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Spatial analysis of mental health and suicide clustering among older adults in North Carolina: An exploratory analysis

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ABSTRACT

Late-in-life suicide is a major public health issue, with adults over 65 comprising 18% of all suicide deaths. Yet, little research has identified geographic concentrations of older populations at-risk for the psychological conditions in the pathway of suicide. This research identified spatial clustering of suicide, anxiety, depression, and self-injury among older adults in North Carolina from 2009-18 and the individual and area-level factors influencing high-risk clusters. Kulldorff's spatial scan statistic identified significant spatial clusters of suicides, using data collected from the violent death reporting system, and anxiety, depression and self-injury, using emergency department admissions data for older adults aged 65 years and over. Logistic regression and generalized estimating equations were used to examine the influence of multiple contextual variables (e.g., rural-urban commuting area codes, racial segregation) and compositional variables (e.g., race, insurance) within high-risk cluster locations. High-risk suicide, anxiety, and depression clusters were identified in the western and northwestern regions of the state, whereas self-injury clusters were predominantly located in central and southeastern North Carolina. Low-income communities were associated with a higher risk of clustering for all mental health outcomes, and primarily Black communities were associated with an increased risk of self-injury clustering. Findings can be applied to public policy to focus suicide prevention efforts on older adults, particularly in low-income communities in rural Appalachia and the central, southeastern portion of North Carolina.

1. Introduction

Older adults (operationalized as persons aged 65 years or older) comprise 18% of all suicide deaths (NCOA, 2021) and are significantly more likely to complete suicide than younger adults and adolescents; 1 in 4 attempts by older adults are successful as compared to 1 in 200 among younger adults and adolescents (Rope, 2021). In addition, older adults tend to choose more lethal methods of suicide (e.g., firearms and hanging) (Bonnewyn et al., 2009). Despite these concerning trends, older adults are much less likely to seek or receive mental health care due in part to limited access and stigma (Bonnewyn et al., 2009; Conner et al., 2010; Conwell and Thompson, 2008). Stigmatization of seeking mental health care is especially pronounced among older adults, specifically older Black adults (Conner et al., 2010). As such, targeted mental health care interventions are needed for older adults, both among at-risk communities and vulnerable demographics.

In North Carolina (NC), older adult mental health is a pressing public health concern, and, as the older adult population is expected to increase in the next decade (NCDHHS, 2021), more research addressing older adult mental health in NC is needed. In NC, older adults admitted for depression and anxiety account for 5% and 6% of all emergency department visits in the state, respectively (NC DETECT, 2021). However, the number of older adults experiencing poor mental health outcomes is likely much higher, as only 48% of all adults in need of mental health care in NC received it in 2015 (SAMHSA, 2015). In general, men are more likely to die by suicide than women at any age (Koo et al., 2017; Law et al., 2016), a trend that remains in NC, with males over 75 having the highest suicide rate in the state (NCVDRS, 2021).

Suicide and mental health clusters are locations with higher-than-expected incidence, given a location's population (Gould and Lake, 2013). This type of clustering may exist from underlying contextual factors, where clustering is explained by exposure to community-level variables (Gould et al., 1994). Our research aligns with approaches

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using a spatial epidemiological framework (Gebreab et al., 2018) and theoretical foundations from *Neighborhoods and Health,* that an individual's social and physical neighborhood alters their health (Duncan and Kawachi, 2018). Many aspects of place, from environmental contamination (Hoisington et al., 2019) to rurality (Guo et al., 2019) and access to community resources (Wickrama and Bryant, 2003) can influence both mental and physical health.

Among the general population, suicide clusters are more prevalent in rural areas (Ngamini Ngui et al., 2014), with suicide rates almost double in rural areas as compared to urban areas (Fontanella et al., 2015). In addition, communities with increased rates of social and economic deprivation (Chaix et al., 2006), limited access to health care and community resources (Guo et al., 2019), and neighborhoods with a higher density of older adults (Johnson et al., 2017) are more likely to exhibit clustering of suicide and poor mental health. However, when investigating older adult mental health and suicide, the spatial patterns and contextual risk factors may differ from those of the general population.

To date, research has focused on identifying spatial suicide clusters for the general population, with US studies focused on Idaho (Kassem, 2019), Ohio (Fontanella et al., 2018), and the entire US (Sy et al., 2019). Recent research has also focused exclusively on understanding escalating suicide rates in youth, particularly in the backdrop of a global pandemic (Loades et al., 2020; Runkle et al., 2022; Sugg et al., 2021). Yet, little work has identified spatial concentrations of older adult mental health and suicide risks, an understudied population despite high suicide and mental health burdens.

To address this research gap, the objective of this exploratory analysis is to identify spatially explicit clusters of older adult suicide, anxiety, depression, and self-injury in North Carolina from 2009-18 and identify community (contextual) and individual (compositional) factors influencing these clusters. Results will inform the locations where targeted interventions among older adults are needed for mental health and suicide prevention.

2. Methods

2.1. Health outcome data

Data on suicide cases were obtained from the NC Violent Death Reporting System (NC VDRS) (CDC, 2021) (Table 1). NC VDRS provides comprehensive reporting of violent deaths and contains additional contextual factors (e.g., manner of death, history of mental health) (CDC, 2021). Manner of death is determined by abstractor review based on information from the death certificate and both law enforcement and medical examiner records (NCDHHS, 2022). Deaths are categorized as suicide, homicide, unintentional firearm, undetermined intent, and legal intervention (NCDHHS, 2022). For this analysis, NC VDRS data was restricted to suicides.

Emergency department (ED) data on mental health outcomes were obtained from the NC Disease Event Tracking and Epidemiologic Collection Tool (NC DETECT) (NC DETECT, 2021) (Table 2). NC DETECT is a syndromic surveillance dataset providing mental health diagnoses from emergency departments throughout NC (NC DETECT, 2021). Mental health outcomes were identified using ICD-9 (before October 2015) and ICD-10 codes (after October 2015). The three mental health outcomes were: anxiety (ICD-9: 300.00, ICD-10 CM: F41.9), depression (ICD-9: 296.2 and 296.3, ICD-10 CM: F32–F33), and self-injury (ICD-9: E950-959, ICD-10 CM: R45.841, T36-T65 + T7, T14.91, X60-X84).

All data were restricted to individuals aged 65+ from 2009-18. The unit of analysis was the ZIP code level, as this is the finest spatial scale at which data are available for both NC VDRS and NC DETECT.

Table 1
Summary of older adult (ages 65+) suicides in North Carolina from 2009-18. Suicide data is from NC-VDRS.

	Suicide (n(%)) $n = 2166$
Year	
2009	143 (6.6)
2010	146 (6.7)
2011	180 (8.3)
2012	209 (9.6)
2013	201 (9.3)
2014	226 (10.4)
2015	254 (11.7)
2016	248 (11.4)
2017	284 (13.1)
2018	275 (12.7)
Age (mean(SD))	74.85 (7.39)
Race	
American Indian	12 (0.6)
Asian/Pacific Islander	10 (0.5)
Black	86 (4.0)
White	2051 (94.7)
Other	7 (0.3)
Sex	
Male	1787 (82.5)
Female	379 (17.5)
Weapon	
Hanging/Strangulation	2484(21.3)
Fall	75(0.6)
Firearm	6807(58.5)
Poisoning	1900(16.3)
Sharp Instrument	159(1.4)
Other	214(1.8)
Prior Suicide Attempt	
No	9802(84.2)
Yes	1837(15.8)
Military Affiliation	
No	1262 (58.3)
Yes	873 (40.3)
Mental Health Condition	
No	1222 (56.4)
Yes	944 (43.6)
Recent Crisis	
No	1537 (71.0)
Yes	629 (29.0)
Poor Physical Health	
No	1016 (46.9)
Yes	1150 (53.1)
Alcohol	
Present	240 (11.1)
Not Present	1663 (76.8)
N/A	126 (5.8)
Unknown	137 (6.3)

2.1.1. Community and individual-level variables

As individuals in communities may have shared contextual or social exposures to community-level risks (Gould et al., 1994), identifying and monitoring suicide and mental health clustering is important. As such, consideration of community-level factors, both social and physical, in addition to individual-level factors, is important when investigating potential drivers of mental health clustering (Table 3). Known contextual, community-level risk factors for older adult mental health include both low population density (including rural areas), high population density (such as inner cities), access to community services, such as community centers (Guo et al., 2019), poor living conditions, residential instability (Cromley et al., 2012), and access to mental health care (Bonnewyn et al., 2009; Conwell and Thompson, 2008). For those seeking care, mental health care is typically through Primary Care Physicians rather than mental health care providers (Bonnewyn et al., 2009; Conner et al., 2010; Conwell and Thompson, 2008).

Previously identified individual-level factors increasing older adult

Table 2
Summary of Emergency Department visits for Anxiety, Depression and Self-Injury in North Carolina among older adults (ages 65+) from 2009-18. Data is from NC-DETECT.

	Anxiety (n(%)) *n:189,040*	Depression (n(%)) *n:141,204*	Self-Injury (n(%)) *n:13,032*
Year			
2009	11846 (6.3)	7625 (5.4)	199 (1.5)
2010	14171 (7.5)	8431 (6.0)	219 (1.7)
2011	14035 (7.4)	8650 (6.1)	223 (1.7)
2012	16142 (8.5)	11168 (7.9)	220 (1.7)
2013	18583 (9.8)	13376 (9.5)	251 (1.9)
2014	19696 (10.4)	14293 (10.1)	301 (2.3)
2015	18705 (9.9)	13816 (9.8)	2790 (21.4)
2016	22521 (11.9)	18072 (12.8)	2892 (22.2)
2017	26904 (14.2)	24225 (17.2)	2858 (21.9)
2018	26437 (14.0)	21548 (15.3)	3079 (23.6)
Age (mean(SD))	75.60 (7.92)	75.72 (8.12)	74.20 (7.70)
Race			
American Indian	945 (1.1)	815 (1.2)	96 (1.0)
Asian/Pacific Islander	285 (0.3)	210 (0.3)	58 (0.6)
Black	10602 (12.4)	8740 (12.5)	2463 (25.8)
White	72881 (85.0)	59463 (84.8)	6769 (70.8)
Other	1075 (1.3)	858 (1.2)	178 (1.9)
Sex			
Male	47203 (25.0)	40775 (28.9)	5024 (38.6)
Female	141692 (75.0)	100303 (71.0)	7984 (61.3)
Unidentified	145 (0.1)	126 (0.1)	24 (0.2)
Disposition Code			
Discharged Home	105756 (57.6)	71350 (52.1)	7947 (63.7)
Transferred	12302 (6.7)	50771 (37.1)	3430 (27.5)
Left before Discharged	2257 (1.2)	313 (0.2)	61 (0.5)
Admitted to Hospital	61855 (33.7)	12301 (9.0)	823 (6.6)
Died	324 (0.2)	1113 (0.8)	139 (1.1)
Other	1267 (0.7)	1094 (0.8)	75 (0.6)
Insurance			
Private	18516 (10.0)	13819 (10.0)	1328 (10.8)
Medicare	149129 (80.8)	111484 (80.7)	9615 (77.9)
Medicaid	2568 (1.4)	2122 (1.5)	146 (1.2)
Worker's Comp	608 (0.3)	477 (0.3)	36 (0.3)
Other Government	725 (0.4)	653 (0.5)	94 (0.8)
Self-pay	1527 (0.8)	1005 (0.7)	150 (1.2)
No Charge	7 (0.0)	3 (0.0)	1(0.0)
Other	11577 (6.3)	8559 (6.2)	965 (7.8)

Table 3
Variables considered as predictors of older adult suicide and mental health clustering in North Carolina, 2009-18.

Variable	Relationship	Citations
Rural Designation	Rural-urban commuting area codes (RUCA) were included to investigate if rurality is a contributing factor, which has a long history of influencing suicide rates was considered for all four mental health outcomes	(Guo et al., 2019; Yoshioka et al., 2021)
Environmental Justice	Toxic Release Inventory (TRI) sites, which represents potential exposure to toxic chemicals was considered for all four mental health outcomes	(Downey and van Willigen, 2005; US EPA, 2013)
Sex	Sex was included because men are more likely to die by suicide than women. Sex was considered for all four mental health outcomes.	(Law et al., 2016; Koo et al., 2017)
Race	Race was considered both individually, and at the community-level with the ICE Race metric for all four mental health outcomes	(Conner et al. 2010; Krieger et al., 2016)
Socioeconomic Status	Socioeconomic status was considered by using the ICE income metric for all four mental health outcomes, and using insurance for anxiety, depression, and self-injury	(Cheung and Chou, 2019; Choi et al., 2019; Cromley et al., 2012; Krieger et al., 2016)
Military Affiliation	Military affiliation was considered for suicide	Pruitt et al. (2019)
Alcohol	Presence of alcohol was considered for suicide regression	(Kaplan et al., 2014; Yuodelis-Flores and Ries, 2015)
Mental Health History	Mental health history, prior suicide attempts, and recent crises were considered for suicide	(Conejero et al., 2018; Sinyor et al., 2016)
Poor Physical Health	Poor physical health was considered for suicide, as poor physical health can increase suicide risk in older adults	(Johnson et al., 2017; Sinyor et al., 2016)

mental health and suicide risk include a history of poor mental health, prior suicide attempts, poor physical health and chronic illness (Sinyor et al., 2016), social isolation, and loss of a spouse (Conejero et al., 2018), lower levels of education and diminished social networks (Marco et al., 2018), substance use (Cromley et al., 2012), a high proportion of male residents (Law et al., 2016), military affiliation (Pruitt et al., 2019) and stigma (Conner et al., 2010). Stigmatization of seeking mental health care is especially pronounced among Black Americans, specifically older Black adults (Conner et al., 2010). As such, targeted mental health care interventions are needed for older adults, both among at-risk communities and vulnerable demographics.

Individual variables derived from NC-VDRS data included sex (male, female), race (Black, White, Indigenous American, Asian, Other/unidentified), prior suicide attempt (yes/no), military affiliation (yes/no), history of mental health conditions (yes/no), recent crisis (yes/no), poor physical health (yes/no), and presence of alcohol (present, not present, N/A, Unknown) (Table 3) (Table 1). History of past mental health conditions, military affiliation, recent crisis, poor physical health, and presence of alcohol were insignificant and removed for lower AIC models.

Individual variables derived from NC DETECT ED data included sex (male, female, unidentified), race (Black, White, Indigenous American, Asian, Other/unidentified), and insurance (private, Medicare, Medicaid, other), (Table 3) (Table 2). Insurance was used as a proxy for socioeconomic status (Marcin et al., 2003), which is associated with poor mental health among older adults (Cheung and Chou, 2019; Choi et al., 2019; Menec et al., 2010).

Community-level variables included rurality, nearby toxic release sites, and the Index of the Concentration of Extremes (ICE) (Krieger et al., 2016) (Table 3). Rurality was considered as it may influence mental health rates, with older adult mental health potentially worse in both low population density (including rural areas), as rural communities are typically mental health professional shortage areas (Morales et al., 2020), and high population density (such as inner cities) areas, which may be attributed to localized deprivation (Guo et al., 2019). Toxic release sites were considered as they have been linked to poor mental health (Downey and van Willigen, 2005). Race and socio-economic status were considered at the community level using the Index of the Concentration of Extremes (Cheung and Chou, 2019; Choi et al., 2019; Cromley et al., 2012; Krieger et al., 2016).

Rurality was measured using Rural-Urban Community Area (RUCA) Codes. RUCA codes consider the distance and direction of the primary commutes from each ZIP Code (USDA, 2020). RUCA codes range from 1, most urban, to 10, most rural (USDA, 2020). RUCA codes were aggregated to depict urban (codes 1–3), suburban (codes 4–6), and rural (codes

7–10) locations (USDA, 2020). Toxic release sites were measured using Toxic Release Inventory data (US EPA, 2013), which indicates if a toxic release site is nearby. The toxic release site was insignificant for all models and removed for lower AIC models.

The Index of the Concentration of Extremes (ICE) is an index that considers extreme concentrations of privilege and deprivation by analyzing the spatial distribution of income and race, using US Census Data to produce three metrics (Krieger et al., 2016). The first metric, ICE: income segregation, measures community income extremes by comparing how many people make over $100,000 per year and under $25,000 per year. ICE: racial segregation compares majority Black versus majority White communities. ICE: racialized economic segregation examines how the distribution of wealth varies depending on race in a community, specifically comparing how many White people make more than $100,000 per year and how many Black people make less than $25,000 per year (Krieger et al., 2016). The ICE metrics range from −1 (least privilege) to +1 (most privileged) (Krieger et al., 2016). For this analysis, ICE metrics were computed as tertiles. The use of tertiles was adapted to improve the interpretability of the regression results.

2.2. Cluster analysis

Kulldorff's spatial scan statistic in SaTScan was used to identify spatial clusters of suicide, anxiety, depression, and self-injury for older adults. The spatial scan statistic is regularly used in epidemiological studies to identify if cases are randomly distributed or clustered (Johnson et al., 2017; Kulldorff, 1997; Perez et al., 2016). In SaTScan, parameters can be modified, including the percent of the population assumed to be at risk, the type of analysis (Bernoulli vs. Poisson distribution), and the number of repetitions (Kulldorff, 1997). We used a spatial discrete Poisson model with a 30% at-risk window to search for high-risk clusters, a window size commonly used in other suicide clustering studies (Fontanella et al., 2018). Sensitivity analyses were also conducted for depression and anxiety, with both 10% and 50% at-risk windows, as these conditions may have a higher number of at-risk populations compared to suicide and self-injury. Cluster locations remained robust using the at-risk window of 30%, which was used for all four health outcomes. For all outcomes, we evaluated clusters with 99999 Monte Carlo replications, as it increases statistical power (Kulldorff, 2022), and rejected the null hypothesis (no clusters) at $p < 0.05$. Clusters were restricted to a minimum of 100 cases over the 10-year study period to limit the detection of exceedingly small clusters. Both hierarchical primary and secondary clusters are reported, which is the SaTScan default. Primary clusters are the most likely clusters, followed by secondary clusters, which are other high-risk cluster locations. In SaTScan, two Relative Risk (RR) values are calculated, one is for the cluster itself, the 'Cluster RR' (Table 4), and the other is a 'Local RR,' which quantifies the RR for each ZIP code in NC (Fig. 1). An RR below one is considered lower risk, and an RR above one is considered higher risk. All SaTScan analyses were adjusted by age (Shah et al., 2016).

2.3. Statistical analysis

Logistic regression (Fontanella et al., 2018; Kassem, 2019) was used for suicide data and generalized estimating equations (GEE) with a binomial distribution (Chong et al., 2013; Harden et al., 2022) and an exchangeable matrix were used to analyze the relative risk of living in anxiety, depression or self-injury cluster separately. The NC-DETECT

Table 4
Spatial cluster analysis results for older adult Suicide, Anxiety, Depression, and Self-Injury in North Carolina from 2009-18. Primary clusters (Cluster 1) are the most likely high-risk cluster locations, followed by secondary clusters, which are other high-risk cluster locations.

Cluster	Location	Observed	Expected	Relative Risk	Standard Error	p-value
Suicide						
1	36.050043, −82.284210	662	572.90	1.22	0.045	0.046
Anxiety						
1	36.23802, −81.7582	50270	34825.43	1.6	0.006	<0.001
2	36.4991, −79.7466	3650	1799.89	2.05	0.034	<0.001
3	35.38042, −80.5279	5574	3678.4	1.53	0.02	<0.001
4	36.29549, −76.2839	1762	894.45	1.98	0.047	<0.001
5	34.73799, −78.8015	7034	5360.4	1.32	0.016	<0.001
6	36.3968, −78.976	644	243.05	2.66	0.104	<0.001
7	34.81261, −79.9808	1820	1204.62	1.52	0.035	<0.001
8	35.81744, −77.0645	655	356.12	1.84	0.072	<0.001
9	36.00981, −79.8765	11664	10249.09	1.15	0.011	<0.001
10	35.13427, −76.9857	1005	746.68	1.35	0.042	<0.001
11	35.4291, −78.1761	3702	3225.1	1.15	0.019	<0.001
12	36.43001, −77.721	768	565.46	1.36	0.049	<0.001
13	35.69-21, −77.6208	3171	2768.85	1.15	0.02	<0.001
14	34.2755, −77.9633	614	457.54	1.34	0.054	<0.001
15	35.34315, −79.7508	314	231.59	1.36	0.077	0.001
Depression						
1	36.503485, −81.135280	52427	42047.01	1.39	0.005	<0.001
2	36.295490, −76.283939	1556	667.63	2.35	0.059	<0.001
3	34.798383, −78.957356	4064	2910.58	1.41	0.021	<0.001
4	35.8111116, −77.262133	1603	1060.13	1.52	0.038	<0.001
5	36.396804, −78.976025	411	181.66	2.27	0.112	<0.001
6	34.931035, −79.780081	969	588.36	1.65	0.053	<0.001
7	35.134273, −76.985669	798	558.36	1.43	0.051	<0.001
8	35.898433, −79.416299	1918	1542.70	1.25	0.028	<0.001
9	34.878597, −77.594930	2168	1769.35	1.23	0.026	<0.001
10	35.491883, −78.343860	695	534.22	1.30	0.049	<0.001
11	35.463219, −79.574769	774	614.07	1.26	0.045	<0.001
12	34.447602, −77.889075	534	409.84	1.30	0.056	<0.001
Self-Injury						
1	35.177013, −78.056594	2251	1630.07	1.46	0.029	<0.001
2	35.868386, −80.315100	1531	1096.42	1.45	0.036	<0.001
3	35.353261, −81.180866	357	200.73	1.80	0.094	<0.001
4	36.445093, −78.874700	186	107.69	1.74	0.127	<0.001
5	34.931035, −79.780081	130	67.03	1.95	0.170	<0.001

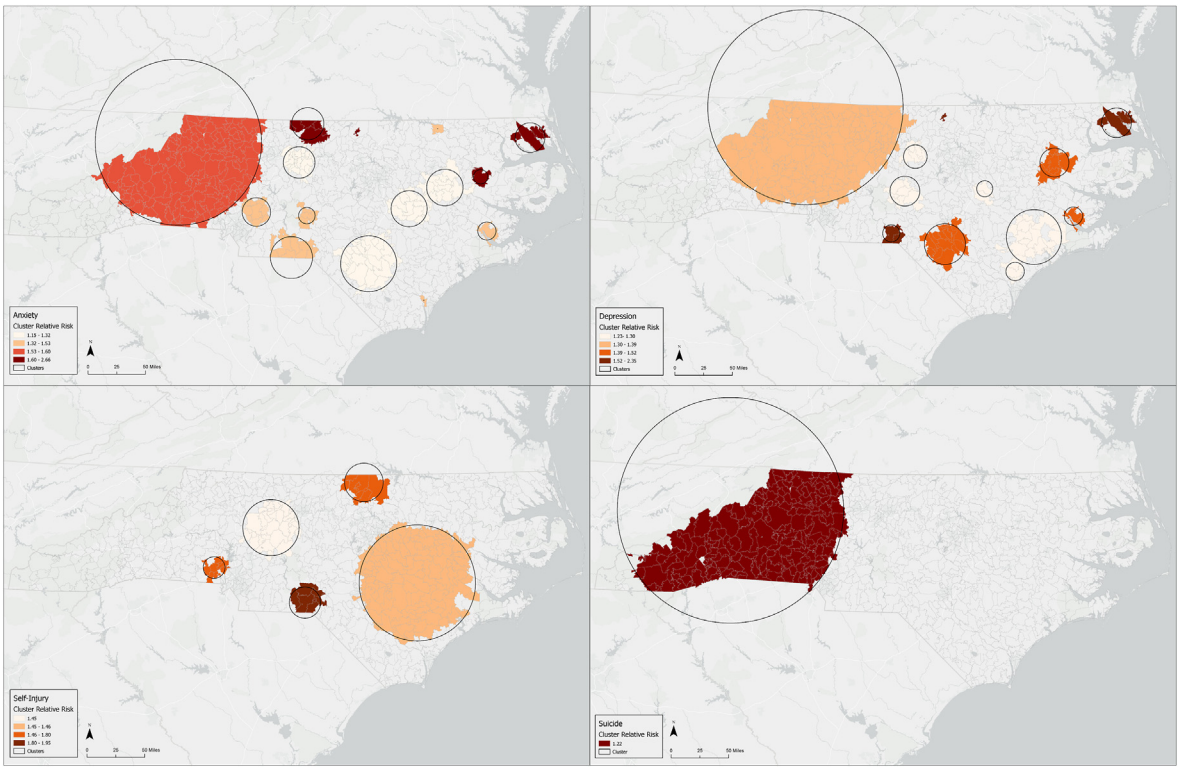

Fig. 1. Cluster Relative Risk (RR) values for Anxiety, Depression, Self-Injury, and Suicide clusters at the ZIP Code level in North Carolina from 2009-18.

data contains repeat ED admission for individual patients (n = 3,975, 241). GEE models are well-equipped to handle missing data and are readily applied when datasets include large numbers of missing values and repeated measures (Twisk and de Vente, 2002). ED data includes missing data for specific variables (e.g., race). Potential covariates were selected based on prior research (Table 3), and final models were selected by comparing models and selecting the one with the lowest AIC (logistic regression) or QIC (GEE).

Multicollinearity was assessed for all variables by calculating the variance inflation factor (VIF). No variables exceeded the VIF threshold of 5; none were removed for violating the assumption of independence (Gareth et al., 2013). All statistical analyses were performed in RStudio 2022.07.1 (RStudio Team, 2022) using 'geepack' (Højsgaard et al., 2022) and 'car' packages (Fox et al., 2022).

3. Results

3.1. Descriptive statistics

Descriptive statistics illustrate that suicides were highest among older male adults (82.5%) and older White adults (94.7%) (Table 1). The number of suicides increased throughout the study period. Firearms were the most common method of suicide (58.5%), and the majority of patients had no prior history of poor mental health (56.4%), a recent crisis (71.0%), or suicide attempts (84.2%).

The majority of ED visits related to mental health outcomes were among White older adults (70.8–85.0%) and female older adults (61.3–75.0%) across all three ED mental health outcomes (Table 2). The majority (77.9–80.8%) of patients have Medicare insurance, and most patients (52.1–63.7%) were discharged home. For all health outcomes, cases have increased in recent years.

3.2. Cluster analysis

Primary suicide, anxiety, and depression clusters were located in western and northwestern NC, and the primary self-injury cluster was located in southeastern NC (Fig. 1). Secondary clustering occurred throughout the state for depression and anxiety, with 12 total clusters identified for depression and 15 identified for anxiety. Self-injury secondary clusters were found in central and southeastern NC, with five total clusters identified. The RR for the suicide cluster was 1.22 and ranged from 1.15 to 2.66 for the mental health outcomes (Table 4). Statewide RRs varied spatially (Fig. 2). To confirm cluster locations, a separate analysis was performed at the county-level for suicide using a 30% at-risk window, which also confirmed a significant cluster in western NC (RR: 1.24, p-value: 0.002) (Supplemental Fig. 1)..

3.3. Regression

Table 5 illustrates community and individual-level results associated with high-risk clusters of suicide (Model 1), self-injury (Model 2), anxiety (Model 3), and depression (Model 4) in older adults. The presence of a toxic release site, an indicator for environmental justice (Table 3), was not found to have a statistically significant effect across all mental health outcomes and was excluded. Recent crisis, history of poor mental health, presence of anti-depressants, poor physical health, and presence of alcohol were not found to have a statistically significant effect and were removed from the suicide model.

3.3.1. Suicide

Older adults in a majority low-income compared to a majority high-income community were 5.5 times more likely to reside in a high-risk suicide cluster (CI:3.88–7.71). Majority Black communities were associated with a lower risk of residence in an older adult suicide cluster (RR:0.03, CI:0.02–0.04). Compared to urban locations, both rural (RR:0.52, CI:0.35–0.77) and suburban (RR:0.34, CI: 0.25–0.46) neighborhoods were associated with a lower risk of being in an older adult suicide cluster. Individual-level results (sex, race) were not significantly associated with the risk of living in a suicide cluster. Though insignificant, older adults with a history of prior suicide attempts were associated

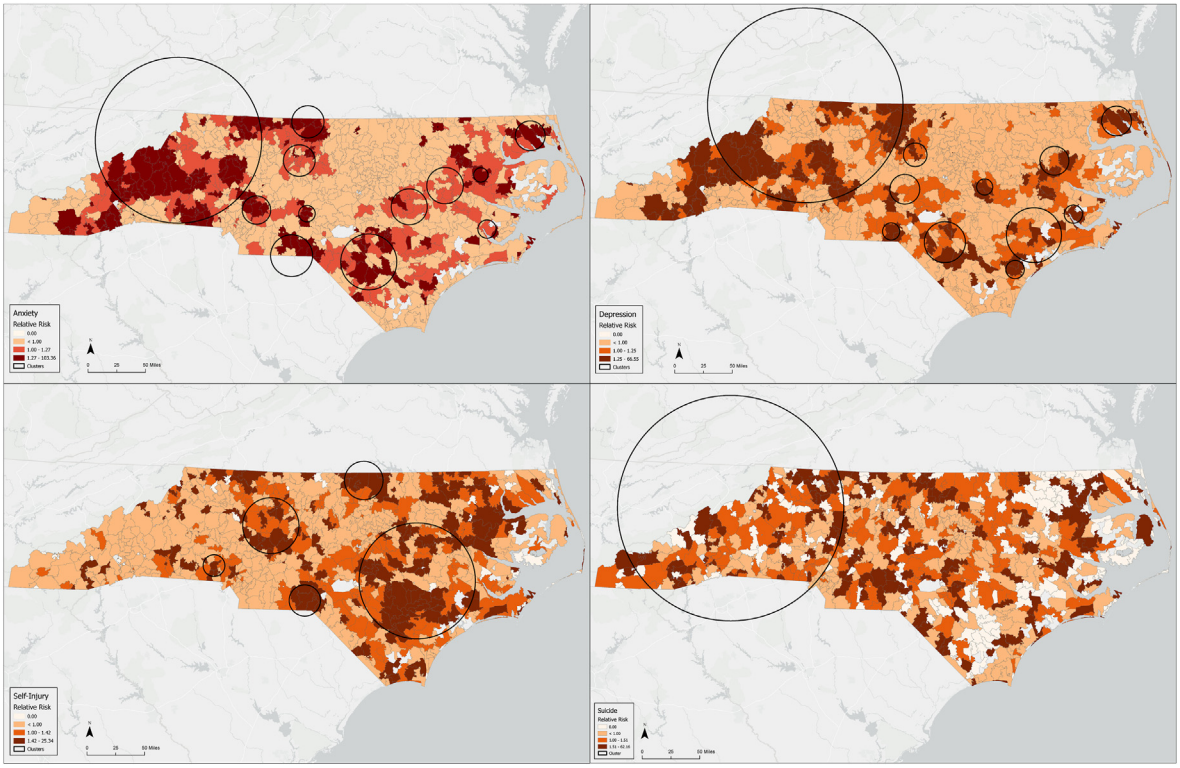

Fig. 2. State-wide Local Relative Risk (RR) values for Anxiety, Depression, Self-Injury, and Suicide clusters at the ZIP Code level in North Carolina from 2009-18.

with a lower risk (OR:0.80, CI:0.52–1.21) of living in a suicide cluster as compared to those with no prior history of suicide attempts.

3.3.2. *Self-injury*

Both ICE racial and economic segregation are significant predictors of an older adult residing in a high-risk self-injury cluster. Residents in majority Black communities were 7.02 times more likely to live in a self-injury cluster as compared to residents in majority White communities (CI:5.90–8.36). As with suicide clustering, both rural (RR:0.66, CI:0.56–0.77) and suburban (RR:0.39, CI:0.34–0.44) locations were associated with a lower risk of being included in a self-injury cluster. At an individual level, Indigenous American (RR:0.49, CI:0.29–0.81), Asian (RR:0.54, CI: 0.29–1.01), and Black older adults (RR:0.88, CI: 0.78–0.98) were associated with a lower risk of living in a self-injury cluster as compared to White older adults. Older adults with Medicare (RR:1.35, CI:1.16–1.58) and 'other' insurance (RR:2.76, CI:2.25–3.38) were associated with a greater risk of living in a self-injury cluster as compared to older adults with private insurance. Though not significant, female older adults (RR:1.02, CI:1.02–1.03) were also associated with a higher risk of living in a self-injury cluster as compared to male older adults.

3.3.3. *Anxiety*

Majority Black (RR:0.46, CI:0.44–0.48) and more racially mixed (RR:0.70, CI:0.67–0.72) communities (i.e., ICE Race) were associated with a lower risk of being in an anxiety cluster as compared to majority White locations. Low-income (RR:5.08, CI:4.86–5.32) and mixed income (RR:2.41, CI:2.33–2.50) communities (i.e., ICE Income) were associated with a higher risk of being identified in an anxiety cluster as compared to high-income locations. Rural locations (RR:0.31, CI:0.30–0.33) were associated with a lower risk of being in an anxiety cluster compared to urban areas. At an individual-level, Black older adults (RR:0.95, CI:0.91–0.99) and other race older adults (RR:0.50, CI:0.44–0.58) were associated with a lower risk of living in an anxiety cluster as compared to White older adults. Older adults with Medicaid (RR:1.26, CI:1.04–1.53) were associated with a greater risk of living in an anxiety cluster as compared to older adults with private insurance. Female older adults (RR:1.03, CI:1.00–1.06) were also associated with a marginally higher risk of living in an anxiety cluster than older adult males.

3.3.4. *Depression*

Racially mixed communities were associated with a higher risk of being identified in a depression cluster (RR:1.19, CI; 1.14–1.24), and the majority of Black communities were associated with a lower risk of being identified in a depression cluster (RR:0.81, CI:0.77–0.85). Low-income (RR:4.08, CI:3.88–4.30) and medium-income (RR:2.53, CI:2.43–2.63) locations were associated with a higher risk of being in a depression cluster as compared to high-income locations. Both rural (RR:0.41, CI:0.39–0.44) and suburban (RR:0.72, CI:0.69–0.75) locations were associated with a lower risk of being found in depression clusters as compared to urban ZIP Codes. At an individual level, Black (RR:0.85, CI:0.80–0.89) and Asian older adults (RR:0.70, CI:0.53–0.93) were associated with a lower risk of living in a depression cluster as compared to older White adults. Older adults with Medicare (RR:0.58, CI:0.55–0.61) were associated with a lower risk of living in a depression cluster as compared to older adults with private insurance. Older female adults (RR:1.07, CI:1.04–1.11) were associated with a higher risk of living in a depression cluster as compared to older male adults.

4. Discussion

This exploratory study aimed to identify spatially explicit clustering of suicides and self-injury, depressive, and anxiety-related emergency department admissions in older adults throughout the state of North Carolina. A secondary aim was to identify community and individual-level factors associated with residence in a high-risk cluster. Unlike previous work, this study considers suicide, in addition to emergency department visits for anxiety, depression, and self-injury, providing additional information on locations at elevated risk for adverse mental health events in older adults. Our study found homogeneity in the most likely high-risk suicide, anxiety, and depression cluster locations, all

Table 5
Community and individual-level predictors of older adult Suicide (Model 1), Self-Injury (Model 2), Anxiety (Model 3) and Depression (Model 4) in North Carolina from 2009-18. Results illustrate relative risk of living in a mental health high-risk cluster as compared to the referent population of White, Male, Urban, Private Insurance, High ICE Income, High ICE Race and no prior mental health history. Models were selected based on the lowest QIC and AIC values.

Model 1 Suicide			Model 2 Self-Injury			Model 3 Anxiety		Model 4 Depression	
Predictor	RR	CI	Predictor	RR	CI	RR	CI	RR	CI
Community Predictors									
ICE Race [Q1: Majority Black]	0.03***	0.02-0.04	ICE Race [Q1: Majority Black]	7.02***	5.90-8.36	0.46***	0.44-0.48	0.81***	0.77-0.85
ICE Race [Q2: Mixed Race]	0.14***	0.11-0.17	ICE Race [Q2: Mixed Race]	4.16***	3.49-4.94	0.70***	0.67-0.72	1.19***	1.14-1.24
ICE Race [Q3: Majority white]	Reference								
ICE Income [Q1: Primarily Low Income]	5.46***	3.88-7.71	ICE Income [Q1: Primarily Low Income]	1.67***	1.44-1.95	5.08***	4.86-5.32	4.08***	3.88-4.30
ICE Income [Q2: Mixed Income]	2.84***	2.20-3.67	ICE Income [Q2: Mixed Income]	2.63***	2.33-2.97	2.41***	2.33-2.50	2.53***	2.43-2.63
ICE Income [Q3: Primarily High-Income]	Reference								
RUCA [Rural]	0.52***	0.35-0.77	RUCA [Rural]	0.66***	0.56-0.77	0.31***	0.30-0.33	0.41***	0.39-0.44
RUCA [Suburban]	0.34***	0.25-0.46	RUCA [Suburban]	0.39***	0.34-0.44	1.02	0.98-1.06	0.72***	0.69-0.75
RUCA [Urban]	Reference								
Individual Predictors									
Race [Indigenous American]	0.31	0.04-1.73	Race [Indigenous American]	0.49**	0.29-0.81	1.12	0.96-1.30	1.05	0.89-1.22
Race [Asian]	0.25	0.01–1.78	Race [Asian]	0.54*	0.29-1.01	0.91	0.72-1.16	0.70**	0.53-0.93
Race [Black]	1.04	0.53-1.91	Race [Black]	0.88**	0.78-0.98	0.95**	0.91-0.99	0.85***	0.80-0.89
Race [Other]	0.00	NA	Race [Other]	1.18	0.81-1.70	0.50***	0.44-0.58	0.64***	0.55-0.74
Race [White]	Reference								
Prior Suicide Attempt [True]	0.80	0.52-1.21	Insurance [Medicare]	1.35***	1.16-1.58	0.75***	0.71-0.79	0.58***	0.55-0.61
Prior Suicide Attempt [False]	Reference		Insurance [Medicaid]	0.68	0.35-1.29	1.26**	1.04-1.53	0.85	0.69-1.05
Sex [Female]	1.27	0.97-1.70	Insurance [Other]	2.76***	2.25-3.38	0.91**	0.84-0.98	1.83***	1.65-2.03
Observations	2153		Insurance [Private]	Reference					
AIC	2019.8		Sex [Female]	1.02	0.93-1.13	1.03*	1.00–1.06	1.07***	1.04-1.11
			Sex [Male]	Reference					
			N	8457		59086		50212	
			Observations	8998		82595		67523	
			QIC	10304.23		105959.43		88313.21	

RR = Relative Risk, CI = Confidence Interval. Significance is determined using multiple logistic regression for suicide, and GEEs for anxiety, depression and self-injury. * <0.10, ** <0.05, *** <0.001.

located in the western part of the state. The primary self-injury cluster, however, is located in the central, southeastern part of the state, suggesting a different vulnerable sub-population of older adults in this location. Both of these locations are relatively impoverished, rural regions in NC. For each mental health outcome, there are a few locations with high local RR values located outside of the identified cluster, suggesting that a high prevalence of older adult suicide, anxiety, depression, or self-injury may be present in these locations, but not enough to elicit significant clustering. These worrying trends may indicate that these areas should be identified as mental health intervention priority areas for the local public health community.

Results revealed that the ICE metric indicating economic segregation was significantly associated with clustering for each of the four health outcomes. This analysis found that primarily low-income locations were more likely to be associated with geographic clustering of suicide and emergency department admissions for self-harm, depression, and anxiety, supporting a large body of literature demonstrating that poverty is a key determinant of mental health (Knifton and Inglis, 2020; Lund, 2012; Ridley et al., 2020).

Previous studies have found suicide rates in poor communities are significantly higher than in wealthier areas (Hoffmann et al., 2019; Knifton and Inglis, 2020; Näher et al., 2020). This worrying trend remains true for older adults, with poverty linked to higher rates of poor mental health (Cheung and Chou, 2019; Choi et al., 2019; Menec et al., 2010), more severe mental health outcomes (Cheung and Chou, 2019), and disproportionate rates of clustering, with poor health outcomes more prevalent in low-income communities (Menec et al., 2010). Impoverished older adults are also more likely to die by suicide than their wealthy counterparts, a trend which is especially pronounced among older adult males (Choi et al., 2019). However, this relationship is complex and requires further exploration, as other studies have found older adult suicide rates are less likely to be influenced by socioeconomic status as compared to other age groups (Burrows et al., 2010; Hawton et al., 2001; Whitley et al., 1999). Our analysis suggests that older adults who visit the ED for depression, anxiety, and self-harm are more likely to reside in economically deprived communities, highlighting the need for additional mental health resources in low-income communities throughout the state of North Carolina.

This analysis found that majority Black communities were associated with a lower risk of being included in anxiety, depression, or suicide clusters but at higher risk of being identified in a self-injury cluster. The increased risk of being in a self-injury cluster for predominately Black communities may be indicative of the recent rise in suicide among Black people (Ramchand et al., 2021), a worrying trend that has persisted with

the onset of the COVID-19 pandemic (Bray et al., 2021). Despite concerning increases in suicide and self-harm rates, overall Black individuals are less likely to seek mental health care, especially older Black adults (Conner et al., 2010), due to stigma (Conner et al., 2010), lack of access to these services (Cook et al., 2017), and general distrust of the medical community (Campbell and Long, 2014). Our findings that predominantly Black communities are associated with a lower overall risk of being in an anxiety or depression cluster may be more indicative of help-seeking behavior for this group rather than mental health need. Additional community-specific health intervention research is needed to better understand the role of residential segregation and mental health needs among older adults.

While our findings show that primary clusters for each mental health outcome were identified in rural and urban regions of North Carolina; we found that rural locations were less likely overall to be identified in high-risk clusters for each of the four mental health outcomes compared to urban areas. This finding is surprising, as rural areas typically have higher mental health burdens and fewer mental health resources available (Morales et al., 2020). Past research (Fontanella et al., 2015) has found rural areas to be at increased risk of poor mental health outcomes and spatial clustering, with adolescent and young adult suicide rates almost twice as high in rural areas as compared to urban areas (Fontanella et al., 2015). However, the rural-urban divide is often thought of as a binary, whereas our study considered suburban/micropolitan areas, in addition to urban and rural areas, at a finer spatial scale (ZIP Code vs county), which may partially explain the difference in findings. Furthermore, prior research by Guo et al. (2019) found that both low population density and high population density areas were associated with older adult mental health clustering, further indicating that the contextual factors associated with older adult mental health may differ from those of the general population.

Despite rural communities found to be at lower risk of clustering, our analysis suggests that predominantly rural mountainous regions, specifically Western North Carolina, may be at increased risk of clustering, as the primary clusters for depression, anxiety and suicide occurred in this region. Western North Carolina has substantial health disparities, due to limited access to mental health care, remote transportation networks and poor social determinants of health, including a large older adult population (MAHEC, 2022), and our results illustrate the need for immediate mental health interventions. Our community-level results indicate that locations vulnerable to geographic clustering of mental health risks in older adults may vary depending on the outcome and that economic privilege may be a better predictor of older adult mental health clustering risk than rurality or race alone.

Findings highlighted racial identity as an important individual-level determinant of residence in a high-risk mental health cluster for older adults. Asian older adults were less likely to live in clusters across all health outcomes, as compared to White older adults. While not significant, the risk of living in a suicide cluster also varied with racial identity, with Black adults more likely to live in a suicide cluster, which further supports recent research highlighting concerning increases in suicide among Black individuals (Bray et al., 2021; Ramchand et al., 2021). Indigenous American older adults were more likely to live in high-risk anxiety and depression clusters. While this result was not significant, it may highlight increased risk of poor mental health outcomes and clustering among older Indigenous adults. Indigenous Americans are much more likely to report poor mental health but are much less likely to seek care due to access and mistrust (MHA, 2022; NAMI, 2022). These findings suggest that different subpopulations may be more vulnerable to specific mental health outcomes, and as such, targeted mental health interventions should take into consideration racial, cultural, and ethnic differences in help-seeking behaviors among older adults.

This analysis also found insurance type to be associated with mental health clustering; however, the relationships varied with mental health outcomes. The majority of our sample of older adults were insured by Medicare or 'other' forms of insurance. Older adults insured by Medicare were more likely to live in a high-risk self-injury or anxiety cluster than individuals with private insurance. There are numerous barriers associated with older adults' inability to obtain mental health services, including individual-level factors like high out-of-pocket costs, inadequate access to transportation, lack of available and accessible mental health services (e.g., rural residence in a mental health professional shortage area), comorbidities that limit mobility, and perceived stigma (PAN, 2021). These individual barriers are further complicated by Medicare policies and associated barriers to treatment that are characterized by limited or temporary telehealth coverage of mental health services, many of which will end at the close of the pandemic, limited coverage, or prohibitively high costs of prescriptions for mental health conditions, and a lack of coverage or reimbursement for some mental health services (e.g., professional counseling) (PAN, 2021).

Though not significant, a history of prior suicide attempts was associated with a reduced risk of living in a suicide cluster. Past research has illustrated that older adults are much more likely to be successful while attempting suicide as compared to other age groups, as older adult suicide attempts are often less impulsive and use more lethal methods (Gramaglia et al., 2022). Our results suggest that individuals with no history of prior suicide attempts are at higher risk of living in a suicide cluster, stressing the importance of targeted, preventative care.

The similarity in spatial cluster patterns, especially with suicide, depression and anxiety further highlights the immediate need for mental health interventions. Furthermore, while the majority of suicides were among older adult males, the majority of all three mental health outcomes were higher among female older adults. These findings emphasize the importance of targeted care; as men are generally less likely to seek mental health care (Parent et al., 2018), but more likely to die by suicide (AFSP, 2022; Koo et al., 2017; Law et al., 2016). Preventative care should target older adult males, and additional mental health resources may be needed to meet the healthcare needs of older adult females.

4.1. Strengths and limitations

Strengths of this study include a high geographic and temporal resolution dataset for mental health outcomes and suicide among adults 65 and older. Furthermore, the consideration of anxiety, depression, and self-injury, in addition to suicide, provides additional information on older adult mental health that can further understanding to offer effective preventative care for both underlying mental health conditions and suicide.

A limitation of this study is the small unit area of analysis, which can result in inflated RR values due to the small population size of some ZIP Codes in NC. However, ZIP Code level analysis does illustrate trends at a small spatial scale, providing important information for preventive care, and, in general, finer-level data provides more accurate clusters than larger areal units (e.g., counties) (Schmiedel et al., 2012), with little loss in cluster detection sensitivity at the ZIP Code level as compared to census-tract level analysis (Jones and Kulldorff, 2012). Limitations exist within the dataset as well. Our data included the transition from ICD-9 to ICD-10 CM codes, which could introduce potential misclassification for mental health outcomes. Nonetheless, our analysis was spatial in nature and did not include spatio-temporal analysis. Additionally, selection bias may exist among the ED population. To mitigate this bias, patients with mental health coded as either primary or secondary ICD 9 and 10 codes are included in this analysis. As such, any individual diagnosed with a mental illness is considered, not only the patients whose primary complaint was mental health related. Lastly, our data lacked information on ethnicity, as such, this study solely looked at race. Future work should investigate both racial and ethnic differences in clustering risk. Finally, our analysis was spatial in nature and did not consider temporal or spatio-temporal clustering.

Mental health-seeking behaviors among older adults vary, particularly as it pertains to culture, race, and ethnicity, with many reluctant to seek care (Teo et al., 2022). One limitation of our study is that we were

unable to collect data on attitudes and/or beliefs toward help-seeking. More research is needed among subgroups to understand how health-promoting factors like high social support, the low stigma associated with mental health help-seeking, preferences for traditional healing (Roh et al., 2017), and healthcare accessibility (Teo et al., 2022) affect individuals' risk of living in mental health clusters.

4.2. Implications and future work

The findings from this analysis have health policy implications by providing spatially explicit locations of vulnerable populations. Targeted mental health interventions are needed in western, central, and southeastern NC to address older adult mental health. Impoverished communities were associated with the greatest risk of living in mental health clusters; health interventions should prioritize low-income communities. Consideration should be given to help-seeking behaviors among subgroups to ensure culturally competent health interventions. In addition to targeted public health outreach, future research should consider the mediating and moderating effects associated with living in a mental health cluster, with methodologies such as multilevel modeling, to further guide targeted mental health interventions and provide an understanding on the causal effects of individual and community predictors on mental health. Additionally, given the rise in suicides and mental health cases in recent years, future work should consider the spatiotemporal trends in older adult mental health clustering.

5. Conclusions

This study identified clusters of poor mental health outcomes among older adults and identified community and individual-level predictors that may increase the risk of residing in a suicide, anxiety, depression, or self-injury cluster. Low-income communities were associated with an increased risk of clustering across all four mental health outcomes. Residential segregation was also associated with clustering; however, this relationship varied based on health outcome, with majority Black communities associated with an increased risk of self-injury clustering, but lower risk of clustering for suicide, anxiety, or depression. At the individual-level, race and socio-economic status were associated with the risk of living in a suicide cluster. Additional research into the help-seeking behaviors of older adults is needed. These results highlight spatially explicit locations of suicide, self-injury, anxiety, and depression clustering and illustrate the role community-level poverty may play as an important driver in adverse mental health outcomes among older adults. These findings can be applied to public policy by focusing attention on rural Appalachia and the central and southeastern regions of NC to develop effective preventative mental health strategies and interventions based on ensuring equitable distribution of community resources for older adults.

Human ethics statement

Data were exempt under human subjects' category #4 for secondary data from Appalachian State University's Institutional Review Board (IRB#19–0270).

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CRediT authorship contribution statement

Sophia C. Ryan: Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. **Jennifer D. Runkle:** Data curation, Methodology, Supervision, Validation, Writing – review & editing. **Lauren M. Andersen:** Resources, Visualization, Writing – review & editing. **Margaret M. Sugg:** Conceptualization, Data curation, Funding acquisition, Methodology, Supervision, Validation, Writing – review & editing.

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.ssmmh.2022.100162.

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