human population densities that inform how individuals live and thrive in that area. Additionally, each location will have a highly varied and unequal socioeconomic development and capacity to respond to or mitigate environmental and health challenges that may present to the local population and any transient members. These health challenges can be influenced by air quality, soil or water contamination, food safety, and overall security.

The topic of environmental influences on health has been extensively explored in recent research by the National Institute of Environmental Health and the Veterans Health Administration. In recent decades, research has expanded to understand the environmental impacts on military service members' health. These research studies have centered on specific environmental exposures such as Agent Orange and Vietnam-era service members and their subsequent generations, especially those who endured Desert Storm, other Southwest Asia (SWA) locations, and burn-pit exposures. There has been a focus on wartime and deployment locations and environmental exposure in both cases; however, there has been minimal research into the culmination exposure due to the frequency of permanent relocation of United States military members and their families.

These environmental influences can be magnified based on the number of environments one has lived in (Wang et al., 2019; National Institute of Environmental Health, 2021). In addition, nomadic populations can extrapolate environmental influences and effects due to facing frequent relocations. For example, one migratory population by trade is members of United States military forces. It is noted by Bond (2016) that a third of the members of the United States military forces permanently relocate annually or undergo a Permanent Change of Duty Station, also known as a PCS. This frequency places the veteran population and their families in new permanent environments four to five times in a 20-year career, not including temporary deployments or TDYs. This globalization of movement and exposure is a fact of life for many of the 1.195 million service members (Bond, 2016) and their families.

Perfluoroalkyl and polyfluoroalkyl substances (PFAS) contain thousands of known chemicals, and they are found in many different consumer, commercial, and industrial products (Environmental Protection Agency, 2022). The environmental exposure to higher than allowable PFAS has been noted to be present and not in compliance with EPA's Safe Drinking Water Act (SOWA) 3rd Unregulated Contaminant Monitoring Rule (UCMR3) allowable limits in 24 DoD drinking water systems and 564 areas surrounding bases (Under Secretary of Defense for Acquisition and Sustainment, 2019). A few animal studies have correlated PFAS as hepatotoxic, immunotoxic, and tumorigenic, noting that they may produce reproductive and developmental toxicity following exposure to pregnant females (Barton et al., 2020). Additionally, PFAS have been connected to many health concerns, including an increased risk in populations of kidney and testicular cancers, as well as changes to immune system response, liver damage, and thyroid disease (Agency for Toxic Substances and Disease Registry, 2022). In one study, military service has been linked to a higher cancer prevalence than those without military service records (Goldberg et al., 2021). Some accounts indicate that the percentage of veterans diagnosed with cancer is nearly 11 percent compared to the 10 percent of those Americans who have never served (Cancer Center, 2020). Researchers have discovered that excessive exposure to environmental pollutants is linked to increased disease risk for military members and veterans; however, this research has been limited to warfare theatre environments and is not all-encompassing for the veteran population (Geretto et al., 2021).

This research study will review the historical background and diverse literature on environmental exposure to PFAS and its implications on health. The theoretical foundation of this study is the ecosocial theory of disease distribution, which identifies the relationships between disease distribution and cumulative exposure (Krieger, 2019), based on examination of over 3000 veteran records to provide quantitative analysis to appraise the influence of the exposure and service relationship.

Background

Certain environmental or occupational hazards can influence the onset or aggregation of medical conditions or poor health outcomes due to exposure risks in lived-in environments. Environmental exposures related to lived-in environments have been linked to specific health concerns such as cancer as far back as the Eighteenth-century (Cohen & Jefferies, 2019). In one study, military service has been linked to a higher cancer prevalence in comparison to those without military service records (Goldberg et al., 2021). Additionally, researchers have noted that excessive exposure to environmental pollutants is linked to increased disease risk for soldiers; however, this research has been limited to the warfare theatre environments and not all-encompassing for the veteran population (Geretto et al., 2021). Environmental exposures are not a military service member-specific risk; however, their unique experiences may influence culmination-related cancer diagnosis.

The environment we live, work, and play can considerably impact individual and community health. These environmental health hazards align in one of five categories: physical, biological, chemical, cultural, and social. In addition, environmental exposure has been linked to various types of poor health outcomes. Some significant health implications solidified by epidemiological, toxicological, and clinical studies include cancer, asthma, cardiovascular disease, and poor birth outcomes (Environmental Protection Agency, 2022). This number has increased over the last decades primarily due to research and technological advancements in determining causation and relationships.

A more common environmental health concern is perfluoroalkyl and polyfluoroalkyl substances (PFAS). According to the Centers for Disease Control and Prevention (CDC) (2022), PFAS contains a large group of manufactured chemicals used since the mid-1950s in various industries and consumer products worldwide. PFAS refers to a class of chemicals that contain over 600 substances (Environmental Protection Agency, 2022). These substances have a large variety of uses, from non-stick cookware to making furniture and clothing stain-resistant and waterproof (Environmental Protection Agency, 2022). One of the many uses was the first aqueous film-forming foam (AFFF), invented by a group of research scientists from the US Naval Research Laboratory in the early 1960s and was later patented in 1966 (Wilkinson et al., 2022).

This substance was deemed the DoD standard for petroleum-based firefighting in the 1970s (Environmental Protection Agency, 2022). It has been noted that PFAS chemical substances do not easily break down in the environment and have been referred to as "forever chemicals." They can be found in public water systems and drinking water wells, soil, and outdoor air near industrial sources or areas with frequent PFAS use (Imir et al., 2021). PFAS have been linked to causing damage to the liver, increased cholesterol levels, increased risk to pregnancy and infant outcomes, increased risk of kidney and testicular cancers, and changes to the immune system (Centers for Disease Control and Prevention, 2022).

A veteran is "a person who served in the active military, naval, or air service, and was discharged or released under conditions other than dishonorable" (Code of Federal Regulations, 2014). According to the Department of Veterans Affairs, the US Veteran population includes nearly 21 million individuals as of 2020 data polls (National Center for Veterans Analysis and Statistics, 2022). Additionally, according to the latest in a series of veteran population projection models, VetPop2020, these numbers will remain consistent for the coming years with a slight variance in the mortality rates to reflect increases in death rates due to the COVID-19 pandemic (National Center for Veterans Analysis and Statistics, 2022). Overall, veteran populations are predominantly male, and male veterans are older than female veterans, with median ages of 65 and 41, respectively (National Center for Veterans Analysis and Statistics, 2020). However, the numbers of minority and female veterans continue to increase. By 2037, it is expected that minority veterans will comprise 32.8% of the total veteran population, compared to the current 23.2% (National Center for Veterans Analysis and Statistics, 2020).

Cancer is a prevalent health concern today, and the World Cancer Research Foundation (2022) has estimated an increase of 18.1 million cancer cases worldwide. Of these, 9.3 million cases were in men and 8.8 million in women (World Cancer Research Foundation, 2022). In 2022, the United States had an estimated 1.9 million new cancer cases diagnosed and 609,360 cancer deaths (American Cancer Society, 2023). The percentage of veterans that have been diagnosed with cancer is nearly 11 percent compared to the 10 percent of those Americans who have never served (Cancer Center, 2020). In one study, military service has been linked to a higher cancer prevalence in comparison to those without military service records (Goldberg et al., 2021). Additionally, with veterans populations being predominantly male, it is significant to note that one in every five male veterans develops prostate cancer (Cancer Center, 2020). Furthermore, only 7% of diagnosed cancers are of hereditary origin, while environmental exposures or environmental factors cause the overwhelming 93% of non-hereditary cancers (Parsa, 2012).

PFAS compounds have been utilized in many industries, including some United States Government (USG) and Department of Defense (DoD) operations. The mid-1960s compounded aqueous film-forming foam (AFFF) was considered a mission-critical PFAS innovation (Imir et al., 2021). This was primarily because it quickly extinguished petroleum-based fires, saving lives and resources for firefighters and individuals in positions with a high risk of petroleum-based fires (Imir et al., 2021). Some of the most common ways humans are exposed to PFAS in AFFF include soil, water, and air contamination, which could be linked to seeped or leached contamination (Imir et al., 2021). For example, in a USG study conducted in 2014 by the Pentagon, over 400 locations had known or suspected PFAS contamination, and over 1600 locations had groundwater that tested above the EPA guidelines for safe water (Sullivan, 2018). The study indicated that PFAS was present and over the EPA allowable limits in 24 DoD drinking water systems and 564 areas surrounding bases (Under Secretary of Defense for Acquisition and Sustainment, 2019). Researchers have discovered that excessive exposure to environmental pollutants, such as PFAS contaminated water, is linked to increased disease risk for soldiers (Geretto et al., 2021). Specifically, PFHxS serum concentration (14.8 ng/mL) was approximately 12 times as high as the US national average. (Barton et al., 2020). In addition, epidemiological studies suggest a link between increased blood PFAS levels and prostate cancer incidence (Imir et al., 2021).

Problem Statement

The specific research problem that will be addressed through this study is the measurement of lifelong environmental exposure to PFAS contaminated water sources and risks regarding the cumulative effects on US veteran's health in relationship with the diagnosis of related health outcomes such as prostate cancer, liver damage, and thyroid disease due to military permanent station moves, not including operational deployment. Although researchers have investigated PFAS and health implications and specific circumstances in veteran health, there is very little or no literature on the cumulative lifelong environmental health effects of PFAS contaminated water sources exposure on veteran health and the diagnosis of prostate cancer, liver damage, and thyroid disease due to military permanent station moves in veterans that utilize veteran healthcare insurance.

The topic was solidified once reviewing the document made available by the Under Secretary of Defense for Acquisition and Sustainment (2019) describing the PFAS levels to be present and over the EPA allowable limits in 24 DoD drinking water systems and 564 areas surrounding different military base locations. It is well-researched that PFAS has been connected to many health concerns. Some notable concerns include an increased risk in kidney and testicular cancer populations, changes to immune system response, liver damage, and thyroid disease (Agency for Toxic Substances and Disease Registry, 2022). Noted in the research provided by Geretto et al. (2021), excessive exposure to environmental pollutants is linked to increased disease risk for soldiers in warfare theatre environments; however, this scenario is not all-encompassing for the veteran population. It has been noted that a third of the US forces service members have a PCS each year, thus changing their environmental exposures to lived-in environments (Bond, 2016).

Purpose of the Study

The purpose of this quantitative study is to explore the association between veterans' diagnosis of prostate cancer, liver damage, and thyroid disease and cumulative environmental exposures of PFAS contaminated water sources due to permanent change of station assignment moves due to US Military service, not to include operational deployments in between 2005-2015. Additionally, this research will explore if a relationship exists between tour lengths over five years and diagnosis of prostate cancer, liver damage, thyroid disease, and cumulative environmental exposures of PFAS contaminated water sources. I will also research for further relationship adjusting for gender, race, tobacco use, and age.

Research Questions

The research questions for this study are as follows:

RQ1: Is there an association between veterans' diagnosis of prostate cancer, liver damage, thyroid disease, and cumulative environmental exposures of PFAS contaminated water sources due to permanent change of station assignment moves in-between 2005-2015 adjusting for gender, race, tobacco use, and age?

Ho1: There is no significant association between US military veterans' diagnosis of prostate cancer, liver damage, thyroid disease, and the impact of cumulative environmental exposures of PFAS contaminated water sources due to permanent change of station assignment moves in between 2005-2015, adjusting for gender, race, tobacco use, and age.

HA1: There is a significant association between US military veterans' diagnosis of prostate cancer, liver damage, thyroid disease, and the impact of cumulative environmental exposures of PFAS contaminated water sources due to permanent change of station assignment moves in between 2005-2015, adjusting for gender, race, tobacco use, and age.

RQ2: Is there an association between US military veterans' diagnosis of prostate cancer, liver damage, thyroid disease, and the impact of cumulative environmental exposures of PFAS contaminated water sources moderated by the extended total tour lengths greater than five years and adjusting for gender, race, tobacco use, and age?

Ho2: There is no significant association between US military veterans' diagnosis of prostate cancer, liver damage, thyroid disease, and the impact of cumulative environmental exposures of PFAS contaminated water sources moderated by the extended total tour lengths greater than five years and adjusting for gender, race, tobacco use, and age.

HA2: There is a significant association between US military veterans' diagnosis of prostate cancer, liver damage, thyroid disease, and the impact of cumulative environmental exposures of PFAS contaminated water sources moderated by the extended total tour lengths greater than five years and adjusting for gender, race, tobacco use, and age.

Nature of the Study

This research is grounded in ecosocial theory of disease distribution, whereby the core constructs are dissected and visualized independently. The environment individuals live in and the migratory nature of service members' lifestyles impact the embodiment and pathways of embodiment when conceptualizing the multiple-domain distribution (Krieger, 2001). An additional rationale for choosing the ecosocial theory of disease distribution is the congruence of the research questions to the core constructs that systematically link social and biological processes across levels (Krieger, 2012).

This quantitative correlational study examines the relationship between a diagnosis of prostate cancer, liver damage, thyroid disease, and environmental exposures to PFAS for veterans. The correlational design for this study enables the discovery of the presence and strength of a relationship between variables without manipulation (Burkholder et al., 2020). This is accomplished by utilizing national secondary data from the NHANES (National Health and Nutrition Examination Survey) public datasets from 2005-2015. By combining the NHANES datasets of Demographic and Health History Questionnaire, Laboratory Data, Dietary Interview, and Environmental Questionnaire, it will be possible to examine the association between the diagnosis of prostate cancer, liver damage, decreased fertility, and thyroid disease among veterans and their cumulative environmental exposures to PFAS contaminated water sources, while adjusting for gender, race, tobacco use, age, and, potentially, dietary factors. This will highlight the prevalence of cancer among the veteran population using the variables cancer type, diagnosis, disease, duty locations, the time assigned at duty locations, age, gender, race, and tobacco use. To collect the necessary data points, the information is extracted from the NHANES 2005-2015 datasets. The data points included in the NHANES dataset from the Demographic and Health History Questionnaire, Laboratory Data, and Environmental Questionnaire include the variables of cancer type, diagnosis, disease, geographic locations, the length of time in locations, age of cancer diagnosis, race, gender, and tobacco use.

Theoretical Framework

The theory that grounds this study and provides a framework is the ecosocial theory of disease distribution. This theory was built upon the foundations of the social production of disease from the 1930s coupled with the 1970s theory of political economy of health infused by incorporating biological explanations, a lifespan perspective, and a multilevel viewpoint over space and time, to describe relationships or association between exposures and disease (Krieger, 2005). This theory and its foundational constructs were initially authored in 1994 by Dr. Nancy Krieger. They have been utilized to describe and explain causal relationships in disease distribution and the cumulative relationship between exposure, resistance, and susceptibility to disease among societal constructs (Krieger, 2019). They combined biological and psychosocial influences on disease occurrence and development (Krieger, 2019). This theory’s baseline of use has been leveraged to build comprehensive pictures of the association of various cancers and health inequities due to societal context to create various population patterns of health or lack of health (Krieger, 2019). Four core constructs work together in synergy to build the foundation of explanation for disease distribution (Krieger, 2019). These constructs are embodiment; pathways to embodiment; the cumulative interplay of exposure, susceptibility, and resistance; agency and accountability (Krieger, 2005). By blending and incorporating biological explanations and a lifespan perspective, scientists and researchers have rigorously investigated whether there are relationships or associations between exposures and disease (Krieger, 2005).

The ecosocial theory of disease distribution has been utilized as a foundation to build substantial research into the relationships in disease distribution and the cumulative association between exposure, resistance, and susceptibility to disease (Krieger, 2019). According to Petteway et al. (2019), this theory has provided critical contributions to a greater understanding of population health to reconnect to social epidemiology. This theory provided the central cohesion in the Latinx study by Olmos et al. (2023), which analyzed the associations in the minority older populations' access to care and the onset of chronic illnesses, amide other societal injustices. In both studies, the research questions have guided these studies, the methods used, and the underpinning of how the ecosocial theory suggests that inequitable race relations simultaneously generate inequitable conditions for some populations (Krieger, 2012).

Many research studies are grounded in either conceptual or theoretical frameworks that explain, predict, and lend to a greater understanding of phenomena or challenge or extend current concepts within a given topic. Some original social epidemiology theories were psychosocial, social production of disease, and ecosocial theory (Krieger, 2001). These theories lack the comprehensive integration of the multi-domain construct to health outcomes and health inequities due to societal context to create various population patterns of health or lack of health (Krieger, 2019). When delving deeper into the psychosocial theories, there is an importance placed on the 'host-agent-environment' that is considered too undefined and does not make distinctions for the contextual environment (Krieger, 2001). Additionally, previous theories did not account for research focused on disease distribution versus only disease causation, and they failed to account for the factors affecting population susceptibility (Krieger, 2001). The ecosocial theory of disease distribution constructs of 'embodiment', 'pathways of embodiment', and the 'dynamic and cumulative relationship between exposure, susceptibility and resistance' complete the guiding concern of who and what is driving the inequalities in health for the veteran population (Krieger, 2001).

The current study related to this theory by dissecting its core constructs and visualizing them independently. The environment one lives in and the service members' continuance to change settings will impact the embodiment and pathways of embodiment when conceptualizing the multiple-domain distribution (Krieger, 2001). Additionally, there are three critical claims to embodiment: bodies tell stories about and cannot be studied divorced from the conditions of our existence; bodies tell stories that often, but not always, match people's stated accounts; and bodies tell stories that people cannot or will not tell, either because they are unable, forbidden, or choose not to tell (Krieger, 2005). An additional rationale for choosing the ecosocial theory of disease distribution is the congruence of the research questions to the core constructs that systematically link social and biological processes across levels (Krieger, 2012).

This research utilized the population of US veterans and the diagnosis of prostate cancer, liver damage, and thyroid disease moderated for time of tour length in a geographic location. The logical connections between the framework presented and the nature of my study include its construct of disease and overall determining patterns of disease distribution aligned with the pathways to embodiment construct of the ecosocial theory of disease distribution being investigated in my study, the environmental exposure of PFAS contaminated water sources, and the diagnosis of prostate cancer for US veteran military members (Krieger, 2012). Additionally, this framework integrates the societal and ecological context with life-course and reasoning to highlight exposure-related disease onset (Doll, 2018).

The ecosocial theory of disease distribution is a framework that examines the complex interactions between environmental, social, and biological factors that contribute to the distribution of disease within populations. This theory recognizes that health is not just a product of individual behavior or genetic predisposition but is also shaped by social and environmental conditions. The constructs of the ecosocial theory of disease distribution that are relevant to the research questions of R1 and R2 include the following:

Environmental exposures. This construct refers to the various environmental factors that individuals are exposed to, such as air pollution, water contamination, and hazardous waste. In the case of the research questions, the focus is on the cumulative environmental exposures of PFAS contaminated water sources due to permanent change of station assignment moves between 2005-2015.

Social context. This construct refers to the social factors that shape health outcomes, such as socioeconomic status, access to healthcare, and cultural beliefs about health. In reference to the research questions, the focus is on the impact of extended total tour lengths greater than five years as a social context factor that may moderate the association between environmental exposures and disease outcomes.

Biological factors. This construct refers to the individual biological factors contributing to disease risks, such as genetics and epigenetics. In the case of the research questions, the focus is on the diagnosis of prostate cancer, liver damage, and thyroid disease, which are all conditions that environmental and biological factors may influence.

Research Questions 1 and 2 align with the ecosocial theory of disease distribution by exploring the complex interactions between environmental, social, and biological factors that contribute to the distribution of disease among US military veterans. The questions specifically focus on the environmental exposure to PFAS contaminated water sources due to permanent change of station assignment moves between 2005-2015 and the potential impact of extended total tour lengths greater than five years as a social context factor.

Literature Search Strategy

Broad and narrow keywords and phrases were included to target an inclusive listing of literature to review. The keywords and phrases targeted were *environmental health, environmental complications, environmental health impact, PFAS, renal cancer, prostate cancer, service members, veterans, Military, enlisted,* and *officer*. In addition, to foster a wide-ranging evaluation of available data, the following databases were included in the literature search: Walden University Library, CINAHL Plus, EMBASE, TOXNET, Medline, PsycINFO, PubMed, SAGE Premier, ScienceDirect, and Veterans Association Million Veteran Program (MVP). All literature searches were conducted to include peer-reviewed publications and research from 2017 to the present date. Seminal literature on the theoretical framework from the originating researcher was used as a time frame exclusion. These sources cultivated over 2500 returns; however, 48 articles have been included as the foundation, as well as in the literature gap analysis.

Literature Review Related to Key Variables and/or Concepts

Veteran healthcare and recently identified limitations have been significant areas of interest in legislation and research. These topics span the entire gamut, including access to care, diagnosis, treatment, and causation or extrapolation of disease. Studies have shown that service members and veterans have a higher prevalence of cancer diagnosis, including brain cancer, gastrointestinal cancer, glioblastoma, and cancer of the head, neck, kidney, pancreas, respiratory or reproductive system, lymphoma, and melanoma (Barth et al., 2017; Goldberg et al., 2021; Veterans Affairs, 2023). As a result, there has been an insurgence in research to provide the foundation for current and future legislation and policy regarding service members and veteran health. This compilation of research centered around deployed environmental exposure to toxic substances, leading to the expansion of available benefits with the passing of the PACT Act in November 2022 (Veterans Affairs, 2023). Research presented by Geretto et al. (2021) has shown that veterans are at a higher risk of environmental exposures, leading to increasingly poor health outcomes due to the culmination of exposures that accompanied service commitment time frames.

Of the 22.3 million veterans receiving care in the United States, only about 9 million receive care at a Veteran Administration Medical Treatment Facility (Burgo-Black et al., 2016). These figures indicate that the general population caregiver is more likely to have healthcare-related interactions with veterans who have sustained physical, mental, or psychosocial needs due to combat or other military service-related timeframes (Burgo-Black et al., 2016). Lindler (2015) further highlighted that military veterans have a variety of potential exposures to infectious diseases and environmentally toxic substances that do not match those of the general public. Lindler (2015) explained that although there is a method to periodically monitor service member environmental exposures with the DoD serum repository, this is typically not used beyond pre- and post-deployment, leaving a gap in home station exposure information and data. The lack of exposure-related information is partly due to the Armed Forces Health Surveillance Center not having a method to provide surveillance for military members outside operational or otherwise deployed environments (Lindler, 2015).

Additionally, it has been noted that the V.A., DoD, and private sector do not currently have a method of sharing Electronic Health Record (EHR) data to provide population-level health monitoring, making patient self-disclosure paramount for appropriate preventative care (Chretien et al., 2016). Furthermore, Geretto et al. (2021) noted that service members often do not report their exposure to environmental pollutants conceivably due to a lack of overall understanding of the possible future health implications or accessible venues. To further complicate the situation, service members and their families are likely to change their geographic area of residence every 3-4 years, forcing a change in their environmental exposures and a lack of consistency in exposures

(Bond, 2016). These factors may increase military environmental exposure and tracking concerns in permanently assigned locations; however, they may not be addressed swiftly due to finding the balance between national security and US military health or exposure mitigation (Lebeda et al., 2020).

In recent years, environmental health implications surrounding service members and the greater veteran population have become a significant concern, specifically linking deployments and poor health outcomes. Although a topic currently under the microscope of many researchers, some of these concerns date back to wars spanning multiple generations. Patterson et al. (2016) completed a study that included members from Operation Ranch Hand and Agent Orange exposure from 1962-1971 and the more significant dermatological health considerations. Some conditions linked to this Vietnam deployed experience are chloracne, porphyria cutanea tarda, non-Hodgkin lymphoma, and soft-tissue sarcomas (Patterson et al., 2016). Other environmental exposures from the 1977-1980 cleanup of Enewetak Atoll, the 1966-1967 B-52 nuclear weapon instance in Spain, and the 1968 Greenland instance have been linked to radiation health implications (Veterans Affairs, 2023). Furthermore, Barth et al. (2017) completed research on the association between brain cancer diagnosis and Iraq War service in 2000-2004 for members potentially exposed to the Khamisiyah Ammunition Storage Facility. In addition, gastrointestinal cancer, glioblastoma, cancer of the head, neck, kidney, pancreas, respiratory or reproductive system, lymphoma, and melanoma have been linked to having association with Gulf War deployments (Veterans Affairs, 2023). In further research presented by Hasan (2021), personnel deployed to the Middle East had an increased risk of environmentally influenced pneumonia acquired from exposure to inorganic and organic materials in dust storms. This exposure has been termed Al Eskan disease, Persian Gulf syndrome, Persian Gulf War syndrome, Gulf War syndrome, or desert dust pneumonitis in different publications and legislation (Hasan, 2021). Geretto et al. (2021) noted that in a cohort of 236 Iran-Iraq war veterans with exposure to mustard gas, 42.5% still demonstrated respiratory complications 15-20 years later.

Deployments are only one location of service member potential exposure, as well as not all members of the US military have participated in a global deployment. The US Military members have operational training exercises to mimic war in less intense environments. These semi-controlled, less tremulous training exercise environments do not indicate zero hazards for the service members; however, they lend insight into the exposure possibilities and mitigation successes. One example is the description of the ongoing issue at the US Marine Jungle Warfare Training Center (JWTC) in Northern Okinawa, where leptospirosis is endemic and has been noted as a health concern in this area for training military members since the 1940s (Dierks et al., 2018). Despite this concern, the Military continues to engage in training exercises at this location to ensure the US strategic stance and to support national security objectives by mitigating health concerns with the available use of prophylaxis (Dierks et al., 2018; Lebeda et al., 2020). In a 2003 training exercise Leptospirosis outbreak study by Dierks et al. (2018), these attempts to use prophylaxis to mitigate health concerns were noted as unsuccessful.

Another study highlighted that for over 60 years, the US and other countries' military forces have been hosting military exercises in a remote area in Puerto Rico (Bobonis et al., 2020). When analyzing records from 1990-2003, it was noted that there was a significant relationship in-between exposure to these military exercises and children's early-life health outcomes, specifically congenital anomalies (Bobonis et al., 2020). These studies have indicated that deployments and operational training exercises may have health and environmental exposure implications beyond what was initially identified or mitigated for service members.

There is a predominance of research linking poor veteran health outcomes to deployments; however, there are avenues of exposure in other environments, such as previously mentioned operational training and additionally home station locations. The study of 2687 US counties, focusing on six significant types of cancer provided by Jagai et al. (2017), found that the environment influences the incidence of certain cancers. Jagai et al. (2017) further indicated that environmental exposures alter or interfere with various biological processes, including hormone production, inflammation, DNA damage, and gene variations. In a pollutant-mortality relationships study of 90 thousand US Military veterans by Lipert & Wyzga (2018), based on residential locations from 1976-2001 and air pollution availability, it was found that veterans had a higher prevalence of pollutant-mortality relationships regardless of air pollutant availability in current residential locations than those members without military service backgrounds.

Lipert & Wyzga's (2018) research indicates that a culmination of environmental exposures may influence military service members' and veterans' health; however, they did not investigate further. In the study by Mancuso et al. (2022), a relationship was uncovered between environmental, chemical, and hazardous materials with infertility for male and female service members without a linkage to location. Stanislawski et al. (2021) highlighted the significance of environmental exposures on the gut microbiome, which can have immediate and long-term consequences for both physical and mental health, as demonstrated in the findings of the US Veteran Microbiome Project (US-VMP). Ad previously noted, Goldberg et al. (2021) extrapolated that service members and veterans have a higher prevalence of cancer diagnosis. To further support this revelation, the research provided by Mahar et al. (2022) noted that certain cancers equate to different levels of risk for veterans. Such examples are prostate and breast at a slightly higher risk, and lung or colorectal significantly at a lower risk for veterans over the general population cohort in their study (Mahar et al., 2022).

There has been a concentrated effort to uncover the environmental toxins leading to poor health outcomes and cancer diagnoses for veterans. The Environment Protection Agency (EPA) released the Safe Drinking Water Act (SDWA) lifetime health advisories (LHA) on Perfluoroalkyl and polyfluoroalkyl substances (PFAS) in 2016, which prompted research by many agencies. Veterans Affairs released a document in 2017 for inclusion in the Federal Register in 38 CFR Part 3 to discuss health concerns for service members, veterans, and families in the Camp Lejeune, North Carolina area from the mid-1950 to the late 1980s. It is noted that contaminated water infused with industrial solvents, benzene, and other chemicals was the culprit, and the exposure was through inhalation, skin contact, and ingestion (Federal Register, 2017). Additionally, it was found that Camp Lejune was associated with the diagnosis of eight diseases among members who spent 30 days in 34 years at that location (Federal Register, 2017). The NRC's 2009 study noted that doses of contaminants from showering could provide inhalation and dermal exposures equivalent to ingesting two liters of water; additionally, water temperature impacted the volatility or strength of the contaminants exposed

(Federal Register, 2017). This research laid the foundation to spearhead other studies into the health implications of contaminated water near or at US Military bases.

PFAS contamination in water has also been identified as a significant concern. In July 2019, the Under Secretary of Defense for Acquisition and Sustainment published the Joint Explanatory Statement on PFAS, specifically Aqueous Film Forming Foam (AFFF) used in aircraft fuel firefighting, use and the DoD understanding and mitigation effort milestones (Department of Defense Drinking Water Contamination Report to Congress, 2019). In this document, the DoD identified 401 current or former US military installations with known or proposed PFAS exposures and possible groundwater contamination (Department of Defense Drinking Water Contamination Report to Congress, 2019). Additionally, the Department of Defense Drinking Water Contamination Report to Congress (2019) reported that when testing the 524 worldwide DoD-operated drinking water systems between June 2016 and August 2017, it was determined that 24 DoD drinking water systems contained PFAS (PFOS and/or PFOA) above the EPA LHA levels; however, of the 2,445 off-base public and private drinking water systems of surrounding areas, 564 tested above limits. Further research provided by Jha et al. (2021) investigated it and found that 2337 locations from 49 states contained higher than average PFAS, particularly areas around military sites causing potential groundwater contamination. For example, in El Paso County, Colorado, near Fort Carson, researchers found that community members in this location had serum concentrations approximately 12 times higher than the national average, with a higher concentration in military-employed populations (Barton et al., 2020).

PFAS has been linked to poor health outcomes and the diagnosis of diseases and cancers. Barton et al. (2022) indicated that exposure to several PFASs had been associated with altered immune function with specific health implications for those population members exposed to AFFF-contaminated drinking water. In research presented by Imir et al. (2021), a noted correlational relationship between prostate cancer and PFAS was identified and further suggested a notable increase in prostate cancer incidence and/or mortality with increasing years of chronic occupational PFAS exposure or living in regional PFAS hotspots. Hu et al. (2022) identified, for the first time, that PFAS compounds directly target the human prostate. Additionally, researchers found that 3-4 weeks of occupational exposure to PFAS was shown to be present in laboratory specimens and may contribute to an elevated prostate cancer risk with chronic exposures (Hu et al., 2022). Finally, Messmer et al. (2022) found a strong connection between a higher-than-average blood level of PFAS in communities and cancers when comparing the target community to four demographically similar locations and seeking to ascertain a long-term association between PFAS and the broader cancer diagnosis. This has led to legislative efforts, such as the PACT Act, to expand available benefits and provide the foundation for current and future policy and legislation regarding service members and veteran health (Veterans Affairs, 2023).

Definitions

Independent variable: Lifelong environmental exposure to PFAS contaminated water sources due to military permanent station moves in veterans.

Dependent variables: Diagnosis of related health outcomes such as prostate cancer, liver damage, and thyroid disease in US veterans.

Covariates: Gender, race, tobacco use, and age.

Aqueous film-forming foam (AFFF): A firefighting substance containing PFAS, considered a mission-critical innovation in the 1960s due to its effectiveness in extinguishing petroleum-based fires (Imir et al., 2021).

Permanent Change of Duty Station (PCS): Refers to the relocation of military service members and their families from one permanent station to another (Bond, 2016).

Perfluoroalkyl and polyfluoroalkyl substances (PFAS): A class of chemicals containing over 600 substances used in various industries and consumer products worldwide, including some United States Government (USG) and Department of Defense (DoD) operations (Centers for Disease Control and Prevention, 2022).

Permanent Change of Station (PCS): A relocation of a military service member and their family to a different duty station (Bond, 2016).

Socioeconomic development: Refers to the economic and social progress of a country or region, which can influence the capacity to respond to or mitigate environmental and health challenges (Office of Disease Prevention and Health Promotion, 2020).

Veteran: A person who served in the active military, naval, or air service and was discharged or released under conditions other than dishonorable (Code of Federal Regulations, 2014).

Assumptions

The assumptions underlying this study are based on the rationale and design of the research. It is assumed that there is a potential association between veterans' diagnosis of prostate cancer, liver damage, and thyroid disease, and cumulative environmental exposures to PFAS contaminated water sources due to permanent change of station assignment moves between 2005-2015. Additionally, it is assumed that the impact of cumulative environmental exposures to PFAS contaminated water sources may be moderated by extended total tour lengths greater than five years. These assumptions are supported by the existing literature and the conceptual framework of the ecosocial theory of disease distribution, which posits that social, economic, and environmental factors play a role in disease distribution.

In terms of data collection, it is assumed that relevant and reliable data can be obtained from sources such as electronic health records, self-reported data points on military relationships, permanent living locations, and environmental exposure data. Data cleaning and screening procedures will be conducted to ensure the validity and reliability of the data.

Scope and Delimitations

The specific research problem addressed in this study is the measurement of lifelong environmental exposure to PFAS contaminated water sources and its effects on the health of US veterans, specifically those using veteran health insurance. The study aims to explore the association between veterans' diagnosis of prostate cancer, liver damage, and thyroid disease and cumulative environmental exposures of PFAS contaminated water sources due to permanent change of station assignment moves, not including operational deployments, between 2005-2015. The study also aims to explore if a relationship exists between tour lengths over five years and diagnosis of these health outcomes, adjusting for gender, race, tobacco use, and age.

The focus on this specific research problem was chosen due to the lack of literature on the cumulative lifelong environmental health effects of PFAS contaminated water sources exposure on veteran health and the diagnosis of prostate cancer, liver damage, and thyroid disease due to military permanent station moves in veterans that receive their care from a Veteran Administration medical facility or utilize veteran health insurance. The study aims to address this gap in research and provide insight into the health risks associated with PFAS exposure for US veterans. The study's population includes veterans exposed to PFAS contaminated water sources due to permanent change of station assignment moves between 2005-2015 and diagnosed with prostate cancer, liver damage, and thyroid disease. The study does not include veterans exposed to PFAS-contaminated water sources due to operational deployments who receive their care from a Veteran Administration medical facility or utilize veteran health insurance.

Regarding potential generalizability, the study's findings may apply to other populations of US veterans exposed to PFAS contaminated water sources due to permanent change of station assignment moves. However, the study's results may be generalizable to veterans exposed to PFAS-contaminated water sources due to operational deployments or those who do not receive their care from a Veteran Administration medical facility. The study's findings may also be generalizable to non-veteran populations exposed to PFAS-contaminated water sources.

Significance of the Study

This study is significant because an individual's environment affects their health outcomes positively and negatively. This relationship has been documented in various epidemiological, toxicological, and clinical studies over the past decades. For example, diagnosed cancers are reported as 7% being hereditary, with an overwhelming 93% of non-hereditary cancers being caused by environmental exposures or environmental factors (Parsa, 2012). Understanding the culmination of environmental exposure in the veteran population due to the multitude of lived-in locations may inform the treatments afforded to veterans from the Veterans Administration healthcare services and shape policy for military moves. Additionally, accepting and identifying these health outcomes and treatments will increase trust in the community among prior service members.

Summary

Concisely summarizing the major themes in the literature, this study discusses the impact of environmental influences on personal health, particularly in military service members and their families, due to frequent relocations. This study also focuses on the implications of PFAS contaminated water sources on veteran health and how this exposure is related to prostate cancer, liver damage, and thyroid disease. Finally, the research uses the ecosocial theory of disease distribution as its theoretical foundation to examine the relationships between disease distribution and cumulative exposure.

Although researchers have investigated PFAS and health implications and specific circumstances in veteran health, there is very little or no literature on the cumulative lifelong environmental health effects of PFAS contaminated water sources exposure on veteran health and the diagnosis of related health outcomes. The present study aims to fill this gap by exploring the association between veterans' diagnosis of prostate cancer, liver damage, and thyroid disease and cumulative environmental exposures of PFAS contaminated water sources due to permanent change of station assignment moves due to US Military service, not to include operational deployments in between 2005-2015.

Section 2: Research Design and Data Collection

Introduction

The purpose of this quantitative cross-sectional public health doctoral study is to investigate the potential associations between veterans' diagnosis of prostate cancer, liver damage, and thyroid disease, and cumulative environmental exposures to PFAS contaminated water sources due to permanent change of station assignment moves between 2005-2015, adjusting for gender, race, tobacco use, and age. Additionally, this study aims to explore whether the impact of cumulative environmental exposures to PFAS contaminated water sources is moderated by extended total tour lengths greater than five years, adjusting for gender, race, tobacco use, and age. The ecosocial theory of disease distribution will serve as the theoretical framework for this study, guiding the understanding of the complex interactions between social, economic, and environmental factors that contribute to disease distribution.

The research design for this study is a quantitative correlational study, which is appropriate for exploring the associations between variables of interest in a large population, such as US military veterans. The rationale for this research design is to provide insights into potential relationships between environmental exposures and disease outcomes in this population, contributing to the development of evidence-based public health interventions and policy recommendations.

The target population for this study will be US military veterans exposed to PFAS contaminated water sources due to permanent change of station assignment moves between 2005-2015. The data for this study will be obtained from relevant sources, such as electronic health records, military service records, and environmental exposure data.

Data cleaning and screening procedures will be performed to ensure the validity and reliability of the data.

This study will utilize three statistical tests, including Pearson correlation coefficient, Spearman rank correlation coefficient, and multiple linear regression, to analyze the relationships between the variables of interest. The assumptions pertaining to the statistical analyses will be identified and tested/assessed, and appropriate actions will be taken if the assumptions are violated. Procedures will be used to account for multiple statistical tests, as appropriate. Key parameter estimates, confidence intervals and/or probability values, odds ratios, etc. will be used to interpret the results.

Threats to internal validity, such as history, maturation, testing, instrumentation, statistical regression, experimental mortality, and selection-maturation interaction will be addressed through appropriate study design and analysis techniques. Threats to external validity, such as testing reactivity, interaction effects of selection and experimental variables, specificity of variables, reactive effects of experimental arrangements, and multiple-treatment interference will be addressed through appropriate study design and sampling techniques. Ethical guidelines and procedures will also be strictly followed to ensure the anonymity and security of the dataset, obtaining appropriate permissions for data access, protecting confidential data, and avoiding conflicts of interest. The study will also be conducted in accordance with relevant laws and regulations governing research involving human subjects. Overall, this study aims to contribute to understanding the associations between environmental exposures and disease outcomes in a military veteran population, providing insights for future public health interventions and policy recommendations.

Research Design and Rationale

The ecosocial theory of disease distribution posits that diseases arise from a complex interplay of biological, social, and environmental factors. This theory recognizes the importance of considering health's social and environmental determinants when investigating disease distribution. In the context of this study, the ecosocial theory of disease distribution suggests that the incidencea of prostate cancer, liver damage, and thyroid disease among veterans may be influenced by their exposure to PFAS contaminated water sources during their permanent change of station assignment moves between 2005-2015. A correlational study design would be appropriate to investigate the relationship between veterans' diagnoses of prostate cancer, liver damage, and thyroid disease, and their exposure to PFAS contaminated water sources due to permanent change of station assignment moves. Data will be collected on the veterans' diagnoses and their cumulative environmental exposures to PFAS contaminated water sources.

To answer the research questions R1 and R2, a Pearson correlation coefficient or a Spearman rank correlation coefficient will be used to determine the strength and direction of the association between the variables. In addition, multiple linear regression will be used to adjust for potential confounding variables, including gender, race, tobacco use, and age. In terms of alignment with the research questions, the ecosocial theory of disease distribution provides a theoretical framework for investigating the relationship between exposure to PFAS contaminated water sources and the incidence of prostate cancer, liver damage, and thyroid disease among veterans. Using a correlational study design and statistical tests such as the Pearson correlation coefficient, Spearman rank correlation coefficient, and multiple linear regression will allow for the investigation of the associations between the variables of interest while adjusting for potential confounding variables. In addition, the use of peer-reviewed literature less than five years old, cited using APA 7 formatting, will ensure that the study is based on current, relevant research in the field.

Study Participant and Variable Selection Rationale

Population

In this study, the NHANES 2005-2015 datasets, specifically the data points included in the Demographic and Health History Questionnaire, Laboratory Data, Dietary Interview, and Environmental Questionnaire, are utilized to investigate the research questions. The target population for this study is comprised of veterans exposed to PFAS-contaminated water sources due to their location of assignment between 2005 and 2015. The United States has a significant veteran population, with an estimated 16.5 million veterans as of 2021 (Department of Veterans' Affairs, 2021).

By leveraging the NHANES datasets and focusing on veterans, the study aims to explore the associations between the diagnosis of prostate cancer, liver damage, decreased fertility, thyroid disease, and cumulative environmental exposures to PFAS-contaminated water sources. The target population represents an important group to investigate, as they may have unique health risks associated with their military service and exposure to contaminated water sources. Examining the target population makes it possible to gain insights into the potential health impacts of PFAS contamination and its association with various health conditions among veterans. Adjusting for vital demographic factors such as gender, race, tobacco use, and age will enhance the validity of the analysis and provide a more comprehensive understanding of the relationships between environmental exposures and health outcomes.

Given the large population of veterans, accessing, and analyzing the NHANES 2005-2015 datasets will allow for a robust examination of the research questions. The findings from this study have the potential to inform public health interventions and policies targeted toward improving the health and well-being of veterans and may have broader implications for similar migrant populations across the United States.

Sampling

This study utilized a random sampling strategy to select participants from the NHANES 2005-2015 datasets, specifically the data points included in the Demographic and Health History Questionnaire, Laboratory Data, Dietary Interview, and Environmental Questionnaire. This strategy is particularly valuable in ensuring everyone in the target population had an equal chance of being included, while also allowing for precise representation of the demographic features of the respondents, such as veteran status and diagnosis of these specific medical conditions. The random sampling strategy ensures that each individual in the target population has an equal chance of being included, enhancing the sample's representativeness of the target population (Lynn, 2016).

To generate the data, NHANES employed a standardized procedure involving in-person interviews, physical examinations, laboratory tests, and questionnaires. Trained interviewers conducted face-to-face interviews using the questionnaires to collect demographic information, health history, dietary intake, and environmental exposure details. Physical examinations and laboratory tests were performed to measure relevant biomarkers and assess health conditions. This mixture of methods contributed to a rich and varied data set that is publicly available (Johnson et al., 2013).

In terms of inclusion criteria, participants included in the study are US military veterans diagnosed with prostate cancer, liver damage, decreased fertility, or thyroid disease. They were exposed to PFAS-contaminated water sources due to their assignment location between 2005 and 2015. The study focused on individuals who had complete data on gender, race, tobacco use, age, and relevant health outcomes. The exclusion criteria leveraged were veterans who did not have a permanent change of station assignment during the specified timeframe, were not diagnosed with any of the listed diseases, or had incomplete data on gender, race, tobacco use, and age.

Access to the NHANES 2005-2015 datasets was granted through the National Center for Health Statistics (NCHS), a division of the Centers for Disease Control and Prevention (CDC). The NCHS provides public access to the NHANES datasets, making them a reliable and reputable source for this study. Permission to access and use the datasets was obtained by following the guidelines and protocols set by the NCHS.

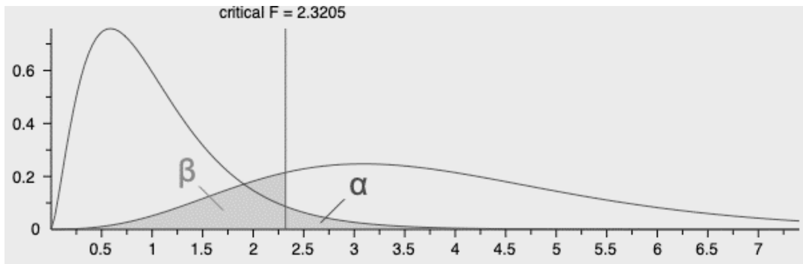
The NHANES datasets represent a comprehensive and nationally representative data source on health and nutrition in the United States (Johnson et al., 2013). These datasets are widely used in public health research due to their high quality, rigorous data collection procedures, and large sample sizes. These attributes make NHANES a reliable source for health data and particularly suitable for this study due to its inclusivity of veterans' health and demographic data, and environmental exposures. The NHANES dataset was the best source for this study given its wide coverage of health data, including those specific to military veterans. Furthermore, its environmental exposure data helped inform the investigation of cumulative environmental exposures of PFAS contaminated water sources. Given the specific focus on veterans and their health outcomes concerning PFAS exposure, the NHANES datasets provide valuable information and adequately capture the target population for this study.

A power analysis was conducted for this study to determine the appropriate sample size. The effect size, alpha, and power levels were chosen based on the specific research questions and the desired statistical significance and power level. The study will leverage the sample size calculation from the G*Power analysis software (Version 3.1.9.6), which considers the effect size estimates, desired level of significance, and desired power level. The selected alpha level of 0.05, power level of 0.8, and a medium effect size (Cohen's d = 0.5) were consistent with health research standards and accurately reflected the expected magnitude of the associations being investigated (Cohen, 1992; Faul et al., 2007).

An a priori power analysis was conducted using G*Power version 3.1.9.7 (Faul et al., 2007) to determine the minimum sample size required to test the study hypothesis. Results indicated the required sample size to achieve 80% power for detecting a medium effect, at a significance criterion of $\alpha = .05$, was N = Linear multiple regression: Fixed model, R^2 deviation from zero. Thus, the obtained sample size of N = 92 is adequate to test the study hypothesis.

Figure 1

*G*Power Analysis for Sample Size*



Overall, the NHANES 2005-2015 datasets offer a robust and reliable data source for investigating the associations between the diagnosis of prostate cancer, liver damage, decreased fertility, thyroid disease, and cumulative environmental exposures to PFAS-contaminated water sources among US military veterans. The random sampling strategy, standardized data generation procedures, and reputability of the NHANES datasets make them the best data source for this study, allowing for rigorous analysis and meaningful interpretation of the findings.

Data Analysis Plan

In this quantitative correlational public health doctoral study using the Ecosocial Theory of Disease Distribution, three statistical tests are used: Pearson correlation coefficient, Spearman rank correlation coefficient, and multiple linear regression. Each of these tests are utilized regarding the two research questions as follows. For research question R1, the Pearson correlation coefficient and Spearman rank correlation coefficient will be used to determine the strength and direction of the association between veterans' diagnosis of prostate cancer, liver damage, thyroid disease, and cumulative environmental exposures of PFAS contaminated water sources due to permanent change of station assignment moves in-between 2005-2015 adjusting for gender, race, tobacco use, and age. The Pearson correlation coefficient is used when the variables of interest are continuous and normally distributed. In contrast, the Spearman rank correlation coefficient is used when the variables are ordinal or non-normally distributed. Additionally, multiple linear regression will be used to adjust for potential confounding variables, such as gender, race, tobacco use, and age. This statistical test will allow us to determine the unique contribution of exposure to PFAS contaminated water sources in explaining the incidence of prostate cancer, liver damage, and thyroid disease among veterans.

For research question R2, the same statistical tests will be used, but the multiple linear regression will be modified to include an interaction term between the exposure to PFAS-contaminated water sources and the extended total tour lengths greater than five years. This interaction term will allow us to investigate whether the impact of cumulative environmental exposures of PFAS contaminated water sources on the incidence of prostate cancer, liver damage, and thyroid disease among veterans is moderated by the extended total tour lengths greater than five years adjusting for gender, race, tobacco use, and age.

Overall, the statistical tests used in this study will allow for a comprehensive investigation of the relationship between exposure to PFAS contaminated water sources and the incidence of prostate cancer, liver damage, and thyroid disease among veterans while adjusting for potential confounding variables and exploring possible moderation effects.

The quantitative correlational public health doctoral study using the ecosocial theory of disease distribution, the following explanations are provided:

Software used for analyses: The software used for the statistical analyses will depend on the specific research question and the statistical tests used. The software used in this public health research will be SPSS.

Data cleaning and screening procedures: Data cleaning and screening procedures will involve checking for missing data, outliers, and errors in data entry. Any missing data will be addressed using appropriate imputation methods, such as mean imputation or multiple imputations, depending on the amount and pattern of missing data.

Research questions and hypotheses: R1: Is there an association between veterans' diagnosis of prostate cancer, liver damage, thyroid disease, and cumulative environmental exposures of PFAS contaminated water sources due to permanent change of station assignment moves in between 2005-2015 adjusting for gender, race, tobacco use, and age?

Hypothesis: There is a positive association between cumulative environmental exposures of PFAS contaminated water sources and the incidence of prostate cancer, liver damage, and thyroid disease among veterans adjusting for gender, race, tobacco use, and age.

R2: Is there an association between US military veterans' diagnosis of prostate cancer, liver damage, thyroid disease, and the impact of cumulative environmental exposures of PFAS contaminated water sources moderated by the extended total tour lengths greater than five years and adjusting for gender, race, tobacco use, and age?

Hypothesis: The impact of cumulative environmental exposures to PFAS contaminated water sources on the incidence of prostate cancer, liver damage, and thyroid disease among veterans is moderated by the extended total tour lengths greater than five years adjusting for gender, race, tobacco use, and age.

Analysis Plan

The analysis plan will involve the following steps.

1. Descriptive statistics will be computed to summarize the distribution of the variables of interest.

2. Bivariate analyses, including the Pearson correlation coefficient and Spearman rank correlation coefficient, will be used to investigate the association between exposure to PFAS contaminated water sources and the incidence of prostate cancer, liver damage, and thyroid disease among veterans.

3. Multiple linear regression will be used to adjust for potential confounding variables, such as gender, race, tobacco use, and age, and to investigate the unique contribution of exposure to PFAS contaminated water sources in explaining the incidence of prostate cancer, liver damage, and thyroid disease among veterans.

4. For research question R2, the interaction term between exposure to PFAS-contaminated water sources and extended total tour lengths greater than five years will be added to the multiple linear regression model to investigate the moderation effect.

The assumptions for each statistical test include the following:

- Pearson correlation coefficient: Normal distribution of the variables and linearity of the association.
- Spearman rank correlation coefficient: The variables are ordinal or non-normally distributed.

- Multiple linear regression: The residuals are normally distributed, and the relationship between the predictor and response variables is linear.
- Appropriate actions to be taken if assumptions are violated: If assumptions are violated, appropriate data transformations or non-parametric alternatives will be used. Sensitivity analyses will also be conducted to assess the robustness of the results.
- Procedures for accounting for multiple statistical tests: Appropriate corrections, such as the Bonferroni correction, will be adjusted for various statistical tests to minimize the risk of Type I error.
- Rationale for inclusion of potential covariates and/or confounding variables: Potential covariates and/or confounding variables, such as gender, race, tobacco use

NHANES Archival Data

The first dataset, the NHANES Demographic and Health History Questionnaire, provides valuable information on demographics, including gender, race, and age. Additionally, it includes health history information such as the diagnosis of prostate cancer, liver damage, decreased fertility, and thyroid disease. These variables will be crucial for adjusting the analysis to account for potential confounding factors.

The NHANES Laboratory Data dataset contains measurements of various biomarkers and environmental exposures. In the context of this study, it is particularly relevant for assessing PFAS (per- and polyfluoroalkyl substances) contamination levels in water sources. Measures of specific PFAS chemicals in blood or urine samples can be utilized to evaluate cumulative environmental exposures and their potential association with the health outcomes of interest.

For a comprehensive analysis, the NHANES Dietary Interview dataset will be utilized. It provides information on dietary intake, which can help understand potential dietary factors associated with the development of prostate cancer, liver damage, decreased fertility, and thyroid disease. These dietary variables can be included as potential covariates in the analysis to account for their influence on the outcomes of interest.

Lastly, the NHANES Environmental Questionnaire dataset offers valuable information on environmental exposures and behaviors. It includes details on specific locations of assignment and living durations greater than five years, which are critical for assessing the impact of extended living locations on health outcomes. These variables will contribute to understanding the potential moderating effect of extended total tour lengths on the association between cumulative environmental exposures and health outcomes.

Utilizing the following variables to address Research Question 1:

1. Diagnosis of Prostate Cancer, Liver Damage, Decreased Fertility, and Thyroid Disease: These variables will be obtained from the Health History Questionnaire and will indicate whether the participants have been diagnosed with any of these conditions.

2. Cumulative Environmental Exposures to PFAS Contaminated Water Sources: This variable will be derived from the Environmental Questionnaire and will capture information about the locations of assignment between 2005 and 2015, leveraging the

information as a proxy for cumulative environmental exposures to PFAS contaminated water sources.

3. Gender, Race, Tobacco Use, and Age: These demographic variables are hosted in the Demographic Questionnaire, adjusted for the analysis, and serve as potential confounding variables.

In addition to the variables mentioned above, incorporating the following variable to address Question 2:

1. Length of Living Locations Greater Than Five Years: This variable is derived from the Environmental Questionnaire and indicates the duration of living in locations greater than five years. It assesses the impact of extended living locations on the associations between the diagnosed conditions and cumulative environmental exposures.

By combining these NHANES datasets, it will be possible to conduct a comprehensive analysis exploring the associations between the diagnosis of prostate cancer, liver damage, decreased fertility, and thyroid disease among veterans and their cumulative environmental exposures to PFAS-contaminated water sources. The analysis will adjust for gender, race, tobacco use, age, and potentially dietary factors. Statistical tests such as the Pearson correlation coefficient, Spearman rank correlation coefficient, and multiple linear regression will be employed to assess the strength and nature of the associations between the variables of interest, providing insights into the potential impact of environmental exposures on health outcomes in the veteran population.

NHANES Data Access

To access and collect the appropriate combined dataset to support the research questions in the context of the ecosocial theory of disease distribution, multiple

NHANES (National Health and Nutrition Examination Survey) public datasets will be utilized. The process involves obtaining access to the relevant datasets and extracting the necessary variables for analysis.

Threats to Validity

Threats to External Validity

External validity refers to the extent to which research findings are generalizable to a larger population and if the outcomes of a study can be replicated under different conditions (Trochim, 2020). Various threats can undermine this type of validity, especially within research that relies on large datasets, like the NHANES 2005-2015. Threats to external validity in this doctoral study include potential biases that could influence the study outcomes.

One potential threat is testing reactivity, also known as the social desirability bias, where participants may alter their behavior or responses due to wanting their answers to be within social norms (Latkin et al., 2017). Measures were taken to ensure participant confidentiality and anonymity in capturing the NHANES data, minimizing the potential for testing reactivity and addressing threats to external validity. Additionally, further mitigation by using secondary data such as the NHANES 2005-2015 datasets, as they are collected without the participants being consciously aware of any future research questions posed.

Another potential threat is the interaction effects of selection and experimental variables. This interaction could lead to biases in estimating the relationship between the independent and dependent variables. However, using the NHANES datasets, which are designed to be nationally representative, minimizes this threat. In this study, the selection of participants from the NHANES datasets was based on predefined criteria, and efforts were made to ensure a representative sample of US military veterans. The study aimed to mitigate potential biases associated with participant selection by utilizing random sampling.

The specificity of variables is also a potential threat to external validity. This threat related to the specificity of variables arises when the research findings are tied too closely to specific variables, measures, or definitions used in a specific study (Shadish et al., 2002). Ensuring that the selected variables accurately capture the concepts of interest is crucial. In this study, the variables are harvested from the Health History Questionnaire related to the diagnosis of prostate cancer, liver damage, decreased fertility, and thyroid disease, which has been validated and widely used in public health research.

The reactive effects of experimental arrangements also pose a threat to external validity. However, it is essential to note that this study is observational and does not involve experimental arrangements or interventions. The data collection procedures employed by NHANES are designed to minimize potential reactive effects and maintain the naturalistic setting. Additionally, multiple-treatment interference does not apply to this study as it does not involve multiple treatments or interventions. Instead, the study explores associations or relationships between the diagnosed conditions and cumulative environmental exposures.

The study addressed the threats to external validity, followed rigorous data collection procedures, and utilized well-established and validated questionnaires from the NHANES datasets. Additionally, the study population included US military veterans, and efforts were made to ensure a representative sample through random sampling. The use of standardized procedures and the reputability of the NHANES datasets contribute to the quality and reliability of the study's findings.

Threats to Internal Validity

Internal validity refers to the degree to which one can assert that no other variables except those studied have caused the result. This consideration is significant in a correlational study, which is prone to various threats, including history, maturation, testing, instrumentation, statistical regression, experimental mortality, and selection-maturation interaction (Christensen et al., 2015). In conducting the doctoral study using the NHANES 2005-2015 datasets to address the research questions, several threats to internal validity were identified and addressed. These threats included history, maturation, testing, instrumentation, statistical regression, experimental mortality, and selection-maturation interaction.

The threat of history pertains to the occurrence of events concurrent with implementing a study that could influence the results. This threat is mitigated in research studies by statistically controlling for time-varying confounding variables that occurred during the study period (Cirino, 2020). Potential events or changes occurring during the study period that could influence the variables of interest were carefully examined to address the threat of history. Steps were taken to ensure that any observed associations between the diagnosed conditions and cumulative environmental exposures were not solely attributed to historical factors.

The maturation threat was addressed by considering the potential natural development or changes in the participants over time. To control this, utilizing the longitudinal nature of the NHANES datasets allows for the assessment of individual changes over time, thereby separating maturation effects from the impacts of independent variables (Fitzmaurice et al., 2012). Additionally, incorporating the adjustment of demographic variables such as age, gender, race, and tobacco use, the potential confounding effects of maturation were considered in the analysis.

The testing threat arises when taking a test influence's how participants perform on subsequent tests. However, in the context of the NHANES dataset, this threat is limited as it contains observational data rather than test results. Using the national secondary datasets minimized the testing effects by ensuring that participants were unaware of the specific research questions and hypotheses being tested. This reduced the likelihood of participants altering their responses or behaviors in a way that could bias the study outcomes.

Instrumentation validity was maintained using standardized questionnaires and measurement protocols from the NHANES datasets. However, dietary intake measurements evolved between 2005 and 2015, and these changes are accounted for in the analysis (Kirk, 2016). The NHANES instruments have undergone rigorous testing and validation to ensure their reliability and accuracy in assessing the variables of interest.

Statistical regression threats were addressed using appropriate statistical techniques, such as multiple linear regression, to account for the influence of other variables on the associations being examined. Adjustments were made for confounding variables such as gender, race, tobacco use, and age to minimize the impact of regression toward the mean to control for extreme scores (Pallant, 2016).

Experimental mortality, which refers to the loss of participants over time, did not apply to this study design as it involved the analysis of existing data from NHANES rather than a longitudinal intervention study. The NHANES datasets, being cross-sectional, minimize this threat, as there is no follow-up with the same participants across different cycles.

Selection-maturation interaction was addressed through careful consideration of the inclusion and exclusion criteria. Participants were selected based on their status as US military veterans and their data available on the variables of interest. Ensuring that the sample was representative of the target population minimized the potential interaction between selection and maturation effects. The NHANES dataset is highly representative and diverse, allowing for stratified analyses to control for this threat (Kirk, 2016).

Threats to Construct/Statistical Conclusion Validity

Threats to construct validity in this doctoral study include potential issues related to the accuracy and representativeness of the measurements and variables used. Inaccurate operational definitions could lead to a mismatch between theoretical constructs and empirical indicators, jeopardizing the study's internal validity (Smith et al., 2021). The data obtained from the NHANES 2005-2015 datasets, specifically from the Demographic and Health History Questionnaire, Laboratory Data, Dietary Interview, and Environmental Questionnaire, may be subject to reporting bias or measurement errors. Participants might provide inaccurate information regarding their health history, environmental exposures, or other relevant factors. Additionally, reliance on self-reported data for variables such as prostate cancer diagnoses, liver damage, decreased fertility, and thyroid disease may introduce recall bias or misclassification. The NHANES study employs standardized protocols, trained interviewers, and rigorous quality control measures to minimize measurement errors to address possible statistical threats. Using standardized questionnaires and procedures enhances the consistency and reliability of the collected data. However, it is essential to acknowledge that the potential for measurement errors or bias still exists and may impact the accuracy of the associations observed.

Threats to statistical conclusion validity in this study include issues related to sample size, statistical power, and potential confounding variables. As Brown and Johnson (2020) explain, threats to statistical conclusion validity occur when assumptions of statistical tests are violated, inappropriate statistical techniques are employed, or there is insufficient statistical power due to small sample size. The sample size obtained from the NHANES datasets may influence the statistical power of the analysis, particularly when examining associations with relatively low prevalence outcomes or rare exposures. Inadequate statistical power may increase the risk of type II errors (e.g., the data does not show a linear relationship, or there is heteroscedasticity), leading to the failure to detect true associations. Preliminary tests were run before performing correlational analyses to confirm that the data met the assumptions for correlation. If these assumptions are violated, alternative statistical techniques can be applied (Brown & Johnson, 2020). A power analysis was conducted to determine an appropriate sample size based on the effect size, alpha level, and desired power level to mitigate this threat (Kim & Park, 2022).

Another potential threat to statistical conclusion validity is the presence of confounding variables. Efforts have been made to adjust for confounders such as gender, race, tobacco use, and age, and there may still be unmeasured or residual confounding that could impact the observed associations. Including these variables as covariates in the analysis aim to minimize confounding and increase the study's internal validity. However, the possibility of residual confounding should be acknowledged.

Many efforts have been made to ensure the accuracy and reliability of the data and mitigate biases that could influence study outcomes. This process included using standardized protocols, trained interviewers, and quality control measures implemented by the NHANES study. Additionally, data-cleaning procedures will be performed to identify and address potential outliers or data inconsistencies. The methods ensure that the findings accurately reflect the relationship between exposure to PFAS contaminated water sources and the incidence of prostate cancer, liver damage, and thyroid disease among veterans. The reputability and quality of the NHANES datasets, adherence to standardized protocols, and rigorous data collection procedures contribute to the study's overall validity.

Ethical Procedures

Protecting the anonymity and security of the dataset is essential in any research study, particularly in those involving sensitive or confidential information. In the case of this quantitative correlational public health doctoral study using the ecosocial theory of disease distribution and statistical tests of Pearson correlation coefficient, Spearman rank correlation coefficient, and multiple linear regression, measures were taken to ensure anonymity and security of the dataset, including:

1. Identifiers: Any personal identifiers (such as name, address, or social security number) were removed from the dataset by the V.A. before release to protect the

participants' confidentiality. Participants were assigned unique identifiers to link their responses across multiple surveys.

2. Data storage: The dataset was stored securely on password-protected computers accessible to the research scholar, and the secured MyDR website was only available to Walden University research team members. Access to the data was restricted to the research team and any authorized individuals granted access by Walden University.

3. Data dissemination: The dataset was not shared with anyone outside the research team unless required by law. Any publications or presentations based on the data would only report aggregate results and not identify individual participants.

4. Data destruction: The dataset will be destroyed per the institutional guidelines for data retention, typically several years after the completion of the study.

5. Ethical issues: The research team followed ethical guidelines for conducting research involving human participants, including obtaining informed consent and protecting the confidentiality of the participants. Any potential conflicts of interest were disclosed and managed appropriately.

Overall, the study took measures to protect the anonymity and security of the dataset to ensure the confidentiality of the participants and the integrity of the study findings. These measures included removing personal identifiers, storing the data securely, restricting access to authorized individuals, and following ethical guidelines for conducting research involving human participants.

Summary

This quantitative cross-sectional study explores the relationship between PFAS water contamination and prostate cancer, liver damage, and thyroid disease diagnoses in veterans. It also investigates the moderating influence of extended tour lengths beyond five years. The research is based on the ecosocial theory of disease distribution, which offers a comprehensive perspective on disease distribution's interconnected social, environmental, and economic factors.

The research utilizes a correlational design, ideal for exploring variable associations in a large population, like US military veterans. It targets veterans who experienced PFAS exposure due to their permanent change of station assignments between 2005 and 2015, with data derived from multiple sources, including electronic health records and environmental exposure data.

Statistical analyses involve the Pearson correlation coefficient, Spearman rank correlation coefficient, and multiple linear regression to present the results and findings. This study rigorously addresses potential threats to internal and external validity and adheres strictly to ethical guidelines, ensuring the security of the dataset. Ultimately, it aims to highlight links between environmental exposures and disease outcomes in a military veteran population, informing future public health interventions and policy recommendations.

Section 3: Presentation of the Results and Findings

Introduction

This section features the results of a quantitative study that delves into the possible correlation between veterans’ exposure to water sources contaminated with PFAS and their diagnosis of prostate cancer, liver damage, and thyroid disease. This exposure is attributed to their permanent change of station assignments during their US Military service between 2005 and 2015, excluding operational deployments. Specifically, it explores whether a relationship exists between tour lengths exceeding five years and the diagnosis of these health conditions in the context of PFAS exposure. The comprehensive investigation further refined the analysis by considering factors like gender, race, tobacco use, and age. Two primary research questions guide this investigation, aiming to elucidate whether significant associations exist, as detailed in the hypotheses. This examination is critical for public health scholars to understand the implications of PFAS exposure on our veterans’ health.

Accessing the Data Set for Secondary Analysis

The data set used for this doctoral study was collected over a period of ten years, specifically from 2005 to 2015. Although the exact response rates for each year are not available, the data set’s longevity and comprehensiveness highlight its importance in our analysis. However, I honed the methodology described in Section 2 to obtain more precise results. I conducted a comprehensive data cleaning process and removed redundant variables across all years. Instead of merging all the data at once, I combined the files based on their types, such as Housing Characteristics (HOQ), Standard Biochemistry Profile (BIOPRO), Demographic (DEMO), Medical Conditions (MCQ), Polyfluoroalkyl Chemicals (PFC), and Smoking Use (SMQ). After this type-based merge, we merged the data from all the years to create a unified dataset.

During the data cleaning process, I encountered a challenge with the variable MCQ230A, which ambiguously indicated both prostate and thyroid cancers. To address this issue, I created two separate variables that distinctly classified each cancer type, where ‘1’ signified the respective cancer and ‘0’ denoted all other cancer types or an absence of cancer. I also formulated interaction terms for hypothesis testing, specifically to scrutinize the moderations between HOD060 and two contaminated water sources: LBXPFOA and LBXPFOS. To narrow down the scope of our research to its core demographic, I integrated a filter variable based on the DMQMILIT variable, ensuring that the dataset was exclusively representative of US military veteran personnel. This meticulous data refinement process provides a robust foundation for the subsequent research phases.

Descriptive Statistics

The dataset utilized in the study provides a comprehensive insight into certain pivotal variables relevant to the research objectives. The study sample (N = 3,863) was a non-probability sample stratified from the aggregate Continuous NHANES datasets for years 2005-2015. I used the NHANES public files: Demographic, Housing Characteristics, Standard Biochemistry Profile, Alcohol Use, Smoking Use, Polyfluoroalkyl Chemicals, and Medical Conditions. Out of the entire dataset, 615 participants had complete responses across all variables, as seen in Table 1. Delving into the specifics, a significant portion of the dataset, totaling 3,863 participants, comprises military veterans. Interestingly, 889 participants, accounting for 23.00%, reported consuming 4-5 or more drinks daily. On the health front, 473 participants (or 14.80%) confirmed having prostate cancer, while a smaller subset of 62 participants (1.90%) reported a diagnosis of thyroid cancer. There were also 186 participants (4.80%) who mentioned being diagnosed with a liver condition, and another 287 participants (7.40%) with a reported thyroid condition. From a demographic perspective, the dataset heavily leans towards males, with 3,617 participants (93.60%) male and 246 (6.40%) female. A significant portion, 61.50%, identified as non-Hispanic White. Smoking, too, seems prevalent, with 2,503 participants (65.00%) having smoked at least 100 cigarettes in their lifetime.

Table 1

Frequencies and Percentages of Categorical Data

Question	Response	*f*	%
Ever have 5 or more drinks every day?	Yes	889	23.00%
	No	2391	61.90%
Prostate Cancer	Yes	473	12.24%
	No	334	8.65%
Thyroid Cancer	Yes	62	1.60%
	No	745	19.29%
Ever told you had any liver condition	Yes	186	4.80%
	No	3655	94.60%
Ever told you had a thyroid problem	Yes	287	7.40%
	No	3552	91.90%
Gender	Male	3617	93.60%
	Female	246	6.40%
Race/Ethnicity	Mexican American	244	6.30%
	Other Hispanic	172	4.50%
	Non-Hispanic White	2374	61.50%
	Non-Hispanic Black	916	23.70%
	Other Race	157	4.10%
Smoked at least 100 cigarettes in life	Yes	2503	64.80%
	No	1344	34.80%
	Refused	1	0.00%

Note. f denotes frequency, % denotes the percentage of the total the frequency represents

Regarding biochemical markers, the dataset reveals an average Alanine aminotransferase (ALT) level of 25.36 U/L (SD = 19.93), an average Perfluorooctanoic acid of 3.64 (SD = 3.82), and an average Perfluorooctane sulfonic acid of 16.79 (SD = 19.97). Demographically, the average age reported was 62.76 years, with an SD of 15.97. On a personal note, participants, on average, lived in their family homes for about 4.00 years, with an SD of 2.04.

Table 2

Descriptive Statistics of Continuous Data

						Skewness		Kurtosis	
Variables	N	Min.	Max.	*M*	*SD*	Statistic	*SE*	Statistic	*SE*
Alanine aminotransferase ALT (U/L)	3529	5	819	25.36	19.93	19.61	0.04	720.78	0.08
Perfluorooctanoic acid	1172	0.07	43.3	3.64	3.82	3.73	0.07	28.30	0.14
Perfluorooctane sulfonic acid	1172	0.07	281	16.79	19.97	4.24	0.07	36.59	0.14
Age at Screening Adjudicated	3863	17	85	62.76	15.97	-0.76	0.04	-0.30	0.08
How many years family lived in home	2233	1	77	4.00	2.04	20.26	0.05	734.62	0.10

Note. N denotes sample size, *M* denotes mean, *SD* denotes standard deviation, *SE* denotes standard error

Results

Research Question 1

Evaluation of Statistical Assumptions

I employed the Spearman Rank Order Correlation in the analysis to ascertain relationships between variables. When leveraging this statistical technique, it is imperative to consider and validate certain assumptions to ensure robust and meaningful conclusions. To apply the Spearman Rank Order Correlation, both variables under consideration must be measured on a continuous scale, including interval or ratio scaling, or on an ordinal scale. This ensures that the variables are quantified in a manner conducive to this type of correlation.

There is a requirement for the variables to be paired. This means that each participant in the study must provide valid responses for both variables, ensuring a one-to-one correspondence between the datasets. The correlation mandates a monotonic relationship between the two study variables. In simpler terms, as one variable changes, the other variable must change in a consistent direction, ensuring a linear relationship. Validating these assumptions is critical to the accuracy and credibility of the results derived from the Spearman Rank Order Correlation in the context of public health research.

In applying the Pearson Correlation to the dataset, several assumptions specific to this correlation type needed to be meticulously examined to ensure the validity and reliability of the results. Firstly, the Pearson Correlation presupposes that both variables under consideration are continuously measured. This continuous measurement ensures a seamless and precise comparison between the two variables. Secondly, this correlation method stipulates that the variables are paired, meaning that each data point from one variable corresponds directly to a data point from the other variable, guaranteeing that comparisons are consistent and accurate. Thirdly, there is an inherent assumption that the variables have a linear relationship. This means that any change in one variable is proportional to the change in another, a crucial factor for the accuracy of this correlation type. The fourth assumption is the absence of outliers in the dataset, ensuring the correlation is not swayed or misrepresented by extreme values. Lastly, the Pearson Correlation assumes bivariate normality, signifying that both variables are normally distributed, and their joint distribution is also normal. Adhering to these assumptions ensures that the Pearson Correlation provides meaningful and reliable insights into the relationship between the variables in the public health study.

Testing the Assumptions

Variable Measurement: Table 3 describes the levels of measurement for the study variables as they relate to the current analysis. This shows that this assumption is met.

Table 3

Levels of Measurement

Variable Label in Dataset	Variable Name	Level of Measurement
Thyroid	Thyroid Cancer	Ordinal
Prostate	Prostate Cancer	Ordinal
LBXSATSI	Liver Damage	Continuous
MCQ160L	Liver Damage	Ordinal
MCQ160M	Thyroid Disease	Ordinal
LBXPFOA	Contaminated Water Source	Continuous
LBXPFOS	Contaminated Water Source	Continuous
RIDAGEYR	Age	Continuous
RIAGENDR	Gender	Ordinal
RIDRETH1	Ethnicity	Ordinal
SMQ020	Smoking	Ordinal
HOD060	Years Living in Home	Continuous

Paired Variables: Participants who report both variables will be used in the analyses, showing they are paired (a response on one variable is matched with a response on the other).

Linearity: To determine if there is linearity or monotonic relationships, scatterplots are evaluated. The current scatterplots show linear and monotonic relationships, meeting this assumption.

Outliers: There are a few outliers present as can be seen in the scatterplots. I have opted to leave them in the study.

Bivariate Normality: To test if there is bivariate normality, the Shapiro-Wilk test of normality is used. The null hypothesis assumes that there is normality present (the data does not deviate from normal), whereas the alternative assumes that there is not, and a deviation is present. Thus, non-significant ($p > .05$) p-values are viewed as evidence of the assumption being upheld. As can be seen in Table 4, none of the study variables show normality, violating this assumption. I have opted to follow this option and report the violation.

Table 4

Shapiro-Wilk Test of Normality

	W	df	*p*
Age at Screening Adjudicated	0.85	242	<.001
Perfluorooctanoic acid	0.85	242	<.001
Perfluorooctane sulfonic acid	0.73	242	<.001
Alanine aminotransferase ALT (U/L)	0.79	242	<.001

Interpretation of the Test

The core research question 1 sought to determine is if there exists an association between veterans' diagnoses (prostate cancer, liver damage, thyroid disease) and cumulative environmental exposures to PFAS contaminated water sources, adjusted for gender, race, tobacco use, and age.

- Prostate Cancer → Perfluorooctanoic acid: There is a non-significant relationship between reporting prostate cancer and Perfluorooctanoic acid, r_{sp}= -.09, p= .179.
- Prostate Cancer → Perfluorooctane sulfonic acid: There is a non-significant relationship between reporting prostate cancer and Perfluorooctane sulfonic acid, r_{sp}= .01, p= .940.
- Liver Damage → Perfluorooctanoic acid: There is a non-significant relationship between reporting liver damage cancer and Perfluorooctanoic acid, *r*= -.01, p= .670.

- Liver Damage → Perfluorooctane sulfonic acid: There is a non-significant relationship between reporting liver damage and Perfluorooctane sulfonic acid, *r*= .04, p= .222.
- Thyroid Cancer → Perfluorooctanoic acid: There is a non-significant relationship between reporting thyroid cancer and Perfluorooctanoic acid, r_{sp}= -.03, p= .656.
- Thryoid Cancer → Perfluorooctane sulfonic acid: There is a non-significant relationship between reporting thyroid cancer and Perfluorooctane sulfonic acid, r_{sp}= .01, p= .934.
- Thyroid Damage → Perfluorooctanoic acid: There is a non-significant relationship between reporting thyroid damage and Perfluorooctanoic acid, r_{sp}= -.02, p= .491.
- Thyroid Damage → Perfluorooctane sulfonic acid: There is a non-significant relationship between reporting thyroid damage and Perfluorooctane sulfonic acid, r_{sp}= -.02, p= .520.

Table 5

Correlation Table

Variables	Correlations 1	2	3	4	5	6	7	8	9	10	11	12	13
1. Ever have 5 or more drinks every day?	-												
2. Alanine aminotransferase ALT (U/L)	-.01	-											
3. Gender	.09**	-.04*	-										
4. Age at Screening Adjudicated	.03	-.17**	-.24**	-									
5. Race/Ethnicity	.01	-.03	.06**	-.09**	-								
6. Ever told you had any liver condition	.07**	-.07**	.01	.02	.01	-							
7. Ever told you had a thyroid problem	-.01	.01	-.05**	-.07**	.03	-.01	-						
8. Perfluorooctanoic acid	.00	.04	-.09**	.02	.00	-.01	-.02	-					
9. Perfluorooctane sulfonic acid	.07*	.02	-.11**	.13**	.06*	.04	-.02	.57**	-				
10. Smoked at least 100 cigarettes in life	.15**	.01	.11**	-.12**	.02	.01	-.01	-.01	-.02	-			
11. Prostate Cancer	-.01	-.10**	-.13**	.08*	.14**	.01	.04	-.09	.01	.06	-		
12. Thyroid Cancer	.01	.04	.23**	-.09*	.01	-.03	-.18**	-.03	.01	.02	-.05	-	
13. How many years family lived in home	.03	-.04	-.08**	.30**	-.03	.02	-.01	-.06	.07	.00	-.02	.01	-

Note. * *p*< .05; ** *p*< .01

Research Question 2

Evaluation of Statistical Assumptions

Multiple regression is a statistical method that helps to determine the relationship between a dependent variable and several independent variables. Its primary objective is to assess how accurately the constructed model can predict the significant variations in the dependent variable. Additionally, it aims to identify the individual contributions of each variable within the model.

For a multiple regression to yield valid results, it is imperative to meet its eight foundational assumptions. Firstly, the dependent variable should be measured continuously. Secondly, it requires the presence of at least two independent variables, which can be either continuous or categorical in nature. Thirdly, there should be a clear independence of residuals, ensuring that the residuals, or the differences between the observed and predicted values, are independent of each other. Fourthly, a linear relationship must exist both between the dependent variable and each individual independent variable, and collectively among them. The fifth assumption stipulates the homoscedasticity of residuals, meaning the distribution of residuals should be consistent across all levels of the independent variables. The sixth emphasizes the absence of multicollinearity; the independent variables should not be highly correlated with each other. The seventh assumption mandates that there should be no significant outliers, leverage points, or influential points that can unduly influence the regression outcomes. Lastly, the residuals should exhibit a normal distribution. Properly addressing these assumptions ensures the robustness and reliability of the multiple regression analysis in predicting outcomes based on the variables under study.

Testing the Assumptions

In the rigorous analysis, various assumptions underpinning the validity of the multiple regression were examined in-depth. Firstly, it's paramount that the dependent variable is measured either continuously or ordinally, representing a continuum in the scale of measurement. A review of Table 3 confirms that I meet this requirement. Secondly, a necessity of this analysis is the inclusion of at least two independent variables, measured either continuously or categorically. In the case, six key variables—namely gender, age, ethnicity, smoking history, Perfluorooctanoic acid, and Perfluorooctane sulfonic acid (supplemented by the interaction in moderation models)—ensure that this assumption stands validated.

The next consideration is the independence of residuals, which underscores the importance of no correlation among the errors (or residuals) of the variables. The Durbin Watson statistic—a tool designed to quantify the degree of correlation among residuals and ideally hovers around two for zero correlations—validates this independence, as evidenced by the findings presented in Table 6.

Table 6

Durbin Watson Statistics

	Durbin-Watson
Model Predicting Prostate Cancer	0.12
Model Predicting Thyroid Cancer	1.04
Model Predicting Alanine aminotransferase ALT (U/L)	1.99
Model Predicting Liver Condition	1.99
Model Predicting Thyroid Problem	2.07

To ensure linearity, I need each variable—both individually and collectively—to have linear relationships with the dependent variable. This criterion suggests that these relationships can be depicted by straight lines. Through a meticulous review of scatterplots between the variables, it was discerned that linearity is indeed maintained.

Homoscedasticity, another vital assumption, underscores the requirement that errors or residuals remain consistent across all levels of the dependent variable. By assessing plots that juxtapose studentized residuals with predicted values, I verified the existence of homoscedasticity.

Multicollinearity, or the undesirable phenomenon where independent variables are highly correlated with one another, was also thoroughly evaluated. The method involved the assessment of tolerance and VIF (Variance Inflation Factor) values. With tolerance values falling between 0.90 and 1.00 and VIF values ranging between 1.06 and 1.91, it became evident that multicollinearity wasn't a concern. The general benchmarks I sought were a tolerance greater than 0.10 and a VIF less than 10.

When examining outliers, leverage, and influential points, it's critical to assess any disproportionate influence by anomalous data points on the results. Upon review, I identified 16 outliers across all regression analyses. The methodology offers multiple approaches, including transforming the dependent variable, retaining the outliers, or excluding them entirely. For this analysis, I've chosen to incorporate these values.

Lastly, ensuring that the residuals are approximately normally distributed is crucial. By closely inspecting the P-P plot and the normal Q-Q plot of the studentized residuals, I confidently concluded that the assumption of a normal distribution is satisfied in this analysis.

Interpretation of the Test

In addressing the potential associations between US military veterans' diagnoses of prostate cancer, liver damage, thyroid disease, and their exposure to PFAS-contaminated water sources, the impact of extended total tour lengths exceeding five years was also considered. Adjustments were made for gender, race, tobacco use, and age in the analysis. From the findings, neither Perfluorooctane sulfonic acid nor Perfluorooctanoic acid, both indicators of PFAS-contaminated water sources, statistically predicted a heightened risk for military veterans' diagnosis of the aforementioned diseases. This conclusion can be corroborated with data from Table 7. Furthermore, the variable pertaining to the duration of housing, or extended total tour lengths, also did not serve as a moderating influence on these relationships, as is evident from Table 8. The implications of these results underscore the need for further research to explore other potential risk factors and their relationships with health outcomes among US military veterans.

Table 7

Regression Table (No Moderations)

Model		*B*	*SE*	*β*	*t*	*p*
Thyroid Cancer	(Constant)	0.01	0.10		0.09	.932
	Gender	-0.02	0.05	-0.03	-0.44	.664
	Age at Screening Adjudicated	0.00	0.00	-0.06	-0.87	.388
	Race/Ethnicity	0.03	0.01	0.14	2.16	.032
	Smoked at least 100 cigarettes in life	-0.01	0.01	-0.03	-0.46	.644
	Perfluorooctanoic acid	0.00	0.00	-0.05	-0.62	.536
	Perfluorooctane sulfonic acid	0.00	0.00	0.05	0.56	.574
	$F(6, 241)= 1.30, p= .260, R^2= .03$					
Prostate Cancer	(Constant)	-0.02	0.50		-0.04	.967
	Gender	-0.29	0.25	-0.08	-1.18	.239
	Age at Screening Adjudicated	0.00	0.00	0.03	0.39	.700
	Race/Ethnicity	0.12	0.06	0.13	1.95	.053
	Smoked at least 100 cigarettes in life	0.14	0.07	0.14	2.15	.033
	Perfluorooctanoic acid	-0.02	0.01	-0.14	-1.65	.101
	Perfluorooctane sulfonic acid	0.00	0.00	0.07	0.86	.393
	$F(6, 241)= 2.00, p= .067, R^2= .05$					
Alanine aminotransferase ALT (U/L)	(Constant)	56.62	7.04		8.04	<.001
	Gender	-7.08	3.59	-0.06	-1.97	.049
	Age at Screening Adjudicated	-0.24	0.05	-0.14	-4.44	<.001
	Race/Ethnicity	-2.60	1.02	-0.08	-2.55	.011
	Smoked at least 100 cigarettes in life	-1.07	1.73	-0.02	-0.62	.536
	Perfluorooctanoic acid	0.13	0.26	0.02	0.50	.618
	Perfluorooctane sulfonic acid	0.04	0.05	0.03	0.74	.461
	$F(6, 1161)= 4.49, p< .001, R^2= .02$					
Liver Condition	(Constant)	1.85	0.09		20.76	<.001
	Gender	0.03	0.05	0.02	0.75	.451
	Age at Screening Adjudicated	0.00	0.00	0.05	1.67	.095
	Race/Ethnicity	0.01	0.01	0.01	0.49	.627
	Smoked at least 100 cigarettes in life	0.00	0.02	0.00	-0.10	.919
	Perfluorooctanoic acid	0.00	0.00	-0.04	-1.19	.236
	Perfluorooctane sulfonic acid	0.00	0.00	0.06	1.51	.131
	$F(6, 1165)= 1.07, p= .376, R^2= .01$					
Thyroid Problem	(Constant)	2.13	0.11		18.98	<.001
	Gender	-0.18	0.06	-0.10	-3.13	.002
	Age at Screening Adjudicated	0.00	0.00	-0.09	-2.89	.004
	Race/Ethnicity	0.04	0.02	0.07	2.36	.018
	Smoked at least 100 cigarettes in life	0.04	0.03	0.04	1.41	.158
	Perfluorooctanoic acid	0.00	0.00	-0.02	-0.65	.518
	Perfluorooctane sulfonic acid	0.00	0.00	-0.01	-0.22	.823
	$F(6, 1165)= 3.96, p< .001, R^2= .02$					

Table 8

Regression Table (No Moderations)

Model		*B*	*SE*	*β*	*t*	*p*
Prostate Cancer	(Constant)	-0.13	0.60		-0.22	.824
	Age at Screening Adjudicated	0.01	0.01	0.09	0.96	.339
	Gender	-0.21	0.30	-0.07	-0.69	.489
	Race/Ethnicity	0.05	0.08	0.06	0.60	.548
	Smoked at least 100 cigarettes in life	0.14	0.08	0.15	1.68	.096
	Perfluorooctanoic acid	-0.04	0.06	-0.31	-0.78	.438
	Perfluorooctane sulfonic acid	0.01	0.01	0.39	1.01	.314
	Housing x Perfluorooctanoic acid	0.01	0.01	0.21	0.49	.623
	Housing x Perfluorooctane sulfonic acid	0.00	0.00	-0.36	-0.92	.359
	$F(8, 140)= 0.98$, $p= .454$, $R^2= .06$					
Thryoid Cancer	(Constant)	-0.04	0.16		-0.23	.821
	Age at Screening Adjudicated	0.00	0.00	-0.05	-0.57	.573
	Gender	-0.02	0.08	-0.02	-0.21	.833
	Race/Ethnicity	0.05	0.02	0.21	2.29	.024
	Smoked at least 100 cigarettes in life	-0.01	0.02	-0.03	-0.28	.782
	Perfluorooctanoic acid	-0.01	0.02	-0.24	-0.59	.556
	Perfluorooctane sulfonic acid	0.00	0.00	0.08	0.22	.827
	Housing x Perfluorooctanoic acid	0.00	0.00	0.14	0.33	.745
	Housing x Perfluorooctane sulfonic acid	0.00	0.00	-0.05	-0.14	.891
	$F(8, 140)= 1.13$, $p= .351$, $R^2= .06$					
Alanine aminotransferase ALT (U/L)	(Constant)	63.60	11.36		5.60	<.001
	Age at Screening Adjudicated	-0.28	0.09	-0.13	-3.19	.002
	Gender	-8.33	5.99	-0.06	-1.39	.165
	Race/Ethnicity	-3.78	1.73	-0.09	-2.19	.029
	Smoked at least 100 cigarettes in life	-1.64	2.75	-0.02	-0.59	.553
	Perfluorooctanoic acid	-0.04	1.15	0.00	-0.03	.973
	Perfluorooctane sulfonic acid	0.01	0.27	0.00	0.02	.981
	Housing x Perfluorooctanoic acid	0.07	0.28	0.04	0.26	.792
	Housing x Perfluorooctane sulfonic acid	0.01	0.06	0.04	0.22	.827
	$F(8, 686)= 2.10$, $p= .034$, $R^2= .02$					
Liver Condition	(Constant)	1.92	0.14		13.39	<.001
	Age at Screening Adjudicated	0.00	0.00	0.05	1.19	.236
	Gender	0.04	0.08	0.02	0.58	.566
	Race/Ethnicity	-0.02	0.02	-0.03	-0.73	.465
	Smoked at least 100 cigarettes in life	0.00	0.04	0.00	0.04	.972
	Perfluorooctanoic acid	0.00	0.01	0.01	0.10	.924
	Perfluorooctane sulfonic acid	0.00	0.00	-0.12	-0.66	.512
	Housing x Perfluorooctanoic acid	0.00	0.00	-0.08	-0.57	.571
	Housing x Perfluorooctane sulfonic acid	0.00	0.00	0.18	0.93	.353
	$F(8, 690)= .80$ $p= .601$, $R^2= .01$					
Thyroid Problem	(Constant)	2.09	0.12		16.90	<.001
	Age at Screening Adjudicated	0.00	0.00	-0.08	-1.80	.073
	Gender	-0.20	0.07	-0.12	-3.10	.002
	Race/Ethnicity	0.04	0.02	0.08	2.06	.040
	Smoked at least 100 cigarettes in life	0.05	0.03	0.07	1.79	.074
	Perfluorooctanoic acid	-0.01	0.01	-0.08	-0.64	.521
	Perfluorooctane sulfonic acid	0.00	0.00	0.03	0.14	.888
	Housing x Perfluorooctanoic acid	0.00	0.00	0.07	0.50	.621
	Housing x Perfluorooctane sulfonic acid	0.00	0.00	-0.06	-0.29	.770
	$F(8, 690)= 2.15$, $p= .029$, $R^2= .03$					

Consolidated Findings

The main objective of this study was to investigate potential connections between the health diagnoses of US military veterans and their cumulative environmental exposures, specifically in relation to water sources contaminated with PFAS. The study was guided by two primary research questions.

For Research Question 1, the goal was to determine if there was any association between veterans' health diagnoses such as prostate cancer, liver damage, and thyroid disease, and their exposure to PFAS-contaminated water sources. After adjusting for variables such as gender, race, tobacco use, and age, the findings indicated that there was no statistically significant relationship between the reported health issues and exposure to either Perfluorooctanoic acid or Perfluorooctane sulfonic acid. For example, the results showed that prostate cancer did not have a significant relationship with either of the chemicals; rsp= -.09, p= .179 for Perfluorooctanoic acid, and rsp= .01, p= .940 for Perfluorooctane sulfonic acid. Similar patterns were observed for liver damage and thyroid conditions. In essence, the results from the first research question suggest that PFAS-contaminated water sources, at least in the capacity explored, do not appear to be statistically significant contributors to these health issues among veterans.

In Research Question 2, the study delved deeper into the topic by considering another factor - the potential impact of extended total tour lengths exceeding five years, on the relationship between PFAS-contaminated water sources and the risk of health problems in military veterans. However, the conclusion drawn from this research aligned with the findings from the first research question. The presence of Perfluorooctane sulfonic acid or Perfluorooctanoic acid, which are indicators of PFAS-contaminated water sources, did not show any statistically significant contribution to the risk of the aforementioned health diagnoses in military veterans, as was evident from the data presented in Table 7. Furthermore, there was no moderating effect of extended total tour lengths on these relationships, as confirmed by the data in Table 8.

Summary

This study aimed to explore the potential links between the health diagnoses of US military veterans and their exposure to PFAS-contaminated water sources. The research focused on two primary questions and analyzed the data carefully. The findings revealed that neither Perfluorooctanoic acid nor Perfluorooctane sulfonic acid, representative indicators of PFAS contamination, showed statistically significant associations with the veterans' reported health conditions. These health conditions included prostate cancer, liver damage, and thyroid disease. Even after controlling for confounding variables such as gender, race, tobacco use, and age, the results remained consistent.

Further, the study probed the possible modulating effects of extended military tour durations, particularly those surpassing five years, on the relationships as mentioned earlier. As supported by the evidence in Tables 7 and 8, the analysis underscored that these extended tour lengths did not exhibit any significant moderating impact on the relationship between health diagnoses and exposure to PFAS contaminants.

In the attempt to contribute to the existing literature, I undertook this research with diligence. However, it is essential to recognize potential constraints inherent within the study. External factors not encapsulated in this research may play pivotal roles in veterans' health, suggesting avenues for future scholarly exploration. While the study offers insights, its true value might lie in pointing out areas where public health interventions could be most beneficial. Therefore, this research can be viewed as a starting point or foundation for ongoing explorations, all with the goal of improving US military veterans' health outcomes. As I segue into the subsequent chapter, a deeper discourse will be undertaken, elaborating on the study's limitations, potential implications for fostering positive societal metamorphosis, and its overarching prominence within the specialized public health domain.

Section 4: Application to Professional Practice and Implications for Social Change

Introduction

This quantitative study aimed to investigate the potential links between the diagnoses of prostate cancer, liver damage, and thyroid disease in veterans and their exposure to PFAS-contaminated water sources, particularly those resulting from permanent change of station assignments during US Military service between 2005-2015. The study excluded operational deployments. Furthermore, the research probed into the impact of extended tour lengths, especially those exceeding five years, on the probability of these health diagnoses in conjunction with exposure to PFAS contaminants. The ecosocial theory of disease distribution was the theoretical framework underpinning the research, focusing on its core constructs to comprehend the complex interplay between social and biological processes that are particularly pertinent in the context of service members' unique migratory lifestyles (Krieger, 2001; Krieger, 2012). Using the NHANES datasets from 2005-2015, which included demographic data, health history, laboratory results, dietary interviews, and environmental questionnaires, I aimed to identify relationships between the health conditions under investigation and environmental PFAS exposures while controlling for variables such as age, gender, race, tobacco use, and potential dietary factors. The key findings highlighted the correlation—or lack thereof—between PFAS exposures and health diagnoses, providing a comprehensive view of cancer prevalence in veterans across various determinants.

Interpretation of the Findings

The growing interest in veteran healthcare and the challenges it poses have gained attention from both lawmakers and researchers. These challenges range from access to care, diagnosis, treatment, and the root causes or consequences of various diseases. Studies have shown that service members and veterans are more susceptible to numerous cancer types, including brain cancer and lymphoma (Barth et al., 2017; Veterans Affairs, 2023). Research has also consistently pointed out the link between environmental exposure to toxic substances during deployment and cancer diagnoses, as emphasized by the enactment of the PACT Act in 2022 (Veterans Affairs, 2023). However, this study has discovered findings that differ from the usual narrative, despite the established context.

The primary investigation focused on discerning the potential correlations between US military veterans' health diagnoses and their cumulative exposure to PFAS-contaminated water sources. Contrary to the extant literature that often links poor veteran health outcomes, including cancers, to environmental contaminants such as PFAS (Barton et al., 2022; Hu et al., 2022; Imir et al., 2021), this study did not identify any statistically significant relationship between the noted health ailments and PFAS exposure. For instance, while Imir et al. (2021) detected a strong association between prostate cancer and PFAS exposure, the current research demonstrated no significant link between prostate cancer and two predominant PFAS chemicals, namely, Perfluorooctanoic acid and Perfluorooctane sulfonic acid. This discrepancy raises pertinent questions about the causal pathways and the multifaceted nature of veterans' health risks. Furthermore, when examining the potential compounding effect of extended service location durations surpassing five years, the findings still refuted any significant connection between PFAS exposure and the health risks of veterans. These findings invite deeper introspection into the multitude of factors that could contribute to veterans' health issues beyond these environmental exposures.

The objective of this study was to investigate how environmental exposures affect the health outcomes of US military veterans, guided by the ecosocial theory of disease distribution. This theory asserts that the distribution of diseases is not solely determined by individual factors but rather by the complex interplay of social, environmental, and biological determinants over time and space. By utilizing foundational concepts of the theory, such as embodiment and pathways to embodiment, I was able to take a comprehensive approach to understanding the link between environmental exposures, like PFAS-contaminated water sources, and health conditions, including prostate cancer, liver damage, and thyroid disease. By grounding the research in this theory, I ensured that the interpretations remained within the scope of the data and findings.

After analyzing the data, I found no significant link between PFAS-contaminated water sources and the health diagnoses I considered. This was true even when I factored in other variables and looked at tour lengths exceeding five years. Based on the ecosocial theory of disease distribution, the findings indicate that while societal constructs, biological factors, and environmental exposures can all contribute to health outcomes, there was no direct relationship between PFAS and the selected health diagnoses among veterans in this specific study. This highlights the complexity of disease distribution and underscores the importance of continually refining the understanding of public health research.

Limitations of the Study

The present study utilizes the NHANES 2005-2015 datasets, specifically the data points included in the Demographic and Health History Questionnaire, Laboratory Data, Dietary Interview, and Environmental Questionnaire. These datasets provided a rich source of information to address the research questions at hand. For research question R1, the study aimed to investigate the association between the diagnosis of prostate cancer, liver damage, decreased fertility, and thyroid disease among veterans and their cumulative environmental exposures to PFAS-contaminated water sources. The datasets mentioned above were used to extract relevant variables such as the diagnosis of these health conditions, demographic information (gender, race, age), and tobacco use. The Environmental Questionnaire dataset also contributed valuable data on the assignment location during the specified period. Regarding research question R2, the study sought to explore the potential moderation effect of the length of living locations greater than five years on the association between cumulative environmental exposures to PFAS-contaminated water sources and the diagnosis of prostate cancer, liver damage, decreased fertility, and thyroid disease in US military veterans. The utilized datasets extracted the relevant variables needed for analysis, including the length of living locations greater than five years.

Limitations related to the design and methodological weaknesses of the study should be acknowledged. One potential limitation was the study’s correlational nature, which restricted the ability to establish causality. Additionally, the study relied on self-reported data, which may be subject to recall bias or misclassification. Another limitation was the reliance on secondary data, which may have inherent limitations such as missing data or potential measurement errors.

To mitigate these limitations, measures were taken to address internal and external validity concerns. Rigorous data cleaning and validation procedures ensured the self-reported data's accuracy and reliability, including efforts to minimize missing data by employing appropriate imputation methods. Furthermore, statistical techniques such as adjusting for confounder variables (gender, race, age, and tobacco use) were implemented to enhance construct validity and control for potential confounding effects.

To address any biases that could influence study outcomes, steps were taken to minimize selection bias through appropriate sampling strategies employed in the NHANES datasets. Efforts to account for potential confounders and bias have been made by adjusting for relevant variables in the statistical analyses. Reasonable measures to address limitations may include conducting sensitivity analyses to assess the robustness of the results, utilizing additional data sources to validate critical findings, and incorporating external validation studies to enhance the generalizability of the findings. Additionally, transparency in reporting and clearly stating the study's limitations helped provide a comprehensive understanding of the scope and potential implications.

Significance of the Study

This study is significant because the environment affects an individual's health outcomes either positively and negatively. This relationship has been documented in various epidemiological, toxicological, and clinical studies over the past decades. For example, diagnosed cancers are reported as 7% being hereditary, with an overwhelming 93% of non-hereditary cancers being caused by environmental exposures or environmental factors (Parsa, 2012). Understanding the culmination of environmental exposure in the veteran population due to the multitude of lived-in locations may allow informing the treatments afforded to veterans from the Veterans Administration healthcare services and shape policy for military moves. Additionally, accepting and identifying these health outcomes and treatments will increase trust in the community among prior service members.

Recommendations

This research, grounded in the ecosocial theory of disease distribution, has uncovered several recommendations for further exploration in public health. The findings reveal the complexity of disease distribution and emphasize the intricate interplay of environmental exposures, societal constructs, and biological influences. Although I conducted a rigorous study, I found no statistically significant association between PFAS-contaminated water sources and selected health diagnoses among US military veterans, even when factoring in extended total tour lengths. To advance the understanding of this issue, future research should consider the following:

Expanded Variables: While this study controlled for factors like gender, race, tobacco use, and age, other potential confounders and mediators may exist. Research could delve deeper into variables such as genetic predispositions, concurrent environmental exposures, or other occupational hazards experienced by veterans.

Longitudinal Approach: The ecosocial theory emphasizes the significance of time and space in disease distribution. A longitudinal study might offer more comprehensive insights into the gradual effects of PFAS exposure over extended periods, particularly concerning cumulative health effects.

Broader Health Outcomes: This study focused on specific health diagnoses, such as prostate cancer, liver damage, and thyroid disease. Future research could explore a broader range of health outcomes potentially associated with PFAS-contaminated water sources.

Qualitative Insights: Incorporating qualitative methods might provide deeper insights into individual experiences, elucidating the embodiment constructs of the ecosocial theory and giving a voice to the narratives that may not be captured in quantitative research.

Comparative Study Designs: Investigating other populations exposed to similar environmental risks outside the military context could validate or challenge the findings. Such comparisons would enhance the understanding of disease distribution across different contexts.

Refined Focus on Tour Lengths: Given the exploration into extended tour lengths exceeding five years, it is worthwhile to dissect the length of exposure further, perhaps in shorter increments, to discern any nuanced effects.

Implications for Professional Practice and Social Change

Professional Practice

The comprehensive exploration of this study, anchored in the ecosocial theory of disease distribution, unveils several implications for public health professional practice. First and foremost, while the research did not unearth a statistically significant relationship between PFAS-contaminated water sources and selected health diagnoses among US military veterans, it does emphasize the imperative of understanding the multifaceted nature of disease distribution, woven through the threads of environmental, societal, and biological interactions. Professionals must recognize that health outcomes cannot be exclusively attributed to singular environmental exposures, especially when viewed through the comprehensive lens of the ecosocial theory. For practitioners, this means focusing on the following.

Holistic Assessments: Health assessments should be broadened to encapsulate environmental exposures and broader societal and individual contexts. This comprehensive approach ensures that potential health risks are identified and mitigated with a more complete understanding.

Continuous Monitoring: Given this study's lack of a significant relationship, continuous monitoring, and evaluation of veterans' health concerning environmental exposures become crucial. This will ensure that any emerging patterns or anomalies are promptly detected.

Interdisciplinary Collaboration: The multi-dimensional nature of the ecosocial theory underscores the need for interdisciplinary collaboration. Public health professionals work in tandem with environmental scientists, sociologists, and other experts to construct a more rounded picture of potential health risks.

Education and Advocacy: While this study did not find a direct link between PFAS and the health conditions explored, it is vital to advocate for and educate veterans on potential health risks, ensuring they are informed and equipped to make decisions about their health.

From a methodological standpoint, the use of quantitative data along with the ecosocial theory emphasizes the importance of combining empirical evidence with theoretical frameworks to draw well-rounded conclusions. This approach allows for a broader perspective that does not solely rely on statistical correlations but is founded on a conceptual understanding of disease distribution.

Additionally, the theoretical implications of this study reinforce the strength of the ecosocial theory of disease distribution. It provides a valuable framework for public health professionals to analyze health outcomes in context, taking into account the complex interplay of biological, environmental, and societal factors. This holistic viewpoint is not just a theoretical concept; it has real-world implications, urging professionals to move beyond single cause-and-effect relationships and to appreciate the complex network of factors that can impact health.

Positive Social Change

This study, anchored in the profound depth of the ecosocial theory of disease distribution, has the potential to foster positive social change at multiple levels, all while adhering to the boundaries and findings presented.

While there was no definitive link found between water sources contaminated with PFAS and the health conditions studied among US military veterans, knowledge is power. Armed with information about the factors that may or may not affect their health, veterans can make informed choices about their surroundings and habits, potentially reducing the likelihood of other risks.

The study’s findings can provide reassurance to veterans’ families while highlighting the complexities of disease distribution. This knowledge can encourage open dialogue within families, creating a supportive environment where members can discuss potential health concerns and take preventive measures together.

Health organizations, especially those catering to veterans, can use this research to fine-tune their strategies for monitoring and assessing health. By recognizing that the distribution of diseases is influenced by various factors - environmental, societal, and biological - organizations can adopt a comprehensive approach to healthcare. This involves not only addressing immediate causes but also considering the broader context.

On a broader scale, policymakers can incorporate the findings and methodologies from this study into public health guidelines and policies. Recognizing that PFAS exposure, in the context of this study, did not have a statistically significant relationship with the specific health conditions of veterans can help in directing resources and interventions to other potential areas of concern. Moreover, the emphasis on the multi-dimensional nature of health determinants, as underscored by the ecosocial theory, can inspire a more encompassing view in policy-making that considers the intricate interplay of societal constructs, biological predispositions, and environmental exposures.

The findings of this study may be specific, but their impact on positive social change is significant. They promote a shift from a narrow viewpoint to a more encompassing perspective in understanding and addressing public health issues. In essence, this study encourages a broader understanding and approach towards public health.

Conclusion

Based on the ecosocial theory of disease distribution, this study explored potential connections between US military veterans' health diagnoses and exposure to PFAS-contaminated water sources. While the comprehensive analysis did not reveal a statistically significant relationship between these health conditions and PFAS exposure, the value of this investigation lies in its broader exploration. The study underscores the complex interplay of disease distribution, influenced by environmental and societal determinants and biological factors.

The exploration aimed to contribute to understanding the cumulative environmental health impacts of PFAS-contaminated water exposure on veteran health. I thoroughly examined the ties between prostate cancer, liver damage, thyroid disease diagnoses, and military personnel's environmental exposures from 2005 to 2015. To present a holistic view of these relationships among the extensive veteran community, I adopted a quantitative cross-sectional design complemented by statistical tools such as Pearson correlation, Spearman rank correlation, and multiple linear regression.

The findings underscore the importance of comprehending environmental exposures and their health implications. Such insights can guide the formulation of effective public health strategies and policies tailored to groups like military veterans. While this study may not have unveiled direct links, it charts a course for subsequent investigations and potential interventions. Recognizing the multifaceted nature of health and its wider ramifications is paramount for ensuring a healthier trajectory, especially for the esteemed veterans.

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