

Association of Neighborhood Socioeconomic Context With Participation in Cardiac Rehabilitation

Justin M. Bachmann, MD, MPH; Shi Huang, PhD; Deepak K. Gupta, MD, MSCI; Loren Lipworth, ScD; Michael T. Mumma, MS; William J. Blot, PhD; Elvis A. Akwo, MD, PhD; Sunil Kripalani, MD, MSc; Mary A. Whooley, MD; Thomas J. Wang, MD; Matthew S. Freiberg, MD, MSc

Background—Cardiac rehabilitation (CR) is underutilized in the United States, with fewer than 20% of eligible patients participating in CR programs. Individual socioeconomic status is associated with CR utilization, but data regarding neighborhood characteristics and CR are sparse. We investigated the association of neighborhood socioeconomic context with CR participation in the SCCS (Southern Community Cohort Study).

Methods and Results—The SCCS is a prospective cohort study of 84 569 adults in the southeastern United States from 2002 to 2009, 52 117 of whom have Medicare or Medicaid claims. Using these data, we identified participants with hospitalizations for myocardial infarction, percutaneous coronary intervention, or coronary artery bypass surgery and ascertained their CR utilization. Neighborhood socioeconomic context was assessed using a neighborhood deprivation index derived from 11 census-tract level variables. We analyzed the association of CR utilization with neighborhood deprivation after adjusting for individual socioeconomic status. A total of 4096 SCCS participants (55% female, 57% black) with claims data were eligible for CR. CR utilization was low, with 340 subjects (8%) participating in CR programs. Study participants residing in the most deprived communities (highest quintile of neighborhood deprivation) were less than half as likely to initiate CR (odds ratio 0.42, 95% confidence interval, 0.27–0.66, $P<0.001$) as those in the lowest quintile. CR participation was inversely associated with all-cause mortality (hazard ratio 0.77, 95% confidence interval, 0.60–0.996, $P<0.05$).

Conclusions—Lower neighborhood socioeconomic context was associated with decreased CR participation independent of individual socioeconomic status. These data invite research on interventions to increase CR access in deprived communities. (*J Am Heart Assoc.* 2017;6:e006260. DOI: 10.1161/JAHA.117.006260.)

Key Words: cardiac rehabilitation • neighborhood deprivation • cardiovascular mortality • socioeconomic position

Cardiac rehabilitation (CR) is a suite of services including prescriptive exercise that is a critical component of the continuum of care for patients with cardiovascular disease (CVD).^{1–3} CR is indicated for patients with acute myocardial infarction, percutaneous coronary intervention, coronary artery bypass surgery, cardiac valve surgery, stable angina, and stable systolic heart failure. CR participation increases quality of life and decreases the risk of all-cause mortality,

CVD mortality,⁴ and recurrent CVD events.⁵ Unfortunately, CR is profoundly underutilized, with only 15% to 20% of eligible patients participating in CR programs nationally.⁶ CR participation rates are particularly low in underrepresented minorities,^{7,8} and are lower than the national average in the southeastern United States.⁸

Barriers to participation in CR are myriad, spanning patient, physician, community, and health system factors, and there

From the Division of Cardiovascular Medicine, Department of Medicine (J.M.B., D.K.G., T.J.W., M.S.F.), Vanderbilt Translational and Clinical Cardiovascular Research Center (J.M.B., S.H., D.K.G., L.L., E.A.A., T.J.W., M.S.F.), Department of Biostatistics (S.H.), Division of Epidemiology, Department of Medicine (L.L., W.J.B., E.A.A.), Vanderbilt Institute for Clinical and Translational Research (M.T.M.), and Division of General Internal Medicine & Public Health (S.K.), Vanderbilt University Medical Center, Nashville, TN; Measurement Science Quality Enhancement Research Initiative, Department of Veterans Affairs (M.A.W.) and Department of Medicine (M.A.W.), University of California San Francisco, San Francisco, CA.

An accompanying Table S1 is available at <http://jaha.ahajournals.org/content/6/10/e006260/DC1/embed/inline-supplementary-material-1.pdf>

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Correspondence to: Justin M. Bachmann, MD, MPH, 2525 West End Ave, Cardiovascular Research, Nashville, TN 37203. E-mail: justin.m.bachmann@vanderbilt.edu

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Clinical Perspective

What Is New?

- Neighborhood socioeconomic characteristics are strongly associated with cardiac rehabilitation attendance, even after adjusting for individual socioeconomic status.

What Are the Clinical Implications?

- Patients living in deprived communities are at greater risk of cardiac rehabilitation nonattendance, illustrating the importance of developing novel methods to expand cardiac rehabilitation access to underserved populations.

are marked ethnic and regional disparities in CR referral and participation rates.⁶ One of these patient factors, individual socioeconomic status, is directly associated with CR participation.⁹ Recently, the effect of a patient's environment (ie, neighborhood socioeconomic context) has been studied with regard to cardiovascular outcomes. High levels of neighborhood deprivation are associated with all-cause¹⁰ and cardiovascular mortality¹¹ independent of socioeconomic status. The effect of neighborhood deprivation on CR participation has not been characterized, however.

In this study, we used the SCCS (Southern Community Cohort Study), a prospective cohort of nearly 85 000 adults in the southeastern United States, to evaluate the effect of neighborhood deprivation on CR participation. The majority of SCCS participants have low income levels, and thus the SCCS represents an ideal population with which to study patterns of CR utilization in deprived communities.

Methods

Data Sources

The SCCS is an ongoing prospective cohort study of over 85 000 adults recruited in 12 southeastern states from 2002 to 2009 to investigate the determinants of cancer and other chronic diseases.¹² Participants were recruited at community health centers or by mail, and completed a survey that collects baseline data on a variety of demographic, social, medical, and lifestyle factors. All study participants gave informed consent upon enrollment.

Data for SCCS participants who receive Medicare coverage were linked to the Centers for Medicare and Medicaid Services Research Identifiable Files by age, sex, date of birth, and Social Security numbers (which are available for >95% of the cohort). Similarly, data for SCCS participants with Medicaid coverage were linked to individual state Medicaid files. Mortality data were obtained from linkage to the National Death Index and the Social Security Administration's

Death Master File. A list of centers providing CR services was obtained by identifying facilities associated with CR claims. We then obtained the geographic coordinates of these facilities.

The institutional review board of Vanderbilt University Medical Center approved the study, as did the SCCS Data and Biospecimen Use Committee.

Participants

The study sample initially included SCCS participants with linked Medicare or Medicaid data and who reside in the United States. Using International Classification of Diseases 9th Revision (ICD-9) codes and Current Procedure Terminology codes, we identified participants who were hospitalized for a qualifying diagnosis (and thus eligible for CR) from 1999 to 2012 and had uninterrupted fee-for-service Medicare or Medicaid coverage for 1 year after the index hospitalization. Qualifying diagnoses included the following: acute myocardial infarction (ICD9 410.xx); percutaneous transluminal coronary angioplasty or coronary stenting (ICD-9 00.66, 17.55, 36.0x or Current Procedure Terminology 92973, 92974, 92980–92982, 92984, 92995, 92996, G0290, G0291); and coronary artery bypass surgery (CABG, ICD-9 36.10–36.16, 36.19, 36.2 or Current Procedure Terminology 33510–33514, 33516–33519, 33521–33523, 33533–33536, 33572, 35600, 93564, S2205–S2209).

Some patients had multiple eligibility diagnoses during the same admission. In these cases, any patient who had a CABG was placed in the CABG category regardless of other diagnoses. Participants who had both an acute myocardial infarction and percutaneous coronary intervention were placed in the acute myocardial infarction category. For patients with more than 1 qualifying admission, the earliest admission was considered the "index" admission.

Neighborhood Deprivation Index

Neighborhood socioeconomic status, as measured by a neighborhood deprivation index (NDI),¹³ was our primary explanatory variable. The SCCS-NDI has been described in prior work.¹⁰ Briefly, a principal components analysis was performed on 20 census tract-level variables among all census tracts of SCCS participants. Based on this analysis, 11 census-tract variables were used to construct the SCCS-NDI: (1) percentage of persons age >25 who did not graduate high school; (2) percentage of males and females age ≥25 years who were unemployed; (3) percentage of males in professional occupations; (4) percentage of housing units with ≥1 occupant per room; (5) percentage of occupied housing units with renter/owner costs >50% of income; (6) percentage of persons with income below the 1999 poverty level; (7)

percentage of female-headed households with dependent children; (8) percentage of households with income <\$30 000 per year; (9) percentage of households with public assistance income; (10) percentage of households with no car; and (11) median household value. The SCCS-NDI was divided into quintiles, with quintile 1 representing the least deprived neighborhoods and quintile 5 representing the most deprived neighborhoods.

Outcomes

Participation in CR programs, defined as a binary variable (yes/no), was the primary outcome. We searched the outpatient Medicare and Medicaid files for CR claims (Current Procedural Terminology codes 93797, 93798, G0422, G0423, or S9472) occurring within 1 year after the index hospitalization.

Secondary outcomes included: (1) cardiac rehabilitation as a continuous variable, defined as the number of sessions attended; (2) all-cause mortality; and (3) cardiovascular mortality, defined by ICD-9 codes 390.0 to 458.9 or their equivalents from ICD-8 or ICD-10. We truncated follow-up for mortality at 10 years to prevent confounding by small sample sizes beyond this time period.

Covariates

We obtained comorbidities from the baseline survey. Comorbid conditions of interest included chronic obstructive pulmonary disease, current smoking, depression, diabetes mellitus, hypertension, obesity, prior myocardial infarction, prior coronary artery bypass grafting, prior stroke, and prior transient ischemic attack. Depression was defined as a Center for Epidemiologic Studies Short Depression Scale 10 (CESD10) score of 10 or greater. Individual socioeconomic status was characterized by annual household income (<\$15 000, \$15 000–\$24 999, or >\$25 000) and educational level (no high school diploma, high school diploma, or college diploma). We also calculated the distance between the participant's residence and the nearest CR center using geocodes.

Statistical Analysis

Baseline characteristics of SCCS participants who attended CR programs were compared with those who did not, using Pearson's χ^2 test and Wilcoxon tests. We used logistic regression to evaluate the effect of individual covariates on CR participation rates. A Cox proportional hazards model for all-cause and cardiovascular mortality was constructed using the same covariates. We also used Kaplan–Meier survival curves to compare all-cause and cardiovascular mortality

between SCCS participants who attended CR and those who did not. We performed sensitivity analyses to account for potential clustering of participants within census tracts (data nonindependence). The Huber-White method was used to adjust standard errors of parametric estimates. Because these results were almost identical to the primary analyses, we reported the analyses without Huber-White adjustment.

All analyses used SAS version 9.4¹⁴ and R version 3.1.2.¹⁵

Results

There were 52 117 SCCS participants who received Medicare or Medicaid coverage from 1999 to 2012. Of these, 4552 were hospitalized for acute myocardial infarction, coronary artery bypass grafting (CABG), or percutaneous coronary intervention and had uninterrupted fee-for-service Medicare or Medicaid coverage for 1 year after the index admission. We excluded 456 SCCS participants because of missing data, yielding a final sample size of 4096 CR-eligible patients. Of the 456 SCCS participants with missing data, 161 (35%) were excluded because of missing household income, 120 (26%) were excluded because of missing education levels, and 64 (14%) were excluded because of missing residence location.

A total of 340 SCCS participants in the sample (8%) initiated CR (Table 1). The number of CR sessions attended had a range of 1 to 36, with a median of 4 sessions and an interquartile range of 3 sessions. A majority of the 4096 study participants were black (57%). Most members of the cohort were poor (70% of participants had a household income of <\$15 000) and 44% had not completed high school. Almost all participants had Medicare or Medicaid as their primary form of insurance, and 16% had some form of private insurance. There was a high burden of cardiovascular disease in this population, with 32% reporting a history of myocardial infarction, 18% reporting prior CABG, and 46% reporting a history of diabetes mellitus.

A neighborhood deprivation index (SCCS-NDI) was constructed to illustrate relative neighborhood socioeconomic status for each SCCS participant's census tract. The SCCS-NDI had a relatively normal distribution (Figure 1). Individual components of the SCCS-NDI, as well as their correlation coefficients with CR, are displayed in Table S1. The SCCS-NDI was strongly associated with the odds of initiating CR after multivariable adjustment (Figure 2). Compared with the lowest quintile of neighborhood deprivation, SCCS participants residing in areas in the highest quintile of neighborhood deprivation were less than half as likely to initiate CR (OR 0.42, 95% confidence interval [CI], 0.27–0.66, $P<0.001$). When analyzed as a continuous variable, there was a 15% decrease in the odds of attending CR for each point increase in the SCCS-NDI (OR 0.85, 95% CI, 0.75–0.96, $P<0.01$).

Table 1. Characteristics of SCCS Participants Eligible for CR (N=4096)

Characteristic	All (N=4096)	CR Nonparticipants (N=3756)	CR Participants (N=340)	P Value
Number of CR sessions attended	n/a	n/a	4 (2, 5)	n/a
Eligibility diagnosis				
AMI	32% (1323)	32% (1207)	34% (116)	<0.001*
PCI	50% (2034)	51% (1924)	32% (110)	
CABG	18% (739)	17% (625)	34% (114)	
Demographic				
Age (y)	59 (52, 66)	59 (52, 66)	64 (57, 69)	<0.001 [†]
Male	45% (1839)	44% (1663)	52% (176)	<0.01*
Black	57% (2331)	58% (2170)	47% (161)	<0.001*
Distance to nearest CR center, km	8.3 (3.8, 24.5)	8.3 (3.8, 25.2)	8.3 (3.6, 17.7)	<0.05 [†]
Neighborhood socioeconomic status				
Neighborhood deprivation index	0.52 (−0.12, 1.45)	0.57 (−0.09, 1.49)	0.15 (−0.38, 0.96)	<0.001*
Individual socioeconomic status				
Education				
Did not complete high school	44% (1788)	45% (1681)	31% (107)	<0.001*
Completed high school	49% (2017)	49% (1839)	52% (178)	
Completed college	7% (291)	6% (236)	16% (55)	
Household income				
<\$15 000	70% (2847)	71% (2675)	51% (172)	<0.001*
\$15 000 to \$24 999	18% (738)	18% (669)	20% (69)	
>\$25 000	12% (511)	11% (412)	29% (99)	
Health insurance				
Private	16% (647)	14% (538)	32% (109)	<0.001*
Medicaid	39% (1596)	40% (1505)	27% (91)	
Medicare	45% (1853)	46% (1713)	41% (140)	
Comorbidities				
BMI	30.2 (26.0, 35.4)	30.3 (26.0, 35.6)	29.9 (26.5, 33.9)	0.54 [†]
COPD	16% (639)	16% (586)	16% (53)	0.99*
CESD10 score	9 (5, 13)	9 (5, 14)	7 (3, 11)	<0.001 [†]
Diabetes mellitus	46% (1875)	46% (1723)	45% (152)	0.68*
Hypertension	78% (3199)	78% (2924)	81% (275)	0.20*
Smoking	39% (1602)	40% (1516)	25% (86)	<0.001*
Stroke/TIA	17% (705)	18% (658)	14% (47)	0.08*

Values are displayed as median, (25th%, 75th%) or percentages, n. AMI indicates acute myocardial infarction; BMI, body mass index; CABG, coronary artery bypass grafting; CESD10, Center for Epidemiologic Studies Short Depression Scale 10; COPD, chronic obstructive pulmonary disease; CR, cardiac rehabilitation; n/a, not applicable; PCI, percutaneous coronary intervention; SCCS, Southern Community Cohort Study; TIA, transient ischemic attack.

*Pearson χ^2 test.

[†]Wilcoxon test.

Older SCCS participants were more likely to participate in CR than younger participants (Table 2). Those who completed college were more likely to attend CR programs as compared with those who did not complete high school (OR 1.61, 95% CI, 1.06–2.44, $P<0.05$), and study participants with a

household income $> \$25\ 000$ were more likely to initiate CR than those making less than \$15 000 a year (OR 1.68, 95% CI, 1.17–2.42, $P<0.01$). Compared with SCCS participants with private insurance, those with only Medicaid or Medicare coverage were less likely to initiate CR. Smokers were also

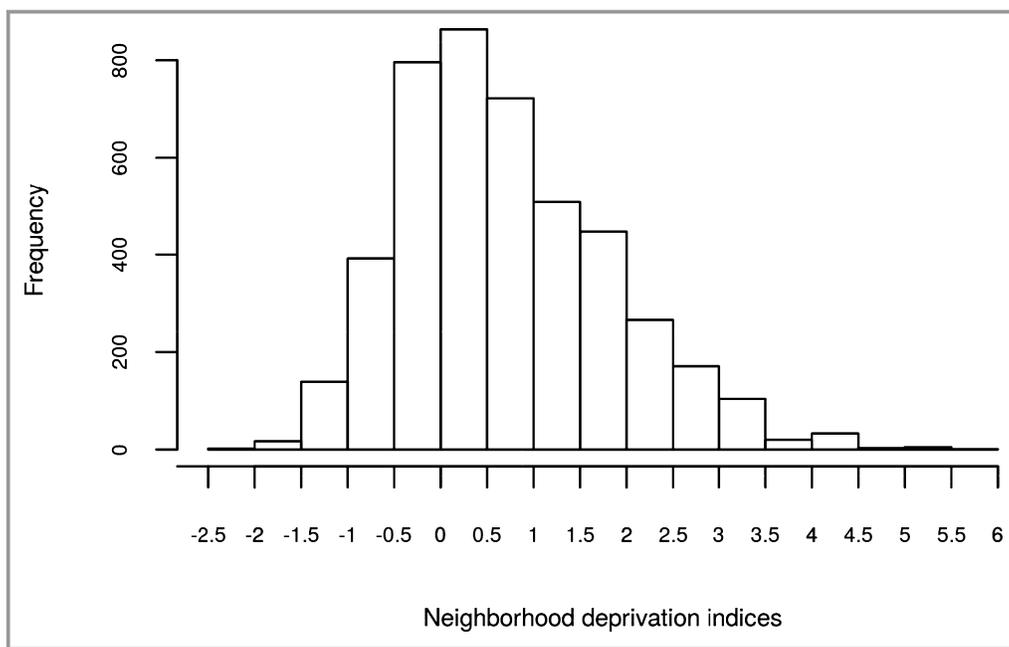


Figure 1. Distribution of neighborhood deprivation indices among Southern Community Cohort Study participants eligible for cardiac rehabilitation (N=4096).

less likely to participate in CR programs as compared with nonsmokers (OR 0.65, 95% CI, 0.49–0.85, $P<0.01$). A change from the 25th quartile of distance from the patient’s residence (3.8 km) to the 75th quartile (25 km) was associated with a 29% decrease in the odds of attending CR (OR 0.71, 95% CI, 0.59–0.84, $P<0.001$).

Among the 4096 SCCS participants in the study sample, there were 1073 all-cause deaths and 426 cardiovascular disease–related deaths over a total of 20 403 person-years of follow-up. There was an inverse association between CR

attendance and all-cause mortality (hazard ratio 0.77, 95% CI, 0.60–0.996, $P<0.05$) after multivariable adjustment (Table 3). A survival curve for all-cause mortality, stratified by CR participants and nonparticipants, is displayed in Figure 3. The association between neighborhood deprivation and all-cause mortality approached statistical significance (hazard ratio 1.09 for 75th versus 25th quartile, 95% CI, 1.0–1.20, $P=0.06$). Black race, male sex, diabetes mellitus, obesity, and smoking were all associated with a higher risk of all-cause mortality. Household income $> \$25\ 000$ was associated with decreased all-cause mortality.

CR participation was associated with a 35% decrease in CVD mortality (hazard ratio 0.65, 95% CI, 0.43–0.99, $P<0.05$) after multivariable adjustment. The survival curve for CVD mortality, stratified by CR participants and nonparticipants, is shown in Figure 4. As with all-cause mortality, the association between neighborhood deprivation and CVD mortality approached statistical significance (hazard ratio 1.15 for 75th versus 25th quartile, 95% CI, 0.99–1.32, $P=0.07$). Black race, male sex, diabetes mellitus, hypertension, and smoking were all associated with an increased risk of CVD mortality.

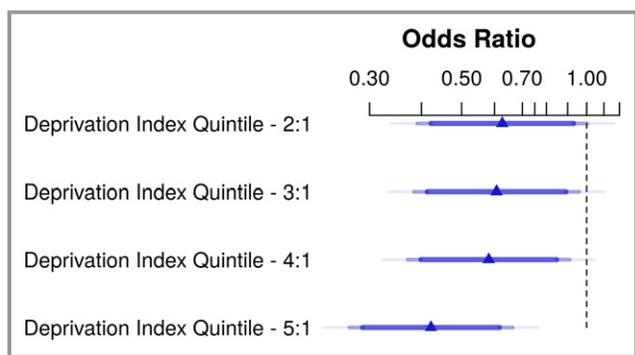


Figure 2. Forest plot of odds ratios of cardiac rehabilitation participation for each quintile of the neighborhood deprivation index, with 90%, 95%, and 99% confidence intervals (N=4096). The first quintile (referent) represents the lowest deprivation, and the fifth quintile represents the highest deprivation. Odds ratios are adjusted for eligibility diagnosis, age, sex, race, distance to the nearest cardiac rehabilitation center, education level, household income, health insurance type, and comorbidities.

Discussion

In this study of SCCS participants, we demonstrate that neighborhood socioeconomic status, as characterized by a neighborhood deprivation index, is strongly associated with the odds of attending CR programs even after adjusting for individual socioeconomic status. Moreover, CR is associated

Table 2. Multivariable-Adjusted Predictors of CR Participation in the SCCS Study (N=4096)

Characteristic	OR*	95% CI	P Value
Eligibility diagnosis			
AMI		Referent	
PCI	0.63	0.48, 0.84	<0.01
CABG	1.78	1.34, 2.38	<0.001
Demographic			
Age (y)			
<50		Referent	
50 to 64	1.57	1.04, 2.39	<0.05
≥65	1.86	1.20, 2.89	<0.01
Male	1.05	0.83, 1.35	0.67
Black	1.02	0.78, 1.33	0.89
Distance to nearest CR center, km (change from 25th quartile to 75th quartile)	0.71	0.59, 0.84	<0.001
Neighborhood socioeconomic status			
Neighborhood deprivation index quintiles			
1 (least deprived)		Referent	
2	0.63	0.39, 1.0	0.051
3	0.61	0.38, 0.96	<0.05
4	0.58	0.37, 0.91	<0.05
5 (most deprived)	0.42	0.27, 0.66	<0.001
Individual socioeconomic status			
Education			
Did not complete high school		Referent	
Completed high school	1.20	0.92, 1.58	0.18
Completed college	1.61	1.06, 2.44	<0.05
Household income			
<\$15 000		Referent	
\$15 000 to \$24 999	1.27	0.93, 1.73	0.14
>\$25 000	1.68	1.17, 2.42	<0.01
Health insurance			
Private		Referent	
Medicaid	0.65	0.44, 0.94	<0.05
Medicare	0.68	0.49, 0.95	<0.05
Comorbidities			
COPD	1.33	0.96, 1.85	0.09
Depression [†]	0.79	0.61, 1.02	0.07
Diabetes mellitus	0.97	0.76, 1.24	0.80
Hypertension	1.25	0.93, 1.70	0.14
Obesity [‡]	1.01	0.79, 1.29	0.96
Prior stroke/TIA	0.84	0.60, 1.17	0.29
Smoking	0.65	0.49, 0.85	<0.01

AMI indicates acute myocardial infarction; BMI, body mass index; CABG, coronary artery bypass grafting; CESD10, Center for Epidemiologic Studies Short Depression Scale 10; CI, confidence interval; COPD, chronic obstructive pulmonary disease; CR, cardiac rehabilitation; OR, odds ratio; PCI, percutaneous coronary intervention; SCCS, Southern Community Cohort Study; TIA, transient ischemic attack.

*The presented effects are from a fully adjusted logistic regression model including all listed covariates.

[†]Denotes CESD10 score ≥10.

[‡]Denotes BMI ≥30.

Table 3. Multivariable-Adjusted Predictors of All-Cause and CVD Mortality in the SCCS (N=4096)

Characteristic	All-Cause Mortality			CVD Mortality		
	HR*	95% CI	P Value	HR*	95% CI	P Value
Cardiac rehabilitation	0.77	0.60, 0.996	<0.05	0.65	0.43, 0.99	<0.05
Eligibility diagnosis						
AMI		Referent			Referent	
PCI	0.78	0.69, 0.90	<0.001	0.66	0.53, 0.82	<0.001
CABG	0.62	0.52, 0.75	<0.0001	0.67	0.51, 0.89	<0.01
Demographic						
Age (y)						
<50		Referent			Referent	
50 to 64	1.39	1.17, 1.64	<0.001	0.93	0.72, 1.19	0.56
≥65	1.94	1.60, 2.35	<0.0001	1.26	0.94, 1.69	0.11
Male	1.28	1.13, 1.45	<0.001	1.43	1.17, 1.75	<0.001
Black	1.36	1.18, 1.56	<0.0001	1.36	1.09, 1.71	<0.05
Neighborhood socioeconomic status						
Neighborhood deprivation index (change from 25th quartile to 75th quartile)	1.09	0.996, 1.196	0.06	1.15	0.99, 1.32	0.065
Individual socioeconomic status						
Education						
Did not complete high school		Referent			Referent	
Completed high school	1.10	0.97, 1.25	0.15	1.04	0.85, 1.28	0.71
Completed college	1.08	0.81, 1.43	0.62	1.07	0.70, 1.64	0.76
Household income						
<\$15 000		Referent			Referent	
\$15 000 to \$24 999	0.85	0.72, 1.01	0.06	0.96	0.74, 1.25	0.76
>\$25 000	0.70	0.54, 0.91	<0.01	0.88	0.60, 1.29	0.52
Health insurance						
Private		Referent			Referent	
Medicaid	1.11	0.89, 1.38	0.35	0.81	0.59, 1.13	0.22
Medicare	1.11	0.90, 1.37	0.33	0.95	0.70, 1.29	0.75
Comorbidities						
COPD	1.13	0.95, 1.33	0.16	1.07	0.81, 1.40	0.64
Depression [†]	1.06	0.94, 1.21	0.35	1.07	0.87, 1.31	0.52
Diabetes mellitus	1.54	1.35, 1.74	<0.0001	1.37	1.12, 1.67	<0.01
Hypertension	1.10	0.94, 1.29	0.23	1.39	1.06, 1.82	<0.05
Obesity [‡]	1.30	1.14, 1.47	<0.0001	1.03	0.84, 1.26	0.81
Prior stroke/TIA	0.92	0.79, 1.08	0.32	1.12	0.88, 1.41	0.36
Smoking	1.43	1.25, 1.63	<0.0001	1.24	1.01, 1.53	<0.05

AMI indicates acute myocardial infarction; BMI, body mass index; CABG, coronary artery bypass grafting; CESD10, Center for Epidemiologic Studies Short Depression Scale 10; CI, confidence interval; COPD, chronic obstructive pulmonary disease; CVD, cardiovascular disease; HR, hazard ratio; PCI, percutaneous coronary intervention; SCCS, SCCS, Southern Community Cohort Study; TIA, transient ischemic attack.

*The presented effects are from a fully adjusted Cox regression model including all listed covariates.

[†]Denotes CESD10 score ≥10.

[‡]Denotes BMI ≥30.

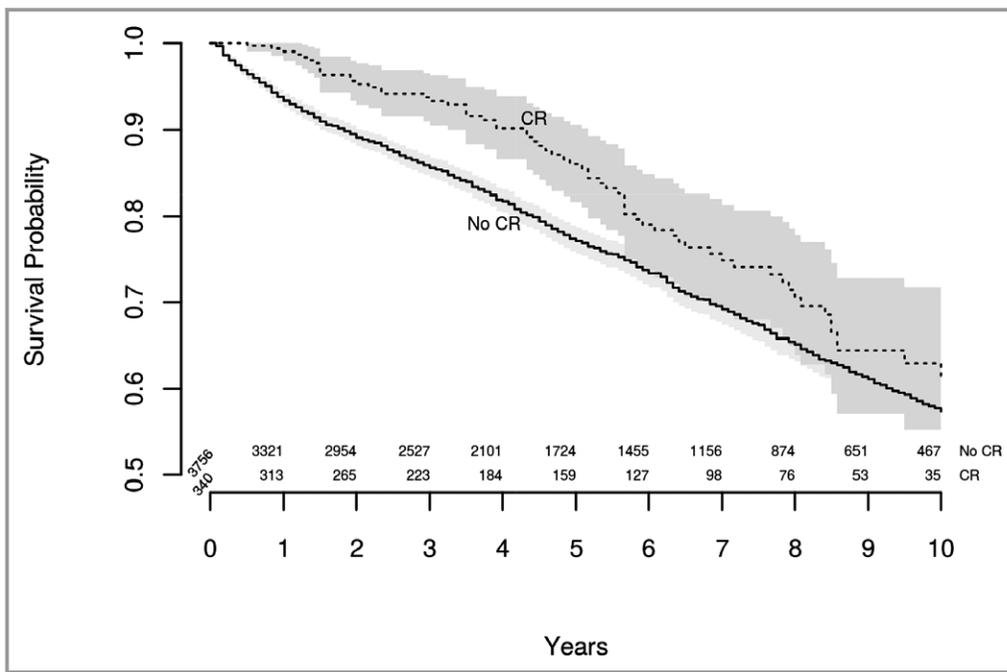


Figure 3. Kaplan–Meier survival curve for all-cause mortality over 10 years of follow-up, stratified by cardiac rehabilitation participants and nonparticipants (N=4096, $P=0.01$ by log-rank test). CR indicates cardiac rehabilitation.

with decreased risk of all-cause and CVD mortality in this population. To our knowledge, this is the first study examining the effect of neighborhood socioeconomic context on CR

participation rates. This is also one of the only studies to evaluate the effect of CR on mortality in a majority black cohort.

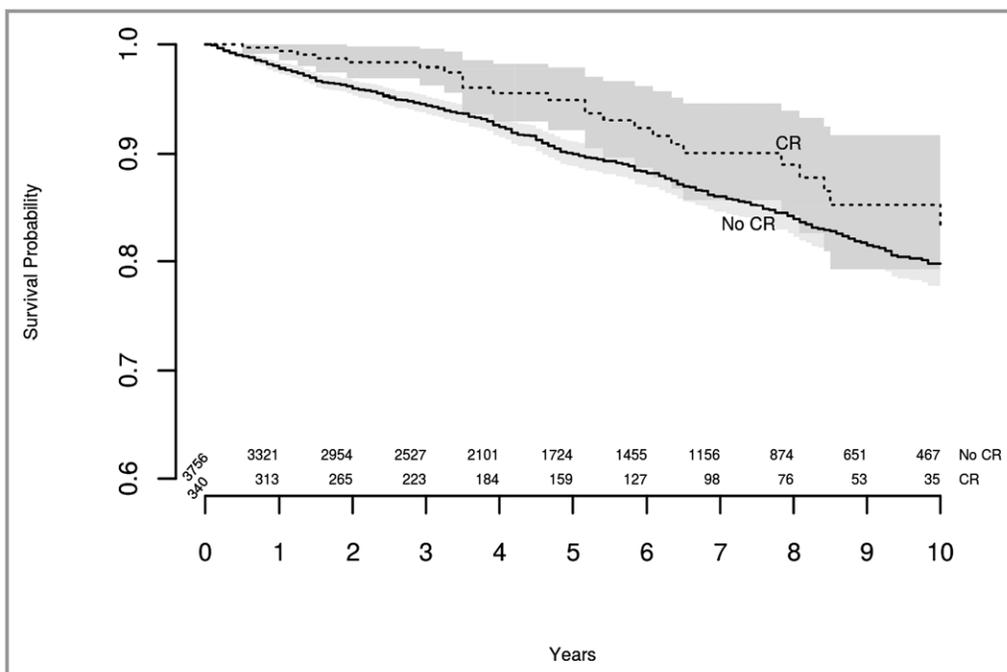


Figure 4. Kaplan–Meier survival curve for cardiovascular mortality over 10 years of follow-up, stratified by cardiac rehabilitation participants and nonparticipants (N=4096, $P=0.051$ by log-rank test). CR indicates cardiac rehabilitation.

Neighborhood deprivation was originally quantified to study perinatal health outcomes,¹³ and associations were quickly identified with all-cause mortality^{10,16} and an increased risk of rehospitalization.¹⁷ The socioeconomic context of neighborhoods was subsequently analyzed with regard to cardiovascular outcomes and found to affect the risk of myocardial infarction¹¹ as well as long-term mortality after myocardial infarction.¹⁸ The interplay of neighborhood socioeconomic context and cardiovascular disease is complex. Neighborhood deprivation is associated with increased higher coronary artery calcium in young, asymptomatic men, and thus may contribute to subclinical atherosclerosis.^{19,20} Deprived neighborhoods often have poor access to supermarkets and healthy food choices, leading to poorer diets and weight gain.^{21–23} Additionally, neighborhood deprivation is associated with negative health behaviors such as smoking and physical inactivity.^{24–27} One of the mechanisms by which neighborhood deprivation affects cardiovascular outcomes may be by diminished access to CR. Barriers to attending CR programs include lack of transportation, caregiver responsibilities, work responsibilities, and copays.^{28–33} Unsurprisingly, individual socioeconomic status (including income and education) is strongly associated with CR participation in prior studies.³⁴ Neighborhood deprivation provides a useful lens with which to view barriers to CR attendance in addition to individual socioeconomic status.

Participants in the SCCS likely experience significant barriers to CR, given the disadvantaged nature of the cohort. Unsurprisingly, the proportion of SCCS participants that initiated CR in our study is very low (8%), and significantly lower than the national average of $\approx 20\%$ of eligible patients.^{7,8,35} Those SCCS participants who did initiate CR attended fewer sessions (median 4, interquartile range 2–5) than Medicare patients nationally, who attend 24 to 25 sessions on average.^{7,8,35} Copays have a particularly detrimental impact on the number of CR sessions attended, especially among low-income patients, as copays are applied for each session. For Medicare patients without supplemental insurance, copays are $\approx \$20$ per session ($\$720$ for a full course of 36 sessions), while Medicaid coverage is variable.³⁶ Attending CR programs was likely financially prohibitive for many SCCS participants. The fact that SCCS patients with private insurance and those with higher income levels were more likely to attend CR programs supports this observation.

We also found that younger SCCS participants were less likely to attend CR. Work responsibilities are a significant barrier to CR in the younger SCCS population, as attending a full course of 36 CR sessions requires a 1-hour commitment 3 times per week for 12 weeks in addition to travel time to and from appointments. Interestingly, active smokers were much less likely to attend CR programs. This association is unfortunate, as CR incorporates smoking cessation therapy,

but it may represent an inherent resistance to risk factor modification and behavior change in this population.

Those SCCS participants who did attend CR programs appear to have experienced significant benefit in the form of decreased mortality. There was a 23% decrease in risk of all-cause mortality and a 35% decrease in risk of CVD mortality associated with CR. These effects are slightly larger than those in other studies, which generally demonstrate that CR is associated with a 20% decrease in all-cause mortality and a 25% decrease in CVD mortality.^{4,37–39} It is certainly feasible that CR would be particularly effective in this cohort. SCCS participants have high burdens of cardiovascular risk factors and low income and educational levels. The risk factor education that occurs within CR, coupled with prescriptive exercise, is likely to be highly efficacious in this population. There is a possibility of healthy cohort bias in our mortality analyses, as patients with more comorbidities are inherently less likely to attend CR. However, we controlled extensively for comorbidities as well as socioeconomic factors in our analyses.

In demonstrating that patients in deprived neighborhoods are at significant risk for CR nonattendance, our analyses invite further research on methods to reach out to these communities. Specifically, home-based CR programs may be well adapted to cardiovascular disease patients in deprived neighborhoods, as they offer the potential to ameliorate CR barriers such as transportation and work responsibilities. Home-based CR programs have demonstrated efficacy in Europe and are now being trialed in the United States.^{40–45} Additionally, efforts to decrease copays associated with CR would be very helpful in expanding access to deprived communities, as these costs are often prohibitive for many patients. Lastly, special efforts could be made to educate younger patients and smokers about the benefits of CR, as these patients are at highest risk of CR nonattendance.

Our analyses have limitations. First, our data were obtained from Centers for Medicare and Medicaid Services administrative claims linked to SCCS records. Claims data are not adjudicated and lack granular data on clinical characteristics. However, Centers for Medicare and Medicaid Services data have been used to effectively study many cardiovascular therapies, including CR, in prior work.^{3,7,8} Second, our analyses were limited to SCCS participants enrolled in fee-for-service Medicare and may not be generalizable to patients enrolled in Medicare private health plans. However, fee-for-service Medicare still accounted for 72% of Medicare beneficiaries in 2013.⁴⁶ Third, 10% of participants were excluded because of missing data. However, a complete case analysis is appropriate in terms of statistical power given the large size of the sample. Fourth, our data on insurance coverage and comorbidities came from self-report. However, self-reported cardiovascular conditions such as hypertension,

diabetes mellitus, and myocardial infarction are generally accurate, and the SCCS questionnaire is a comprehensive instrument.^{12,47,48} Lastly, we were unable to determine whether or not a SCCS participant was referred to CR with the available claims data. Future studies could examine the association of neighborhood deprivation with CR referral as well.

In summary, we found that lower neighborhood socioeconomic context, as quantified by a NDI, was associated with decreased CR participation independent of individual socioeconomic status. Participation in CR programs was associated with a significant decrease in all-cause and cardiovascular mortality in this majority black cohort. Our work invites further study on barriers to CR use in deprived communities and strategies to circumvent these barriers through outreach efforts.

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Disclosures

None.

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SUPPLEMENTAL MATERIAL

Table S1. Census tract components of the Southern Community Cohort Study Neighborhood Deprivation Index, stratified by cardiac rehabilitation usage (N=4096).

Characteristic	CR non-participants N=3756	CR participants N=340	p-value*	Polyserial correlation coefficient with CR†
Percentage of persons age \geq 25 that did not graduate HS	25, 32, 40	20, 28, 37	<0.001	-0.17
Percentage of males and females age who are unemployed	5.4, 8.2, 13.3	4.0, 6.2, 10.0	<0.001	-0.19
Percent males in professional occupations	5.7, 8.6, 12.7	6.7, 9.7, 14.4	<0.001	0.09
Percentage of housing units with \geq 1 occupant per room	2.6, 4.9, 8.4	1.7, 3.9, 6.4	<0.001	-0.12
Percentage of occupied housing units with renter/owner costs >50% of income	10, 14.2, 19.7	8.6, 12.0, 17.4	<0.001	-0.15
Percentage of persons with income below the 1999 poverty status	15, 23, 35	11, 18, 28	<0.001	-0.18
Percent female headed households with dependent children	6.8, 11.3, 17.8	5.6, 8.9, 14.5	<0.001	-0.11
Percentage of households with income <\$30,000 per year	45, 55, 67	38, 50, 62	<0.001	-0.18
Percentage of households with public assistance income	2.4, 4.3, 7.3	2.2, 3.7, 6.9	0.001	-0.08
Percentage of households with no car	7.1, 13.0, 22.3	5.3, 9.5, 17.8	<0.001	-0.12
Median household value	\$45075, \$56700, \$74925	\$52825, \$67100, \$89700	<0.001	0.13

CR, cardiac rehabilitation.
 All values are reported as medians and interquartile ranges (25th%, 50th%, 75th%).
 *Wilcoxon test.
 †All p-values <0.05.