



Evaluation of neighborhood resources and mental health in American military Veterans using geographic information systems

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ABSTRACT

Neighborhood-level social determinants are increasingly recognized as factors shaping mental health in adults. Data-driven informatics methods and geographic information systems (GIS) offer innovative approaches for quantifying neighborhood attributes and studying their influence on mental health. Guided by a modification of Andersen's Behavioral Model of Health Service Use framework, this cross-sectional study examined associations of neighborhood resource groups with psychological distress and depressive symptoms in 1,528 U.S. Veterans. Data came from the Veteran Affairs (VA) Health Services Research and Development Proactive Mental Health trial and publicly available sources. Hierarchical clustering based on the proportions of neighborhood resources within walkable distance was used to identify neighborhood resource groups and generalized estimating equations analyzed the association of identified neighborhood resource groups with mental health outcomes. Few resources were found in walkable areas except alcohol and/or tobacco outlets. In clustering analysis, four meaningful neighborhood groups were identified characterized by alcohol and tobacco outlets. Living in an alcohol-permissive and tobacco-restrictive neighborhood was associated with increased psychological distress but not depressive symptoms. Living in urban or rural areas and access to VA care facilities were not associated with either outcome. These findings can be used in developing community-based mental health-promoting interventions and public health policies such as zoning policies to regulate alcohol outlets in neighborhoods. Augmenting community-based services with Veteran-specialized services in neighborhoods where Veterans live provides opportunities for improving their mental health.

1. Introduction

Military Veterans are at high risk for mental health disorders such as depression, post-traumatic stress disorder (PTSD), and substance use disorder (Vogt, 2011). Mental health conditions complicate chronic diseases, and lead to impaired quality of life, disability, suicide and other premature deaths, and higher health care costs (Greenberg et al., 2015; Larson et al., 2001; Penninx et al., 2001; Wang et al., 2017). The majority of Veterans use VA health services, although those residing outside of urban areas may not have access to VA mental health-related

services in their neighborhoods. Lack of access to VA and non-VA facilities or services supporting mental health can lead to inadequate prevention and treatment of psychological symptoms and increase the risk of negative health consequences (Hester, 2017; Patel and Saxena, 2014). In this context, the Department of Veterans Affairs Strategic Plan prioritizes increasing access to mental and behavioral health care by delivering services in primary care clinics (U.S. Department of Veterans Affairs, 2018).

Research suggests that having fewer neighborhood resources decreases the quality of life among rural-residing Veterans (Weeks et al.,

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2004). In contrast, having more neighborhood resources such as physical activity facilities, cultural services, and a greater natural greenness decreased depression in community-dwelling adults with chronic conditions (Garipey et al., 2015). Communities, defined as neighborhoods, need to be incorporated in comprehensive approaches to support Veterans' mental and behavioral health care needs in addition to the VA healthcare system. However, there is limited evidence on how neighborhood resources may influence mental health outcomes, specifically depressive symptoms and psychological distress, which are prevalent among Veterans. Gaining a better understanding of the accessibility and availability of neighborhood resources influencing mental health would be important in developing personalized interventions and community services for Veterans.

This study explored the distribution patterns of neighborhood resources and examined their availability, accessibility, and associations with mental health outcomes among Veterans. Specific objectives were to: 1) identify the patterns of neighborhood resources related to psychological distress and depressive symptoms; and 2) examine relationships between patterns of neighborhood resources and psychological distress and depressive symptoms among Veterans.

2. Methods

2.1. Study design and data sources

A modification of Andersen's Behavioral Model of Health Service Use (Andersen and Newman, 1973; Supplemental Fig. 1) was used to select variables for this study because it includes individual- and neighborhood-characteristics relevant to mental and behavioral health care utilization and outcomes. Predisposing, enabling, and need characteristics at the individual-level influence mental health care utilization. Neighborhood characteristics include those health-related services available to the individual. This study focused on the direct relationships between neighborhood resources and mental health care for Veterans.

This secondary data analysis used baseline data from the VA Proactive Mental Health trial, which was a randomized controlled trial investigating a smoking cessation intervention at VA Medical Centers in four cities (Tampa, Florida [FL]; Minneapolis, Minnesota [MN]; New York City, New York [NY]; and Houston, Texas [TX]) conducted between 2014 and 2015 (Rogers et al., 2014). Data sources to measure neighborhood resources were obtained from online publicly available sources (Appendix 1). IRB review and approval was exempted because University of Minnesota IRB determined that this study does not involving human subjects as defined by DHHS and FDA regulations due to using the existing and de-identified datasets (IRB ID: STUDY00007858).

2.2. Sample

Participants of Proactive Mental Health trial were current smokers and had a mental health clinic visit in the past 12 months. A subsample of 1,528 participants (age 21+) met eligibility criteria (Fig. 1) for these analyses. Inclusion criteria were: 1) lived in FL, NY, MN or TX; and 2) had completed the Kessler Psychological Distress Scale-6 (K6) and the Patient Health Questionnaire-8 (PHQ-8) at baseline. Participants living in counties that had fewer than six participants were excluded because a minimum of five cases in a neighborhood is needed to detect the effects of the neighborhood on health outcomes (Hoyle and Gottfredson, 2015; Lorah, 2018; Maas and Hox, 2005). Participants residing in Wisconsin were excluded due to the unavailability of neighborhood resources data.

2.3. Measures

Psychological distress was measured by the Kessler Psychological Distress Scale-6 (K6) (Kessler et al., 2002). This widely-used, self-report scale measures anxiety and depressive symptoms during the past month.

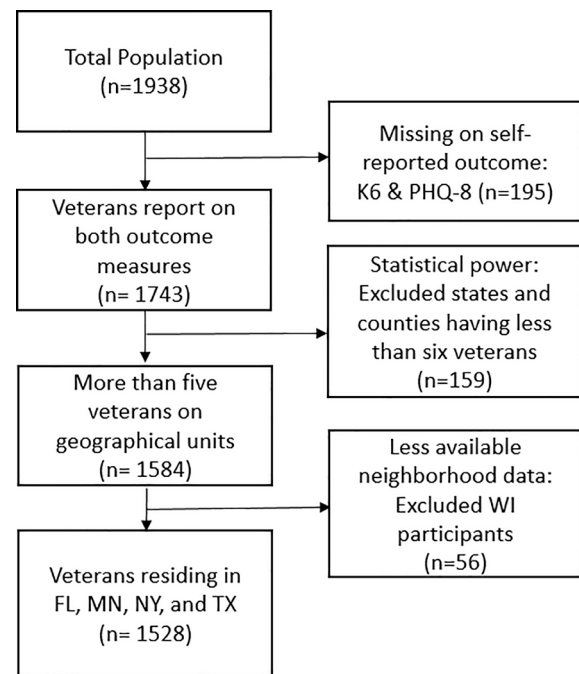


Fig. 1. Flowchart of subsample selection. Note. K6, Kessler psychological distress scale 6; PHQ-8, patient health questionnaire-8; WI, Wisconsin; FL, Florida; MN, Minnesota; NY, New York; TX, Texas.

Total scores range from 6 to 30, with higher scores indicating higher levels of psychological distress. Depressive symptoms were measured by the Patient Health Questionnaire-8 (PHQ-8) (Pressler et al., 2011; Wells et al., 2013). The PHQ-8 asks the number of days in the past two weeks when participant had experienced a particular depressive symptom. Total scores range from 0 to 24, with higher scores indicating higher levels of depressive symptoms.

The primary independent variable included neighborhood groups identified by clustering. Neighborhood resources included alcohol, and tobacco outlets, churches, libraries, community-based centers (community centers, recreation centers, YMCAs [CBC]), parks, and Veteran-related organizations (American Legion, Veterans of Foreign Wars, and Vet center [VRO]). Secondary variables included the total number of each neighborhood resource within a 400 m buffer and the closest distance in kilometer to each neighborhood.

Control variables included neighborhood- and individual-predisposing, enabling and need characteristics. The Area Deprivation Index (ADI), a validated measure of neighborhood socioeconomic status has been linked to health outcomes (Jung et al., 2018; Durfey et al., 2019). The ADI was computed for each census block group with a ranking from the least disadvantage to the most disadvantage in quintile (University of Wisconsin School of Medicine Public Health, 2019). VA urban, rural, and highly rural (URH) classifications, based on the US Census Bureau delineations were used to differentiate urban and rural areas (Kaboli and Glasgow, 2011). The VA defines accessibility to a VA healthcare system (VAHCS) by using drive time in minutes. The average drive time in minutes to the nearest VAHCS from participants' residences was calculated by using network analysis with VA administrative data.

Individual predisposing characteristics included participants' self-reported data from the Proactive Mental Health trial at baseline on their age, gender, race, ethnicity, educational attainment, and marital status, alcohol use and smoking behavior. Alcohol use was assessed as the frequency participants have a drink containing alcohol. Smoking behavior was assessed as the number of daily smoked cigarettes. Enabling characteristics included participants' annual income, employment status, and levels of financial stress. Stress due to financial

situations was rated using a scale from 1 to 10, with higher scores indicating greater stress. Self-rated general health status using a single item on a scale ranging from 0 (excellent) to 4 (poor), comorbidity using the Charlson Comorbidity Index (CCI) (Hall et al., 2004), and pain using the Pain, Enjoyment, General (PEG) activity scale ranging from 1 to 10 were included as need characteristics (Krebs et al., 2009).

2.4. Data preparation

Neighborhood resources addresses data (alcohol, and tobacco outlets, churches, libraries, CBCs, parks, and VROs) were collected and geocoded using Environmental Systems Research Institute (ESRI) world geocoding service (Redlands, CA). All geocoded data of neighborhood resources were aggregated for a 400-meter buffer around participants' addresses to calculate the total number of resources in each buffer. A 400-meter buffer area is typically used as the walkable distance representing approximately a 10-minute walk for vulnerable populations (Rantakokko et al., 2018; Yong and Diez-Roux, 2012). The proportion of each neighborhood resource to the total number of neighborhood resources within a buffer was calculated for clustering analysis. The distance in kilometers from participants' homes to the closest neighborhood facility was calculated using Euclidean distance. Data management of survey and spatial datasets of neighborhood resources was performed using RStudio (version 3.6.1) and ESRI ArcMap (version 10.6.1).

2.5. Analysis strategy

Hierarchical clustering analysis was used to identify the patterns of neighborhood resources groups using the agglomerative approach (García et al., 2015). Ward distance of dissimilarity metric was used as a link function (Murtagh and Legendre, 2014). The Elbow method (within-cluster-sum of squared errors) and Silhouette method (similarity metric) guided the decision for optimal numbers of neighborhood groups (Kodinariya and Makwana, 2013; Pruinelli et al., 2018; Zambelli, 2016).

Identified neighborhood groups were included as the primary independent variable. Correlational analysis among individual-level covariates were conducted to check for multicollinearity. Multivariable models examined relationships between the primary independent variable with psychological distress and depressive symptoms including covariates from individual-predisposing, enabling, and need factors, and neighborhood-predisposing and enabling factors. Generalized estimating equations (GEE) were estimated to adjust for the clustering of participants at their county-levels (Hubbard et al., 2010), using an exchangeable covariance structure (Ballinger, 2004). Goodness-of-fit was calculated and compared using R-squared to determine the final model with selected covariates. All statistical analyses were conducted using the RStudio (version 3.6.1).

3. Results

Participants were a mean age of 58 years, with most being men and Non-Hispanic (Table 1). Race was diverse, with White and African Americans. More than half of the sample had completed education beyond high school and married/coupled participants made up 41% of the sample. More than one-third of Veterans were more frequent drinkers at least 2–4 times a month. The median number of cigarettes smoked was less than one pack a day. Over half of participants' annual income was less than \$20,000. The majority were unable to work or disabled, retired, or not working. On average, participants felt moderate financial stress.

Participants had on average 1.7 chronic conditions, with substance use disorder and depression. Average pain-level was rated as moderate, with participants reporting their general health status as "good." Most participants lived in urban areas. The average neighborhood

Table 1

Individual, neighborhood, and health status characteristics of participants (n = 1,528).

Variables	Mean ± SD or N (%)
<i>Individual Predisposing Characteristics</i>	
Age	58.1 ± 11.5
Male gender	1,316 (86.2)
Race	
White	924 (61.0)
Black/African American	501 (33.1)
Other	89 (5.9)
Non-Hispanic ethnicity	1,391 (91.0)
Education	
≤ High school	617 (40.9)
Associate Degree	210 (13.9)
College degree	493 (32.7)
Graduate degree	135 (8.9)
Other	54 (3.6)
Marital status	622 (40.9)
Married/Coupled	102 (6.7)
Separated	421 (27.7)
Divorced	116 (7.6)
Widowed	260 (17.1)
Single, never married	
Frequency of alcohol use	519 (34.3)
Never	323 (21.3)
Monthly or less	228 (15.0)
2–4 times a month	204 (13.5)
2–3 times a week	241 (15.9)
4 or more times a week	
Cigarettes per day	14.9 ± 10.5
<i>Individual Enabling Characteristics</i>	
Annual income	316 (22.4)
<\$10,000	437 (31.0)
\$10,000–\$20,000	381 (27.1)
\$20,001–\$40,000	180 (12.8)
\$40,000–\$60,000	94 (6.7)
>\$60,001	
Employment	388 (26.8)
Employed	173 (11.9)
Out of work	424 (29.3)
Retired	464 (32.0)
Unable to work/disabled	
Financial stress ¹	5.6 ± 2.5
<i>Individual Need Characteristics</i>	
Charlson comorbidity index ²	1.7 ± 4.2
Primary psychiatric diagnosis	
Substance use	611 (47.3)
Depression	200 (15.5)
PTSD	119 (9.2)
Serious mental illness	101 (7.8)
Unspecific alcohol dependence	101 (7.8)
Anxiety	82 (6.4)
Other	77 (6.0)
PEG score ³	5.0 ± 2.8
General health status ⁴	2.3 ± 1.0
<i>Neighborhood Predisposing Characteristics</i>	
Area deprivation index ⁵	56.5 ± 30.1
Urban residence	1,335 (87.4)
<i>Neighborhood Enabling Characteristic</i>	
Drive time to closest VA care (min), Median (IQR)	21.0 (14.3, 32.7)

Notes. IQR, Interquartile Range; PEG, pain, enjoyment, and general activity; PTSD, post-traumatic stress disorder; SD, Standard Deviation; VA, Veteran Affairs; 1. Financial stress ranged 1 to 10, indicating higher scores meaning higher stress; 2. Charlson comorbidity index ranged 0 to 37; 3. PEG score ranged 1 to 10, with higher scores indicating higher pain level; 4. General health status ranged 1 to 5 with higher scores indicating worse health status; 5. Area Deprivation Index ranged 1 to 100 with higher scores indicating more deprived areas.

deprivation-level was a little above half of the country. The median average drive time to the closest VAHCS was 21.0 min. The mean score of psychological distress (K6) was 14.1 and the mean score of depressive symptoms (PHQ-8) was 9.1.

3.1. Neighborhood resources

Around 40% of neighborhoods within a 400 m buffer around participants' homes contained alcohol outlets, and more than half had tobacco outlets (Table 2). In contrast, very few (4%) neighborhoods contained community-based centers. <10% of neighborhoods had public libraries, and only a quarter contained religious places. Only 4% of participants' neighborhoods had VROs.

Few resources were available within 400 m around participants' homes except alcohol or tobacco outlets. The median number of alcohol outlets, community-based centers, public libraries, religious places, VROs, and the median proportion of the total park areas within a 400 m buffer was 0; the exception was tobacco outlets (Median = 1).

Four neighborhood groups were identified (Table 3). Groups were characterized by combinations of alcohol and/or tobacco outlets in neighborhoods. Except for the mean proportion of religious places in the fourth group, the variation in mean proportions of other neighborhood resources was too small to differentiate characteristics between groups. The identified groups were: Group 1, alcohol and tobacco-restrictive neighborhood (Low alcohol & Low tobacco); Group 2, alcohol and tobacco-permissive neighborhood (Medium alcohol & Medium tobacco); Group 3, alcohol-permissive and tobacco-restrictive neighborhood (High alcohol & Low tobacco); Group 4, alcohol-restrictive and tobacco-permissive neighborhood (Low alcohol & High tobacco).

3.2. Relationships between neighborhood and mental health outcomes

Living in an alcohol and tobacco-permissive neighborhood (Group 2) compared to living in an alcohol and tobacco-restrictive neighborhood (Group 1) was associated with significant increases in participants' psychological distress and depressive symptoms (Table 4). Living in an alcohol-permissive and tobacco-restrictive neighborhood (Group 3) compared to living in an alcohol and tobacco-restrictive neighborhood (Group 1) was also significantly associated with increases in both psychological distress and depressive symptoms.

Higher numbers of alcohol outlets were associated with increases of psychological distress and depressive symptoms. A higher number of VROs were associated with decreases in depressive symptoms (Table 5).

Table 2
Measures of neighborhood resources for Veteran participants (n = 1,528).

Resource	Presence ¹	Total Number ¹	Distance (km)
	N (%)	Median (IQR)	Median (IQR)
Alcohol outlet		0 (0.0, 1.0)	0.52 (0.27, 0.93)
Yes	601 (39.3)		
No	927 (60.7)		
Tobacco outlets		1 (0.0, 4.0)	0.40 (0.15, 0.86)
Yes	774 (50.6)		
No	754 (49.4)		
Community-based centers		0 (0.0, 0.0)	2.72 (1.23, 6.41)
Yes	57 (3.7)		
No	1,471 (96.3)		
Public libraries		0 (0.0, 0.0)	1.88 (0.80, 3.92)
Yes	126 (8.2)		
No	1,402 (91.8)		
Religious places		0 (0.0, 0.0)	1.02 (0.41, 2.38)
Yes	374 (24.5)		
No	1,154 (75.5)		
Veteran-related organizations		0 (0.0, 0.0)	2.33 (1.31, 4.56)
Yes	63 (4.1)		
No	1,465 (95.9)		
Parks	Presence¹	Proportion²	Distance (km)
Yes	676 (44.2)	0 (0, 0.02)	0.47 (0.22, 1.11)
No	852 (55.8)		

Notes. IQR, Interquartile Range. 1. Presence and total number of neighborhood resources estimated within a 400 m buffer. 2. Proportion of park areas was calculated by total areas of park dividing by 400 m circular areas.

Living closer to tobacco outlets was associated with higher psychological distress and living far from VROs was associated with higher levels of psychological distress or depressive symptoms among Veterans (Table 6).

3.3. Multivariate analysis of relationships between neighborhood groups and mental health outcomes

Living in an alcohol-permissive and tobacco-restrictive neighborhood (Group 3) compared to living in an alcohol and tobacco-restrictive neighborhood (Group 1) remained significantly associated with increases in psychological distress but not depressive symptoms after adjustment for covariates (Table 7). The predisposing neighborhood characteristic assessed by the ADI was significantly associated with decreases in psychological distress and depressive symptoms for participants living in the fourth deprived areas (60–80th percentile) compared to those living in the least deprived areas (0–20th percentile). Place of residence (urban vs rural areas) and average drive time to the closest VAHCS did not significantly affect either outcome.

4. Discussion

This cross-sectional study is the first to identify influential neighborhood groups by clustering and to examine their relationships with psychological distress and depressive symptoms among Veterans. Results suggest that living in an alcohol-permissive and tobacco-restrictive neighborhood is associated with significantly increased psychological distress but not depressive symptoms. Unexpectedly, living in a certain level of deprived neighborhoods was significantly associated with a decrease of psychological distress and depressive symptoms.

4.1. Neighborhood group identified using clustering

Four meaningful neighborhood groups were identified that were differentiated by alcohol or tobacco outlets. Other neighborhood resources were not located near participants' residences providing insufficient information to construct neighborhood groups such as CBCs, public libraries, or VROs. Use of clustering analysis to find meaningful groups with attributes that explain mental health outcomes is a recent innovation. Prior studies have used clustering analysis to group Indonesian providences with area-based health profiles (Paramita et al., 2020), and to identify meaningful patients' groups with health conditions such as end-stage chronic diseases (Finamore et al., 2021) and liver transplant (Pruinelli et al., 2016). Also, this method allowed to create the independent variable of neighborhood attributes to examine the relationships between availability or accessibility of neighborhood resources and mental health outcomes.

4.2. Neighborhood resources and mental health

Living in an alcohol-permissive and tobacco-restrictive neighborhood group (High alcohol & Low tobacco), was significantly associated with higher psychological distress is aligned with prior research that exposure to liquor stores increased the risk of hospital admission for anxiety, stress, and depression (Pereira et al., 2013). In contrast, neither the alcohol-restrictive and tobacco-permissive neighborhood group nor the alcohol and tobacco-permissive neighborhood group was significantly related to either mental health outcome. This suggests that the existence of alcohol outlets near neighborhoods for Veterans is an important factor in relating to their psychological distress. This association might be explained by lower perception of neighborhood safety as higher density of alcohol outlets are associated with higher rates of violence or crime, which are related to mental health outcomes (Gorman et al., 2001; Gruenewald et al., 2006; Zhu et al., 2004). Alcohol outlets included on-premises facilities such as bars, pubs, or restaurants selling alcohol where social interactions can occur (Centers for Disease Control

Table 3

Mean proportions of each neighborhood resource (at 400 m buffer) across the four groups derived from hierarchical clustering analysis.

Group ¹	N	Alcohol %	Tobacco %	VRO %	Park %	CBC %	Library %	Religious %
1	698	0.01	0.01	0.02	0.03	0.02	0.01	0.03
2	241	0.44	0.52	0.00	0.02	0.00	0.01	0.02
3	175	0.78	0.16	0.01	0.01	0.01	0.00	0.04
4	414	0.04	0.83	0.00	0.04	0.00	0.01	0.11

Notes. CBC, community-based center; VRO, Veteran-related organization. 1. Group1: alcohol and tobacco-restrictive neighborhood group (Low alcohol & Low tobacco); Group2: alcohol and tobacco-permissive neighborhood group (Medium alcohol & Medium tobacco); Group3: alcohol-permissive and tobacco-restrictive neighborhood group (High alcohol & Low tobacco); Group4: alcohol-restrictive and tobacco-permissive neighborhood group (Low alcohol & High tobacco). #alcohol outlets, #tobacco outlets, #VROs, #CBCs, #libraries, # religious places were divided by #total neighborhood resources within a 400 m area, total park areas were divided by 400 m circular areas. Each proportion of neighborhood resource was used for clustering analysis.

Table 4

Unadjusted GEE analysis of associations between neighborhood groups and mental health outcomes.

Group	K6		PHQ-8	
	β (SE)	95% CI	β (SE)	95% CI
2 vs. 1	0.89 (0.44)	(0.03, 1.75)*	1.28 (0.50)	(0.31, 2.26)**
3 vs. 1	1.32 (0.54)	(0.26, 2.38)*	1.86 (0.62)	(0.64, 3.07)**
4 vs. 1	0.56 (0.38)	(-0.18, 1.31)	0.47 (0.44)	(-0.39, 1.32)

Notes. CI, Confidence interval; GEE, Generalized Estimating Equation; K6, Kessler Psychological Distress Scale-6; PHQ-8, Patient Health Questionnaire-8; SE, Standard error. *** <0.001, ** <0.01, * <0.05. Bolded numbers indicate statistically significant at the P < .05 level.

Table 5

Unadjusted GEE analysis of associations between the total number of neighborhood resources and mental health outcomes (n = 1,528).

	K6		PHQ-8	
	β (SE)	95% CI	β (SE)	95% CI
# Alcohol outlets	0.16 (0.08)	(0.00, 0.32)*	0.25 (0.11)	(0.05, 0.46)*
# Tobacco outlets	0.05 (0.03)	(-0.01, 0.11)	0.06 (0.04)	(-0.01, 0.13)
# Community-based centers	0.22 (0.76)	(-1.27, 1.72)	0.97 (0.86)	(-0.72, 2.65)
# Public libraries	-0.87 (0.66)	(-2.17, 0.43)	-0.83 (0.76)	(-2.32, 0.66)
# Religious places	-0.18 (0.17)	(-0.52, 0.16)	-0.23 (0.19)	(-0.61, 0.14)
# Veteran-related organizations	-0.66 (0.52)	(-1.68, 0.36)	-1.44 (0.58)	(-2.57, -0.31)*
Presence of park				
Yes vs. No	0.16 (0.33)	(-0.50, 0.81)	-0.11 (0.38)	(-0.85, 0.64)

Note. GEE, Generalized Estimating Equations; K6, Kessler Psychological Distress Scale-6; PHQ-8, Patient Health Questionnaire-8; CI, Confidence interval; SE, Standard error; Significance codes, *** <0.001, ** <0.01, * <0.05, † <0.10. Bolded numbers indicate statistically significant at the p < .05.

and Prevention, 2017).

Results from the bivariate analyses showed having more VROs in walkable areas or living closer to VROs had associated with decreases depressive symptoms among Veterans. This finding indicates other neighborhood resources were not significantly related to either mental health outcome. These findings suggest that having Veteran-specific resources located closer, within their communities, may be advantageous for influencing better mental health outcomes for Veterans.

4.3. Neighborhood-related characteristics and mental health

Unexpected results showed that living in a deprived neighborhood at 60–80th percentile was associated with lower psychological distress and depressive symptoms in Veterans compared to those Veterans living in the least deprived neighborhood. This finding was not consistent with

Table 6

Unadjusted GEE analysis of associations between the closest distances to neighborhood resources and mental health outcomes (n = 1,528).

	K6		PHQ-8	
	β (SE)	95% CI	β (SE)	95% CI
Alcohol outlet (km)	-0.11 (0.10)	(-0.30, 0.08)	-0.18 (0.10)	(-0.38, 0.01)
Tobacco outlet (km)	-0.39 (0.15)	(-0.69, -0.09)*	-0.33 (0.18)	(-0.66, 0.05)
Community-based center (km)	0.01 (0.01)	(-0.01, 0.03)	0.01 (0.01)	(-0.01, 0.03)
Public library (km)	0.00 (0.02)	(-0.04, 0.05)	-0.01 (0.02)	(-0.05, 0.03)
Religious places (km)	0.00 (0.04)	(-0.08, 0.07)	-0.03 (0.04)	(-0.10, 0.05)
VRO (km)	0.12 (0.06)	(0.01, 0.23)*	0.18 (0.07)	(0.05, 0.31)**
Park (km)	0.05 (0.07)	(-0.09, 0.20)	0.03 (0.08)	(-0.13, 0.19)

Note. GEE, Generalized Estimating Equations; K6, Kessler Psychological Distress Scale-6; PHQ-8, Patient Health Questionnaire-8; CI, Confidence interval; SE, Standard error; Significance codes; VRO, Veteran-related organization, *** <0.001, ** <0.01, * <0.05. Bolded numbers indicate statistically significant at the p < .05 level.

previous studies that reported significant relationships of living in deprived areas with negative mental health outcomes (Bond et al., 2012; Kelley-Moore et al., 2016). Those deprived areas may have mental health supportive characteristics for Veterans that were not measured in this study. For example, community-based social support may mitigate psychological distress or depressive symptoms for Veterans living in relatively deprived areas compared to Veterans living in less deprived areas with reduced social support or social cohesion.

Mental health outcomes of Veterans did not differ whether they lived in urban or rural areas. Results are aligned with research on the effects of urban–rural differences on mental health which varied on individual and/or community-based conditions (Verheij, 1996). This suggests that having more Veterans-friendly resources close to Veterans’ neighborhoods might be more important in explaining their mental health than living in urban or rural areas.

In contrast to prior research related to primary care clinics (Tomita et al., 2017), the distance to the closest VAHCS was not related to mental health outcomes. This finding contrasts with a qualitative study targeting a Veteran population that found the distance to VA facilities was one of the barriers to accessing proper mental health care (Cheney et al., 2018). Even though the distance to VAHCS can be a potential barrier in receiving proper mental health care, other barriers such as the stigma of being labeled with a mental health disorder (Vogt, 2011) are strongly related to use of VA mental health care services that influence mental health outcomes.

4.4. Future practice and research implications

Many Veterans returning from military service do not pursue needed

Table 7
Adjusted GEE analysis of associations between neighborhood and mental health outcomes.

	K6		PHQ-8	
	β (SE)	95% CI	β (SE)	95% CI
Neighborhood Group 2 vs. 1	0.18 (0.42)	(-0.64, 1.00)	-0.18 (0.45)	(-1.06, 0.70)
3 vs. 1	0.96 (0.45)	(0.08, 1.84)	0.90 (0.49)	(-0.06, 1.86)
4 vs. 1	0.29 (0.38)	(-0.45, 1.03)	-0.09 (0.42)	(-0.91, 0.73)
Neighborhood Predisposing Characteristics				
ADI 2 vs.1	-0.59 (0.46)	(-1.49, 0.31)	-0.08 (0.54)	(-1.24, 0.88)
3 vs. 1	-0.58 (0.46)	(-1.48, 0.32)	-0.86 (0.54)	(-1.92, 0.20)
4 vs. 1	-2.04 (0.52)	(-3.06, -1.02)***	-1.78 (0.55)	(-2.86, -0.70)**
5 vs. 1	-0.88 (0.46)	(-1.78, 0.02)	-0.73 (0.47)	(-1.63, 0.17)
Urban vs. Rural	0.06 (0.52)	(-0.96, 1.08)	0.39 (0.56)	(-0.71, 1.49)
Neighborhood Enabling Characteristic				
Drive time to the closest VA (min)	0.01 (0.01)	(-0.01, 0.03)	0.00 (0.01)	(-0.02, 0.02)
Individual Predisposing Characteristics				
Age	-0.06 (0.02)	(-0.10, -0.03)***	-0.06 (0.02)	(-0.09, -0.03)***
Male vs. Female	-0.79 (0.41)	(-1.59, 0.02)	-0.57 (0.45)	(-1.46, 0.32)
Race				
Black vs. White	0.02 (0.35)	(-0.68, 0.71)	0.55 (0.41)	(-0.24, 1.35)
Others vs. White	1.08 (0.68)	(-0.25, 2.42)	0.33 (0.70)	(-1.04, 1.71)
Hispanic vs. Non-Hispanic	0.30 (0.49)	(-0.66, 1.27)	0.93 (0.59)	(-0.23, 2.10)
Education				
Associates degree vs. ≤ High school	-0.77 (0.42)	(-1.60, 0.06)	-0.75 (0.49)	(-1.70, 0.20)
College graduate vs. ≤ High school	-0.66 (0.33)	(-1.30, -0.01)*	-0.34 (0.36)	(-1.05, 0.36)
Graduate + vs. ≤ High school	-0.94 (0.48)	(-1.88, 0.01)	-0.63 (0.52)	(-1.65, 0.40)
Other vs. ≤ High school	-0.81 (0.74)	(-2.26, 0.64)	0.28 (0.79)	(-1.27, 1.82)
Marital Status				
Separated vs. Coupled	0.09 (0.64)	(-1.16, 1.35)	0.54 (0.66)	(-0.75, 1.83)
Divorced vs. Coupled	-0.20 (0.34)	(-0.86, 0.47)	0.07 (0.37)	(-0.65, 0.79)
Widowed vs. Coupled	1.63 (0.56)	(0.54, 2.72)**	1.18 (0.59)	(0.03, 2.34)*
Single, never married vs. Coupled	0.14 (0.43)	(-0.71, 0.99)	0.06 (0.48)	(-0.87, 0.99)
Frequency of alcohol use				
Monthly or less vs. Never	-0.54 (0.37)	(-1.26, 0.18)	-0.33 (0.40)	(-1.12, 0.47)
2-4 times a month vs. Never	-0.49 (0.40)	(-1.28, 0.30)	-0.42 (0.43)	(-1.26, 0.42)
2-3 times a week vs. Never	-0.86 (0.43)	(-1.71, -0.02)*	-1.06 (0.47)	(-1.97, -0.14)*
4 + a week vs. Never	0.25 (0.46)	(-0.65, 1.15)	0.63 (0.51)	(-0.36, 1.63)
Cigarettes per day	0.00 (0.01)	(-0.02, 0.03)	0.02 (0.02)	(-0.01, 0.06)
Individual Enabling Characteristics				
Annual income				
\$10,000-\$20,000 vs. <\$10,000	0.24 (0.41)	(-0.57, 1.05)	0.84 (0.44)	(-0.03, 1.70)
\$20,001-\$40,000 vs. <\$10,000	0.55 (0.46)	(-0.35, 1.44)	1.08 (0.47)	(0.15, 2.01)*
\$40,001-\$60,000 vs. <\$10,000	1.74 (0.58)	(0.59, 2.88)**	2.41 (0.60)	(1.24, 3.58)***
>\$60,001 vs. <\$10,000	0.43 (0.66)	(-0.85, 1.72)	1.08 (0.66)	(-0.21, 2.36)

Table 7 (continued)

	K6		PHQ-8	
	β (SE)	95% CI	β (SE)	95% CI
Employment				
Out of work vs. Employed	1.20 (0.52)	(0.18, 2.23)*	0.70 (0.57)	(-0.41, 1.82)
Retired vs. Employed	1.08 (0.43)	(0.24, 1.91)*	0.87 (0.45)	(-0.01, 1.74)
Unable to work/ disabled vs. Employed	1.56 (0.43)	(0.72, 2.40)***	1.23 (0.46)	(0.33, 2.13)**
Financial stress	0.87 (0.07)	(0.74, 0.99)***	0.89 (0.07)	(0.76, 1.03)***
Individual Need Characteristics				
Charlson comorbidity index	-0.03 (0.03)	(-0.09, 0.03)	-0.02 (0.04)	(-0.09, 0.05)
PEG	0.52 (0.06)	(0.40, 0.64)***	0.80 (0.07)	(0.66, 0.93)***
General health status ¹	0.54 (0.17)	(0.20, 0.87)**	1.14 (0.18)	(0.78, 1.50)***

Note. CI, Confidence interval; GEE, Generalized Estimating Equations; K6, Kessler Psychological Distress Scale-6; PHQ-8, Patient Health Questionnaire-8; SE, Standard error; Significance codes, *** <0.001, ** <0.01, * <0.05. VA, Veteran Affairs Healthcare System; Bolded numbers indicate statistically significant at the P < .05 level.

1. General health status ranged 1 to 5 indicating higher score meaning worse health status.

mental health and behavioral care services because of their personal beliefs or the stigma of being labeled as a mental health patient (Vogt, 2011). Available and accessible primary care or informal neighborhood resources supportive for mental health can play an important role (World Health Organization, 2001). An important practice implication from this study is that we need to think about providing specialized services for Veterans' mental health care within non-VA community-based resources closer to their neighborhood locations. This will require increased partnerships between non-VA community-based resources and the VA. Risk factors in the neighborhood are important to consider when designing future mental health interventions as well as in developing zoning and enforcement policies. Results from this study indicated that living in a neighborhood with a higher density of alcohol outlets was associated with an increased level of psychological distress in Veterans. Previous research has also indicated that alcohol outlet oversaturation can have negative public health consequences (Campbell et al., 2009), and reducing and regulating alcohol outlet density may decrease these consequences (Hippensteel et al., 2019).

Future research should use informatics and GIS methods to identify neighborhood groups in different populations and examine how they relate to mental health outcomes. Mobile devices using real-time geocoded data can be used to define the neighborhood or identify frequently used neighborhood resources related to mental health outcomes. Future studies are needed to further examine factors in the causal pathway between neighborhood resources and mental health using longitudinal study designs.

4.5. Strengths and limitations

A strength of this study was the use of clustering analysis to identify neighborhood groups by neighborhood resources calculating the proportion of each neighborhood resource to total number of neighborhood resources within 400 m distance areas. This method can be used to create neighborhood groups in other populations or regions. This study minimized the multicollinearity among multiple neighborhood variables as predictor variables by using social and physical environmental characteristics. The bias due to social neighborhood characteristics was minimized by using a composite variable, the ADI, which was a widely and consistently used index in more than 25 prior studies. This study adopted GEE models to adjust the county-level variance and included

residence of place as a covariate to explain complex relationships of neighborhood resources with mental health outcomes.

Study limitations included the fact that using 400 m circular neighborhood areas from a participant's residence to aggregate neighborhood attributes could introduce different results than using different size of circular neighborhood areas or census tracts. There may be up to 5 year-difference between collection of individual-level variables from Proactive Mental Health trial and neighborhood resources data, which could only be accessed in the most current version of neighborhood resources data from the initially created version. However, the neighborhood physical features may not change frequently and non-differential measurement error across neighborhood groups can be minimized. Our analysis was not able to account for residential self-selection bias resulting from unmeasured neighborhood selection factors such as preference for walkability to alcohol outlets or VA services. Although our model adjusts for broad numbers of covariates, this adjustment does not adequately control for neighborhood preferences or other residential selection factors. Future research will greatly benefit from longitudinal study designs that are better able to address self-selection bias through temporal ordering of exposure and outcome and controlling for unmeasured "within-Veteran" characteristics (Boone-Heinonen et al., 2011). By using secondary datasets, we were unable to control for physical or mental disabilities and participants in the original trial were all smokers and the results may not generalize for non-smokers population.

5. Conclusions

The availability and accessibility as well as the type of neighborhood resources in walkable neighborhoods have an important role in Veterans' mental health outcomes. Resources such as alcohol outlets are negatively related to mental health, while VROs in walkable areas can be positive resources for Veterans. The effect of living in deprived neighborhoods on mental health may be attenuated by having community-based resources specific to Veterans' unique needs. Results can be used in developing community-based interventions and public policies influencing mental health. Zoning policies regulating and enforcing the saturation of alcohol outlets in neighborhoods may improve mental health. Community-based healthcare and social services are encouraged to partner with the VA to offer Veteran-friendly neighborhood resources supportive of mental health.

CRedit authorship contribution statement

Young Shin Park: Conceptualization, Data curation, Methodology, Software, Investigation, Writing – original draft, Visualization. **Jean F. Wyman:** Conceptualization, Validation, Writing – review & editing, Project administration, Supervision. **Barbara J. McMorris:** Methodology, Formal analysis, Writing – review & editing. **Lisiane Pruinelli:** Methodology, Formal analysis, Writing – review & editing. **Ying Song:** Methodology, Writing – review & editing. **Merrie J. Kaas:** Writing – review & editing. **Scott E. Sherman:** Writing – review & editing. **Steven Fu:** Writing – review & editing, Supervision, Resources, Funding acquisition.

Declaration of Competing Interest

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

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.pmedr.2021.101546>.

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