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ORIGINAL RESEARCH

Neighborhood Resources and Health Outcomes Among Stroke Survivors in a Population-Based Cohort

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BACKGROUND: Stroke survivors believe neighborhood resources such as community centers are beneficial; however, little is known about the influence of these resources on stroke outcomes. We evaluated whether residing in neighborhoods with greater resource density is associated with favorable post-stroke outcomes.

METHODS AND RESULTS: We included Mexican American and non-Hispanic White stroke survivors from the Brain Attack Surveillance in Corpus Christi project (2009–2019). The exposure was density of neighborhood resources (eg, community centers, restaurants, stores) within a residential census tract at stroke onset. Outcomes included time to death and recurrence, and at 3 months following stroke: disability (activities of daily living/instrumental activities of daily living), cognition (Modified Mini-Mental State Exam), depression (Patient Health Questionnaire-8), and quality of life (abbreviated Stroke-Specific Quality of Life scale). We fit multivariable Cox regression and mixed linear models. We considered interactions with stroke severity, ethnicity, and sex. Among 1786 stroke survivors, median age was 64 years (interquartile range, 56–73), 55% men, and 62% Mexican American. Resource density was not associated with death, recurrence, or depression. Greater resource density (75th versus 25th percentile) was associated with more favorable cognition (Modified Mini-Mental State Exam mean difference=0.838, 95% CI=0.092, 1.584) and among moderate–severe stroke survivors, with more favorable functioning (activities of daily living/instrumental activities of daily living=−0.156 [95% CI, −0.284 to 0.027]) and quality of life (abbreviated Stroke-Specific Quality of Life scale=0.194 [95% CI, 0.029–0.359]).

CONCLUSIONS: We observed associations between greater resource density and cognition overall and with functioning and quality of life among moderate–severe stroke survivors. Further research is needed to confirm these findings and determine if neighborhood resources may be a tool for recovery.

Key Words: activities of daily living ■ census tract ■ cognition ■ depression ■ quality of life ■ recurrence ■ stroke

Based on the Global Burden of Disease Study (2016), roughly 24% of Americans will experience a stroke in their lifetime.[1] Stroke is a leading cause of disability and death, particularly among older adults.[2] Findings from the Health and Retirement Study (1998–2014) indicate a substantial number of healthy years lost due to death or disability among middle-aged to older adults who suffer a stroke.[3] Due to the impact of stroke (eg, disability, depression), survivors are thought to spend increased time in their neighborhood; thus, we expect neighborhood environments to be important for recovery.[3–6] Previous research has largely focused on the impact of individual factors on poststroke outcomes, and there is little empirical knowledge on

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RESEARCH PERSPECTIVE

What Is New?

- Greater neighborhood resource density was associated with more favorable 3-month poststroke cognitive scores among stroke survivors.
- Greater neighborhood resource density was associated with more favorable 3-month poststroke functioning and quality-of-life scores among moderate–severe stroke survivors.

What Question Should Be Addressed Next?

- Future research should confirm these findings in other study populations, investigate potential mechanisms, and consider other neighborhood features that may support poststroke health outcomes.

Nonstandard Abbreviations and Acronyms

3MSE	Modified Mini-Mental State Examination
SS-QoL	abbreviated Stroke-Specific Quality of Life scale

how the neighborhood environments may influence poststroke outcomes.

Individual factors such as the severity of the stroke, sex, and race and ethnicity likely interact with the survivor's environment to influence poststroke outcomes.[7–9] Higher neighborhood socioeconomic status (SES) is associated with more favorable poststroke outcomes of functioning, quality of life (QOL), depression, stroke recurrence, and death, particularly among moderate–severe stroke survivors.[8,10–15] One potential explanation is that higher SES neighborhoods may have more resources providing beneficial opportunities for poststroke physical activity, socialization, and cognitive stimulation.[16–18] Qualitative researchers have concluded that stroke survivors and their caregivers believe availability of community centers, places to exercise, eateries, and stores to be beneficial for recovery.[19,20] Cross-sectional studies of survivors of primarily milder strokes have reported conflicting findings on the benefits of neighborhood resources on poststroke physical activity.[17,21–24] A population-based cohort study reported that neighborhood density of recreation centers may be beneficial to poststroke functioning and QOL among moderate–severe stroke survivors.[9] It remains unclear whether resources, overall, are beneficial to poststroke outcomes.

Our objective was to test the hypothesis that residing in neighborhoods with greater resource density would be favorably associated with all-cause death, stroke recurrence, and 3-month poststroke functioning, cognition, QOL, and depressive symptoms, particularly among moderate–severe stroke survivors.

METHODS

Because of the sensitive and potentially identifying nature of the data collected for this study, qualified researchers trained in human subject confidentiality protocols may request access to the data set and SAS program codes from the author, Dr Lynda Lisabeth, at llisabet@umich.edu.

Study Population

The study population was acquired from the Brain Attack Surveillance in Corpus Christi project, a population-based cohort previously described.[25] Active surveillance of emergency department and hospital admissions and passive surveillance of hospital discharge records were conducted to identify all stroke cases among persons aged at least 45 years residing in Nueces County, Texas, a predominantly urban area.[25,26] The Brain Attack Surveillance in Corpus Christi project enrolled 3965 persons with incident stroke (ischemic or intracerebral hemorrhage) occurring in 2009 to 2019. Stroke fellowship–trained physicians validated all strokes using source documentation and standard clinical definitions.[26,27] The institutional review boards at the University of Michigan and 2 local hospital systems approved the Brain Attack Surveillance in Corpus Christi project. Written informed consent was obtained from participants or their proxy.

We excluded people institutionalized before the stroke (N=167), who did not complete the initial interview (N=1074), who completed by proxy (eg, relative; N=787), and if the residential census tract was unknown (N=9). We excluded 142 stroke survivors who were not Mexican American or non-Hispanic White (98 non-Hispanic Black, 9 Hispanic Black, 16 non-Hispanic American Indian, 6 non-Hispanic Asian, and 10 Hispanic Asian) stroke survivors due to the small numbers in these racial groups reflecting the Nueces County, Texas, population.[28] This yielded 1786 people for death and stroke recurrence outcomes (Figure 1). For 3-month poststroke outcomes, we included 1284 survivors after additionally excluding people who died within 90-days after a stroke (N=39) and those who didn't complete the follow-up interview (N=426) or completed by proxy (N=37).

Exposure

Information on resources and square land miles by census tract was available through 2017 from the

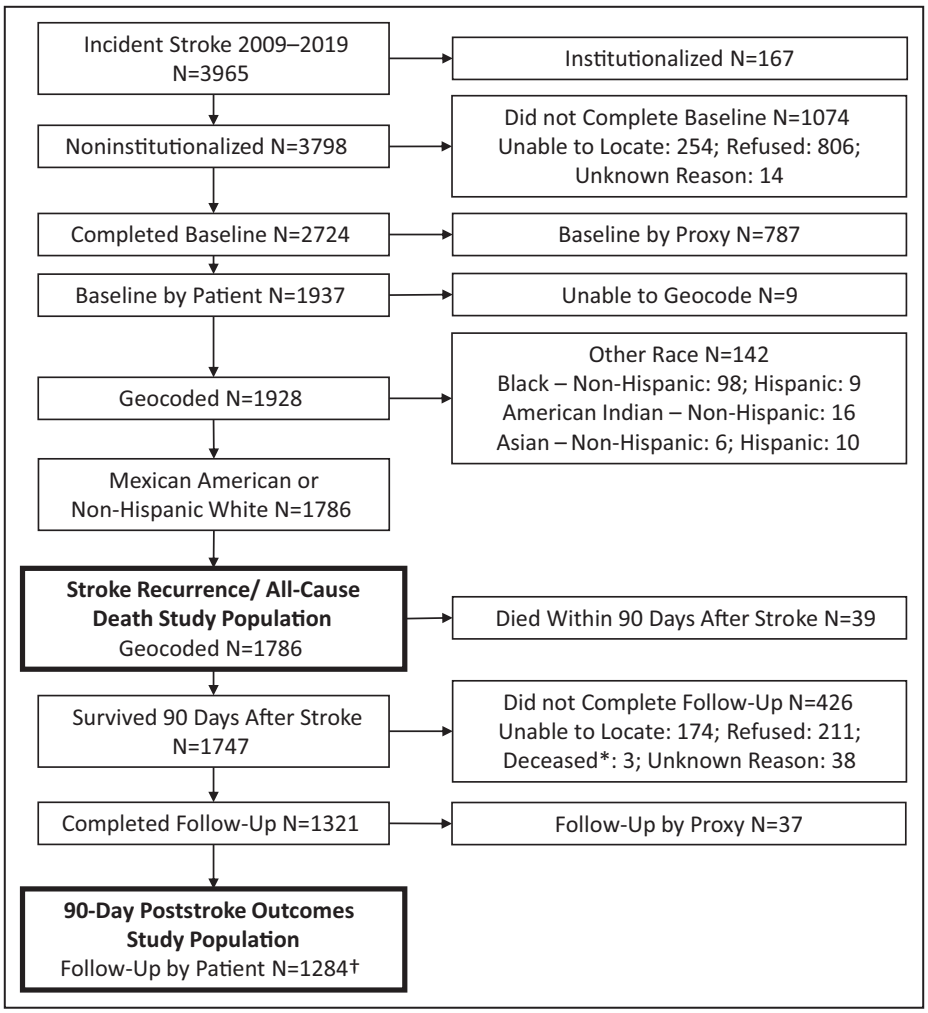

Figure 1. Eligibility flow chart.
*Survived 90 days after stroke but died before completion of follow-up interview. †Quality of life collected from 2010 to 2019, N=1189; depression collected from 2011 to 2019, N=1086.

National Neighborhood Data Archive.[29–32] Resources were identified using the North American Industry Classification System and included places that have been reported as possible facilitators of physical activity, socialization, or cognitive stimulation outside one's home/work (Table S1).[9,33–38] These included stores; entertainment, intellectual, recreation, and religious centers and eating/drinking places. We linked resource density by year of stroke and survivor's residential census tract around the time of hospital admission. Survivors with stroke in 2018 to 2019 were matched to the closest available data (2017).

Outcomes

Stroke recurrences were identified using the surveillance methods described above. We defined recurrence to be the first validated ischemic or hemorrhagic stroke identified after the incident stroke.[39] All-cause death data were obtained from the Texas Department of State Health Services death certificate database.[39] The Brain Attack Surveillance in Corpus Christi project uses a probabilistic record linkage software to match death certificate data with participants.[39] We censored on date of death (stroke recurrence model) or December 31, 2019, whichever occurred first.

Outcomes of functioning, cognition, depressive symptoms, and QOL were evaluated at 3 months following the incident stroke. Self-ratings of difficulty on activities of daily living (ADL) and instrumental ADL (IADL) were averaged to assess functioning (total score range, 1–4).[8,27] The Modified Mini-Mental State Examination (3MSE) provided a measure of global cognition (total score range, 0–100).[27] The Patient Health Questionnaire 8 was administered to assess depressive symptoms (total score range, 0–24).[8,40] The abbreviated Stroke-Specific QOL scale (SS-QoL) was used to measure health-related QOL (total score

range, 1–5).[8,41] Lower scores for the ADL/IADL and Patient Health Questionnaire 8 and higher scores on the 3MSE and SS-QoL are more favorable.

Covariates

We conducted a literature review to identify risk factors for each outcome and created directed acyclic graphs and identified a minimal set of covariates for which to adjust to reduce confounding.[42,43] Risk factors identified included key demographics such as age, sex, and race and ethnicity, and socioeconomic status.[44–47] Also important were prestroke social support (eg, marital status, living with someone, and social network), prestroke health (eg, presence of comorbidities, cognitive status, depression), and health behaviors (eg, smoking, and excessive alcohol use).[44–50] These individual and interpersonal risk factors for stroke health outcomes are likely to be associated with our exposure (density of neighborhood resources) due to self-selection into a neighborhood (eg, due to financial means or desire to live somewhere with certain resources) or the aggregate of these characteristics among residents creating a demand for the neighborhood resource.[51,52] Additionally, neighborhood-level characteristics such as neighborhood-level SES and other attributes like availability of public transportation, sidewalk presence/quality, and perceptions of safety are likely to be associated with neighborhood resources and risk factors for subsequent poststroke health outcomes.[7,38,53–56] Below is the minimal set of covariates we ascertained for this study and included in our analysis.

We assessed the following by interview or medical record abstraction:

1. Demographics: age in years (categorized by quantiles), sex (male or female), race and ethnicity (non-Hispanic White or Mexican American).
2. Individual SES: education (less thanhigh school, high school, greater than high school) and whether insured.
3. Prestroke health: disability (modified Rankin scale), cognition (informant questionnaire on cognitive decline in the elderly), self-reported depression or antidepressant use, ever smoker, and comorbidity score (includes following comorbidities: amyotrophic lateral sclerosis, atrial fibrillation, cancer, chronic obstructive pulmonary disease, coronary heart disease or myocardial infarction, dementia or Alzheimer disease, diabetes, end-stage renal disease, epilepsy, excessive alcohol use, heart failure, hyperlipidemia, hypertension, and Parkinson disease).[8]
4. Interpersonal factors: marital status (single/never married, married/living with someone, widowed, divorced/separated) and social support score, as previously described.[8]
5. Neighborhood SES: disadvantage score and affluence score as previously described (obtained from National Neighborhood Data Archive and linked by residential census tract and year of stroke with closest 5-year period available: 2008 to 2012 and 2013 to 2017).[32,57]
6. Stroke characteristics: stroke type (ischemic or intracerebral hemorrhage), initial stroke severity (National Institutes of Health Stroke Scale as abstracted from medical records or by validated algorithm, dichotomized as mild [<5] or moderate–severe [≥5]).[8,58,59]

Statistical Analysis

We conducted analyses to describe the overall population and by resource density quartile. We described categorical variables using frequencies and percentages and continuous variables using means and SDs where normally distributed, otherwise using medians and interquartile range (IQRs). We evaluated differences by resource density quartiles with χ^2 or ANOVA tests.

We fit Cox regression models using a shared frailty model accounting for clustering by residential census tract to determine the hazard ratio of recurrence or death associated with an IQR difference in neighborhood resource density (reflects high versus low density). We fit mixed linear models for 3-month poststroke outcomes allowing for random intercepts by residential census tract. We applied inverse probability weighting to account for potential selection bias and to upweight those in the study who were similar to those excluded from the study. The applied weights were the inverse product of the probabilities generated by logistic regression models for participating in the baseline assessment, completing the baseline assessment by oneself and without a proxy, and for the 3-month poststroke outcomes only, participating in the follow-up assessment. We then applied chained multiple imputation to account for selection bias that might have occurred if we excluded people with missing data using all available data from study populations for each outcome. All variables except for prestroke cognition were missing for <5% of participants (Table S2). We sequentially adjusted for the covariates described herein. Additionally, we considered effect modification by stroke severity, race and ethnicity, or sex by including interaction terms. A priori, we considered significance on the basis of coefficient magnitudes, 95% CIs, and *P* values (main effect, P=0.05; interactions, P=0.15).[8,60,61] We conducted post hoc analysis to calculate the minimum detectable effect size for an IQR increase in neighborhood resources for each outcome measure and intraclass correlation combination (Table S3). With our sample sizes, we will be able to detect relatively small effect sizes that are in line with previous findings.

We calculated Hedges' *g* to evaluate the effect size of each outcome scale.[61] We conducted sensitivity analyses to consider whether the survivor moved (data available 2014–2019) by excluding people who indicated they moved at follow-up. We conducted analyses with SAS 9.4 (SAS Institute, Inc., Cary, NC) and adhered to Strengthening the Reporting of Observational Studies in Epidemiology reporting guidelines.[62]

RESULTS

Among 1786 stroke survivors, 408 deaths and 189 stroke recurrences occurred over a median follow-up of 1380 days for death and 1222 days for recurrence (Table 1). Median age was 64 years, 55% were men, 51% were married or living with someone, 62% were Mexican American individuals, 70% completed at least high school, and 82% had insurance. Most initial strokes were ischemic (91%) and of mild severity (74%). The stroke survivors resided in 78 census tracts within Nueces County, with a median 1.10 (IQR, 0.66–3.13) square land miles. Median resource density was 39.5 (IQR,15.9–71.7) resources per square land mile. Resources with the greatest density included retail businesses, eating/drinking places, personal care establishments, and religious organizations (Table S1). In census tracts with a greater density of resources, there was a greater proportion of Mexican American survivors, higher median disadvantage score, and lower median affluence score (Table 1). A higher proportion of survivors died during follow-up among neighborhoods in the upper quartile of resource density. Study population characteristics for the 1284 stroke survivors included in analyses of 3-month poststroke outcomes were similar to the 1786 survivors presented in Table 1 (data not shown). Median 3-month poststroke outcomes were 1.8 (IQR, 1.2–2.5) for ADL/IADL, 81 (IQR, 73–85) for 3MSE, 3.8 (IQR, 2.8–4.5) for SSQoL, and 5.0 (IQR, 1.0–11.0) for Patient Health Questionnaire 8.

We did not observe an increased hazard for death or recurrence associated with density of resources (HR, 1.006 [95% CI, 0.834–1.214]; HR, 0.975 [95% CI, 0.743–1.279], respectively; Table 2, model 7: fully adjusted). Stroke severity, sex, and race and ethnicity did not modify these associations (Table 2, models 8–10). Restricting to survivors of stroke in 2014 to 2019 (N=1111) and excluding people who moved (N=45) yielded similar results.

Greater resource density was associated with more favorable cognition among stroke survivors (3MSE mean difference [75th versus 25th percentile] = 0.838 [95% CI, 0.092–1.584]; Table 3, model 7). Stroke severity modified associations with ADL/IADL and SS-QoL (*P*=0.0145 and *P*=0.0779, respectively; Table 3, model 8). Among moderate–severe stroke survivors only, greater resource density was associated with more favorable functioning (ADL/IADL mean difference, 0.156 [95% CI=-0.284, −0.027]) and QOL (SS-QoL mean difference, 0.194 [95% CI, 0.029–0.359]; Table 3, model 8). Resource density was not associated with depressive symptoms (Table 3, Patient Health Questionnaire 8). Sex and race and ethnicity did not modify any associations with poststroke outcomes (interaction term for sex: ADL/IADL, *P*=0.2036; 3MSE, *P*=0.2963; SS-QoL, *P*=0.6459; interaction term for race and ethnicity: ADL/IADL, *P*=0.4540; 3MSE, *P*=0.3145; SS-QoL, *P*=0.9322; Table 3, models 9 and 10). Table S4 provides the calculated Hedges' *g*; we note minimal effect sizes for all outcome measures ($g < 0.2$).[61] After restricting to survivors of stroke in 2014 to 2019 (N=787) and excluding people who moved (N=42), we observed similar associations (Figure 2). For cognition, the association remained when restricting to 2014 to 2019; however, it was attenuated and no longer significant (Figure 2). Additionally, sex appeared to modify this association (*P*=0.1178), with a larger mean difference among men (Figure 2). Excluding those who moved yielded similar results to the 2014 to 2019 population for functioning, cognition, and QOL (Figure 2). Other than portrayed in Figure 2, stroke severity, sex, and race and ethnicity did not modify these associations (*P*>0.15).

DISCUSSION

Among survivors of a moderate–severe stroke, resource density was associated with more favorable functioning and QOL 3 months after stroke and was associated with better cognition in the general stroke survivor population (did not depend on stroke severity); however, effect sizes were minimal. Resource density wasn't associated with depressive symptoms, all-cause death, or stroke recurrence. These results suggest that higher neighborhood resource density may be beneficial to stroke survivors, particularly those with moderate–severe strokes.

Our findings contribute to the scarce research on the potential effect of neighborhood environments on poststroke outcomes. We previously reported neighborhood SES and density of recreation centers to have similar favorable associations among those with moderate–severe stroke.[8,9] We did not identify any studies considering the exposure of neighborhood resource density with poststroke outcomes; however, we did identify 3 publications evaluating a similar exposure: walk score.[22–24] Walk score is a measure of walkability based on the person's proximity to a variety of neighborhood resources.[22–24] Two of the publications indicated no association between walk score and physical activity, and 1 publication indicated those with greater physical and cognitive ability generally resided in areas

Table 1. Study Population Characteristics by Resource Density Among Stroke Survivors 2009–2019 (N=1786)*

Characteristics	Overall (N=1786)	Resource density				*P* value†
		<15.9 (n=452)	15.9–39.5 (n=441)	39.5–71.7 (n=449)	>71.7 (n=444)	
Resource density, median (IQR)	39.5 (15.9–71.7)	5.8 (3.4–12.0)	27.5 (22.9–33.0)	56.5 (48.0–63.5)	88.8 (78.4–111.5)	<0.0001
Age, y, median (IQR)	64.0 (56.0–73.0)	65.0 (57.0–73.0)	64.0 (56.0–73.0)	64.0 (56.0–73.0)	64.0 (56.0–74.0)	0.5168
Age, y, quartiles, n (%)						0.6049
<56	406 (23)	99 (22)	98 (22)	110 (25)	99 (22)	
56–64	440 (25)	99 (22)	121 (27)	99 (22)	110 (25)	
64–73	460 (26)	131 (29)	108 (25)	131 (29)	107 (24)	
≥73	480 (27)	123 (27)	114 (26)	115 (26)	128 (29)	
Sex, n (%)						0.3648
Male	982 (55)	252 (56)	238 (54)	260 (58)	232 (52)	
Female	804 (45)	200 (44)	203 (46)	189 (42)	212 (48)	
Race and ethnicity, n (%)						<0.0001
Mexican American	1114 (62)	266 (59)	234 (53)	342 (76)	272 (61)	
Non-Hispanic White	672 (38)	186 (41)	207 (47)	107 (24)	172 (39)	
Education attainment, n (%)						0.3949
Less than high school	541 (30)	137 (30)	117 (27)	152 (34)	135 (30)	
High school	535 (30)	139 (31)	134 (30)	127 (28)	135 (30)	
Greater than high school	710 (40)	176 (39)	190 (43)	170 (38)	174 (39)	
Health insurance status, n (%)						0.7576
Insured	1445 (82)	372 (84)	358 (82)	360 (81)	355 (82)	
No insurance	316 (18)	73 (16)	78 (18)	85 (19)	80 (18)	
Modified Rankin Scale score, n (%)‡						0.5504
No disability	622 (35)	171 (38)	154 (36)	157 (35)	140 (32)	
No significant disability	317 (18)	69 (16)	82 (19)	84 (19)	82 (19)	
Slight disability	585 (33)	152 (34)	135 (31)	144 (32)	154 (35)	
Moderate disability	154 (9)	41 (9)	39 (9)	36 (8)	38 (9)	
Moderately severe to severe disability	84 (5)	13 (3)	24 (6)	25 (6)	22 (5)	
IQCODE, median (IQR)	3.0 (3.0–3.2)	3.0 (3.0–3.1)	3.0 (3.0–3.1)	3.0 (3.0–3.2)	3.0 (3.0–3.3)	0.0030
Depression, n (%)‡						0.3318
No depression	1175 (66)	314 (70)	283 (64)	292 (66)	286 (65)	
Depression diagnosis or antidepressant use	595 (34)	136 (30)	157 (36)	150 (34)	152 (35)	
Comorbid score, median (IQR)	2.0 (1.0–3.0)	2.0 (1.0–3.0)	2.0 (1.0–3.0)	3.0 (1.0–4.0)	2.0 (1.0–3.0)	0.5264
Amyotrophic lateral sclerosis, n (%)	2 (0)	0 (0)	2 (0)	0 (0)	0 (0)	
Atrial fibrillation, n (%)	180 (10)	44 (10)	55 (12)	37 (8)	44 (10)	0.2093
Cancer, n (%)	189 (11)	52 (12)	58 (13)	30 (7)	49 (11)	0.0129
Chronic obstructive pulmonary disease, n (%)	186 (10)	45 (10)	53 (12)	45 (10)	43 (10)	0.6492
Coronary heart disease or myocardial infarction, n (%)	425 (24)	116 (26)	101 (23)	117 (26)	91 (21)	0.1720
Dementia or Alzheimer disease, n (%)	44 (2)	8 (2)	11 (2)	11 (2)	14 (3)	0.6180
Diabetes, n (%)‡	816 (46)	195 (43)	196 (44)	224 (50)	201 (45)	0.1968
End-stage renal disease, n (%)	50 (3)	7 (2)	11 (2)	15 (3)	17 (4)	0.1746
Epilepsy, n (%)	34 (2)	8 (2)	8 (2)	8 (2)	10 (2)	0.9429
Heart failure, n (%)	108 (6)	29 (6)	27 (6)	30 (7)	22 (5)	0.7143
Hyperlipidemia, n (%)	825 (46.2)	207 (46)	203 (46)	224 (50)	191 (43)	0.2307
Hypertension, n (%)	1416 (79)	366 (81)	347 (79)	363 (81)	340 (77)	0.3168

(*Continued*)

Table 1. Continued

Characteristics	Overall (N=1786)	Resource density				*P* value[†]
		<15.9 (n=452)	15.9–39.5 (n=441)	39.5–71.7 (n=449)	>71.7 (n=444)	
Parkinson disease, n (%)	13 (1)	2 (0)	3 (1)	5 (1)	3 (1)	
Excessive alcohol use, n (%)	139 (8)	35 (8)	37 (8)	27 (6)	40 (9)	0.3740
Smoking status, n (%)[‡]						0.0889
Never smoked	1017 (57)	269 (60)	229 (52)	259 (58)	260 (59)	
Ever smoker	767 (43)	182 (40)	212 (48)	190 (42)	183 (41)	
Marital status, n (%)[‡]						0.1506
Single/never married	162 (9)	27 (6)	47 (11)	41 (9)	47 (11)	
Married/living with someone	902 (51)	237 (52)	225 (51)	234 (52)	206 (46)	
Widowed	315 (18)	81 (18)	67 (15)	76 (17)	91 (21)	
Divorced/Separated	407 (23)	107 (24)	102 (23)	98 (22)	100 (23)	
Social support scale, mean ±SD	9.2±3.2	9.2±3.1	9.1±3.2	9.2±3.3	9.2±3.2	0.9401
Neighborhood disadvantage score, mean ±SD	0.12±0.06	0.12±0.08	0.11±0.06	0.13±0.06	0.14±0.05	<0.0001
Neighborhood affluence score, mean ±SD	0.26±0.14	0.29±0.14	0.28±0.15	0.23±0.15	0.23±0.11	<0.0001
Stroke type, n (%)						0.4196
Ischemic	1623 (91)	419 (93)	401 (91)	403 (90)	400 (90)	
Intracerebral hemorrhage	163 (9)	33 (7)	40 (9)	46 (10)	44 (10)	
Stroke severity (NIHSS), n (%)						0.0697
Mild (<5)	1318 (74)	351 (78)	317 (73)	337 (75)	313 (71)	
Moderate–Severe (≥5)	456 (26)	98 (22)	120 (28)	110 (25)	128 (29)	
Stroke recurrence, n (%)						0.3611
Censored	1581 (89)	409 (91)	391 (89)	396 (88)	385 (87)	
Second stroke	205 (12)	43 (10)	50 (11)	53 (12)	59 (13)	
Days of follow-up for recurrence,[§] median (IQR)	1222.0 (502.0–2152.0)	1164.5 (490.0–2085.0)	965.0 (468.0–1871.0)	1068.0 (467.0–1771.0)	1660.5 (724.0–2715.5)	<0.0001
All-cause death, n (%)						0.0431
Censored	1345 (75)	355 (79)	331 (75)	345 (77)	314 (71)	
Expired	441 (25)	97 (22)	110 (25)	104 (23)	130 (29)	
Days of follow-up for death,[‖] median (IQR)	1379.5 (617.0–2294.0)	1295.0 (600.5–2158.5)	1129.0 (552.0–2001.0)	1234.0 (540.0–1903.0)	1950.0 (970.0–2.847.5)	<0.0001
ADL/IADL score, median (IQR)[**]	1.8 (1.2–2.5)	1.7 (1.2–2.5)	1.7 (1.2–2.4)	1.9 (1.3–2.5)	1.8 (1.2–2.5)	0.5569
3MSE score, median (IQR)[¶]	81.0 (73.0–85.0)	80.0 (73.0–85.0)	81.0 (74.0–85.0)	80.0 (70.0–84.0)	81.0 (73.0–86.0)	0.1871
SS-QoL score, median (IQR)[#]	3.8 (2.8–4.5)	3.7 (2.8–4.5)	3.8 (2.9–4.6)	3.7 (2.8–4.4)	3.8 (2.9–4.4)	0.4486
PHQ-8 score, median (IQR)[**]	5.0 (1.0–11.0)	5.0 (1.0–10.0)	4.0 (1.0–10.0)	6.0 (3.0–12.0)	5.0 (1.0–11.0)	0.0788

3MSE indicates Modified Mini-Mental State Examination; ADL/IADL, activities of daily living/instrumental activities of daily living; IQCODE, Informant Questionnaire on Cognitive Decline in the Elderly; IQR, interquartile range; NIHSS, National Institutes of Health Stroke Scale; PHQ-8, Patient Health Questionnaire 8; SS-QoL, abbreviated Stroke Specific Quality of Life Scale.

*Numbers relate to analytic population for death/recurrence, unless otherwise noted. Other populations are similar.

[†]χ^2 or ANOVA test. For categorical variables where expected cell count was <5 for >50% of cells, *P* value associated with χ^2 test is not provided as test is likely not valid.

[‡]Some participants missing data.

[§]Censored at death or December 31, 2019.

[‖]Censored at December 31, 2019.

[¶]ADL/IADL and 3MSE population (2009–2019; N=1284).

[#]SS-QoL population (2010–2019; N=1189).

[**]PHQ-8 population (2011–2019; N=1086).

Table 2. HR for Stroke Recurrence and All-Cause Death, 25th Relative to 75th Percentile of Resource Density (N=1786)

Model*	All-cause death (event=441)		Stroke recurrence (event=205)	
	HR (95% CI)	*P* value	HR (95% CI)	*P* value
1: Unadjusted	1.040 (0.865–1.249)	0.6777	1.003 (0.775–1.297)	0.9832
2: 1+Demographics	1.039 (0.865–1.248)	0.6791	0.991 (0.759–1.294)	0.9483
3: 2+Individual SES	1.043 (0.868–1.253)	0.6543	0.990 (0.758–1.293)	0.9435
4: 3+Prestroke health and behaviors	1.019 (0.849–1.223)	0.8386	0.986 (0.755–1.287)	0.9156
5: 4+Interpersonal factors	1.017 (0.847–1.222)	0.8528	0.978 (0.748–1.279)	0.8701
6: 5+Neighborhood SES	1.013 (0.840–1.221)	0.8918	0.968 (0.737–1.270)	0.8131
7: 6+Stroke type and severity	1.006 (0.834–1.214)	0.9498	0.975 (0.743–1.279)	0.8552
8: 7+Stroke severity interaction Mild Moderate–severe	1.063 (0.858–1.317)‡ 0.859 (0.591–1.248)‡	0.3276† 0.5777 0.4238	1.011 (0.749–1.366)‡ 0.842 (0.458–1.550)‡	0.5956† 0.9417 0.5817
9: 7+Sex interaction Male Female	0.914 (0.706–1.182)‡ 1.126 (0.861–1.473)‡	0.2622† 0.4907 0.3854	0.985 (0.694–1.398)‡ 0.961 (0.629–1.468)‡	0.9296† 0.9320 0.8535
10: 7+Race and ethnicity interaction Mexican American Non-Hispanic White	1.088 (0.847–1.397)‡ 0.918 (0.694–1.213)‡	0.3677† 0.5110 0.5459	0.963 (0.693–1.339)‡ 0.999 (0.632–1.581)‡	0.8962† 0.8230 0.9981

HR indicates hazard ratio; and SES, socioeconomic status.

*(1) Unadjusted model sequentially adjusted for (2) age quartile, sex, race and ethnicity; (3) education attainment, insurance; (4) modified Rankin scale, informant questionnaire on cognitive decline in the elderly, depression, comorbidity score, smoking; (5) marital, social support score; (6) neighborhood disadvantage score, neighborhood affluence score; (7) stroke type and severity. Interactions terms applied to model 7 for (8) stroke severity, (9) sex, and (10) race and ethnicity.

†Interaction term *P* value.

‡HR computed for each stratum of interaction term using coefficients for resource density and interaction terms.

with lower walk score (contrary to what we would expect on the basis of our findings).[22–24] These studies were limited by a cross-sectional design, inclusion of prevalent stroke survivors, and the eligibility criteria (eg, those who could walk and without health conditions impacting mobility or communication ability) likely resulted in a mild-stroke survivor population and may not be generalizable to those who experience moderate–severe stroke.[22–24] The current study benefited from a longitudinal design using a population-based cohort and the ability to consider stroke severity/control for many confounders.

There are several potential mechanisms by which neighborhood resources may impact stroke outcomes. Neighborhood resources are posited to provide opportunities for poststroke physical activity, socialization, community engagement, and cognitive stimulation (eg, navigating, conversing, and decision making).[16–18] Among older adults, studies have supported associations between overall neighborhood resources with physical activity, social participation, and health outcomes like cognition, QOL, and depression.[37,38,55,63] Neighborhood resources may be particularly important to stroke survivors who are reported to spend more time in their neighborhood than those of similar age who have not had a stroke.[6,45,64–66]

The potential benefit of neighborhood resources may have implications for rehabilitation for community-dwelling stroke survivors. One component of poststroke rehabilitation is physical activity.[67] Stroke survivors are often physically inactive despite recommendations.[67] The American Heart Association/American Stroke Association recommends addressing commonly reported environmental barriers, such as lack of availability or awareness of opportunities for physical activity.[67] A qualitative study on integrating the environment into poststroke rehabilitation reported that rehabilitation tended to be generic and include little consideration of the environment beyond the home.[68] Kylen et al highlighted that survivors believed their rehabilitation would benefit from not only considering obstacles in the home but also neighborhood resources.[68] The neighborhood resources we included are purported to be beneficial by stroke survivors, their caregivers, and older adults in general.[9,19,20,33–38] Our findings suggest that neighborhood resources may be beneficial for stroke recovery efforts; however, these benefits may be small and not noticeable by the survivors or their caregivers.

This study has some limitations. The study was conducted in an urban area in Texas, and results may not be generalizable to other regions. This study may not be generalizable to rural areas or regions with

Table 3. Difference in 3-Month Poststroke Outcomes Associated With an IQR Difference in Density of Resources

Model*	ADL/IADL (N=1284)		3MSE (N=1284)	
	IQR difference (95% CI)	*P* value	IQR difference (95% CI)	*P* value
1: Unadjusted	0.051 (−0.035 to 0.138)	0.2441	0.343 (−0.841 to 1.526)	0.5703
2: 1+Demographics	0.042 (−0.033 to 0.117)	0.2734	0.319 (−0.665 to 1.304)	0.5250
3: 2+Individual SES	0.043 (−0.029 to 0.114)	0.2419	0.279 (−0.498 to 1.055)	0.4819
4: 3+Prestroke health and behaviors	0.021 (−0.042 to 0.084)	0.5185	0.549 (−0.201 to 1.300)	0.1514
5: 4+Interpersonal factors	0.016 (−0.046 to 0.078)	0.6156	0.608 (0.376 to −0.130)	0.1065
6: 5+Neighborhood SES	−0.008 (−0.068 to 0.053)	0.8077	0.776 (0.030 to 1.522)	0.0415
7: 6+Stroke type and severity	−0.015 (−0.075 to 0.045)	0.6207	0.838 (0.092 to 1.584)	0.0277
8: 7+Stroke severity interaction Mild Moderate–severe	0.020 (−0.046 to 0.086)‡ −0.156 (−0.284 to −0.027)‡	0.0145† 0.5502 0.0176	0.613 (−0.216 to 1.443)‡ 1.714 (−0.004 to 3.433)‡	0.2591† 0.1474 0.0506
9: 7+Sex interaction Male Female	0.019 (−0.061 to 0.098) −0.054 (−0.139 to 0.031)	0.2036† 0.6407 0.2154	1.217 (0.187 to 2.247)‡ 0.411 (−0.684 to 1.506)‡	0.2963† 0.0206 0.4615
10: 7+Race and ethnicity interaction Mexican American Non-Hispanic White	0.003 (−0.074 to 0.081)‡ −0.041 (−0.131 to 0.049)‡	0.4540† 0.9321 0.3753	1.167 (0.194 to 2.140)‡ 0.381 (−0.789 to 1.551)	0.3145† 0.0188 0.5232
	SS-QoL (N=1189)		PHQ-8 (N=1086)	
1: Unadjusted	−0.016 (−0.123 to 0.092)	0.7759	0.114 (−0.529 to 0.757)	0.7281
2: 1+Demographics	−0.007 (−0.098 to 0.085)	0.8861	0.097 (−0.440 to 0.634)	0.7232
3: 2+Individual SES	−0.003 (−0.088 to 0.081)	0.9372	0.098 (−0.418 to 0.614)	0.7100
4: 3+Prestroke health and behaviors	0.028 (−0.043 to 0.100)	0.4410	−0.036 (−0.529 to 0.457)	0.8854
5: 4+Interpersonal factors	0.029 (−0.042 to 0.100)	0.4187	−0.033 (−0.529 to 0.463)	0.8962
6: 5+Neighborhood SES	0.051 (−0.019 to 0.121)	0.1502	−0.065 (−0.549 to 0.419)	0.7915
7: 6+Stroke type and severity	0.058 (−0.010 to 0.125)	0.0933	−0.083 (−0.569 to 0.404)	0.7385
8: 7+Stroke severity interaction Mild Moderate–severe	0.025 (−0.051 to 0.102) 0.194 (0.029 to 0.359)	0.0779† 0.5186 0.0214	−0.034 (−0.581 to 0.514) −0.294 (−1.461 to 0.872)	0.6966† 0.9042 0.6207
9: 7+Sex interaction Male Female	0.074 (−0.022 to 0.170) 0.039 (−0.067 to 0.145)	0.6459† 0.1293 0.4689	−0.420 (−1.093 to 0.253) −0.317 (−0.420 to 1.054)	0.1583† 0.2215 0.3990
10: 7+Race and ethnicity interaction Mexican American Non-Hispanic White	0.060 (−0.061 to 0.151) 0.054 (−0.053 to 0.161)	0.9322† 0.1941 0.3206	0.013 (−0.646 to 0.672) −0.205 (−0.959 to 0.549)	0.6761† 0.9701 0.5935

3MSE indicates Modified Mini-Mental State Exam; ADL/IADL, activities of daily living/instrumental activities of daily living; HR, hazard ratio; IQR, interquartile range; PHQ-8, Patient Health Questionnaire 8; SES, socioeconomic status; and SS-QoL, abbreviated Stroke-Specific Quality of Life scale.

*(1) Unadjusted model sequentially adjusted for (2) age quartile, sex, race and ethnicity; (3) education attainment, insurance; (4) modified Rankin scale, informant questionnaire on cognitive decline in the elderly, depression, comorbidity score, smoking; (5) marital status, social support score; (6) neighborhood disadvantage score, neighborhood affluence score; (7) stroke type and severity. Interactions terms applied to model 7 for (8) stroke severity, (9) sex, and (10) race and ethnicity.

†Interaction term *P* value.

‡HRs computed for each stratum of interaction term using coefficients for resource density and interaction terms.

different cultures or colder climates. This study may not be generalizable to areas reflecting different racial and ethnic distributions, particularly those racial and ethnic groups we were not able to include; however, we did not identify race and ethnicity as an effect modifier between non-Hispanic White and Mexican American individuals.[8,9] We also note our exposure used resource density within the residential census tract as a proxy for frequenting these resources.[30,35] We did not assess whether survivors frequented these resources or other intermediates (eg, physical activity, socialization). Additionally, we defined neighborhood with census tract, which may have resulted in misclassification of resources frequented.[18,69] This is likely to be nondifferential and bias findings toward the null and could be a possible reason for the minimal differences observed. Furthermore, we don't know if certain types of resources may be more or less beneficial than other types of resources. Of note, we included fast food places and post offices; however, reported results conflict and these resources may be detrimental.[18,19,33–35] If resources that are detrimental rather than beneficial

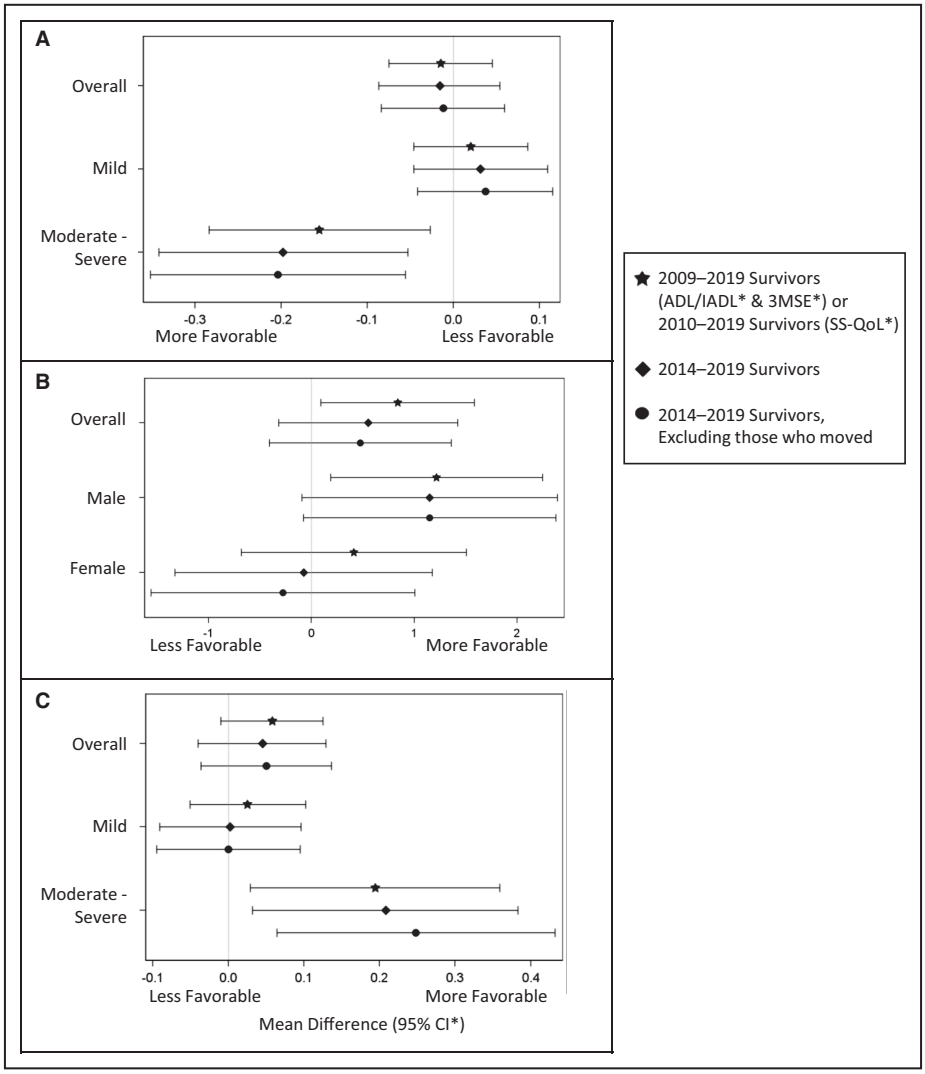

Figure 2. Average difference in 90-day poststroke outcomes associated with interquartile range difference in density of resources.
A, Functioning (ADL/IADL)*—overall and by stroke severity. **B**, Cognition (3MSE)*—overall and by sex. **C**, Quality of Life (SS-QoL)*—overall and by stroke severity. 3MSE indicates Modified Mini-Mental State Exam; ADL/IADL, activities of daily living/instrumental activities of daily living; SS-QoL, abbreviated Stroke-Specific Quality of Life scale.

are included in our measure of neighborhood resource density, we would expect this to have reduced the observed effect size and biased our results toward the null. There remains potential confounding, particularly due to individual factors related to self-selection into a neighborhood (eg, prior health status, comorbidities, and health behaviors), although we controlled for many individual-level factors.[52] Other sources of residual confounding include neighborhood factors like sidewalk quality, public transit availability, and safety; these are, in part, controlled by adjustment for neighborhood SES.[19,21,53] We also acknowledge lack of data on the use of secondary prevention medications. Following a stroke, the use of secondary prevention medications is an important prognostic factor and expected to have a significant impact on stroke outcomes. However, the use of these medications seems unlikely to be associated with our exposure through self-selection into a neighborhood. Therefore, the use of secondary prevention medications is not likely to confound the association between neighborhood resources and poststroke outcomes.

In conclusion, we observed that greater neighborhood resource density was associated with more favorable cognition among overall stroke survivors and with more favorable functioning and QOL among moderate–severe stroke survivors; however, differences were minimal. Further research is needed to confirm these findings and identify potential mechanisms. We also observed no association between neighborhood

resource density and poststroke recurrence, death, or depression. Future research is needed to determine whether certain types of resources or other neighborhood features may have a greater effect on poststroke outcomes and support secondary stroke prevention, poststroke survival, or reduced poststroke depression.

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Supplemental Material

Tables S1–S4

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