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The relationship between SDOH disparities and COVID-19 test positivity: A retrospective cohort study of United States veterans

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Abstract

The relationship between SDOH disparities and COVID-19 test positivity: A retrospective cohort study of United States veterans

Introduction: Social determinants of health disparities (SDOH) with COVID-19 test positivity within high-risk populations is a focus in post-pandemic era. One of the largest integrated health care systems is housed by the United States Department of Veteran Affairs. The Veteran Health Administration (VHA) holds one of the largest populations that consist of electronic health records of available data across 1,293 VA facilities in the United States. The overall goal of this study is to understand the association between SDOH disparities with COVID-19 test positivity. Specific aims include: 1) to identify individual SDOH exposures while adjusting for demographics and all other SDOH exposures that impact the risk of testing positive for COVID-19; and 2) to examine the potential impact of geographic location (urban versus rural) in the relationship between SDOH disparities and COVID-19 test positivity. Results from this study can aid in developing public health policies and tailor interventions in high-risk areas to prevent the spread of disease.

Methods: This is a cross-sectional study of veterans seeking COVID-19 inpatient and outpatient care at the VHA. Eligible participants included all veterans who had a record of COVID-19 testing and were defined as a veteran patient who received inpatient or outpatient testing for COVID-19 from the VA between January 1, 2019 through September 30, 2020. Social determinants of health exposures education, marital status, household size, number of children, household income, and rural-urban commuting area (RUCA) were collected from the USVETS database. Demographic variables age, gender, and race/ethnicity were used for descriptive analysis and as confounding covariates. A bivariate analysis was conducted to examine individual SDOH exposures and demographics with the outcome of testing positive for COVID-19. A multivariable regression analysis was conducted to identify SDOH exposures associated with testing positive for COVID-19 after adjusting for demographics and all other SDOH exposures. Rural/urban are defined as residential location and were used in a final analysis exploring effect modification in the relationship between SDOH disparities and COVID-19 test positivity.

Results: Of the veterans who received inpatient and outpatient care for COVID-19, 89% were male, 67% were non-Hispanic white, and 23% were non-Hispanic Black. The overall average age was 61 years. After adjusting for confounders age, gender, and race/ethnicity and all other SDOH covariates, there was a higher test positivity among veterans that had a household income less than or equal to $39,999 compared to those that earn more than or equal to $75,000 (OR 1.07, 95% CI: 1.06, 1.09), completed high school compared to those who completed graduated school (OR 1.07, 95% CI: 1.06, 1.09), had four or more persons living in the household compared to those living alone (OR 1.22, 95% CI: 1.20, 1.24), had three or more children compared to those with no children (OR 1.14, 95% CI: 1.11, 1.18), and lived in rural areas compared to those living in urban areas (OR 1.17, 95% CI: 1.16, 1.18). There were no differences between rural versus urban in the relationship between SDOH variables and COVID-19 test positivity.

Discussion: Findings of this study demonstrated that certain SDOH exposures, including income, education level, household size, and the presence of children in the household, are associated with an increased risk of veterans t4esting positive for COVID-19. This suggests that veterans facing these disparities are more vulnerable to the disease. There were no significant differences after stratifying on urban/rural in the relationship between SDOH disparities and COVID-19 test positivity. Future research should examine access to care in vulnerable populations where risk of testing positive was higher to improve data collection and testing in rural communities. The results of this study emphasize the importance of raising awareness about these disparities and their impact on veterans' health outcomes and can inform public health policies and initiatives aimed at reducing COVID-19 risk among veterans. Policymakers should consider the social factors highlighted in this study when designing and implementing interventions. This study contributes to our understanding of the impact of SDOH on COVID-19 risk among veterans and underscores the importance of addressing these disparities through targeted interventions. This knowledge can help improve the health and well-being of veterans living in vulnerable populations in the United States.

The relationship between SDOH status and COVID-19 test positivity: A retrospective cohort study of United States veterans

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I. Introduction

As of October 2023, there has been a total of 103 million COVID-19 cases in the United States since the start of the pandemic in March 2020 (1). Throughout the pandemic, researchers focused on interventions methods to combat the spread of COVID-19 infections in the world. The burden of COVID-19 was driven by several factors; however, there is evidence that social inequalities in combination with race played a key role in high prevalent cases throughout the world (2,3). Social determinants of health (SDOH) have been identified as contributing to the disparities in COVID-19 outcomes. SDOH defined by the World Health Organization (WHO) are factors that can influence health equity in both a positive and negative way. SDOH factors include but are not limited to education, marital status, household size, number of children, household income, and rural-urban (4). Identifying SDOH factors that address health disparities within populations with high prevalence of COVID-19 is a focus in public health in post-pandemic era.

The COVID-19 emergency lockdowns impacted SDOH factors and inequalities in health such as loss of jobs, loss of income, overcrowding, urbanity, and essential worker roles (2,5–7). There is evidence that inequalities in exposure to SDOH factors such as low-income increases the risk for most infectious diseases such as COVID-19 (5–11). One study examining the association between SDOH exposures with COVID-19 test positivity in the state of New York found that those living in low-income areas had proportionately more COVID-19 positive test (12). Across the United States, low-income workers were designated as essential workers during the emergency lockdown which increased their exposure to COVID-19 infection (2,5–7,10). A systemic review analyzing occupations and income wages found that low-income workers had a higher risk for COVID-19 infection due to likelihood of public transportation usage and

increased contact with consumers (2). The majority of low-income occupations are occupied by minority ethnic groups living in areas of higher socio-economic deprivation (2,13). It is documented that in areas of higher socio-economic deprivation there is reduced access to care which contributed to the unequal distribution of COVID-19 infection throughout the United States (2,14,15). However, many of these studies reported individual state-level data with smaller populations. While these studies provide important insights, there is a need for research that examines these disparities on a national scale.

Some studies have indicated that the most COVID-19 cases occurred in disadvantaged populations where education and income were key exposures in the distribution of COVID-19 infection (5,16–20). Education and income have been described in the literature as main contributors that played important roles in the drive of disease. First, the lack of education about the disease from the government caused an increase in the misperception of COVID-19 among those with low-income and no college education (21). Second, the increased prevalence of cases occurred in risk-populations where education and income levels were lower (5,11,12,17,19,20,22). In contrast, two other studies found that increased prevalence of COVID-19 cases occurred in high median income populations (17,18). It is evident that increased COVID-19 positive test occurred in populations where education level was low (5,16–18,20–26). However, two studies had conflicting results for the relationship between income and COVID-19 test positivity, suggesting more research is needed. One challenge in understanding the relationship between SDOH factors and COVID-19 is that many studies rely on county-level data, which is limited in capturing the diversity of populations within larger geographic areas. Studies that employ larger and more diverse populations can help provide a clearer picture of how education and income influence testing positive for COVID-19.

Many other studies have used a deprivation index as a composite measure for SDOH exposures with COVID-19 test positivity (19,20,23,27). These social factors may include education, household income, number of children, marital status, and number of people living in household. Populations of high deprivation are likely to have low education, low household income, having more than one child, single parents, household size greater than three persons. Researchers have found that those living in more-deprived/disadvantaged areas had a higher risk for testing positive for COVID-19 (19,20,23,27). Evidence suggests that overcrowded housing in disadvantaged areas increased the risk of transmission of COVID-19 infection and maintaining physical distancing was a challenge in such settings. Moreover, many low-income workers, often with low education, in disadvantaged areas were deemed essential workers during the pandemic. Due to the nature of their jobs, essential workers faced a higher risk of exposure to the virus because of close contact with the public and difficulty to social distancing within their work settings. Although, the studies reported evidence that more-deprived populations are associated with increased odds for testing positive for COVID-19, data were reported from community-level and county-level in specific high-risk states, suggesting more evidence is needed to fully understand SDOH disparities on a national-level.

Moreover, much of the literature focuses on urban communities rather than rural communities when examining the association between SDOH disparities and COVID-19 test positivity. Emerging research has identified urban communities as higher risk populations for COVID-19 test positivity (16,19,20,22–24,28). Similarly, other studies found that urban communities were more heavily dense with minority populations with low-income and low education levels which explains the distribution of cases in urban areas (12,19,20,22–24,29). Minority populations in the literature are described as Black, Asian, Hispanic, American Indian

or Alaska Native, and Native Hawaiian or Pacific Islander. Evidence in the literature suggests that minority populations in urban areas are at higher risk for COVID-19 test positivity due to the likelihood of minorities having low education levels and occupying low-income jobs compared to white people in urban areas (12,19,20,22-24,29). Race/ethnicity has been shown to be a confounder in the relationship between income and education with COVID-19 test positivity in urban communities. However, comparable evidence is limited in rural communities, suggesting the need for more research to understand the effect of geographic location in the relationship between SDOH disparities with COVID-19 test positivity.

In summary, there are several limitations with existing research examining the relationship between SDOH factors and COVID-19 test positivity. First, much of the literature used deprivation scales to measure social factors associated with COVID-19 test positivity, which combines SDOH variables without considering the individual impact that each variable may have with the outcome, and adjustments needed for potential confounders. Second, many of the studies examined SDOH disparities with COVID-19 test positivity in urban populations. The lack of research evidence in rural populations suggests a need to examine potential differences between rural and urban populations in the relationship between SDOH with COVID-19 test positivity. Third, many of the studies utilized community, county, and state-level data, which may have limited generalizability.

The United States Department of Veteran Affairs (VA) is one population that could be important to examine given its large population and geographic distribution throughout the country. The VA has the largest integrated health care system that provides free health care to over 9 million veterans every year (30). The Veteran Health Administration (VHA) houses one of the largest datasets that holds electronic health records across 1,293 VA facilities in the United

States. Individual demographics and COVID-19 information is included in the dataset and have been utilized in several studies to investigate the association of SDOH, comorbidities, and mortality rates with COVID-19 in the veteran population.

In one VA study, researchers explored potential disparities with two outcomes: COVID-19 testing, and COVID-19 test positivity. Results indicated that minority veterans (i.e., Black/African American and Hispanic) who lived in counties where crowded housing was prevalent were more likely to receive a COVID-19 positive test compared to veterans that were white (30). However, there was no difference among veterans by income inequities, unemployment rate, and poverty indices. This study also examined differences by geographic location and found that after adjusting for demographics, veterans living in rural areas were associated with lower odds of COVID-19 testing and test positivity compared to veterans living in urban areas (30). These results are consistent with other studies that have found a relationship between urbanicity and COVID-19 test positivity (12,20,23,34), and suggest a potential disparity in testing access or utilization between urban and rural populations. Identifying and addressing these disparities is crucial for ensuring equitable access to testing and subsequent public health interventions.

Another VA study did not find significant differences between education and overcrowded houses with COVID-19 in a race/ethnicity stratified model (31). In this study, race/ethnicity was categorized by white, Black, and other, where as “other” included all other races (Asian, American Indian/Alaska Native, and Native Hawaiian/Pacific Islander). Among white, Black, and other races/ethnicities, veterans without a college degree and living in overcrowded homes had a higher risk of testing positive for COVID-19 (31). Due to current literature stratifying on race/ethnicity in the relationship between SDOH and COVID-19, there is

a need to examine the variation of race/ethnicity as a controlling factor to isolate the impact of SDOH on COVID-19. Although understanding the role of SDOH and demographics with COVID-19 is essential for promoting health equity, by controlling for demographics allows for researchers to provide a clearer understanding of how social factors contribute to health disparities.

Findings from recent VA studies examining only urban populations highlights an important gap in the understanding of how SDOH disparities associated with COVID-19 differ between rural and urban areas. Additionally, VA studies stratified race/ethnicity, which aims to prove no differences among race, but raises the need to isolate the impact of SDOH on COVID-19. While it is important to consider race/ethnicity for health equity, examining demographics as potential confounders is critical in this analysis to reduce bias. The overall goal of this study is to understand the association between SDOH disparities with COVID-19 test positivity. Specific aims include, to identify individual SDOH exposures while adjusting for demographics and all other SDOH exposures that impact the risk of testing positive for COVID-19; and to examine the potential impact of geographic location (urban versus rural) in the relationship between SDOH disparities and COVID-19 test positivity. Results from this study can aid in developing public health policies and tailor interventions in high-risk areas to prevent the spread of disease.

II. Methods

A. Study Design

This is a cross-sectional study of veterans seeking COVID-19 care at the Veterans Health Administration (VHA). The United States VHA serves 9 million veterans in inpatient and outpatient care at over 1,293 Veteran Affairs (VA) healthcare facilities throughout the United States. All veteran patient health records are recorded and stored in a national electronic single

database. This study was approved by the institutional review board of the Atlanta VA Research and Development Committee and granted a waiver of informed consent.

B. Study Population

The study population included veteran patients who received inpatient or outpatient testing for COVID-19 from the VA between January 1, 2019 through September 30, 2020. Eligible participants included all veterans who had a record of COVID-19 testing. Only veterans with data in each SDOH field were included in the study population.

C. Data Sources

Data for this analysis was collected from three sources: (1) clinical and demographic information from the Corporate Data Warehouse (CDW); (2) Social Determinants of Health (SDOH) factors from the United States Veterans Eligibility Trends and Statistics (USVETS); and (3) COVID-19 information on all participants from the VA's COVID-19 Share Data Resource (CSDR), created by the VA to capture COVID-19 information on all veterans during the pandemic.

D. Data Measures

Outcome

The outcome for this study was retrieved from the CSDR and was classified as a confirmed severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) (COVID-19) positive test. Veterans with at least one COVID-19 positive test were coded as "ever positive" and veterans who tested negative for COVID-19 was coded as "never positive".

Exposures

Social determinants of health exposures were collected from the USVETS database. The SDOH exposures used for this study were education, marital status, household size, number of

children, household income, and rural-urban commuting area (RUCA) (32). Household income was reported as an estimated median income and was trichotomized into three quartile levels: less than $39,999, $40,000 and $74,999, and greater than $75,000. Marital status was defined as single or married. Education was defined as the highest degree earned among veterans that were tested for COVID-19 and is characterized as completed high school, completed vocational/technical school, completed college, and completed graduate school. Household size was categorized as living alone, two persons, three persons, and four or more persons living in the household. The number of children under 18 years of age in the household was defined by having no children, one child, two children, and three or more children. Rural/urban location was characterized by the VA based on zip-code and county. The VA defines urban as a highly denser populated area consisting of cities, and rural as a lesser dense populated area with less than seven people per square mile not consisting of cities (33).

Missing data for the SDOH measures included household income 45,711 (3.1%), marital status 315,593 (21.4%), education 409,590 (27.7%), household size 45,711 (3.1%), number of children 38,445 (2.6%), and rural/urban 20,028 (1.4%). For each SDOH variable, missing data was handled in the descriptive analysis by using imputed values to include these categories. However, missing data were excluded in the regression models to prevent reporting bias; for example, veterans may not accurately remember their household income, which can lead to an inaccurate representation of the data.

Covariates

Demographic variables age, gender and race/ethnicity were retrieved from the CDW and used to describe the study population and as covariates in the multivariable regression model. Age was examined as both a continuous variable and trichotomized into three categories <50

years, 50 to 64 years, and ≥65 years. Gender was defined as male or female with no other descriptive gender details. Race and ethnicity were combined and categorized as Non-Hispanic Black/African American, Non-Hispanic white, Asian, American Indian or Alaskan Native, Native Hawaiian or Pacific Islander, and Hispanic.

E. Analysis

Selected demographics and SDOH characteristics were examined using frequency distribution (counts and percentage) for the total population that tested for COVID-19, and stratified by those who tested negative, and those who had at least 1 or more positive COVID-19 test at the VA. Age was the only variable described using mean and standard deviation. Bivariate analysis was used to analyze the relationship between veterans that tested negative and veterans that tested positive using chi-square test and t-tests. A bivariate analysis was constructed to assess the individual association of SDOH exposures and demographic characteristics with the outcome of COVID-19 test positivity.

Several logistic regression models were constructed to assess SDOH exposures with COVID-19 test positivity. To answer the first aim, three models were constructed. The first model examined covariates and each SDOH exposures separately with COVID-19 test positivity. The second model included a multivariable logistic regression that analyzed each SDOH exposure variable adjusted for all other SDOH exposures. The third model analyzed a multivariable logistic regression adjusted for both covariates and all other SDOH exposures. To address the second aim, two more models were developed that stratified by rural and urban location. The first model included SDOH exposures separately associated with testing positive for COVID-19, unadjusted for covariates. The second model included SDOH exposures separately associated with testing positive for COVID-19, adjusted for covariates. Results from

all models were described using odds ratio (OR) and 95% confidence intervals (CI). All analyses were performed using SAS Enterprise Guide version 8.2 (SAS Institute, Cary, NC).

III. Results

In this study, 1,476,332 Veterans received inpatient or outpatient testing for COVID-19 between January 1, 2019 and September 30, 2020, with 25% (n=369,974) having at least one positive test, and 75% (n=1,106,358) testing negative.

Most participants were male (88.9%), 67.2% were non-Hispanic white, and 23% were non-Hispanic Black. The overall average age was 61 years. Among the veterans that were tested, 25% tested positive for COVID-19. Veterans that tested positive compared to those that tested negative were more likely to have only completed high school, married, with three or more persons living in the household, one or more children, a household income less than or equal to $39,999, and live in rural areas (p-value<0.0001) (Table 1).

The bivariate analysis in Table 2 reports the association of demographic characteristics and SDOH exposures independently with COVID-19 test positivity. Black/African American (OR 0.97, 95% CI: 0.96, 0.98) and Asian (OR 0.84, 95% CI: 0.81, 0.87) veterans had lower odds of testing positive for COVID-19 compared to white veterans. While, Hispanic (OR 1.17, 95% CI: 1.15, 1.18), American Indian/Alaska Native (OR 1.17, 95% CI: 1.12, 1.22), Native Hawaiian/Pacific Islander (OR 1.05, 95% CI: 1.01, 1.09) veterans had higher odds of testing positive for COVID-19 compared to white veterans. Veterans with a household income less than or equal to $39,999 (OR 1.02, 95% CI: 1.01, 1.03) had higher odds of testing positive for COVID-19 compared to those with a household income greater than or equal to $75,000. There was a higher test positivity for veterans with four or more people living in the household (OR 1.25, 95% CI: 1.24, 1.27) compared to those living alone, and three or more children (OR 1.41,

95% CI: 1.37, 1.45) compared to those with no children. Veterans that lived in rural areas had higher odds of testing positive (OR 1.16, 955 CI: 1.15, 1.17) compared to those living in urban areas.

Table 3 reports two multivariable regression models. Model 1 reports SDOH exposures adjusted for all other SDOH covariates. There was a higher test positivity for veterans that had household income less than or equal to $39,999 (OR 1.05, 95% CI: 1.03, 1.06) compared to those that earned greater than or equal to $75,000, completed high school (OR 1.14, 95% CI: 1.13, 1.16) compared to those that completed graduated school, had four or more persons living in the household (OR 1.14, 95% CI: 1.12, 1.16) compared to those that live alone, had three or more children (OR 1.27, 95% CI: 1.24, 1.31) compared to those with no children, and lived in rural areas (OR 1.14, 95% CI: 1.13, 1.15) compared to those that lived in urban areas. Model 2 reports SDOH exposures adjusted for all other SDOH covariates, and the covariates age, gender, and race/ethnicity. Results indicate a higher test positivity among veterans that had four or more persons living in the household (OR 1.22, 95% CI: 1.20, 1.24) compared to those living alone, and those that lived in rural areas (OR 1.17, 95% CI: 1.16, 1.18) compared to those living in urban areas.

Table 4 reports the stratified analysis examining whether the association between SDOH with COVID-19 test positivity varies by living in rural or urban areas. In model 1, there were no significant differences found between veterans living in rural versus urban areas. After adjusting for covariates in model 2, there were no significant differences found between veterans living in rural versus urban areas.

IV. Discussion

This study explored the association between SDOH disparities and COVID-19 test positivity and the effect of rural versus urban in this relationship. There was a higher test positivity among veterans with a household income less than or equal to $39,999, completed high school, who were married, with two or more persons living in the household, and one or more children. There were no significant differences observed among veterans living in rural versus urban areas.

Our demographic results were inconsistent with racial disparities reported in previous studies. This study observed lower odds with testing positive for COVID-19 for non-Hispanic Black and Asian compared to non-Hispanic white. Other researchers have observed a higher test positivity for non-Hispanic Black with low-income compared to non-Hispanic white (16,18,24,25). Decreased odds for non-Hispanic Black and Asian compared to non-Hispanic white with COVID-19 test positivity suggests that the relationship between race/ethnicity is likely to have an association with the presence of SDOH exposures. Moreover, in our results, other minority populations such as Hispanic, American Indian/Alaska Native, and Native Hawaiian/Pacific Islander had a higher test positivity compared to non-Hispanic white veterans. These results are consisted with the literature that observed a higher risk for COVID-19 infections among minority populations compared to non-Hispanic white (2,18,23,24,28,31,32).

Our results were consistent with household income reported in most of the literature (2,12,17,20,21). In this study, when household income was examined as an independent variable, there was a higher test positivity among veterans that earn less than or equal to $39,999. After adjusting for all other SDOH covariates, age, gender, and race/ethnicity, the odds increased for test positivity, suggesting that household income has a higher impact with testing positive in the

presence of other SDOH factors and covariates. Similarly, researchers observed higher test positivity among those with low-income (5-11, 12). However, after stratifying on rural versus urban, there were no differences observed between low-income veterans living in rural versus urban areas, suggesting that household income has an impact on testing positive in both vulnerable and resourceful populations. Current literature has identified household income in urban communities as a leading driver for COVID-19 infections during the pandemic, suggesting that COVID-19 had a higher impact on low-income workers living in urban areas (16,18,20,21,23,24). These findings suggest that the focus of current literature is urban populations, and this is likely due to the lack of reported data in rural populations to analyze household income with COVID-19.

Education as an SDOH exposure with COVID-19 test positivity was also consistent with the literature (12,17,20). When modeled separately, education had higher odds with testing positive for veterans that only completed high school, suggesting that low education has a great impact on the risk of testing positive for COVID-19. Our results align with other research observing increased positive test where education level was low (5,16-18,20-26). Additionally, this study also examined higher odds for low education levels with testing positive after adjusting for all other SDOH covariates, suggesting that education has a high risk for COVID-19 with the presence of other SDOH exposures as well. These results are consistent with previous studies that found that education combined with other SDOH variables has a greater impact with testing positive for COVID-19 (19,20,23,27). Moreover, after stratifying on rural versus urban, there were no differences observed in the relationship between education and COVID-19 test positivity, suggesting that the risk of testing positive for COVID-19 for veterans with low education is the same in both rural and urban areas.

Urbanicity was the only variable inconsistent with the literature (12,20,23,34). This study examined higher odds with testing positive for veterans living in rural areas compared to those living in urban areas. In contrast, previous studies reported that living in urban areas was associated with higher odds for COVID-19 test positivity (12,20,23,34). These observed differences are likely due to differences in timeframe of which data was collected from and various study population sizes examined among the studies. There were no significant differences found after stratifying urban and rural areas in the relationships between SDOH disparities with COVID-19 test positivity. However, current literature found that urban communities have higher risk for SDOH disparities associated with COVID-19 test positivity compared to those living in rural communities (16,19,20,22-24,28). This is likely due to current research examining smaller populations such as community and state-level, and the lack of available data for COVID-19 testing in rural populations.

Living in crowded homes and having more than one child was also consistent with the literature (19,20,23,27). After adjusting for all other SDOH covariates, veterans that lived in a household with four or more persons and had more than one child had higher odds of test positivity, which aligns with current literature that observed the same results (19,20,23,27).

This study has at least three strengths. First, this study was able to utilize a national dataset from the VHA with demographic, clinical, and social determinants of health information on all veterans across the United States. Second, this study examined SDOH exposures separately and together in a model with the outcome of test positivity unlike other research studies that observed SDOH variables using deprivation scales, which does not capture independent variable relationship with COVID-19. Lastly, this study was able to utilize data

from rural populations to examine differences by rural and urban areas. The findings of other studies focusing on urban areas had limited generalizability.

Despite these strengths, there were at least two limitations. First, the high percentage of missing data with the SDOH variables could have potentially introduce reporting bias and affect the validity and generalizability of the study results. In each SDOH field, an extra value was imputed to separate veterans with missing data from veterans with available data to prevent bias in the results. If there were fewer missing data, the results would reflect the overall experience of all veterans, and possibly introduce recall bias in the results, in which veterans could not recall information, but would report inaccurate information in SDOH fields. Second, it is reported in the literature that veterans living in rural populations are less likely to be tested for COVID-19 (30). This may be the result of Veterans living in rural areas having longer distances from the residential homes to VA facilities and do not have internet access at home to support VA telehealth services which was used for screening for COVID-19 if COVID-19 testing was needed during the pandemic. For example, veterans living in Hollis, AK must travel over 1,000 miles from their residential home to the closest VA facility for care (35). Only 2.8 out of 4.7 million veterans are actively enrolled and utilize the VA's health care facilities (35). If more rural veterans were actively enrolled and used VA facilities, a larger rural population may produce significant differences between rural/urban.

Future research can expand on this study by conducting spatial analyses examining the relationship between SDOH exposures and COVID-19 test positivity. This type of analysis can provide insight on distribution of COVID-19 geographically in relations to SDOH exposures, and guide intervention strategies to reduce health disparities in specific regions. Occupation and employment status were not investigated as SDOH exposures in this study but may have an

impact on individual risk of COVID-19 test positivity. A better understanding of the role of occupation and employment status can assist with a better understanding of COVID-19 test positivity in workplaces and assist with reducing the spread of disease. Lastly, understanding health disparities for veterans in rural areas can help improve access to care and help advocate intervention strategies to reduce the burden of future diseases.

Findings from this study demonstrate implications that SDOH disparities are associated with COVID-19 test positivity and are relevant to public health decision-making policies for the burden of disease. Policymakers can utilize these findings to allocate resources in high-risk populations to improve access to testing and care in vulnerable populations. VA researchers can use these results to improve surveillance efforts and develop intervention programs for rural communities to improve access to testing. In future efforts, this study will provide additional support to raise awareness for intervention strategies needed in vulnerable populations of the United States.

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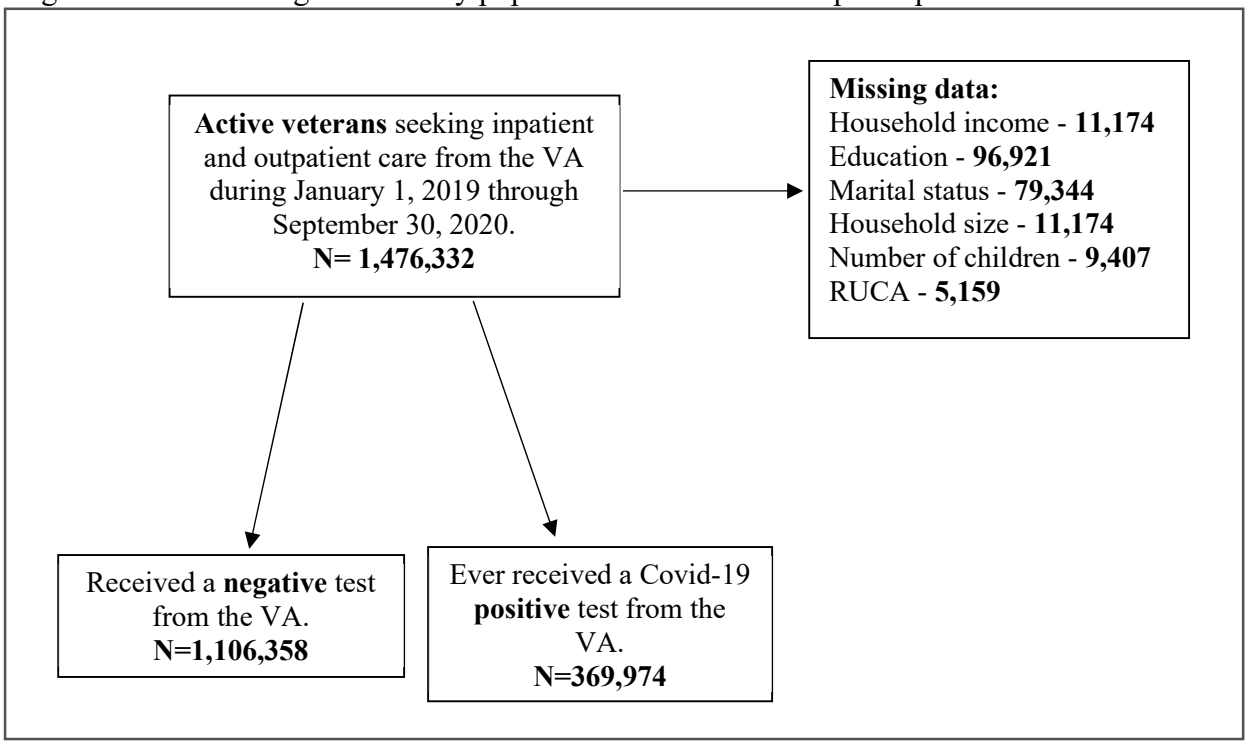
Figure 1. Consort Diagram of study population and selection of participants.



*Missing do not reflect a unique individual.

Figure 2. Directed Acyclic Graph for SDOH exposures association with COVID-19 test positivity.

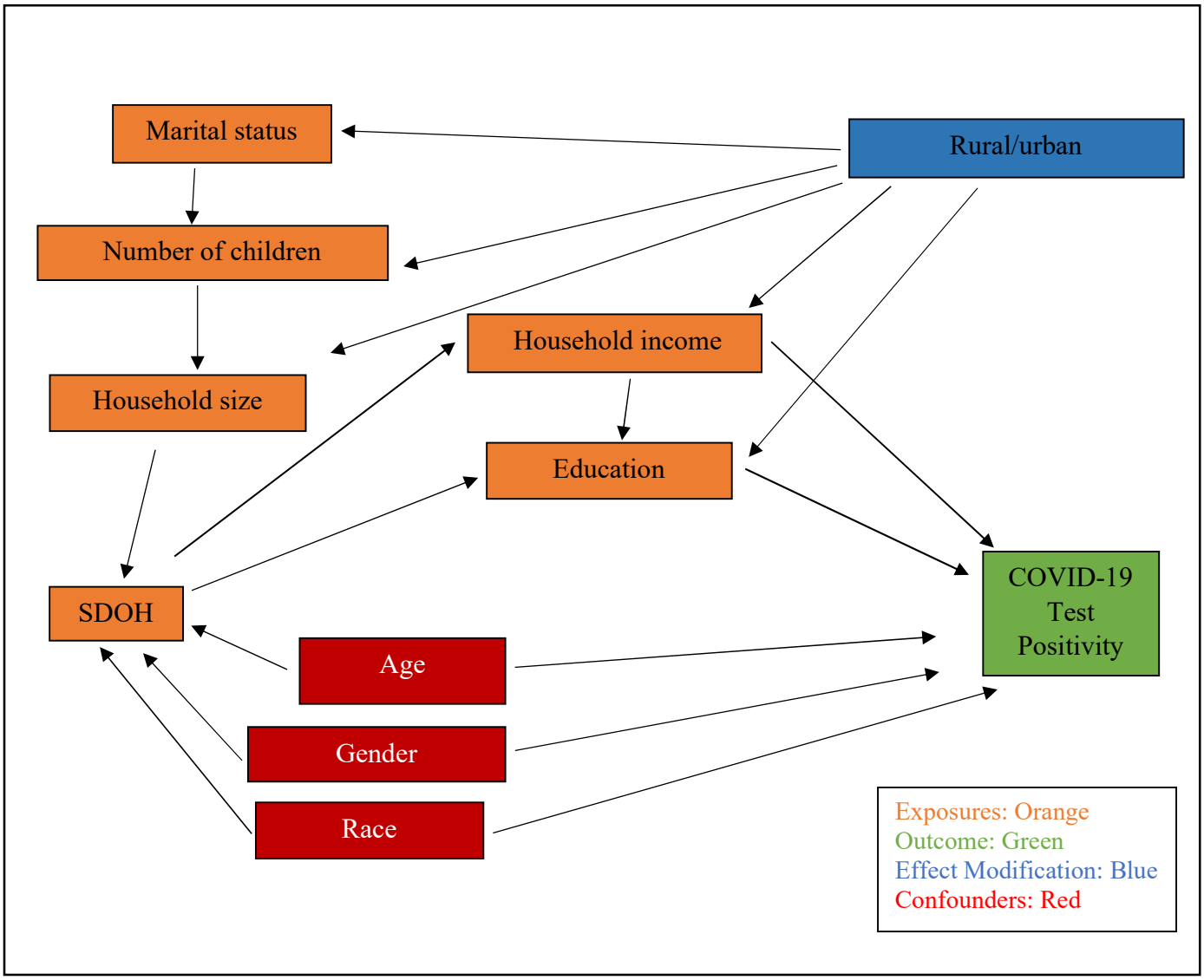


Table 1. Selected demographics of veterans characterized by those who received inpatient or outpatient testing for COVID-19, a negative COVID-19 test, and at least 1 positive Covid-19 test between January 1, 2019 through September 30, 2020, N=1,476,332

Characteristics	**Those who were tested for COVID-19, N=1,476,332**		**Those who tested negative for COVID-19 N= 1,106,358**		**Those who have ≥1 COVID-19 positive test N=369,974**		**Chi-square (p-value)**
Age, years, mean (SD)	61.1	15.9	61.6	15.7	59.5	16.6	<.0001
	N	%	N	%	N	%	
Gender							<.0001
Male	1,313,829	88.9	986,071	89.1	327,758	88.6	
Female	162,503	11.1	120,287	10.9	42,216	11.4	
Race/Ethnicity							<.0001
Non-Hispanic White	991,486	67.2	743,827	67.2	247,659	66.9	
Non-Hispanic Black/African American	339,393	23.0	256,472	23.2	82,921	22.4	
Hispanic	105,295	7.1	75,827	6.9	29,468	8.0	
Asian	17,301	1.2	13,515	1.2	3,786	1.0	
American Indian or Alaska Native	10,813	0.7	7,787	0.7	3,026	0.8	
Native Hawaiian or Pacific Islander	12,044	0.8	8,930	0.8	3,114	0.8	
Education							<.0001
Graduate school	119,785	8.2	9,062	0.8	28,403	7.7	
High school	584,264	39.6	431,023	39.0	153,241	41.4	
Vocational/technical school	12,218	0.8	262,222	23.7	3,156	1.0	
College	350,475	23.7	91,382	8.3	88,253	23.9	
Missing	409,590	27.7	312,669	28.3	96,921	26.2	
Marital status							<.0001
Married	584,932	39.6	432,431	39.1	152,501	41.2	
Single	575,807	39.0	437,678	39.6	138,129	37.3	
Missing	315,593	21.4	236,249	21.4	79,344	21.5	
Household size							<.0001
1 person	423,794	28.7	325,410	29.4	98,384	26.6	
2 persons	390,836	26.5	295,197	26.7	95,639	25.9	
3 persons	302,642	20.5	223,892	20.2	78,750	21.3	
≥4 persons	313,349	21.2	227,322	20.6	86,027	23.3	
Missing	45,711	3.1	34,537	3.1	11,174	3.0	
Number of children							<.0001
No children	910,825	61.7	691,997	62.6	218,828	59.2	
1 child	431,329	29.2	317,723	28.7	113,606	30.7	
2 children	70,870	4.8	50,394	4.6	20,476	5.5	
3 or more children	24,863	1.7	17,206	1.6	7,657	2.1	
Missing	38,445	2.6	29,038	2.6	9,407	2.5	
Household income							<.0001
≤$39,999	565,154	38.3	389,294	35.2	141,323	38.2	
$40,000 and $74,999	552,530	37.4	412,594	37.3	139,936	37.8	
≥$75,000	358,648	24.3	269,933	24.4	88,715	24.0	

Missing	45,711	3.1	34,537	3.1	11,174	3.0	
Urban/Rural							<.0001
Urban	1,219,020	82.6	919,220	83.1	299,800	81.0	
Rural	237,284	16.1	172,269	15.6	65,015	17.6	
Missing	20,028	1.4	14,869	1.3	5,159	1.4	

Table 2. Bivariate analysis demographics and SDOH factors with Covid-19 test positivity, N= 1,476,332

Characteristics	Odds ratio	95% CI
Demographics		
Age		
<50 years	Ref	
50-64 years	0.78	0.77, 0.79
≥65 years	0.69	0.68, 0.69
Gender		
Male	Ref	
Female	0.95	0.94, 0.96
Race		
White	Ref	
Black/African American	0.97	0.96, 0.98
Hispanic	1.17	1.15, 1.18
Asian	0.84	0.81, 0.87
American Indian or Alaska Native	1.17	1.12, 1.22
Native Hawaiian or Pacific Islander	1.05	1.01, 1.09
Social Determinants of Health		
Household income		
≥$75,000	Ref	
$40,000 and $74,999	1.03	1.02, 1.04
≤$39,999	1.02	1.01, 1.03
Education		
Graduate school	Ref	
High School	1.14	1.13, 1.16
College	1.08	1.07, 1.10
Vocational/technical school	1.12	1.07, 1.17
Marital status		
Single	Ref	
Married	1.12	1.11, 1.13
Household size		
1 person	Ref	
2 persons	1.07	1.06, 1.08
3 persons	1.16	1.15, 1.18
≥4 persons	1.25	1.24, 1.27
Number of children		
No children	Ref	
1 child	1.13	1.12, 1.14
2 children	1.29	1.26, 1.31
3 or more children	1.41	1.37, 1.45
Urban/Rural		
Urban	Ref	
Rural	1.16	1.15, 1.17

Table 3. Multivariable regression analysis of SDOH with Covid-19 test positivity, N=1,476,332

Characteristics	Model 1		Model 2	
	Odds ratio	95% CI	Odds ratio	95% CI
Household income				
≥$75,000	Ref			
$40,000 and $74,999	1.03	1.02, 1.04	1.05	1.04, 1.06
≤$39,999	1.05	1.03, 1.06	1.07	1.06, 1.09
Education				
Graduate school	Ref	-	-	-
High school	1.14	1.13, 1.16	1.07	1.06, 1.09
College	1.08	1.06, 1.10	1.06	1.04, 1.07
Vocational/technical school	1.11	1.07, 1.16	1.07	1.02, 1.11
Marital status				
Single	Ref			
Married	1.04	1.03, 1.05	1.07	1.06, 1.08
Household size				
1 person	Ref			
2 persons	1.05	1.04, 1.06	1.09	1.08, 1.11
3 persons	1.10	1.08, 1.12	1.16	1.14, 1.18
≥4 persons	1.14	1.12, 1.16	1.22	1.20, 1.24
Number of children				
No children	Ref			
1 child	1.06	1.05, 1.07	1.01	1.00, 1.02
2 children	1.16	1.14, 1.19	1.07	1.05, 1.09
3 or more children	1.27	1.24, 1.31	1.14	1.11, 1.18
Urban/Rural				
Urban	Ref			
Rural	1.14	1.13, 1.15	1.17	1.16, 1.18

Model 1: adjusted for all other SDOH covariates.
Model 2: adjusted for all other SDOH covariates, age, gender, & race/ethnicity.

Table 4. Multivariable analysis of SDOH with COVID-19 test positivity stratified by rural/urban, N=1,476,332

	RUCA							
	Model 1 (unadjusted)				Model 2 (adjusted)			
	Rural		Urban		Rural		Urban	
Characteristics	**Odds ratio**	**95% CI**	**Odds ratio**	**95% CI**	**Odds ratio**	**95% CI**	**Odds ratio**	**95% CI**
Household income								
≥$75,000	Ref	-	Ref	-	Ref	-	Ref	-
$40,000 and $74,999	1.02	1.00, 1.05	1.04	1.03, 1.05	1.03	1.01, 1.05	1.06	1.05,1.07
≤$39,999	1.07	1.04, 1.09	1.09	1.07, 1.11	1.09	1.06, 1.11	1.12	1.10, 1.14
Education								
Graduate school	Ref	-	Ref	-	Ref	-	Ref	-
High school	1.07	1.05, 1.10	1.07	1.06, 1.08	1.05	1.03, 1.07	1.04	1.03, 1.05
College	1.15	1.12, 1.18	1.15	1.12, 1.17	1.09	1.07, 1.12	1.08	1.06, 1.11
Vocational/technical school	1.23	1.19, 1.27	1.23	1.19, 1.27	1.14	1.10, 1.17	1.13	1.09, 1.17
Marital status								
Single	Ref	-	Ref	-	Ref	-	Ref	-
Married	1.03	1.02, 1.04	1.05	1.04, 1.05	1.04	1.03, 1.05	1.04	1.04, 1.05
Household size								
1 person	Ref	-	Ref	-	Ref	-	Ref	-
2 persons	1.16	1.15, 1.18	1.15	1.14, 1.16	1.19	1.18, 1.21	1.17	1.16, 1.18
3 persons	1.26	1.23, 1.28	1.24	1.22, 1.26	1.30	1.28, 1.33	1.28	1.26, 1.30
≥4 persons	1.36	1.32, 1.40	1.34	1.31, 1.37	1.42	1.38, 1.47	1.39	1.36, 1.43
Number of children								
No children	Ref	-	Ref	-	Ref	-	Ref	-
1 child	1.09	1.08, 1.10	1.08	1.07, 1.08	1.07	1.06, 1.08	1.06	1.06, 1.07
2 children	1.19	1.17, 1.21	1.18	1.16, 1.19	1.15	1.13, 1.17	1.14	1.12, 1.15
3 or more children	1.30	1.27, 1.34	1.29	1.26, 1.31	1.23	1.20, 1.27	1.22	1.19, 1.25

Model 1: effect modification of rural/urban in the relationship of SDOH with COVID-19 test positivity.
Model 2: effect modification of rural/urban in the relationship between SDOH and COVID-19 test positivity adjusted for age, gender, and race/ethnicity.