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Original article

Exploring Place-Based Differences in Suicide and Suicide-Related Outcomes Among North Carolina Adolescents and Young Adults

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A B S T R A C T

Purpose: Suicide is an ongoing public health crisis among youth and adolescents, and few studies have investigated the spatial patterning in the United States among this subpopulation. Potential precursors to suicide in this vulnerable group are also on the rise, including nonfatal self-injury.
Methods: This study uses emergency department data, death certificates, and violent death reporting system data for North Carolina from 2009 to 2018 to investigate spatial clusters of self-injury and suicide.
Results: Findings show that the demographic characteristics of individuals committing fatal and nonfatal self-injury are quite different. Self-injury and completed suicides exhibited different geographical patterns. Area-level measures like micropolitan status and measures of racial and income segregation predicted the presence of high-risk suicide clusters. Suicides among Native Americans and veteran status/military personnel also were associated with higher risk suicide clusters.
Discussion: Future interventions should target these specific high-risk locations for immediate reductions in adolescent and youth suicides.
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IMPLICATIONS AND CONTRIBUTION

These results provide important insight into locations in need of targeted suicide prevention efforts for adolescents and young adults. Suicide prevention treatments for adolescents and young adults should be implemented with consideration of location and specific individual- and area-level correlations that give rise to a higher risk of spatial clustering from suicide and self-injury.

Suicide is a leading cause of death among Americans, with US rates rising nearly 30% since 1999 and there is concern that rates may increase further in response to the COVID-19 pandemic [1,2]. Adolescents and young adults shoulder a significant burden of risk whereby suicide is the second leading cause of death among persons 10–24 years of age. Suicide in this group has increased by 57% from 2007 to 2018 [3]. Within the state of North Carolina (NC), suicide also increased at an alarming rate of 38.6% among persons aged 10–24 years during the same time period [4]. Increases in suicide rates among youth have paralleled large increases in underlying mental health conditions for this age group, including depression [5] and suicidal ideation [6].

A growing number of studies have highlighted the importance of detecting and monitoring suicide clusters, which emerge from either social (person-to-person) or shared contextual exposures [7]. A suicide cluster is often defined as a statistically higher number of deaths by suicide than would be expected in a

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given area and can be identified as a targeted location for intervention to prevent further harm. Several explanations exist for the presence of clusters, including the following: (1) potential contagion, or when one suicide is a stimulus for others to imitate the suicide act; and (2) contextual exposures, or when a cluster is explained by a broader consideration of the socioenvironmental factors acting at the community level. For instance, Durkheim's [8] seminal work demonstrated the geographic variations in suicide and suggested that a lack of social integration and regulation, such as rapid economic and demographic changes, in the same locations contribute to suicide clustering. More recent work has explored other contributory factors using a spatial epidemiology framework for geographic differences [9], identifying contextual risk factors including a lack of access to mental health care [10], low socioeconomic status [11], increased access to lethal means [12], or a higher prevalence of underlying or undiagnosed mental health conditions [13].

Despite consistent evidence of increased spatial patterning and suicide prevalence among specific populations and widespread understanding that neighborhoods (i.e., place) alter health, few research studies in the United States have employed advanced geographic methods to identify locations with high suicide risk [14]. To our knowledge, no state-level studies have assessed other related mental health disorders, such as self-injury. This study aims to identify spatial clusters of completed suicide and self-injury across the state of NC for adolescents and young adults (10–24 years old) and assess differences in demographic and contextual exposures within these clusters. We hypothesize that contextual exposure influences suicide clustering in NC and contributes to elevated self-injury in select NC locations. Place-based community approaches are needed to address rising suicide and mental disorder rates by arming decision-makers, health officials, and medical providers with data on the specific geospatial locations within their service area in need of targeted interventions.

Methods

Data

This ecological study included two outcomes for NC youth between the age of 10 and 24: (1) those who died by suicide or (2) those who visited the emergency department (ED) for self-injury from 2009 to 2018. Completed suicides were identified from the North Carolina Violent Death Reporting System, and geolocations were determined using death certificate data which included the residential addresses of the deceased. ED data for the second outcome variable, self-injury, were provided by the North Carolina Disease Event Tracking and Epidemiologic Collection Tool, which provides statewide surveillance for 117 EDs (99%) in the state of NC at the residential zip code for all ED patients [15]. ED visits for self-injury were flagged using both ICD-9 and ICD-10 (International Classification of Diseases, Ninth and Tenth Revision Codes) injury codes since NC transitioned to ICD-10 codes in October 2015. ICD-9 codes included E950–E959 codes that are well-established in previous literature as intentional self-inflicted injury [16]. ICD-10 codes included R45.851, T36–T65 + T7, T14.91, and X60-84, which included a suicide attempt, suicidal ideation, self-harm, and poisoning. These codes are more likely to capture suicidality in this younger demographic, as demonstrated by Insel and Gould [17] and our preliminary analysis (Table A1). Detailed information on the outcomes of interest can be found in Table A1. Mapping and analyses were conducted at the residential zip code level, the smallest spatial scale (n = 808 unique zip codes) available for both datasets. Data were exempt under human subjects category #4 for secondary data from Appalachian State University's Institutional Review Board as datasets were provided in a deidentified format from the North Carolina Department of Public Health (IRB#19–0270).

Contextual individual and community variables

Age, gender identity, and access to mental health services have been cited as important predictors of adolescent suicide risks [18]. For this analysis, we included the all-available individual-level data on the following covariates: age in years, sex (male, female), and race/ethnicity (non-Hispanic White, non-Hispanic Black, Hispanic, non-Hispanic American Indian, non-Hispanic Asian, Other). For young people who completed suicide, we included the method of suicide (firearm, hanging/strangulation, other).

Important neighbhorhood contextual variables associated with increased risk of suicidality included the presence of healthcare providers and the well-established Index Concentration of Extremes (ICE) to characterize two primary spatial indicators of neighborhood deprivation: residential poverty and residential segregation [19]. ICE identifies the extent to which a population is concentrated into extremes of deprivation (−1) or privilege (+1) and is considered a useful complement to area-level poverty for public health monitoring [19]. ICE is similar to other spatial measures of residential segregation such as the Local Divergence Index [20]. ICE values were calculated from variables in the American Community Survey 5-year estimates (2008–2011) using the following equation: $ICE_q = (T_{aq} - T_{pq})/T_q$, where T_{aq} represents the population density at the q location, and T_{aq}, T_{pq} represents population density of group a, p in the location of q [20]. The ICE metric included two metrics: (1) racial segregation (ICE_Race) and (2) income segregation (ICE_Income) [19].

Prior research has shown that more suicides occur in rural areas for this age group, particularly for firearm-related death by suicide [21,22]. As a measure of the rural-urban continuum, rural-urban community codes (RUCA) were aggregated into four levels: (1) Metropolitan (RUCA codes 1–3); (2) Micropolitan (RUCA codes 4–6); (3) Small Town Core (RUCA codes 7–9); and (4) Rural Areas (RUCA code 10) (Figure A1) [23]. Finally, we included measures from the Health Professional Shortage Area dataset on the number of mental health facilities in each zip code (n = 808) and census data on the percent of the population insured, divorced (i.e., a proxy for parental separation/divorce) [24], and occupying a rental home (i.e., a proxy for social isolation) [25].

Statistical and spatial analysis

Descriptive statistics were computed separately for each outcome, completed suicide and self-injury, and significance was reported at a p-value <.05. Kulldorff's Spatial Scan Statistic was used for the detection of spatial clusters of self-injury and suicide outcomes [26]. This statistic implements a large number of scanning windows of different sizes until a user-defined maximum radius is reached. A likelihood ratio test is used to calculate the likelihood of finding the observed number of health outcomes inside and outside of each circular window iteration, and the circle with the maximum likelihood is determined to be the most likely cluster (i.e., the cluster least likely to have occurred by chance). The spatial clusters were calculated using a

20% window of populations at risk; however, 30% was also tested. The smaller window allowed for the identification of more localized clusters, even though cluster locations were similar throughout each window size iteration. Based on the null hypothesis, clusters were validated using Monte-Carlo replications ($n > 999$ replications) to test the likelihood of a given cluster outcome. The expected number of cases, the observed number of cases, the locations included, the relative risk, the p-value ($<.05$), and the standard error were calculated for each cluster. All analyses were implemented in SaTScan v9.4.2 software [26] and adjusted for age and gender distributions at the zip code level using population estimates except suicide, which was only adjusted by age due to a large portion of the sample being predominately male (80.5%).

Generalized estimating equations with an exchangeable matrix were used to account for the repeated cases within zip codes for the ED data ($n = 3{,}593$ repeat cases), whereas logistic regression was used for mortality data since it did not include repeated measures. Models were performed separately for individual- and community-level variables (i.e., ICE measures of racialized and economic segregation) for each individual outcome, and a final model incorporated significant factors from individual- and community-level models to determine the most influential factors for cluster occurrence. Multicollinearity was assessed using the variance inflation factor, and all independent variables were under two, indicating a lack of collinearity between predictors. Adjusted risk ratios (RR) and their confidence intervals (CIs) were estimated for individual and community factors.

Results

A total of 48,865 ED visits for self-injury and a total of 1,398 suicides occurred in the same time period for NC. Suicide decedents were predominately male (80.5%), non-Hispanic White (72.9%), and occurred from firearm death. The average age of suicides was 19.7, and 17.9 for self-injury (Table 1). The RR for self-injury clusters ranged from 1.31 to 2.33, and from 1.36 to 3.57 for suicide clusters across NC (Figures 1 and 2). An RR of <1 corresponds to a lower-than-expected risk of suicide or self-injury, while a ratio of >1 indicated excess risk in that area.

Spatial clusters

Four significant spatial clusters were observed for suicide outcomes in the northwestern part of the state, southern piedmont, coastal plain, and coastal regions, with a relative risk as high as 3.57 in Cluster #2 (Figure 1). The pattern altered with self-injury having larger and more significant clustering in eastern NC (Table 2, Figure 2).

Regression results

Table 3 shows individual- and community-level factors (e.g., explanatory or predictor variables) associated with geographic spatial clusters at high risk for suicides (Model 1) and self-injury (Model 2) in NC youth (e.g., response or outcome variable).

Suicide clusters

Compared to metropolitan areas (i.e., >50,000 people), micropolitan (i.e., urban areas 10,000–50,000 people) throughout NC were 1.69 times more likely to be designated as a location of a high-risk suicide cluster (CI: 1.23–2.34). Suicides in the lowest tertile for ICE Race (i.e., Q1, predominately Black neighborhood) were associated with a lower risk of occurring in a suicide cluster (CI: 0.08–0.15) compared to the highest

Table 1
NC-VDRS[a] and NC-DETECT[b] emergency department visits for suicide and self-injury, 2009–2018

	Strata	Suicide,[a] n (%) N = 1,398	Self-injury,[b] n (%) N = 48,865
Age, mean (SD)		19.73 (3.32)	17.96 (3.81)
Sex (%)	Male	1,126 (80.5)	18,319 (37.5)
	Female	272 (19.5)	30,481 (62.5)
Race/ethnicity (%)	Hispanic	91 (6.5)	N/A
	Non-Hispanic White	1,019 (72.9)	14,399 (29.4)
	Non-Hispanic Black	224 (16.0)	7,946 (16.3)
	Non-Hispanic American Indian	25 (1.8)	298 (0.6)
	Non-Hispanic Asian	31 (2.2)	243 (0.5)
	Other or Not identified	8 (0.6)	25,961 (53.1)
Weapon type (%)	Firearm	734 (52.5)	N/A
	Poisoning	84 (6.0)	N/A
	Hanging, strangulation, suffocation	530 (37.9)	N/A
	Unknown or other	50 (3.6)	N/A
Incident year (%)	2009	90 (6.4)	3,201 (6.6)
	2010	101 (7.2)	3,155 (6.5)
	2011	100 (7.2)	3,218 (6.6)
	2012	134 (9.6)	3,526 (7.2)
	2013	121 (8.7)	3,444 (7.0)
	2014	147 (10.5)	3,937 (8.1)
	2015	159 (11.4)	4,587 (9.4)
	2016	169 (12.1)	7,756 (15.9)
	2017	188 (13.4)	7,676 (15.7)
	2018	189 (13.5)	8,365 (17.1)

ED = emergency department; N/A = not applicable; NC-DETECT = North Carolina Disease Event Tracking and Epidemiologic Collection Tool; SD = standard deviation; SUSI = self-harm and suicidal ideation; VDRS = violent death and reporting system.

[a] North Carolina violent death and reporting system.

[b] North Carolina Disease Event Tracking and Epidemiologic Collection Tool.

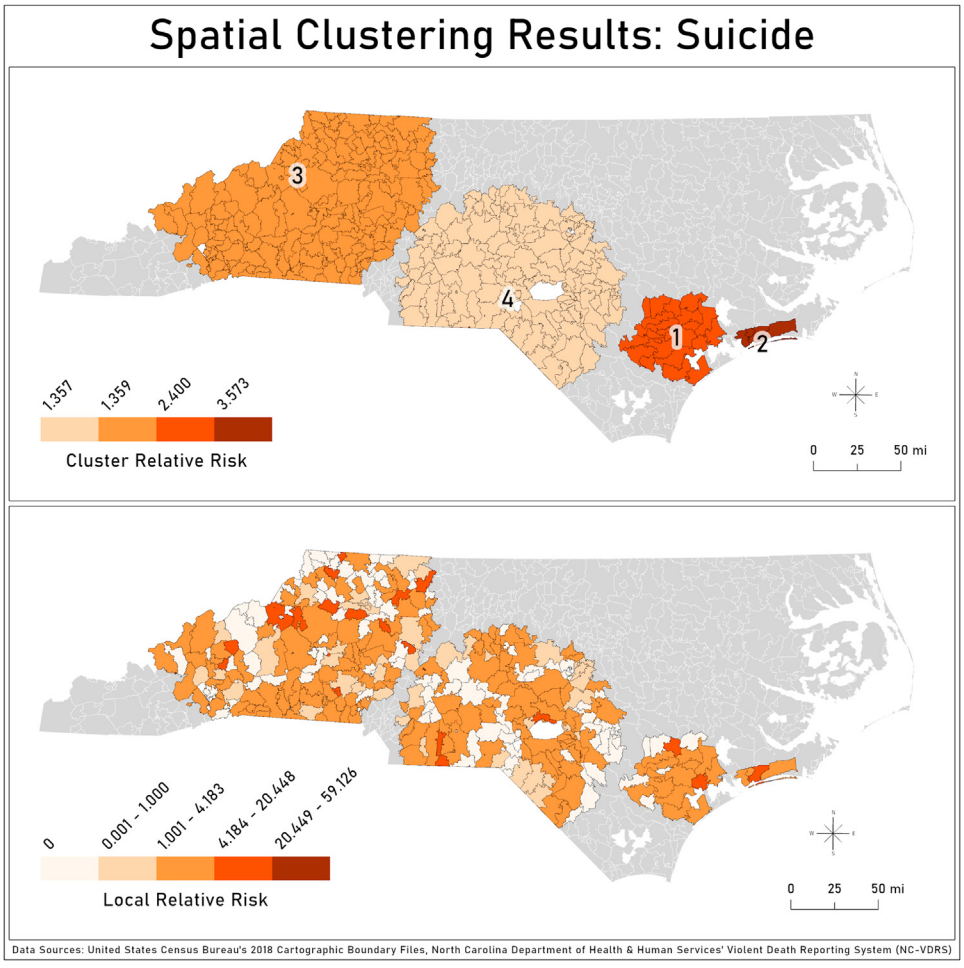

Figure 1. Suicide clustering results from the NC-VDRS, displaying spatial clusters (top) and local relative risk (bottom). NC-VDRS = North Carolina Violent Death Reporting System.

tertile for ICE Race (i.e., Q3, predominantly White neighborhood). In addition, suicides in lower-income locations (ICE Income Q1-Q2, CI: 1.83–5.06) were 2.5 times more likely to occur in clusters than in high-income locations (ICE Income Q3). Compared to Whites, American Indian suicides were 14.03 (CI: 4.70–60.7) times more likely to occur in suicide clusters than non-Hispanic Whites; however, sample sizes are small ($n = 25$). Individual-level predictors like education level, gender, weapon type (i.e., firearm, hanging/strangulation), and suicide characteristics (e.g., previous mental health, drug history) were not significant predictors for cluster presence. Community-level characteristics like the number of renters were also insignificant.

Self-injury clusters

Compared to Whites, minority youth (e.g., Non-Hispanic Blacks or Hispanics), in general, were less likely to reside in a high-risk cluster for self-injury. The risk of residing in a high-risk cluster for self-injury was highest for Medicaid (RR: 1.41, CI: 1.33-1.50), other government insurance (RR: 1.90, CI: 1.67–2.17), and self-pay (RR: 1.16, CI: 1.07–1.25) compared to commercial insurance. Compared to metropolitan areas, micropolitan areas were 83% more likely to be located in geographic clusters of self-injury, and a high percentage of the divorced populace were important predictors for determining the clustering of self-injury. Predominately low-income neighborhoods (i.e., ICE Income - Q1) were nearly 13 times more likely to co-occur in a self-injury cluster than the predominantly high-income neighborhoods (CI: 11.62–14.00).

Discussion

This study aimed to identify individual and community contextual factors that predict spatial clusters of completed suicide and self-injury across the state of NC for adolescents and young adults (10–24 years old) from 2008 to 2019. Unlike previous work, our study included other mental health outcomes beyond suicide and was specifically focused on identifying spatial patterns among a younger demographic for a Southern state in the United States. We found significant geographic heterogeneity in high-risk clusters for suicide and self-injury. Most surprisingly, we noted that suicide in adolescents and young adults was up to 3.5 times more likely in high-risk spatial clusters than in locations outside of clusters. Contrary to other national studies at the county-spatial scale [1], we observed over a 60%

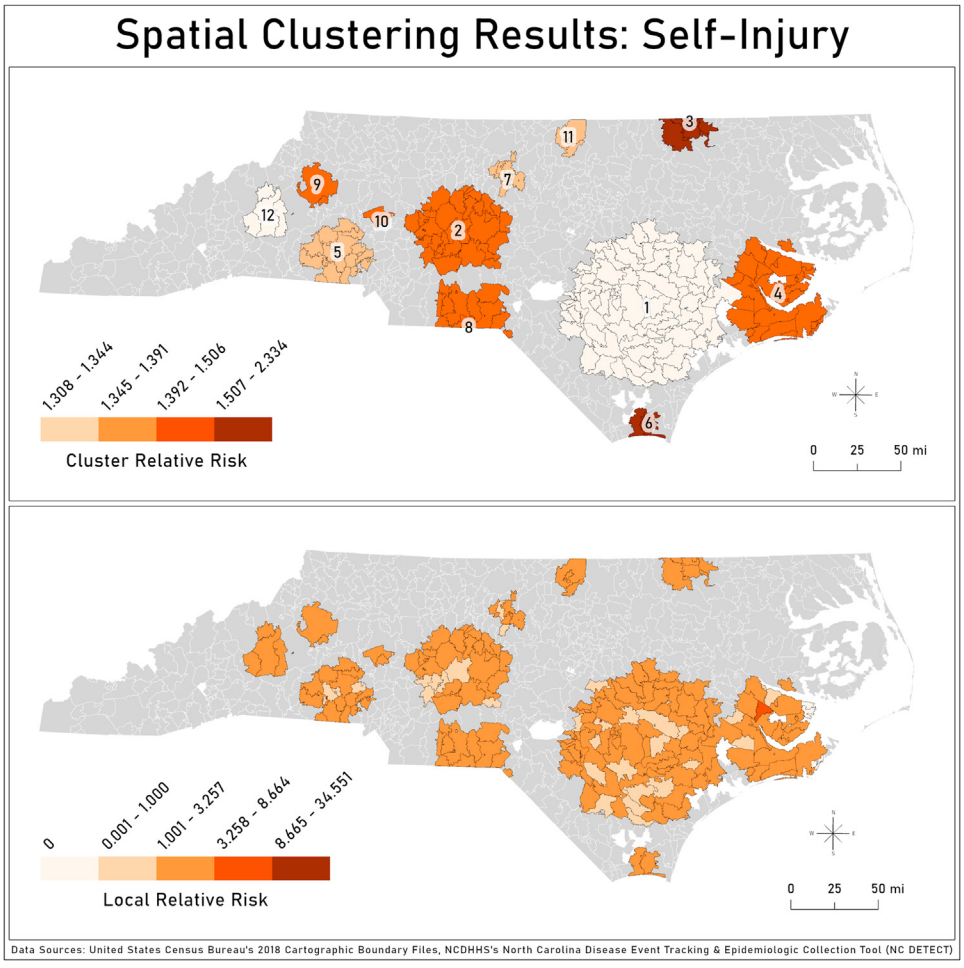

Figure 2. Self-injury clustering results from the NC-DETECT, displaying spatial clusters (top) and local relative risk (bottom). NC-DETECT = North Carolina Disease Event Tracking and Epidemiologic Collection Tool.

increase in excess risk for suicide and self-injury in micropolitan locations and a reduction in risk in most rural locations [1], highlighting the need to understand rural-urban disparities at more localized scales.

Suicide was found in four distinct spatial clusters. High-risk suicide clusters corresponded to self-harm clusters in eastern NC and central and western NC. One notable finding revealed that the highest risk for suicide clustering was

Table 2
Spatial cluster analysis of suicide and self-injury for adolescents and young adults (10–24 years olds) in North Carolina, 2009–2018

Name	Location	# ZCTAs in cluster	mi2 in cluster	Observed	Expected	Relative risk	Standard error	*p*-value
Suicide								
Cluster #1	34.735, −77.901 (Wallace)	20	1941.06	55	23.46	2.40	0.32	<.001
Cluster #2	34.665, −77.029 (Emerald Isle)	7	271.50	27	7.67	3.57	0.68	<.001
Cluster #3	36.259, −81.842 (Sugar Grove)	190	10803.82	318	249.17	1.36	0.07	.012
Cluster #4	35.055, −79.593 (Hoffman)	137	9294.85	309	242.04	1.36	0.07	.016
Self-injury								
Cluster #1	34.978, −78.188 (Turkey)	80	6442.83	5,091	3898.95	1.34	0.02	<.001
Cluster #2	35.608, −80.090 (Denton)	33	2118.70	3,033	2125.40	1.46	0.03	<.001
Cluster #3	36.512, −77.726 (Gaston)	6	397.13	398	171.35	2.33	0.12	<.001
Cluster #4	35.081, −76.861 (Grantsboro)	36	2113.31	1,296	871.27	1.50	0.04	<.001
Cluster #5	35.418, −81.321 (Crouse)	22	1002.03	1,865	1356.32	1.39	0.03	<.001
Cluster #6	34.019, −78.173 (Antioch)	3	202.91	179	88.71	2.02	0.15	<.001
Cluster #7	36.038, −79.603 (Sedalia)	7	240.10	657	479.51	1.38	0.05	<.001
Cluster #8	34.813, −79.981 (McFarlan)	12	927.02	421	290.24	1.46	0.07	<.001
Cluster #9	35.978, −81.544 (Happy Valley)	2	350.66	339	229.56	1.48	0.08	<.001
Cluster #10	35.681, −80.876 (Troutman)	2	115.45	268	178.27	1.51	0.09	<.001
Cluster #11	36.397, −78.976 (Roxboro)	3	257.30	185	133.27	1.39	0.10	.065
Cluster #12	35.712, −82.037 (Marion)	6	531.08	261	199.78	1.31	0.08	.091

ZCTAs = ZIP Code Tabulation Areas.

Table 3
Model output for the adjusted risk ratios for spatial clusters for the 10–24 age groups combined, 2009–2018 for Model 1: all completed suicide (n = 1,398) and Model 2: self-injury ED visits (n = 48,865), all adjusted by year

Predictors	Risk ratio	Confidence intervals	*p*-value
MODEL 1: Individual predictors for *suicide* high-risk clusters			
Military label [Yes]	1.86	1.25–2.78	.002
Military label [No]	Reference		
Hispanic	0.97	0.64–1.48	.902
Black	0.74	0.54–1.01	.061
American Indian/Alaskan Native	14.04	4.70–60.77	<.001
Asian	0.51	0.23–1.09	.092
White	Reference		
MODEL 1: Community predictors for *suicide* high-risk clusters			
Micropolitan [RUCA-2]	1.69	1.23–2.34	.001
Small rural town [RUCA-3]	0.51	0.28–0.91	.023
Rural and isolated [RUCA-4]	0.31	0.17–0.55	<.001
Metropolitan [RUCA-1]	Reference		
% Divorced	1.08	1.02–1.14	<.001
ICE income[a]			
Q1 [Low - predominately low income]	2.53	1.83–3.53	<.001
Q2 [Medium]	3.75	2.80–5.06	<.001
Q3 [High - predominately high income]	Reference		
ICE race[a]			
Q1 [Low - predominately non-Hispanic Black]	0.11	0.08–0.15	<.001
Q2 [Medium]	0.31	0.23–0.41	<.001
Q3 [High - predominately non-Hispanic White]	Reference		
MODEL 2: Individual predictors for *self-injury* high-risk clusters			
Asian	0.68	0.43–1.05	.084
Black	0.90	0.84–0.97	.008
Native American	0.39	0.24–0.62	<.001
Pacific Islander	1.12	0.18–6.97	.905
Not available or Other	1.16	1.07–1.26	<.001
White	Reference		
Medicaid	1.41	1.33–1.50	<.001
Workers' compensation	0.65	0.46–0.92	.012
Other government	1.90	1.67–2.17	<.001
Self-pay	1.16	1.07–1.25	<.001
Unknown or Other[b]	0.83	0.75–0.93	.001
Insurance company	Reference		
MODEL 2: Community predictors for *self-injury* high-risk clusters			
Micropolitan [RUCA-2]	1.83	1.71–1.95	<.001
Small rural town [RUCA-3]	1.19	1.07–1.32	<.001
Rural and isolated [RUCA-4]	0.75	0.65–0.86	<.001
Metropolitan [RUCA-1]	Reference		
% Divorced	1.08	1.06–1.10	<.001
Mental health facilities [Yes]	0.86	0.81–0.92	<.001
Mental health facilities [No]	Reference		
ICE income[a]			
Q1 [Low - predominately low income]	12.76	11.62–14.00	<.001
Q2 [Medium]	10.03	9.21–10.93	<.001
Q3 [High - predominately high income]	Reference		
ICE race[a]			
Q1 [Low - predominately non-Hispanic black]	0.72	0.68–0.77	<.001
Q2 [Medium]	1.48	1.39–1.58	<.001
Q3 [High - predominately non-Hispanic White]	Reference		

VIF remained under 2 (Supplemental Table 2).
[a] Tercile breaks and distribution for ICE race and income variables are shown in supplemental materials.
[b] Unknown or Other included multiple insurance types including no charge, unknown, other.

found on the coast in eastern NC, highlighting the need for immediate public health action in locations that have previously not been considered "high risk." These patterns in high-risk locations may also be the result of suicide contagion, a phenomenon theorized as a possible mechanism for suicide clustering where one suicide spurs the occurrence of subsequent suicide through "imitation," although the underlying mechanism is still unknown [27,28]. Expansion of crisis interventions in settings, such as schools, is recommended to prevent suicide contagion. Surveillance mapping techniques, like SaTScan, can provide the necessary locational information on where more targeted interventions are immediately needed [29].

Similar to previous work in NC, we found an high risk suicide clusters among youth in the western part of the state [30]. This predominately rural location has been well-established as an area with elevated suicide and a location with new programs such as Carolina Network for School Mental Health which partners with organizations to improve outcomes for unmet mental health needs.

Our results on excess suicide cluster risk among Native American youth corroborate findings from Australia that native or indigenous suicides are more likely to occur in clusters than nonindigenous suicides [31]. Earlier work in the United States showed that indigenous communities are a common setting for suicide clusters [32]. Our study found that Black youth suicides were significantly less likely to occur in suicide clusters despite an increasing rate of Black youth suicides in the United States [13]. We also determined that military status was strongly associated with suicide clusters, highlighting that this subpopulation is not only at higher risk for suicide, but military personnel suicides occur in similar locations [33].

Spatial measures of social polarization, including residential segregation (ICE Race) and areal poverty (ICE Income), were also important drivers of cluster occurrence. Traditionally, studies consistently show that racial segregation is a stronger predictor of health inequities [20], and we found segregation was significantly associated with clusters of self-injury and suicide. Predominately White neighborhoods (i.e., high ICE value; Q3) were a large driver for suicide clusters compared to predominately Black neighborhoods (i.e., low ICE value; Q1). Black suicides and self-injury were less likely to occur in spatial clusters across NC. Our findings may change as suicide attempts continue to rise for Black youth in NC [34]. Nonetheless, our results highlight that residential segregation should be investigated further as a contextual variable that may relate to access to timely mental health services, social support, or cultural cohesion and influence the occurrence of suicide and self-injury clusters.

Across the two outcomes, higher income segregation (i.e., ICE Income) was highly associated with cluster presence for both self-injury and suicide. An excess risk of presence in a suicide or self-injury cluster was significantly higher in the least affluent (i.e., most economically deprived) compared to the most affluent (i.e., least economically deprived) zip codes. Our work supports prior research that has shown that youth suicidality is higher in economically disadvantaged or socially isolated neighborhoods [35], with research pointing to social context, social connectedness/support, victimization, and higher prevalence of hopelessness as important determinants of suicidal behavior [36,37]. However, spatial analyses like ours have shown mixed results concerning relationship between income inequality and suicide across the United States [38]. These results are further supported by a systematic review identifying only 25% of studies support a statistically significant association between income inequality among those who completed suicide and 25% of studies finding opposing effects with results varying based on the geographic unit of analysis, population, and study location [39].

We found that high-risk suicide clusters were most likely in micropolitan areas or locations with connections to urban locations rather than rural/isolated and metropolitan areas. Our results contrast with the national analysis of the same demographic, which demonstrated greater rates of adolescent and young adult suicide in most rural locations [1,22,40]. Several explanations may explain our differences, including the use of 2010 RUCA codes rather than 2003 codes, the spatial unit (i.e., zip code rather than a county), the study area (i.e., NC vs. the United States), as well as the time period (i.e., 9 years vs. longer time periods). Nonetheless, our work highlights the need for more work examining trends in suicide among the rural-urban continuum and for the use of subcounty data to examine rural-urban trends, as large spatial units like the county can mask fine-scale rural-urban patterns.

Recent literature found that North Carolina has the poorest record in the country in providing mental health services to children, with 72% of NC children diagnosed with mental health conditions that have not met with a licensed mental health provider [41]. We found no significant relationship between mental health facilities and suicides but a positive association for ED visits of self-injury, with lower odds of clustering if mental health facilities were present. The use of the ED for an unaddressed mental health condition indicates inadequate access to mental health services.

A major factor in suicide deaths among adolescents is access to highly lethal methods, such as firearms and dangerous medications. For example, 56% of teen suicide deaths in rural western NC from 1999 to 2016 involved firearms, a higher than the overall state average (~ 50%). However, contrary to this finding, suicides related to firearms were not a significant predictor of suicides, despite being the most common means of suicide (e.g., 53% of adolescent suicides are related to firearms). This finding highlights the universal need for firearm prevention across the entire state of NC rather than select high-risk locations.

Other area-level factors, including divorce, predicted cluster occurrence. Parental divorce has been shown as a potential factor in adolescent suicide [24] by reducing family ties [8]. High rates of divorce within the community may also serve as an indicator of social integration at the community and requires further investigation.

Our analysis has several noteworthy implications; first, the use of SaTScan provides targeted spatial information on adolescent populations experiencing elevated risk of suicide and self-injury. This information has translational implications for optimizing the location of interventions and reallocating limited resources to areas with significant clustering. In addition, our work, conducted at a subcounty scale (i.e., zip code), found differing results for youth and adolescents that highlight the need for research at smaller spatial scales to identify relevant contextual factors (e.g., micropolitan status, racial segregation). Future work should include high-resolution spatial data and important granularities of rural-urban disparities.

Strengths and limitations

This study leverages multiple large data sources, including two comprehensive databases of ED visits and completed suicides, to examine self-injury and suicide patterns. This is an improvement over previous work, which has primarily used one data source (e.g., suicide data) at a more aggregate spatial scale (e.g., county level). Moreover, unlike other work, our work includes a state located in the southeastern United States, an understudied location, which encompasses multiple urban centers (e.g., Charlotte, Raleigh) and rural populations in the mountains and coastal plain. This finding provides a diverse population to analyze the spatial heterogeneity of self-injury and suicide outcomes. Finally, the use of spatial scan statistics, like SaTScan, allows for the adjustment of covariates (e.g., age, gender) and limits preselection bias by not requiring a priori number of cases within each cluster [42].

It is important to emphasize the ecological nature of the study results, which is based on the zip code level results and for a limited period of 2009–2018. The time period was restricted due to the limited nature of ED visits, which were not reliably available until 2009. In addition, our time period included the transition from ICD-9 to ICD-10 codes. To ensure homogeneity of

codes, we included ICD-10 codes that incorporated poisoning to provide a representative sample of self-injury, suicide ideation, and suicide attempt [17]. These ICD-10 codes mostly closely align with ICD-9 codes to ensure a longer time period and representative sample but likely overestimate self-injury. Although the zip code level provides a subcounty resolution, the spatial scale also has inherent limitations (Grubesic 2008) [43], as these codes are created for postal service delivery rather than spatial analysis. Our analysis should be replicated if future data are available at finer scales besides zip code. Finally, important contextual variables (e.g., ICE) were limited to a shorter time period (e.g., 2008–2013) and generalized to our entire study time period (2009–2018). This difference has the potential to introduce a temporal mismatch between area-level contextual variables and cluster results. However, our analysis focused on spatial clustering and identifying spatial area level correlates with high-risk clusters rather than spatiotemporal patterns.

Conclusions

This study examined suicide and self-injury outcomes for adolescents and young adults in NC, a state in the southeastern United States. We found significant spatial trends in self-injury and suicide outcomes. The risk for adolescent and youth suicide was three times higher in high-risk clusters than in areas outside the clusters. Factors strongly associated with suicide include being Native American, previous military history, and living in a micropolitan. Interventions targeted at adolescent and youth mental health should be aware of the unique characteristics and environments of adolescent suicides to offer tailored strategies and interventions for this vulnerable demographic.

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Supplementary Data

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