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A Closer Look at Rural-Urban Health Disparities: Associations Between Obesity and Rurality Vary by Geospatial and Sociodemographic Factors

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Abstract

Background: Obesity affects over one-third of older adults in the United States. Both aging and obesity contribute to an increased risk for chronic disease, early mortality, and additional health care utilization. Obesity rates are higher in rural areas than in urban areas, although findings are mixed. The objectives of this study are to assess potential nonlinearity in the association between rurality and obesity, and to evaluate the potential for socioeconomic status and geographic area to moderate the associations between rurality and obesity.

Methods: Using a representative sample of adults aged 65 and above from the Behavioral Risk Factor Surveillance System, obesity (BMI $\geq$ 30 kg/m^2) was modeled against the primary exposure of rural-urban status, as measured by the Index of Relative Rurality. Binary logistic regression models were used to estimate the odds of obesity by rurality both as a continuous variable and by decile of rurality. Models were then stratified by per-capita income and state to assess potential moderation by these factors.

Results: The prevalence of obesity in older adults was highest in intermediate rurality areas (OR in rurality decile #5 1.134, 95% CI: 1.086-1.184) and lowest in the most rural and most urban areas. Obesity was highest in low- and middle-income areas, regardless of rural-urban status. In high-income areas, obesity among older adults was highest in areas of intermediate rurality and lowest in the most rural areas (OR 0.726, 95% CI: 0.606-0.870) and more urban areas, showing a J-shaped association. There were substantial differences in the associations between rurality and obesity in older adults among states.

Conclusion: Associations between rurality and obesity varied by degree of rurality, socioeconomic status, and geography. Therefore, traditional "one-size-fits-all" approaches to reducing rural-urban health disparities in older adults may be more effective if tailored to the area-specific rural-urban gradients in health.

Key words elderly, health disparities, obesity, rurality, socioeconomic status.

Obesity is a growing worldwide epidemic, affecting millions of people across the globe. In the United States, the obesity epidemic remains perhaps the most critical public health challenge of the 21st century. More than two-thirds of the adult population (68.5%) in the United States are considered overweight or obese, with a body mass index (BMI) between 25 and 30 kg/m^2, or obese (BMI > 30 kg/m^2).[1] Consequences of obesity encompass both physical and mental health problems throughout the life span, including: diabetes, high blood pressure, coronary artery disease, cerebrovascular disease, some cancers, infertility, chronic stress, depression, and sleep disorders.[2,3] The direct national cost of health care treating conditions associated with overweight and obesity combined was $113.9 billion in 2010, representing 5%-10% of all US health care spending.[1,4]

The obesity epidemic remains particularly problematic for older adults. In 2012, the prevalence of overweight and obesity was 71.3% in the population age 60+, nearly 20% higher than those in the population age 20-39.[1] Furthermore, the obesity prevalence in older adults has tripled since the early 1980s.[3] Although obesity prevalence and, arguably, its associated health risks are most pronounced in middle-aged adults (aged 40-59), obesity in older adults has important health implications that materialize specifically in older age groups. For instance, a study of the National Health Interview Survey (NHIS) suggested that obese older adults, compared to their nonobese counterparts, have a significantly higher likelihood of having disabilities associated with activities of daily living (ADLs), such as bathing, toileting, and mobility.[5] As the population ages, the proportion of older adults in the entire US population will increase from 13% to approximately 20% by 2030.[6] Furthermore, the baby boomers who are entering these older age categories have significantly higher rates of chronic disease, including obesity, than members of the previous generation when they were the same age.[7,8]

However, the prevalence of obesity is not uniform throughout the country and varies by geography.[9,10] We know that place-based characteristics have a profound effect on both population and individual health.[11] Understanding and addressing the specific characteristics of those geographic regions that promote higher rates of obesity remains a critical public health challenge.[12] Beyond the contributions of medical care, health behaviors, and genetics, it is critical to understand how one's residential environment affects health and s wellness.[13]

One specific place-based characteristic that is known to affect health is rural-urban status. Rural-urban health disparities have been observed for multiple health outcomes, including various cancers,[14,15] cardiovascular disease,[16,17] and all-cause mortality.[18,19] Moreover, it is also well-established that the prevalence of obesity is substantially higher in rural compared to urban areas of the United States.[19] Although some studies have observed notable rural-urban disparities in obesity[20,21] and obesity-related health care services utilization,[22] comparatively few studies have focused specifically on rural-urban disparities in obesity in older adults. Rural older adults may be especially vulnerable due to functional limitations, geographic isolation, limited resources and income, and other factors.

In addition, existing studies on rural-urban health disparities have considered rural-urban status as either a dichotomous[23,24] or 3-level ordinal measure.[20] This approach limits the potential to observe more complex, nonlinear associations between rural-urban status and obesity that could have implications for policy and programs to combat the obesity epidemic at the population level.[25] Defining what it actually means to be "rural" or "urban" is another challenge in addressing rural-urban health disparities. Rural-urban status is complex and multidimensional. However, existing measures of rural-urban status often do not include critical demographic, cultural, social, and economic differences across rural places that may vary from region to region.[26] Furthermore, the definition of a rural area is often context-specific and may not be comparable among regions.[27] Most studies that examine rural-urban health disparities consider an entire region, area, or country in the analysis. However, this approach may mask differences in the associations between rurality and health within smaller geographic regions.

On the other hand, one well-established place-based characteristic that plays an integral role in population health is socioeconomic status (SES).[27-31] Populations living in areas of high wealth and education with low poverty rates and income inequality generally fare better in terms of multiple health outcomes compared to those living in low SES areas.[28,29] Although the associations between SES and population health are well-documented,[28-33] the interaction of SES and rural-urban status and their joint effect on health, particularly obesity, are not well understood. One study showed that SES was more predictive of obesity in urban areas than in rural areas, suggesting a joint effect of these 2 measures on obesity prevalence.[33] Additional studies suggest that rural-urban status may moderate the associations between SES and other health outcomes.[8,34] However, there is limited research examining how associations between SES and obesity in older adults may vary by rural-urban status.

Therefore, to address these gaps in existing research on rural-urban disparities in older adult health, this study uses the following 3 objectives: First, we examine the association between rural-urban status and obesity and the possibility for that association to be nonlinear. Second, we assess the potential for SES to moderate the association between obesity and rural-urban status. Lastly, we examine how the association between obesity in seniors and rural-urban status varies by state across the United States.

Methods

Data Sources

Two primary data sources were used in this analysis. The outcome measure and all individual-level covariates were abstracted from the 2012 Behavioral Risk Factor Surveillance System (BRFSS), an annual national telephone-based survey administered by the Centers for Disease Control and Prevention and conducted by state public health agencies, covering nearly 500,000 respondents across the United States and its territories.[35] Rural-urban status was obtained from the 2010 US Decennial Census (US Bureau of the Census) using 4 measures of rural-urban status described below: population size, population density, percentage of urban residents, and county distance to the closest metropolitan area.

Outcome Measure

Obesity was used as the primary outcome measure in this study. Respondents were asked to report height and weight. These measures were used to calculate a respondent's BMI, which was then dichotomized into obese (BMI $\geq$ 30) or nonobese (BMI $<$ 30). The analysis was restricted to individuals age 65 and above and living in the contiguous United States due to anomalies in the geographies of both Alaska and Hawaii that make measuring rurality distinct from the contiguous 48 states.

Exposure Measure

The primary exposure measure was rural-urban status of each respondent's county of residence. Since there is no one unique, widely-accepted measure of rural-urban status in the health literature,[27,36] we used a composite measure of rural-urban status: the Index of Relative Rurality (IRR).[37] The IRR is based on 4 equally weighted dimensions abstracted from the 2010 US Decennial Census: population size, population density, percentage of urban residents, and inverse county distance to the closest metropolitan area. The IRR is a continuous variable ranging from 0 (most rural) to 1 (most urban) and was binned into deciles (10 bins ranked from most rural to most urban, each containing 10% of the data) in the analysis. Descriptive statistics for the analytical sample and each of the IRR deciles are provided in Tables S1 and S2, respectively (available online only).

Covariates

All individual-level covariates were obtained from the 2012 BRFSS database. Age was obtained for all respondents on the continuous scale. Categorical covariates used in this analysis include sex, race/ethnicity, marital status, individual income, and highest education attained. Additional covariates from BRFSS were considered, but they were not included in the final models due to collinearity with the other covariates after an exploratory analysis. We also used county-level per-capita income from the 2010 Decennial Census as a place-based covariate and effect modifier for the second study objective.

Statistical Analysis

Descriptive statistics were obtained for all variables described above. Exposure variables and covariates were assessed overall, and we compared obese respondents to nonobese respondents using chi-square tests for categorical exposures and covariates, and Wilcoxon rank-sum tests for the continuous, but right-skewed, age variable.

For the first objective, we modeled the outcome of obesity (yes/no) against IRR to quantify potential associations between obesity and rural-urban status using logistic regression. Rural-urban status, as measured through the IRR, was modeled in 2 ways: linear and nonlinear. For the linear models, county-specific IRR was used in its original form as a continuous measure of rural-urban status. For the nonlinear models, county-specific IRR decile was converted to a series of 10 indicator variables to assess nonlinearity in the association between obesity and rural-urban status. In the nonlinear models, the highest (most urban) IRR decile variable was used as the reference group in the model. A series of 6 models were examined: Model 1 was an "unadjusted" model with IRR in its original form as a continuous measure as the only exposure. Model 2 was an "adjusted" model using continuous IRR and all individual-level covariates. Model 3 was a "fully adjusted" model that included all of the individual-level covariates plus county-level per-capita income. Models 4-6, the nonlinear models, were identical to the linear models (Models 1-3), except that these models used IRR decile in place of the continuous measure of IRR. Model fit was evaluated using Nagelkerke R-squared statistics for each of the 6 models. Only the available data were used in the analysis, as the percentage of missing data on BMI was low (less than 5%) and assumed to be missing-at-random.

For the second objective, to estimate the potential for area-level socioeconomic status to modify observed associations between rural-urban status and obesity, the adjusted logistic regression model from the previous objective was used and stratified by county per-capita income tertile. The third objective assesses whether those prospective associations, or lack thereof, observed on the national level might differ by state. Therefore, for this objective, we used the same exposures, covariates, outcomes, and logistic regression methods described above, but we stratified the analysis by state. The models for the second and third objectives adjusted for age, sex, race, marital status, individual income, and education. Model fit was evaluated using the same measure described above. We also estimated weighted obesity prevalence in older adults by state and rurality decile. All analyses were weighted using the sample weight provided in the BRFSS data. All statistical analyses were conducted using SAS version 9.3 (SAS Institute, Inc., Cary, NC, USA) and IBM-SPSS version 22 (IBM Corp., Armonk, NY, USA). ArcGIS version 10 (Esri, Redlands, CA, USA) was used for mapping.

Results

Sample Characteristics

Obesity was most prevalent in the third and fourth deciles of rural-urban status, and it was lowest in the most rural and most urban areas (Table 1). Increasing age was associated with a reduction of obesity, whereas there were no statistically significant differences in the likelihood of obesity between males and females. Non-Hispanic blacks had the highest prevalence of obesity among all racial and ethnic groups examined (37.7%), while Asians had the lowest obesity prevalence (10.2%). Obesity prevalence decreased with increasing education and personal income, and it was highest in those who were divorced (31.4%), separated (33.9%), and never married (32.1%). Counties with a higher prevalence of obesity tended to lie in the South and Appalachian regions, as well as in parts of the Midwest and interior California (Figure 1, Panel A). A map displaying the geographic distribution of rural-urban status by county is provided in Figure 1, Panel B, showing the most rural counties to be in the Plains, intermountain West, the Mississippi Delta, Appalachians, and northern New England.

National Analysis

The first objective assessed the potential for a nonlinear association between rural-urban status and obesity (Table 2). As a continuous measure, decreasing rurality was associated with a reduction in the likelihood of obesity (OR 0.929, 95% CI: 0.918-0.939; Model 1). This association remained after adjustment for socioeconomic and demographic factors (OR 0.955, 95% CI: 0.944-0.967; Model 2), but it became nonsignificant after adjustment for county-level per-capita income (Model 3). In the unadjusted nonlinear model (Model 4), the likelihood of obesity was significantly higher in the 6 most rural deciles of US counties, compared to the most urban decile. In the adjusted models (Models 5 and 6), the respondents living in the intermediate rural-urban status deciles were significantly more likely to be obese than those living in the most urban areas. The best-fitting models were Models 2 and 3 using the continuous measure of rurality, and Models 5 and 6 using indicator variables for rurality.

Socioeconomic Status as an Effect Modifier

The second objective evaluated the possibility that area-level SES modifies the associations between rural-urban status and health. Maps of both county-level per-capita income and of per-capita income and IRR together can be found in Figure 1, Panels C and D, respectively. Overall per-capita income was highest in the Northeast and Northern Plains states, and lowest in the South, Appalachian, and Southwest regions. Counties in the Northern Plains are best classified as rural and wealthy, as opposed to the wealthy counties in the Northeast, which are generally urban or of intermediate rurality. Most of the concentrated areas of low income counties in the Deep South are rural or of intermediate rurality. Model results are displayed in Table 3. For the counties in the lowest-income tertile, no statistically significant associations existed between obesity and rural-urban status. For the counties in the middle- and high-income tertiles, those respondents living in areas of intermediate rural-urban status (deciles 4-6) were significantly more likely to be obese than those living in the most urban areas. In high-income counties, however, individuals living in the most rural counties were significantly less likely (OR 0.726, 95% CI: 0.606-0.870) than those in the most urban decile to be obese. Model-adjusted prevalence of obesity in the 65+ population by rural-urban status decile and income can be found in Figure 2. With a few exceptions, obesity prevalence increased with decreasing per-capita income. The magnitude of this increase was substantially higher in the highest-income counties compared with the lowest- and middle-income counties. Obesity prevalence peaked in counties of intermediate rurality, but the exact peak depended upon income.

State-Level Analysis

Figure 3 shows the model-adjusted prevalence of obesity for each decile of rural-urban status in each state, where data were available. Orange and red squares indicate areas of obesity prevalence that are higher than the US prevalence (28.4%), whereas blue and green rectangles show areas of low obesity prevalence compared to that of the United States. Obesity prevalence in the United States is shown in the top row of squares and highlights

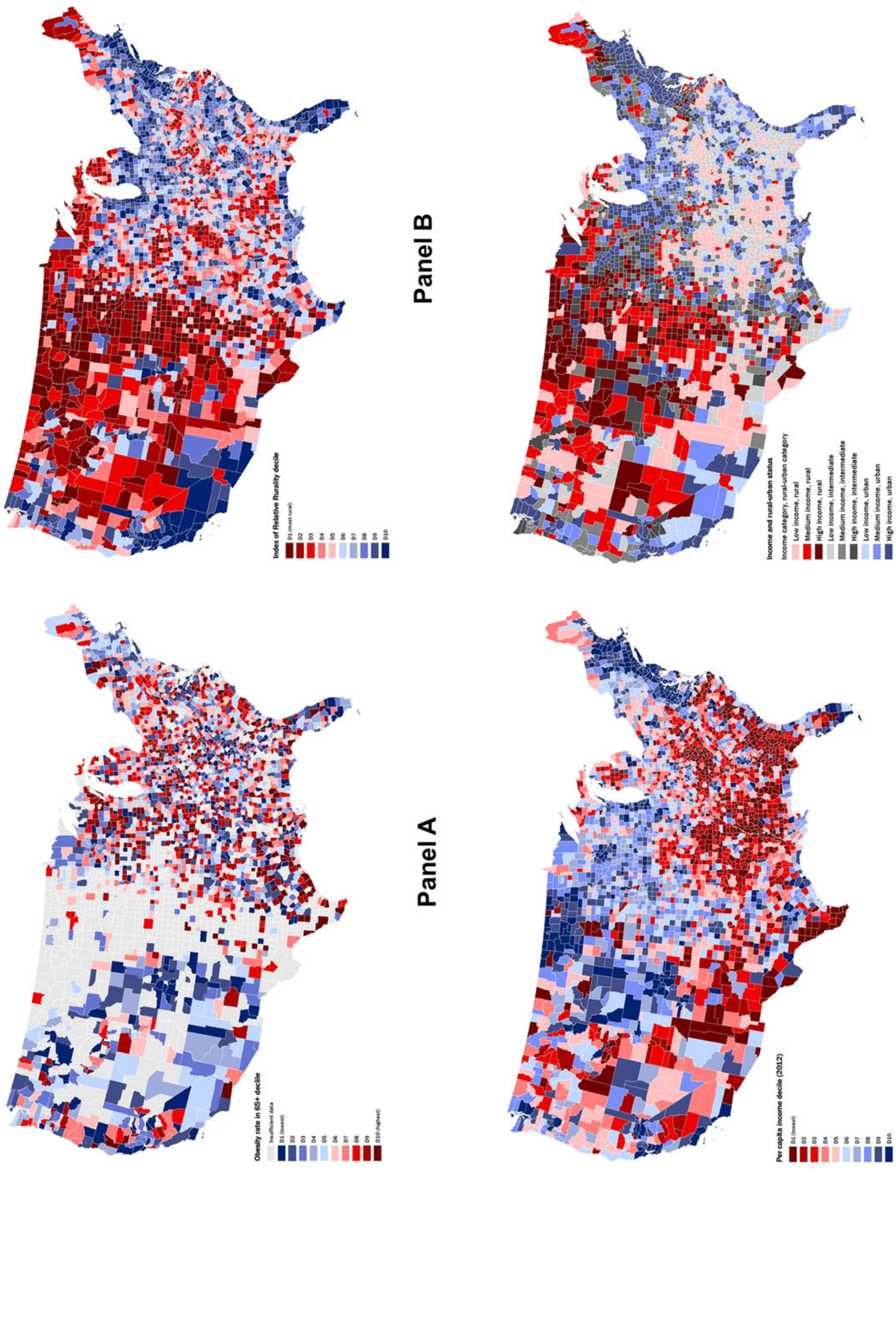


Figure 1 Figure 1 County-Level Obesity Prevalence in 65+ Population (Panel A), Rural-Urban Status (Panel B), Per-Capita Income (Panel C), and Income and Rural-Urban Status Combined (Panel D).

Table 1 Descriptive Characteristics for BRFSS Study Sample (aged 65+)

		Overall	Obese N (%)	Nonobese N (%)	*P* Value
Index of relative rurality decile	D1 (most rural)	10,541	2,929 (27.8)	7,612 (72.2)	<.001
	D2	11,604	3,458 (29.8)	8,146 (70.2)	
	D3	14,783	4,582 (31.0)	10,201 (69.0)	
	D4	16,791	5,303 (31.6)	11,488 (68.4)	
	D5	17,262	4,994 (28.9)	12,268 (71.1)	
	D6	19,294	5,554 (28.8)	13,730 (71.2)	
	D7	20,231	5,326 (26.3)	14,905 (73.7)	
	D8	19,484	5,096 (26.2)	14,388 (73.8)	
	D9	18,740	5,003 (26.7)	13,737 (73.3)	
	D10 (most urban)	25,606	6,764 (26.4)	18,842 (73.6)	
Age	Mean (SD)	70.0 (7.9)	68.4 (6.8)	70.7 (8.2)	<.001
Sex	Male	75,576	21,304 (28.2)	54,272 (71.8)	.561
	Female	98,758	27,714 (28.1)	71,044 (71.9)	
Race	White	152,139	41,766 (27.5)	110,373 (72.5)	<.001
	Black	13,378	5,046 (37.7)	8,332 (62.3)	
	Asian	2,113	215 (10.2)	1,898 (89.8)	
	NHPI	336	78 (23.2)	258 (76.8)	
	AIAN	1,855	580 (31.3)	1,275 (68.7)	
	Other	2,202	684 (31.1)	1,518 (28.9)	
Marital status	Married	103,877	28,738 (27.7)	75,139 (72.3)	<.001
	Divorced	24,160	7,584 (31.4)	16,576 (68.6)	
	Widowed	34,400	8,968 (26.1)	25,432 (73.9)	
	Separated	2,563	869 (33.9)	1,694 (66.1)	
	Never married	6,962	2,234 (32.1)	4,728 (67.9)	
	Member of unmarried couple	1,878	511 (27.2)	1,367 (72.8)	
Annual income ($)	<15k	16,501	5,539 (33.6)	10,962 (66.4)	<.001
	15-25k	29,744	9,503 (31.9)	20,241 (68.1)	
	25-35k	19,671	5,785 (29.4)	13,886 (70.6)	
	35-50k	24,661	7,037 (28.5)	17,624 (71.5)	
	50k+	57,026	14,687 (25.8)	42,339 (74.2)	
Education	Less than high school	17,549	6,040 (34.4)	11,509 (65.6)	<.001
	High school or equivalent	53,270	15,996 (30.0)	37,274 (70.0)	
	Some college	44,685	13,149 (29.4)	31,536 (70.6)	
	College or greater	58,536	13,763 (23.5)	44,773 (76.5)	

the results observed in the first study objective: obesity is most prevalent in rural and peri-urban counties and lower in urban areas. These general trends were consistent for many individual states. However, in many states, these trends differed considerably from national trends. In Louisiana, for example, obesity was above 37% for IRR deciles 2, 4, and 10. In Kentucky, obesity was significantly lower in the rural areas than in 3 of the 4 most urban deciles. The prevalence of obesity in the 65+ population in California was actually the lowest in the fourth IRR decile, the same decile that had the highest national obesity prevalence.

Discussion

The results highlight several key properties of the association between obesity in older adults and rural-urban status. First, the obesity-rurality association is complex and nonlinear, which is somewhat contradictory to previous studies. The preponderance of evidence in prior research suggests simply that rural residents have worse health than urban residents.[17-25] This rural-urban disparity was also observed in our study for obesity in older adults, except that in the most rural areas, the prevalence of obesity was actually lower than in areas of intermediate rurality. Next, these associations between obesity and rural-urban status vary by SES. Although in the counties with the lowest socioeconomic status, the likelihood of obesity was not significantly associated with rural-urban status, for middle- and high-income counties, the likelihood of obesity was highest in the areas of intermediate rural-urban status and lowest in the most urban areas. In the high-income counties, the likelihood of obesity was also significantly lower in the

Table 2 Odds Ratios (and 95% Confidence Intervals) of Obesity From Logistic Regression Models of Rural-Urban Status

		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
County-level rural-urban status	Continuous IRR	**0.929 (0.918-0.939)**	**0.955 (0.944-0.967)**	0.992 (0.978-1.006)			
County-level rural-urban status (deciles)	D1 (most rural)				**1.072 (1.019-1.128)**	0.996 (0.945-1.050)	**0.909 (0.860-0.960)**
	D2				**1.182 (1.126-1.241)**	**1.103 (1.049-1.160)**	1.007 (0.955-1.061)
	D3				**1.251 (1.197-1.308)**	**1.182 (1.129-1.238)**	**1.085 (1.034-1.139)**
	D4				**1.286 (1.232-1.342)**	**1.241 (1.187-1.297)**	**1.170 (1.118-1.224)**
	D5				**1.134 (1.086-1.184)**	**1.120 (1.071-1.171)**	**1.074 (1.027-1.124)**
	D6				**1.129 (1.083-1.177)**	**1.114 (1.067-1.163)**	**1.076 (1.030-1.124)**
	D7				0.995 (0.955-1.038)	1.001 (0.959-1.046)	0.989 (0.947-1.033)
	D8				0.986 (0.946-1.029)	0.999 (0.956-1.043)	0.974 (0.932-1.018)
	D9				1.014 (0.972-1.059)	0.994 (0.952-1.039)	0.998 (0.955-1.043)
	D10 (most urban) (ref)				–	–	–
Age			**0.957 (0.956-0.959)**	**0.958 (0.956-0.960)**		**0.957 (0.956-0.959)**	**0.958 (0.956-0.959)**
Sex	Female		**0.970 (0.948-0.992)**	**0.968 (0.947-0.990)**		**0.970 (0.948-0.992)**	**0.969 (0.947-0.991)**
	Male (ref)		–	–		–	–
Race	Black		**1.371 (1.319-1.425)**	**1.355 (1.303-1.408)**		**1.385 (1.332-1.440)**	**1.367 (1.315-1.422)**
	Asian		**0.302 (0.262-0.349)**	**0.307 (0.266-0.355)**		**0.307 (0.266-0.355)**	**0.312 (0.270-0.360)**
	NHPI		**0.714 (0.552-0.923)**	**0.713 (0.551-0.922)**		**0.724 (0.559-0.936)**	**0.722 (0.559-0.935)**
	AIAN		0.947 (0.856-1.047)	0.940 (0.850-1.040)		0.956 (0.864-1.057)	0.949 (0.858-1.050)
	Other		0.990 (0.902-1.086)	0.997 (0.908-1.094)		0.995 (0.906-1.092)	1.001 (0.912-1.099)
	White (ref)		–	–		–	–
Marital status	Married		**1.147 (1.033-1.273)**	**1.135 (1.023-1.260)**		**1.135 (1.022-1.260)**	**1.125 (1.013-1.249)**
	Divorced		**1.144 (1.028-1.273)**	**1.140 (1.024-1.269)**		**1.135 (1.019-1.263)**	**1.131 (1.016-1.260)**
	Widowed		**1.202 (1.080-1.338)**	**1.194 (1.072-1.329)**		**1.189 (1.068-1.325)**	**1.182 (1.062-1.317)**
	Separated		1.099 (0.961-1.257)	1.096 (0.958-1.254)		1.094 (0.957-1.252)	1.093 (0.956-1.250)
	Never married		**1.231 (1.097-1.383)**	**1.231 (1.096-1.382)**		**1.226 (1.092-1.377)**	**1.227 (1.092-1.378)**
	Unmarried couple (ref)		–	–		–	–
Income ($)	<15k		**1.273 (1.217-1.331)**	**1.241 (1.187-1.298)**		**1.276 (1.220-1.334)**	**1.246 (1.192-1.303)**
	15-25k		**1.311 (1.265-1.359)**	**1.284 (1.239-1.331)**		**1.312 (1.266-1.360)**	**1.286 (1.240-1.333)**
	25-35k		**1.880 (1.135-1.227)**	**1.159 (1.115-1.206)**		**1.180 (1.135-1.227)**	**1.160 (1.116-1.207)**
	35-50k		**1.136 (1.097-1.176)**	**1.120 (1.082-1.160)**		**1.135 (1.096-1.176)**	**1.120 (1.081-1.160)**
	50k+ (ref)		–	–		–	–
Education	Less than high school		**1.618 (1.552-1.687)**	**1.583 (1.518-1.652)**		**1.608 (1.542-1.677)**	**1.576 (1.511-1.644)**
	High school		**1.359 (1.319-1.400)**	**1.345 (1.306-1.386)**		**1.349 (1.310-1.390)**	**1.336 (1.297-1.377)**
	Some college		**1.303 (1.265-1.342)**	**1.289 (1.252-1.328)**		**1.297 (1.259-1.336)**	**1.285 (1.247-1.323)**
	College (ref)		–	–		–	–
County-level per-capita income (per thousand US dollars)		**0.988 (0.986-0.990)**			**0.989 (0.987-0.991)**		
Nagelkerke R^2 value	0.001	0.048	0.049	0.003	0.049	0.050	

Note: Bold values represent statistically significant associations ($P < .05$).

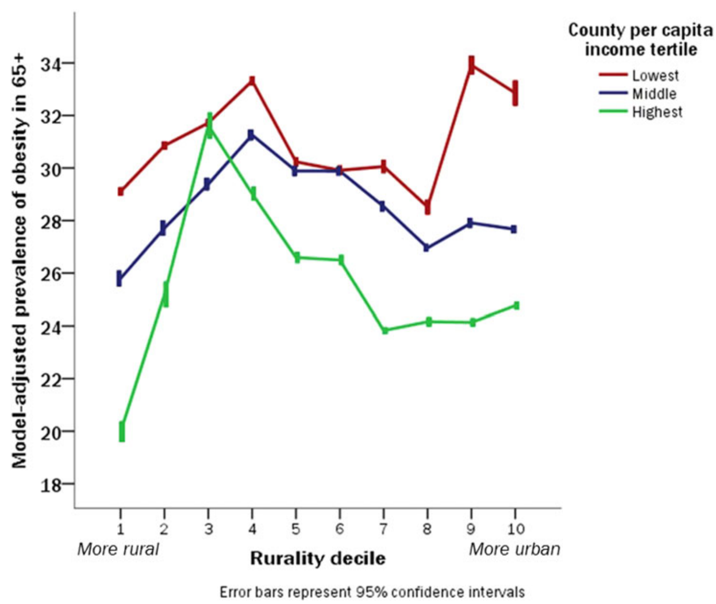
Models 1-3 use the continuous IRR variable as the primary exposure variable, and Models 4-6 use IRR decile as the primary exposure variables. Models 1 and 4 are the bivariate models, Models 2 and 5 include socioeconomic status and other demographic variables. Models 3 and 6 contain all Model 2 and 5 variables plus per-capita income.

Table 3 Odds Ratios (and 95% Confidence Intervals) of Obesity From Logistic Regression Models, Overall and by Tertile of County-Level Per-Capita Income

			Per-capita income tertile		
		Overall	Lowest	Middle	Highest
County rurality decile	D1 (most rural)	**0.909 (0.860-0.960)**	0.903 (0.795-1.026)	0.939 (0.838-1.052)	**0.726 (0.606-0.870)**
	D2	1.007 (0.955-1.061)	0.978 (0.861-1.110)	1.028 (0.930-1.136)	0.977 (0.813-1.174)
	D3	**1.085 (1.034-1.139)**	1.030 (0.910-1.167)	1.082 (0.990-1.183)	**1.335 (1.165-1.530)**
	D4	**1.170 (1.118-1.224)**	1.121 (0.988-1.271)	**1.198 (1.111-1.290)**	**1.167 (1.071-1.271)**
	D5	**1.074 (1.027-1.124)**	1.003 (0.883-1.140)	**1.120 (1.041-1.205)**	1.071 (0.990-1.158)
	D6	**1.076 (1.030-1.124)**	0.987 (0.868-1.122)	**1.118 (1.042-1.199)**	**1.089 (1.014-1.169)**
	D7	0.989 (0.947-1.033)	0.986 (0.861-1.130)	1.059 (0.984-1.141)	**0.930 (0.875-0.990)**
	D8	0.974 (0.932-1.018)	0.919 (0.799-1.058)	0.998 (0.936-1.065)	0.971 (0.906-1.042)
	D9	0.998 (0.955-1.043)	1.057 (0.913-1.224)	1.002 (0.934-1.075)	0.966 (0.907-1.029)
	D10 (most urban) (ref)	–	–	–	–

Note: Odds Ratios adjusted for age, sex, race, marital status, individual income, and education.
Bold values represent statistically significant association ($P < .05$).

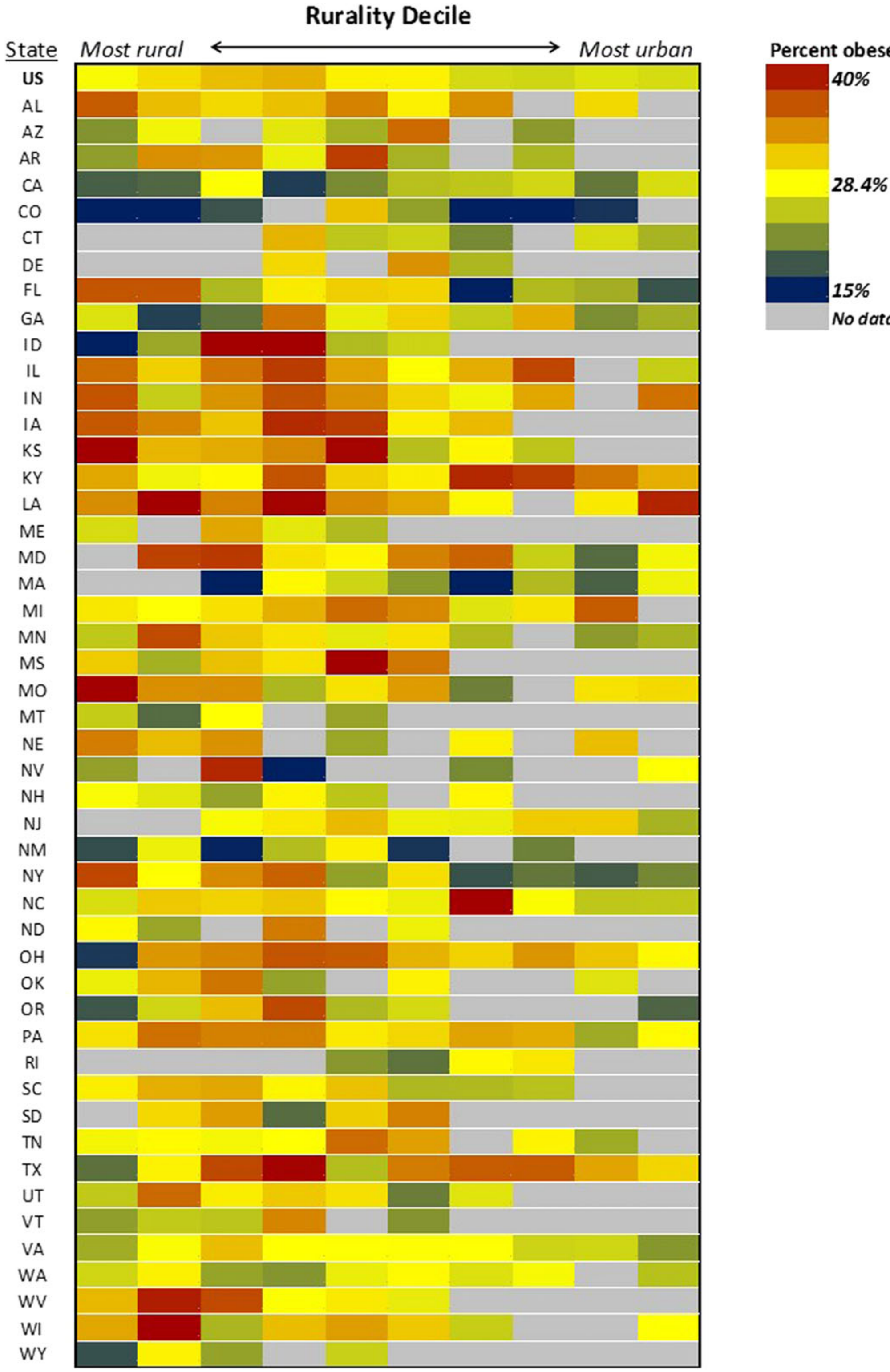
Figure 2 Figure 2 Model-Adjusted Prevalence of Obesity in the US Population Aged 65+ by County Per-Capita Income Tertile and Rural-Urban Status Decile. Adjusted for age, sex, race, marital status, individual income, and education.



most rural places. Therefore, socioeconomic status exerts a powerful (but different) influence on obesity depending on geographical context, and SES should be considered in measures of rural-urban health disparities. Lastly, these associations between obesity and rural-urban character were not uniform throughout the United States and varied considerably by state.

These findings underscore the notion that in assessing rural-urban health disparities in older adults, the associations are more complex than simply "rural versus urban." Research in this field should continue to take a more comprehensive view of how we define and measure rurality, because it provides a better understanding (and accuracy) of health outcomes and disparities that may have otherwise been masked if using a binary "rural/urban" variable. The nonlinear association between rural-urban status and obesity is consistent with a small number of prior studies. One study observed a J-shaped association between having a sedentary lifestyle and rural-urban status using a measure of rural-urban status with 5 levels.[38] The results of another study that examined all-cause mortality and rural-urban status were consistent with our results.[39] That study used a 9-level ordinal measure of rural-urban status and found that

Figure 3 State-Specific, Model-Adjusted Prevalence of Obesity in the 65+ Population by Rural-Urban Status. Adjusted for age, sex, race, marital status, individual income, and education.[a]



[a]Red and orange represent areas in which obesity is above the US prevalence (28%); blue and green areas represent areas in which obesity is below the US prevalence. Gray areas represent rurality deciles and states in which there were either no respondents or no counties in that state in that categorization.

mortality was highest in areas of intermediate to high rurality. Similar to our findings, mortality was lower in the areas of highest rurality, as well as in the lowest rurality areas, showing a J- or U-shaped association. Our findings extend the work of these previous studies by demonstrating that findings of studies conducted in one rural area may not always be applicable to other, seemingly similar rural areas in other parts of the country.

There are numerous effective and promising interventions available to assist rural residents and health care providers to address obesity.[40] Many of these interventions are specifically targeted to rural residents, while others can be adapted to rural residents. The findings of our research suggest that, perhaps, to maximize effectiveness, there are 2 factors that should be taken into account. First, our findings suggest that in some parts of the country, rural populations are not at an increased risk of obesity. Therefore, programs and interventions designed to reduce rural-urban disparities in obesity may not be as effective in those areas. Second, more must be known about the aspects of rural life that may truly be driving the increased likelihood of obesity throughout different parts of the country.

Although there is no clear and universally accepted rationale that explains the observed complex associations between rural-urban status and obesity, some possible explanations do exist. Rural populations, regardless of age or wealth, experience higher than average morbidity and reduced access to high-quality health care services.[41] Residents of rural areas experience higher rates of social and physical isolation, reducing access to stores and medical services.[24,42] Older adults living in rural areas may find it more difficult to seek appropriate medical care to manage chronic conditions, such as obesity, because medical specialists are less likely to practice in rural areas than in urban areas.[21,43]

However, these possible explanations do not fully account for the fact that in the most rural areas, obesity prevalence was actually lower than in areas of intermediate rurality. Although no studies have directly examined the potential for nonlinear associations between obesity and rurality, our results potentially contradict previous findings of rural-urban disparities in other health outcomes, such as later-stage cancer risk.[44] In that study, the authors observed a similar J-shaped association between cancer risk and rurality, but the most rural areas actually had the highest cancer risk. Another example is a 2001 study of premature limiting long-term illness in the United Kingdom. That study also observed that poor health outcomes were highest in the most remote and most urban areas.[45] Similar findings were observed in a study of mental health outcomes.[46] Our study is among the first to observe that extremely rural populations may experience better health outcomes than other rural residents. The explanations for these observations are not clear, however.

Our study is among the first to examine the associations between obesity and rural-urban health status using a continuous measure of rurality utilizing a large, national sample of older adults. In this analysis, we treated rural-urban status as both a continuous predictor variable, and as a series of ordinal indicator variables to account for potential nonlinearity. Using this approach, we observed that, although there were significant linear trends in obesity, important nonlinear trends would have been masked had we used rural-urban status as a continuous predictor alone, with potentially important implications for policy targeting rural-urban health disparities and future research. This type of approach should be considered in other studies assessing rural/urban health disparities. The findings of the study suggested that the associations between obesity and rural-urban status were stronger in higher-income counties and in certain states. Such findings underscore the idea that current "one-size-fits-all" approaches to policies and programs designed to reduce rural-urban disparities may need to be tailored to the particular needs of the deprived area.[47,48] Positive findings from a program or policy to reduce obesity and promote health for older adults in one type of local area may not be as effective in seemingly similar areas across the United States. Therefore, such programs and emerging interventions should be mindful not only of addressing general "rural-urban" health disparities, but they should also account for the substantial intrarural variability in what it means to be "rural," what aspects of rural life are truly driving those disparities, and what can be done to address those factors in tailoring interventions to have the greatest impact in reducing health disparities, particularly in older adults. Future research can more fully explore what aspects of rural or urban life impact different aspects of health and health behaviors.

Limitations

The findings of this empirical study should be interpreted with several limitations in mind. First, rural-urban status is multidimensional.[26] Using a composite index of rural-urban status (the IRR), those aspects of rural or urban living that truly contribute to the observed association and affect health are masked. Future studies could explore how unique characteristics of rural or urban environments, such as distance to health care facilities, food deserts, recreational activities, and infrastructure, help promote or hinder health. Second, place-based characteristics (per-capita income and IRR) were ascertained on the county level. Although "county" is among the smallest unit of geography used in many health studies, counties themselves can be heterogeneous and may not represent the associations that may be occurring on smaller geographic levels. Furthermore, counties are largely administrative, and the composition and overall size of counties may vary across regions. Third, we examined personal income and education level as measures of SES in this analysis, which, for older adults, may be less indicative of SES than accumulated wealth. However, we were limited by the variables in BRFSS, which did not assess personal assets and other aspects of wealth. Next, because this analysis was cross-sectional, causality could not be assessed. There is a slight temporal discordance between the rurality measures, which were obtained from the 2010 US Census, and the 2012 BRFSS data for the outcome and covariate measures used in the analysis. We elected to use 2010 data instead of data from the American Community Survey, which would have better coincided with the 2012 BRFSS data, because the American Community Survey data is subject to a small amount of sampling error, since it is a survey and not a full census. Likewise, we did not account for potential spatial autocorrelation, which may account for some of the variability in the observed obesity-rurality associations. This analysis did not test for formal interactions between SES and rurality and their association with obesity in older adults. The BRFSS sample size included in this analysis was over 100,000 older adults. Therefore, the analysis presented has high statistical power to detect somewhat weak associations. Residual confounding from unmeasured variables or variables not considered in this analysis, such as diet and physical activity, may affect the associations between obesity and rurality. Another important limitation is that the IRR, like many measures of rurality, does not fully take into account all of the demographic, cultural, social, and economic aspects of rurality. Respondents in the "overweight" category (BMI 25-29.9) were not included in the "obese" group, which may bias the results. Future studies can provide a more detailed analysis into the various BMI category comparisons, such as underweight, normal, and those with severe obesity, as well. Finally, these findings may represent the current population of older adults but cannot necessarily be extended to the aging baby boomers who are just beginning to enter the 65+ age category.

Conclusion

Despite these limitations, these findings suggest that place-based characteristics may play a role in health promotion for older adults. To maximize the effectiveness of strategies aimed at reducing health disparities in older adults and promoting positive aging, the relationship between place-of-residence and health must be better addressed.[38] As the population ages, the need to understand and address these disparities to promote health, both in older adults as well as the adult population as a whole, should be a major research priority. Therefore, understanding the specific elements of rurality that impact health can inform policies, programs, and other interventions designed to protect health and reduce preventable morbidity, especially in areas with limited resources.

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Supporting Information

Additional supporting information may be found in the online version of this article at the publisher's web site.

Table S1. Descriptive Characteristics for BRFSS Study Sample (Aged 65+)
Table S2. Characteristics of the Deciles of the Index of Relative Rurality