Racial Residential Segregation and Colorectal Cancer Mortality in the Mississippi Delta Region

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Abstract

Background

Few studies have examined the effects of segregation on colorectal cancer (CRC) outcomes, and none has determined if rurality moderates the effect of segregation on CRC mortality. We examined whether the effect of segregation on CRC mortality was moderated by rurality in the Mississippi Delta Region, an economically distressed and historically segregated region of the United States.

Methods

Using data from the US Census Bureau and the Surveillance, Epidemiology, and End Results (SEER) program, we estimated linear mixed-effects models with state-level random effects in which Black and White CRC mortality rates in Delta Region counties (N = 252) were regressed on county rurality, White-Black residential segregation indices, an interaction term for these two variables, and a vector of socioeconomic control variables. Missing data were replaced with values generated via random forest imputation.

Results

Segregation was a risk factor for Black CRC mortality in urban Delta counties but was associated with lower Black CRC mortality in rural counties (B = − 23.30 [95% CI = − 38.51, − 7.92]). For Whites, living in a rural area did not moderate the relationship between segregation and CRC mortality, though White CRC mortality was inversely associated with White population proportion (B = − 7.12 [95% CI = − 10.66, − 3.43]).

Conclusions

Health outcomes related to segregation vary by racial, contextual and community factors. We give possible explanations for our findings and provide implications for practice and recommendations for further research to better understand the CRC mortality burden in segregated communities.

Background

Colorectal cancer (CRC) is the third most commonly diagnosed cancer and the second leading cause of cancer-related deaths among American adults [1]. While CRC mortality rates have decreased from 28.6 per 100,000 population in 1976 to 14.1 in 2014, higher mortality rates persist in the lower Mississippi Delta Region [2]. The Delta Region is comprised of 252 largely rural counties and parishes along the Mississippi River from Missouri, Illinois, Kentucky, Arkansas, Tennessee, Mississippi, Louisiana, and the Alabama “Black Belt” region [3]. From 2008–2012, CRC mortality rates in these eight states were higher in

Delta Region counties than in non-Delta counties [4]. Because of these elevated CRC mortality rates, a cluster of 94 counties in the Delta Region has been designated as the nation's largest CRC mortality "hotspot."[2] The Delta has a larger representation of poor Black residents; families living in low socio-economic conditions [5]; and higher rates of smoking, obesity, hypertension, and diabetes [6]. These factors, among others, contribute to the higher mortality burden in the Delta.

The largely-rural Delta Region is heavily segregated by race, with poorer health outcomes concentrated in its predominantly-Black Census blocks [7]. Individuals living in segregated areas have multiple negative health outcomes, such as poorer cardiovascular health [8], increased infant mortality [9], higher obesity rates [10], and reduced access to health care [11]. Although urban racial residential segregation has continued to decrease in the US as a whole, the opposite trend has occurred in rural areas [12]. Research has shown that highly-segregated Black neighborhoods often lack resources like hospitals, pharmacies, and full-service restaurants that lend social capital to residents [11, 13]. This disparity may be even more pronounced in segregated rural areas, where factors such as poverty and travel distance make it difficult enough to access resources.

While trends between rurality and cancer mortality are well known [4, 14–16], the confounding effect of race and residential segregation remains blurry. A systematic review of segregation and racial cancer disparities noted that 70% of included studies found that segregation contributed in some way to cancer, though not always negatively [17]. In highly-segregated areas, some studies report lower breast cancer and all-cause mortality for Black but not White women [18], higher breast cancer mortality for Black but not White women [19], and no associations between segregation and Black female breast cancer mortality [20–21] or survival [20]. For lung cancer, segregation has been linked to higher mortality rates for Black residents, but for White residents living in segregated areas, this association is either lower [22] or non-existent [23]. Given that the evidence on the effect of segregation on cancer outcomes is inconclusive, further investigation is needed to better understand these associations to assess allocation of resources and education for underserved and disparate populations in segregated areas.

For Delta residents, accounting for racial residential segregation is an important, but less investigated, structural and social determinant of health [7, 24]. Previous studies have investigated relationships between segregation and CRC outcomes throughout the continuum, including early-stage CRC diagnosis [25], late-stage CRC diagnosis [26], and treatment [24]. To date, few studies have examined the effects of segregation on CRC outcomes, and none has determined if rurality moderates the effect of segregation on CRC mortality among Black and White residents. Given that the Delta Region (1) encompasses the largest "hotspot" for CRC mortality (2) contains both rural and urban counties (as classified by rural-urban continuum code), and (3) contains regions that have been historically racially segregated, it provides a unique context within which to achieve the purpose of this study: to explore relationships between racial residential segregation and CRC mortality and determine whether effects of segregation differ by race and between rural and urban Delta residents.

Methods

Study Design and Outcome Variable

We used an ecological study design, with counties in the Delta Region as the unit of analysis (N = 252), in order to determine whether county rurality moderated the relationship between racial residential segregation and CRC mortality rates—our main outcome variable—for Blacks and Whites. We calculated age-standardized colorectal cancer mortality rates per 100,000 for Whites and Blacks separately in each Delta county for the most recently available time interval (2011–2015) using the National Cancer Institute's Surveillance, Epidemiology, and End Results (SEER) SEER*Stat (version 8.3.5), software that collects data from both SEER cancer registries and the National Center for Health Statistics [27]. Delta counties were identified using the Delta Regional Authority website [28].

Independent Variables

Racial residential segregation for Whites and Blacks in each Delta county was calculated with the multilevel index of dissimilarity (MLID), which improves upon the original index of dissimilarity by measuring the spatial clustering of segregation [29]. The MLID was calculated for each Delta county using 2011–2015 United States Census Bureau population count data for Whites and Blacks in three nested within-county Census geographies: block groups, tracts, and county subdivisions [30]. We used the Missouri Census Data Center Geographic Correspondence Engine (Geocorr) in order to map tracts onto county subdivisions, as some census tracts overlapped county subdivision boundaries [31]. According to Harris and Owen [29], the MLID can range from 0 (i.e., no segregation) to 1 (i.e., total segregation). Each county's MLID was calculated using the "MLID" package in R Studio version 3.6.1.

We determined county rurality using 2013 rural-urban continuum codes (RUCC) from the United States Department of Agriculture (USDA) [32]. RUCCs from the USDA range from 1 (i.e., counties in metro areas with populations greater than 1,000,000) to 9 (i.e., completely rural or an urban population greater than 2,500, not adjacent to a metro area). Similar to Zahnd and colleagues' approach [33], we dichotomized all RUCCs to indicate whether a county was urban (RUCCs 1 to 3) or rural (RUCCs 4 to 9).

Control Variables

We included several control variables in our analysis to isolate the effects of rurality and racial residential segregation on CRC mortality rates. Manser and Bauerfeind's [34] systematic review revealed that CRC mortality was strongly associated with socioeconomic factors, such as low income, lower levels of education, and overcrowding. We included these factors as direct measures of socioeconomic status.

First, using the same data we used to calculate county MLIDs, we calculated the proportion of each county's population that was Black and the proportion of each county's population that was White. Second, we determined the proportion of Blacks and Whites, separately, in each county who reported a household income of less than $20,000 between 2011–2015 using data from the United States Census Bureau [30]. Third, we determined the proportion of Blacks and Whites, separately, in each county who reported having never completed high school between 2011–2015 using data from the United States Census Bureau [30]. Fourth, we determined the proportion of Blacks and Whites, separately, in each

county who reported living arrangements involving more than 1 occupant per room in the house (i.e., “overcrowding”) between 2011–2015 using data from the United States Census Bureau [30].

Data Analysis

Because 166 counties exhibited suppressed CRC mortality rates for Blacks and 59 counties exhibited suppressed CRC mortality rates for Whites (because of small population numbers), we implemented random forest imputation [35] using the “missForest” package in R Studio to estimate the Black or White CRC mortality rate for counties with suppressed rates—allowing for analysis of all 252 counties in the Delta Region. Then, we generated county-boundary choropleth maps of White CRC mortality rates and Black CRC mortality rates—using the “spdep” package in R Studio—in order to spatially represent the distribution of race-specific CRC mortality rates.

Lastly, we estimated two linear mixed-effects regression models using the “lme4” package in R Studio [36]. In the first model, we regressed Black CRC mortality rates on county rurality and MLIDs, as well as an interaction term of rurality and MLID, while controlling for Black-specific county-level socioeconomic factors and allowing for a random intercept by state. In the second model, we regressed White CRC mortality rates on county rurality and MLIDs, as well as an interaction term of rurality and MLID, while controlling for White-specific county-level socioeconomic factors and allowing for a random intercept by state. As all data were obtained from deidentified public use data sets, it was determined that institutional review board approval was not required for this study.

Results

Table 1 shows that the Delta Region county average was similar in the imputed (M = 28.55, SD = 7.22) and non-imputed datasets (M = 28.19, SD = 7.64) for Black CRC mortality and also for White CRC mortality in the imputed (M = 18.89, SD = 5.31) and non-imputed datasets (M = 18.57, SD = 5.19), thus allowing us to proceed with analysis. Figure 1 provides the geographic distribution of county-level White and Black CRC mortality rates in the Delta Region. Black CRC mortality rates were highest – at 62 per 100,000 – in Shannon county, Missouri, and Sharkey county, Mississippi, while White CRC mortality rates were highest – at 39 per 100,000 – in Wilkinson county, Mississippi, Jefferson Davis county, Mississippi, and Dallas county, Arkansas.

Table 1
Average colorectal cancer (CRC) mortality rates in Mississippi Delta Region counties by rural-urban designation.

	Mean	SE	Lower 95% CI	Upper 95% CI
White CRC Morality Rate				
All Counties	18.89	0.33	18.24	19.55
Urban Counties	16.82	0.57	15.70	17.93
Rural Counties	19.66	0.39	18.89	20.43
Black CRC Mortality Rate				
All Counties	28.55	0.46	27.65	29.44
Urban Counties	26.36	0.79	24.81	27.91
Rural Counties	29.36	0.54	28.29	30.42

Linear mixed-model results showing relationships between county rurality, racial residential segregation, and CRC mortality rates are shown in Table 1. Omnibus results of the Black CRC mortality model were statistically significant, compared to the null model in which the state random effect was the only predictor variable, $F_{(7, 227.86)} = 7.88$, $p < 0.001$. The interaction term of county rurality and segregation was statistically significant, indicating that county rurality moderated the effect of segregation on Black CRC mortality rates. As shown in Fig. 2, while segregation was a protective factor against Black CRC mortality in rural Delta counties, it was a risk factor for Black CRC mortality in urban Delta counties. Covariates associated with higher Black CRC mortality included lower educational attainment and overcrowding.

Table 2

Multi-level factors associated with colorectal cancer mortality rates for Blacks and Whites in United States counties, 2011–2015

	Model: Black CRC Mortality			Model: White CRC Mortality		
Variable	B	[95% CI]		B	[95% CI]	
Fixed Effects						
Intercept	13.93	[5.91, 22.08]	*	19.58	[12.78, 26.04]	*
Population Proportion[a]	2.41	[−2.80, 7.23]		−7.12	[−10.66, − 3.43]	*
Income < $20,000[b]	−4.31	[−8.67, 0.08]		7.80	[−7.00, 23.36]	
Education < HS[c]	16.92	[10.45, 23.11]	*	26.22	[9.78, 42.16]	*
Overcrowding[d]	52.293	[24.76, 78.61]	*	10.46	[−48.79, 69.41]	
Rural	14.27	[6.14, 22.40]	*	−2.67	[−8.67, 3.40]	
Segregation[e]	16.14	[1.96, 30.28]	*	−5.96	[−16.39, 4.80]	
Rural x Segregation	−23.30	[−38.51, − 7.91]	*	7.91	[−3.46, 19.16]	
Random Effect Intercepts						
Alabama	−0.84	[−3.22, 1.54]		−1.97	[−3.67, − 0.26]	*
Arkansas	0.85	[−0.93, 2.63]		1.55	[0.26, 2.85]	*
Illinois	0.19	[−2.38, 2.76]		1.38	[−0.45, 3.21]	
Kentucky	1.99	[−0.34, 4.33]		−1.19	[−2.87, 0.48]	
Louisiana	−3.99	[−5.56, − 2.41]	*	−0.57	[−1.72, 0.58]	
Missouri	1.18	[−0.88, 3.25]		0.73	[−0.76, 2.23]	
Mississippi	−1.08	[−2.78, 0.61]		0.46	[−0.78, 1.70]	
Tennessee	1.69	[−0.64, 4.03]		−0.40	[−2.07, 1.28]	

[a] Black population proportion for the Black CRC model and White population proportion for the White CRC model

[b] Proportion of the specific racial group in a county making less than $20,000 per year

[c] Proportion of the specific racial group with less than a high school education

[d] Proportion of the specific racial group living in a residence with more than one occupant per room

[e] Measured with the multilevel index of dissimilarity (MLID)

* Statistically significant coefficient based on a 95% confidence interval

Discussion

Our models suggested that racial residential segregation was a risk factor for Black CRC mortality in urban Delta Region counties, a finding aligned with other CRC disparities research [24, 37]. However, we discovered an inverse relationship in rural Delta counties, namely that racial segregation was associated with lower CRC mortality. While this finding may seem surprising, the relationship between residential segregation and Black cancer outcomes remains unclear. Some studies have found detrimental outcomes (as we did for urban locales) [22–23], while others have shown protective effects (as we did for rural locales) [18, 26, 38], and others have reported non-association [19, 21, 39–40]. It is clear that the interaction of rurality and race, especially in segregated communities, deserves additional exploration in health research. A few hypotheses might provide insight into our novel findings.

First, after the insurance mandate of the Affordable Care Act (ACA) in 2014, multiple positive health outcomes were observed, including increased probability of physician visits and a reduction of overall uninsurance, with reduction in uninsurance seen more prominently in Blacks than in Whites [41]. Furthermore, increases in the percentage of people covered were found to be much greater in rural, compared to urban, settings [42]. Conceivably, rural Black residents of the Delta Region may have benefitted particularly strongly from the ACA, thereby resulting in decreased CRC mortality. Future analyses should compare CRC mortality trends by race in urban and rural Delta counties in years prior to and after the introduction of the ACA to explore whether it might explain why Black residents in segregated rural regions of the Delta experience lower rates of CRC mortality.

A second potential explanation for our findings is that rural segregated communities may have unique features that do not exist in their segregated urban analogues. Ethnic enclaves—geographical areas marked by large concentrations of people of similar races or ethnicities that often feature organizations led by members of these communities—have been shown to impart health benefits via different pathways, such as shared cultural norms [43], stronger social networks [39], increased social capital [18], and less exposure to racism-related stress [40]. However, other highly-segregated areas may be cut off from resources, access, and knowledge [8–11], thus perpetuating unequal balances of power or resources and leaving communities of color with smaller social networks and less support [18]. It is possible that these disparities are more pronounced in urban areas and that social bonds may be stronger in segregated rural communities, thus leading to improved health outcomes.

It is nonetheless important to remember that racial residential segregation is a system of oppression comprised of multiple factors that lend to long-term health outcomes. Due to segregation, Black communities have historically-entrenched and socially- and politically-enforced barriers to economic, educational, and health resources, implications from which continue to be felt today. Although the findings of this paper identified an association between reduced CRC mortality and rural Black segregation, it is important to acknowledge that multiple factors likely drive this relationship, thus underscoring the necessity for continued research dedicated to understanding the long-term effects of segregation on health outcomes.

Finally, it should be noted that our county-level data do not fully capture individual-level factors—such as comorbidities, screening data, median-age of death, or other risk factors—that might partly explain our findings. Data from the 2012–2015 Behavioral Risk Factor Surveillance System (BRFSS) show that rural Blacks self-report lower health-related quality of life, higher cost-related barriers to seeking treatment, lower CRC screening rates, and more comorbidities than rural Whites [44]. Furthermore, precancerous polyps, many of which have little or no symptoms, can take upwards of a decade to progress to CRC [45]. Perhaps, then, rural Blacks in the Delta Region are dying prematurely from complications of other causes (i.e., multiple chronic conditions) *before* dying from the slower developing consequences of CRC. Poor, rural Black residents have nearly three times greater risk for premature mortality than their more affluent Black and White urban counterparts [46]. Moreover, death rates from the five leading causes of death are highest in rural areas of the United States [47]. Given that the Delta Region as a whole has one of the lowest life expectancies in the country [48], our findings might not fully capture the entire picture related to trends in Black CRC mortality in the Delta Region.

Limitations

While this study imparts critical evidence in the still-inconclusive literature on the effects of racial residential segregation on health outcomes by examining how rurality moderates the relationship between segregation and colorectal cancer mortality, our findings should be interpreted with a few limitations in mind. First, we only examined one geographically isolated area of the United States, the Mississippi Delta Region. Although this region was selected purposively due to its overwhelming colorectal cancer mortality burden [2], researchers should investigate other rural, isolated areas to determine whether they differ from the Delta. Second, many counties in our analysis had missing data for CRC mortality and were thus replaced with values generated via random forest imputation. Although our imputed and non-imputed datasets were similar, there is the possibility that the imputed CRC mortality rates in this study did not truly reflect the CRC mortality rate in a particular county with missing data. Third, our study is limited by the snapshot of health represented from 2011–2015, and general implications about the effects of a socially- and legislatively-enforced historical phenomenon like segregation on health outcomes are thus limited. Fourth, given that the county was the unit of analysis in this study, we were unable to control for individual-level covariates (e.g., stage at diagnosis, median age, comorbidity scores, and individual insurance coverage) that may have partly explained our findings. Finally, our study is correlational in nature and, as such, no causal effects can be inferred based on our findings.

Conclusion

To date, few studies have examined the effects of racial residential segregation on CRC outcomes, and to the best of our knowledge, none has determined whether rurality moderates the effect of segregation on CRC mortality in Black and White residents. Here, we used the Mississippi Delta Region as a frame of reference, given its history of racial segregation, combination of rural and urban counties, and highest incidence of CRC mortality of any “hotspot” in the US [2]. What we found was that segregation was a

protective factor against rural Black CRC mortality, a risk factor for urban Black CRC mortality, and that it was not a significant factor for White CRC mortality irrespective of rurality. We also found a negative correlation between percent White population and White CRC mortality. Taken together, these findings suggest that segregation affects White and Black residents differently, especially in rural areas. Future research should examine individual-level factors that may help explicate this rural-urban disparity. Collectively, these findings can help inform community-engaged evidence-based practices to reduce cancer burden in segregated rural areas.

Abbreviations

ACA: Affordable Care Act; BRFSS: Behavioral Risk Factor Surveillance System; CRC: Colorectal Cancer; MLID: Multilevel Index of Dissimilarity; RUCC: Rural-Urban Continuum Code; SEER: Surveillance, Epidemiology, & End Results; USDA: United States Department of Agriculture

Declarations

Ethics approval and consent to participate. Because this study examined public use blinded data, this study was not considered human subjects research by Southern Illinois University.

Consent for publication. Not applicable.

Competing interests. None to report.

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Authors' contributions. AK-D conceived of the study, identified data sets, and handled lead authorship. JM provided statistical analysis and writing for methods and results. ML organized, edited, and provided authorship within the introduction and discussion sections. AJ contributed to writing and editing the manuscript, and MY obtained data and wrote in contribution to the introduction and discussion sections. All authors have read and reviewed the manuscript.

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Availability of data and materials. Available upon request of the corresponding author

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Figures

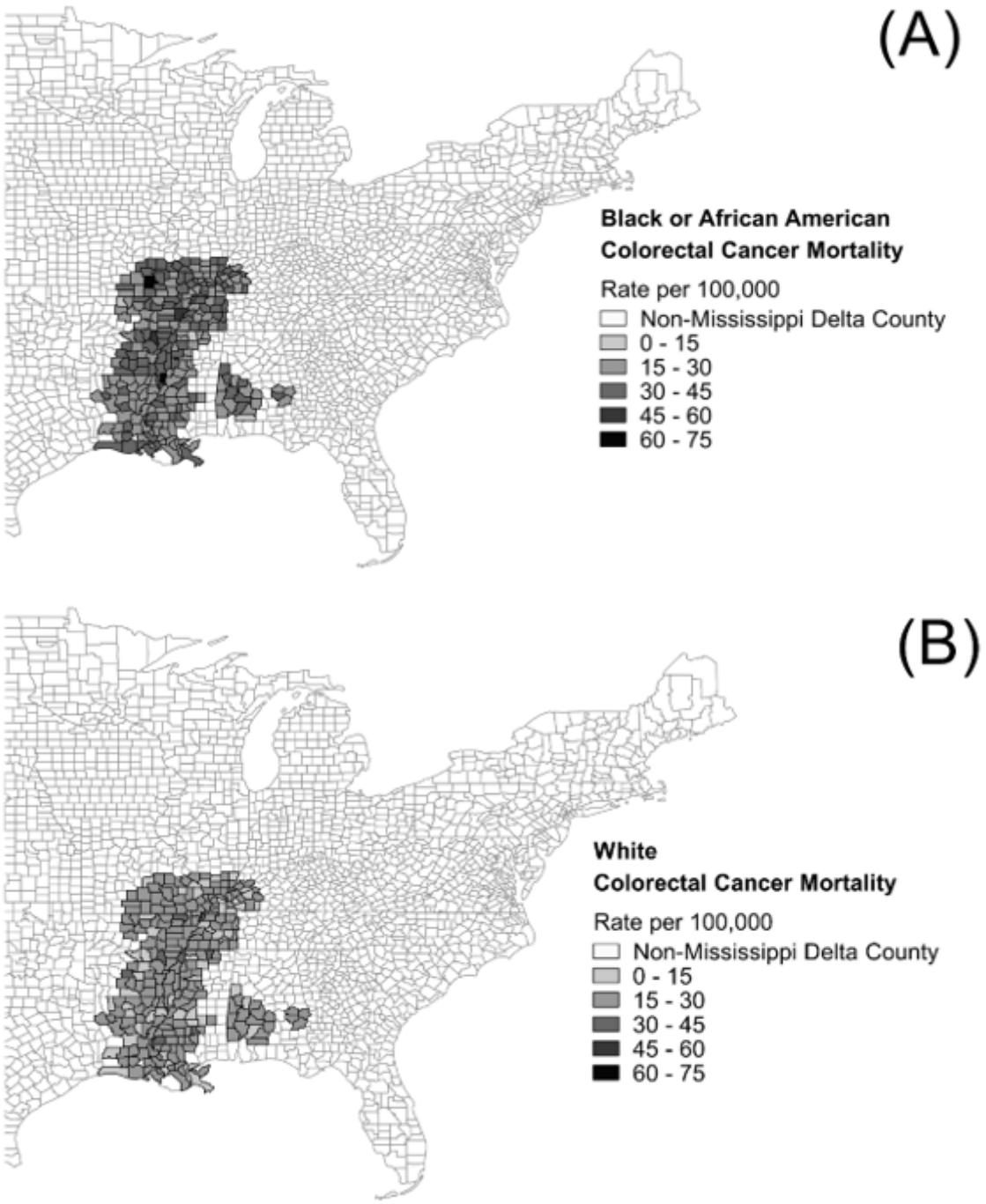

Figure 1

Black (A) and White (B) colorectal cancer mortality rates per 100,000 between 2011-2015 for counties in the Mississippi Delta Region. Map created by JM using ESRI ArcGIS 10.5.1, https://www.esri.com/en-us/home.

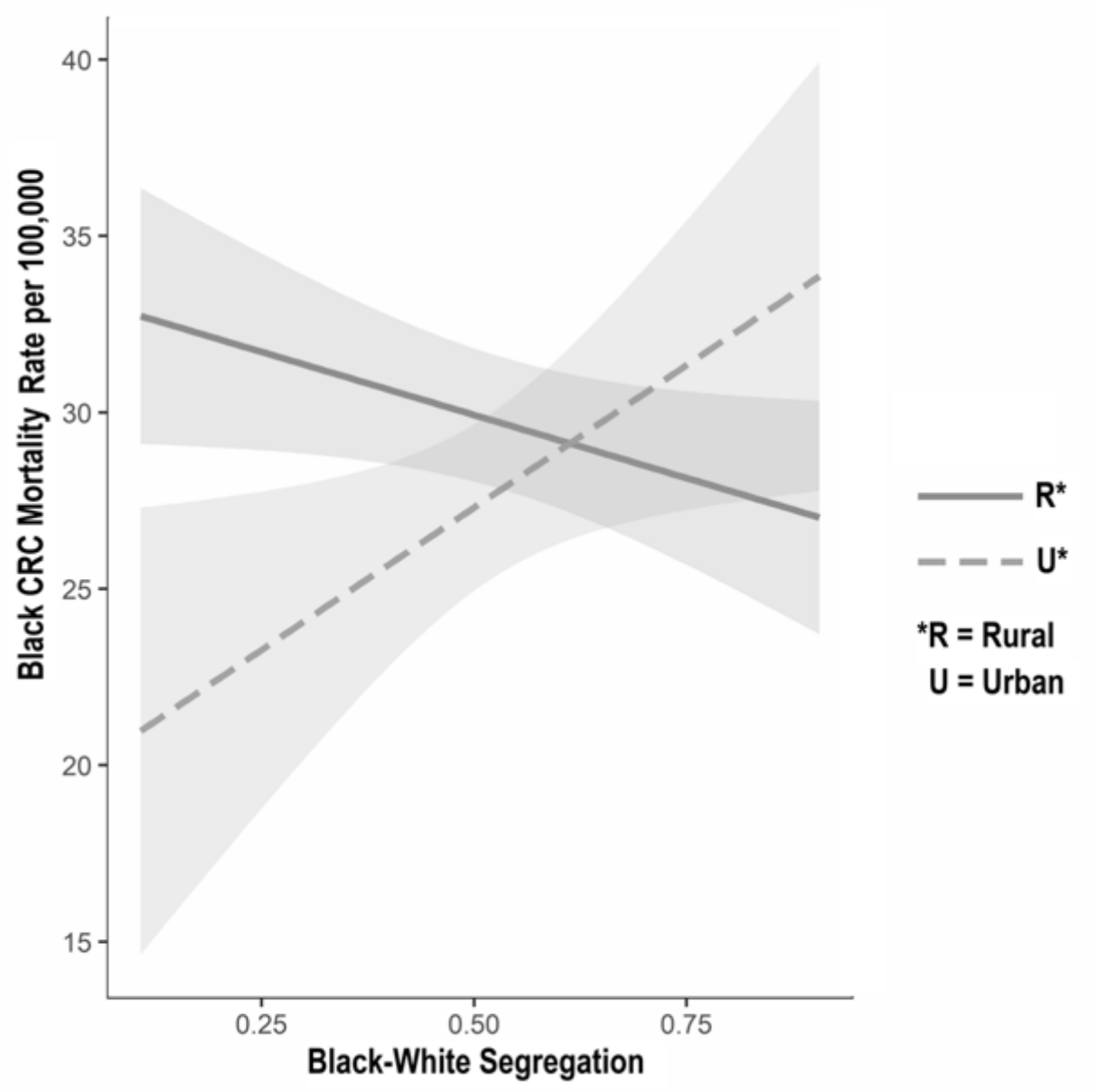

Figure 2

Interaction plot (with shaded confidence intervals) showing the moderating effect of county rurality on the relationship between Black-White residential segregation (MLID) and Black colorectal cancer mortality rates.