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Examination of cardiovascular risk factors and rurality in Appalachian children

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ABSTRACT

Introduction: The prevalence of childhood cardiovascular disease (CVD) risk factors often increases in more rural geographic regions in the USA. However, research on the topic often has conflicting results. Researchers note differences in definitions of rurality and other factors that would lead to differences in inference, including appropriate use of statistical clustering analysis, representative data, and inclusion of individual-level covariates. The present study's objective was to examine CVD risk factors during childhood by geographic distribution in the US Appalachian region as a first step towards understanding the health disparities in this area.

Methods: Rurality and CVD risk factors (including blood pressure, body-mass index (BMI), and cholesterol) were examined in a large, representative sample of fifth-grade students (*N*=73 014) from an Appalachian state in the USA. A six-category Rural-Urban Continuum Codes classification system was used to define rurality regions. Mixed modeling analysis was used to appropriately cluster individuals within 725 unique zip codes in each of these six regions, and allowed for including several individual-level socioeconomic factors as covariates.

Results: Rural areas had better outcomes for certain CVD risk factors (lowest low-density lipoprotein cholesterol (LDL-C), and blood pressure (BP) and highest high-density lipoprotein cholesterol (HDL-C)) whereas mid-sized metro and town areas presented with the worst CVD risk factors (highest BMI% above ideal, mean diastolic BP, LDL-C, total cholesterol, triglyceride levels and lowest HDL-C) outcomes in children and adolescence in this Appalachian state.

Conclusions: Counter to the study hypothesis, mid-sized metro areas presented with the worst CVD risk factors outcomes in children and adolescence in the Appalachian state. This data contradicts previous literature suggesting a straightforward link between rurality and cardiovascular risk factors. Future research should include a longitudinal design and explore some of the mechanisms between cardiovascular risk factors and rurality.

Key words: cardiovascular disease, child health, geography, USA.

Introduction

Cardiovascular disease (CVD) mortality is the leading cause of death in the USA[1]. CVD risk factors including high blood pressure (BP), poor lipid profile, and impaired glucose tolerance are now prevalent in youth as well as in adults[2,3]. Data from National Health and Nutrition Examination Survey (NHANES) shows that, in the USA, 14% of adolescents had elevated BP, 22% had borderline-to-high or high low-density lipoprotein cholesterol (LDL-C), 6% had low high-density lipoprotein cholesterol (HDL-C) (NHANES: 1999–2008)[4] and 32% children aged 2–19 years were either overweight or obese (NHANES: 2009–2010)[5]. Pediatric obesity also increases the likelihood of development of other CVD risk factors during childhood and adolescence[2]. Moreover, research shows that childhood CVD risk factors such as obesity, high BP, and abnormal lipids also track over time into adulthood[6].

Several studies have examined CVD risk factor prevalence and its contributing factors by stratified analysis of various sociodemographic characteristics (such as age, gender, racial/ethnic background and income)[4,5,7-9]; a select few have examined these differences by urban and rural geographic distribution in the USA. These studies have revealed mixed findings by age. For example, data from a nationally representative study showed that older rural children (12–19 years) had 30% higher odds of being overweight or obese compared to urban children, although no significant differences were observed in younger children (2–11 years)[10]. A recent meta-analysis using data of US children aged 2–19 years found that rural children compared to urban children are 26% more likely to be obese (odds ratio (OR)=1.26; 95% confidence interval (CI)=1.21–1.32)[11].

Different states have different rural/urban prevalence distributions by CVD risk factors as well. For example, a study in North Carolina found no differences in total cholesterol (TC) and BP of rural and urban children, but found obesity rates to be significantly greater for rural children within the state[12]. Another study demonstrated a significantly higher prevalence of obesity in rural children when compared to children living in metropolitan centers of Pennsylvania[13].

The mixed findings on the differences of urban/rural prevalence of various childhood CVD risk factors suggest the importance of investigating this issue further. Some researchers suggest that merely living in a certain geographic location is not, in itself, a risk factor, but factors that differ between urban/rural residence contribute to the observed differences in CVD risk factors[14]. Others argue that there remains a strong link between rurality and obesity that cannot be explained by demographic factors alone[15].

Some researchers have reasoned that the mixed findings may be due to the broad classification of urban/rural (81% vs 19%) or metropolitan/non-metropolitan areas (85% vs 15%)[11]. A nationally representative study using census block-group level found no significant associations between urban/rural status and childhood obesity after controlling for individual-level and zip code-level covariates[16]. In comparison, researchers using nationally representative data of grade 7–12 students classified neighborhood patterns in six categories and found that adolescents in select neighborhoods, including those living in rural working class, ex-urban, and mixed-race urban areas, were approximately 30% more likely to be overweight compared to those living in the newer suburban areas, independent of age, race, and socioeconomic status[17]. Thus, carefully defining urban and rural locations may be an important piece of the puzzle. In order to overcome the limitations of the broad classification system, the US Department of Agriculture has introduced a multitier classification scheme derived from the Office of Management and Budget and US Census definitions, which includes the Urban Influence Codes, Rural–Urban Continuum Codes (RUCC), and the Rural-Urban Commuting Area[18]. For the purpose of this study the authors used the nine-tier RUCC classification system, which is based on county-level data that can be matched to zip codes, and broken down into finer residential groups, beyond urban/rural, which is particularly useful for the analysis of trends in non-metro areas that are related to population density and metro influence.

Beyond the broad classifications of urban or rural location definitions, there remain conflicting results regarding the influence of rural or urban living on cardiovascular risk factors in children. A recent systematic review notes a lack of several key factors needed to make accurate conclusions from the data, including representative data, appropriate use of clustering, controlling for individual socioeconomic factors, longitudinal designs and intermediate mechanisms between environmental characteristics and cardiometabolic risk factors[19]. Thus, in addition to carefully defining rural urban divisions, this study includes several of these predefined factors, including appropriate use of statistical clustering analysis, representative data, and inclusion of some individual socioeconomic factors.

This exploration of the topic begins in a section of the USA with a large rural population. The Appalachian region consists of 420 counties in 13 states of which 42% of the population lives in rural areas[20]. Appalachian populations generally have higher rates of CVD risk factors and CVD mortality compared to the rest of the nation[21]. According to the Behavioral Risk Factor Surveillance System 2013 survey, West Virginia, a state entirely located in the Appalachian region, now ranks number one in adult obesity in the nation[22]. The 2011 Youth Risk Behavior Survey showed that 15.7% of adolescents were overweight and 14.6% were obese in West Virginia compared to the national averages of 15.2% and 13% respectively[23].

In order to understand the geographic disparities in youth CVD risk factors, the authors aim to examine rurality and CVD risk factors in a large, representative sample from the Appalachian state of West Virginia, using appropriate clustering analytic techniques and controlling for several individual-level socioeconomic factors. It is hypothesized that more rural regions will be associated with poor CVD risk factor outcomes. Examining CVD risk factors during childhood by geographic distribution in the Appalachian region is the first step towards understanding the health disparities in this area.

Methods

The Coronary Artery Risk Detection In Appalachian Communities (CARDIAC) project started as a small school-based CVD surveillance project piloted in three rural West Virginia counties in 1998, and now includes services to all 55 West Virginia counties and more than 480 schools. For nearly two decades, CARDIAC has provided information to participating families, communities, the state and nation[24] about chronic illnesses including hyperlipidemia[25], abnormal blood lipids and obesity[26,27], asthma[28], decreasing cholesterol risk[29], pre-diabetic conditions[30], health behaviors[31], and intervention factors[32,33]. Average findings for the program period demonstrate that from 1998 to 2014, 47.1% of fifth-grade students in West Virginia were either overweight or obese (body-mass index (BMI) percentile≥85th). Only fifth-grade participants receive lipid profiles and thus are the only participants included in this study.

With an active consent process for parents of fifth-grade participants, response rates by year range from 31% to 49% since 1998. These response rates for a health surveillance program are typical of the active consent process in elementary and middle school settings[34,35]. Previous work has shown that the differences between participants and non-participants are minimal. Non-participants are less likely to have a primary care provider and to have health insurance, but there is no difference in BMI or any other demographic variables analyzed in the present study[36].

Measures

The comprehensive risk screening for fifth-grade participants included calculation of BMI from height and weight, resting diastolic BP (DBP) and systolic BP (SBP), and either a fasting or non-fasting lipid profile (FLP).

Children's heights (cm) and weights (kg) were measured using the SECA Road Rod stadiometer and the SECA 840 Personal Digital Scale. Students were asked to remove shoes and outerwear prior to height and weight measurements.

These measurements were used to determine each child's BMI and BMI percentile, calculated using CDC Epi Info v3.5.4 (Centers for Disease Control and Prevention; http://www.cdc.gov/epiinfo). Percentage above ideal BMI (BMI% above ideal) was calculated using 100*log base e (BMI/median BMI)[37] to control for age, gender and height and avoid the ceiling effect seen when using BMI percentile.

BP was taken after the child had been resting for 5 minutes. The first Korotkoff sound was used to record SBP and the fifth Korotkoff sound was used to record DBP.

All cholesterol levels were obtained in either a private area of the school or children were given a voucher to have an FLP conducted in a nationally available laboratory network or hospital. The FLP data analyzed in this manuscript start in 2003, and do not include any finger-stick obtained cholesterol levels (1998–2002) in order to avoid potential bias due to different methods of cholesterol measurements. Consistent blood specimens were taken since 2003, and all labs (hospital and the laboratory) used consistent methods to process the specimens.

RUCC were retrieved by zip code from the Missouri Census Data Center using the Beale 2003 RUCC code; multiple codes within zip codes were resolved by taking the largest proportion within the zip code. RUCC, a nine-point classification system based on county-level data, was further reduced to six categories for this analysis: large metro (counties in metro areas of ≥1 million people), metro (250 000–1 million), small metro (<250 000), non-metro urban (≥20 000), urban (2500–20 000), and rural (<2500).

Other covariates included parent-reported child birth date and calculated age at screening date, gender, race (six categories: *white*, *black*, *Asian*, *Hispanic*, *bi-racial*, and *other*), and mother's education (six categories: *eighth grade or less*, *some high school*, *high school or GED* [General Educational Development test], *some college or technical training*, *college graduate*, *completed graduate school*).

Statistical analysis

Data for CARDIAC were stored in the Statistical Package for the Social Sciences v21 (IBM; http://spss.com). All analyses conducted in this manuscript used Statistical Analysis Software v9.4 (SAS Institute; http://www.sas.com). ArcGIS Desktop v10 (Environmental Systems Research Institute; http://www.esri.com/arcgis) was used to develop RUCC maps. The data for this project include 73 014 fifth-grade children who participated in CARDIAC between 2003 and 2014. Missing data was assumed to be either missing completely at random or missing at random, and dealt with using pairwise deletion.

The statistical approach used a clustered design nesting individual children's FLP, BMI and BP results within their home zip code coded using RUCC and controlling for individual and socioeconomic status covariates. CARDIAC participants were matched to the RUCC code data file clustered in 725 zip codes. Triglycerides (TRIG) were log-transformed for the analyses. No interaction terms between socioeconomic status indicators and outcome variables were significant; results presented here include a two-level random-effects linear mixed model (students nested within zip codes) with a variance components covariance structure (chosen via Akaike information criterion fit) and restricted maximum likelihood estimation. Reference categories within the mixed model for categorical variables were set to *white* (race), *male* (gender), *some high school* (mother's education), and *rural* (RUCC). Least square means are presented with all pairwise comparisons between RUCC categories conducted with type I error adjusted for using Tukey–Kramer method, alpha set to 0.05.

Ethics approval

West Virginia University Institutional Review Board approved the study protocol (IRB 1606162244).

Results

RUCC classification using the six-category system can be seen in Figure 1. Table 1 shows number of CARDIAC participants within each region.

Table 1: Demographics of Coronary Artery Risk Detection In Appalachian Communities fifth-grade participants (*N*=73 014)

Variable	*N* (valid %)	
Six-category RUCC	70 878	
Large metro	2224 (3.14)	
Metro	14 188 (20.02)	
Small metro	17 193 (24.26)	
Non-metro urban	12 387 (17.48)	
Town	20 528 (28.96)	
Rural	4358 (6.15)	
Gender	73 014	
Female	39 154 (53.63)	
Male	33 860 (46.37)	
Mother's education	57 417	
Eighth grade or less	1093 (1.90)	
Some high school	4140 (7.21)	
High school or GED	19 063 (33.20)	
Some college	16 407 (28.58)	
College	12 743 (22.19)	
Graduate school	3971 (6.92)	
Race	70 376	
White	65 112 (92.52)	
Black	2071 (2.94)	
Asian	341 (0.48)	
Hispanic	566 (0.80)	
Bi-racial	1975 (2.81)	
Other	311 (0.44)	
	N	**Mean (SD)**
Student age	72 699	10.97 (0.52)
BMI% ideal	71 703	18.58 (22.80)
TRIG	54 986	91.60 (55.64)
TC	55 116	160.60 (28.43)
HDL-C	55 001	50.66 (12.27)
LDL-C	54 916	92.22 (25.33)
SBP	72 145	108.20 (11.87)
DBP	72 073	68.03 (9.42)

BMI, body-mass index. DBP, diastolic blood pressure. GED, General Educational Development test. HDL-C, high-density lipoprotein cholesterol. LDL-C, low-density lipoprotein cholesterol. RUCC, Rural–Urban Continuum Codes. SBP, systolic blood pressure. SD, standard deviation. TC, total cholesterol. TRIG, triglycerides.

Significant nested omnibus effects were seen for all outcomes after controlling for covariates, including BMI, HDL, SBP, DBP, log-transformed TRIG, LDL, and TC ($p<0.0001$; Table 2). However, posthoc comparisons disputed the hypothesis that rural areas would have significantly higher risk factors than urban or metro areas (Fig2). Specific outcomes are presented in more detail below. Omnibus type 3 tests of fixed effects are presented in text along with least square means and adjusted *p*-values for significant pairwise comparisons; all fixed effects are presented in more detail in Table 2.

Outcomes

BMI% above ideal: Significant type 3 test of fixed effects for RUCC, $F(5, 53\,229)=15.57$, $p<0.0001$; race, $F(5)=20.32$, $p<0.0001$; gender, $F(1)=65.22$, $p<0.0001$; and maternal education, $F(5)=33.8$, $p<0.0001$; but not student age ($p=0.69$). Mid-sized metro (mean=22.09) and urban (mean=22.13) had significantly higher means than large metro (mean=17.72) and small metro (mean=18.41, all adjusted $p<0.05$). Rural (mean=20.64) and non-metro urban (mean=20.64) were significantly higher means than small metro (all adjusted $p<0.05$).

Table 2: Solution for fixed effects of outcomes

Effect for BMI percentage Model: F(5, 53 229)=15.57, *p*<0.0001					
Intercept		22.01	2.38	9.26	<0.0001
Student age		–0.08	0.20	–0.40	0.6921
Student race **(referent: white)**	Asian	–5.63	1.42	–3.97	<0.0001
	Bi-racial	4.02	0.60	6.73	<0.0001
	Black	3.72	0.62	5.96	<0.0001
	Hispanic	2.34	1.18	1.98	0.0482
	Other	3.48	1.51	2.30	0.0213
Student gender (referent: male)	Female	–1.60	0.20	–8.08	<0.0001
Mother's education **(referent: some high school)**	Eighth grade or less	2.29	0.81	2.81	0.0049
	High school	–0.38	0.41	–0.93	0.3528
	Some college	–1.00	0.42	–2.41	0.0161
	College	–2.86	0.43	–6.64	<0.0001
	Graduate school	–4.06	0.53	–7.62	<0.0001
RUCC category **(referent: rural)**	Large metro	–2.93	1.27	–2.30	0.0217
	Mid-sized metro	1.45	0.64	2.25	0.0243
	Small metro	–2.23	0.65	–3.43	0.0006
	Non-metro urban	0.00	0.70	0.00	0.9969
	Town	1.49	0.59	2.53	0.0113
Effect for HDL-C Model: F(5, 44 984)=17.66, *p*<0.0001					
Intercept		62.25	1.40	44.57	<0.0001
Student age		–0.87	0.12	–7.30	<0.0001
Student race **(referent: white)**	Asian	3.79	0.80	4.71	<0.0001
	Bi-racial	1.72	0.34	5.07	<0.0001
	Black	3.60	0.36	10.04	<.0001
	Hispanic	0.94	0.66	1.43	0.1525
	Other	0.19	0.86	0.22	0.8289
Student gender (referent: male)	Female	–2.19	0.11	–19.25	<0.0001
Mother's education **(referent: some high school)**	Eighth grade or less	–0.05	0.49	–0.11	0.9131
	High school	0.36	0.24	1.51	0.131
	Some college	0.86	0.24	3.53	0.0004
	College	1.67	0.25	6.63	<0.0001
	Graduate school	2.02	0.31	6.52	<0.0001
RUCC category **(referent: rural)**	Large metro	0.65	1.00	0.65	0.5165
	Mid-sized metro	–3.31	0.46	–7.24	<0.0001
	Small metro	–0.96	0.47	–2.04	0.0414
	Non-metro urban	–3.13	0.50	–6.27	<0.0001
	Town	–2.47	0.42	–5.95	<0.0001
Effect for SBP Model: F(5, 53 224)=6.06, *p*<0.0001					
Intercept		86.64	1.26	68.99	<0.0001
Student age		1.92	0.11	18.11	<0.0001
Student race **(referent: white)**	Asian	–2.10	0.74	–2.84	0.0045
	Bi-racial	1.12	0.31	3.60	0.0003
	Black	1.15	0.33	3.52	0.0004
	Hispanic	0.08	0.62	0.13	0.8982
	Other	–0.60	0.79	–0.76	0.4472
Student gender (referent: male)	Female	–0.64	0.10	–6.26	<0.0001

Table 2: cont'd

Effect for SBP Model: F(5, 53 224)=6.06, *p*<0.0001					
Mother's education (referent: some high school)	Eighth grade or less	0.01	0.42	0.03	0.9788
	High school	−0.26	0.21	−1.22	0.2222
	Some college	−0.35	0.22	−1.63	0.1026
	College	−0.75	0.22	−3.36	0.0008
	Graduate school	−1.22	0.28	−4.39	<0.0001
RUCC category (referent: rural)	Large metro	1.52	1.02	1.48	0.1377
	Mid-sized metro	1.83	0.45	4.03	<0.0001
	Small metro	0.49	0.47	1.04	0.299
	Non-metro urban	1.31	0.50	2.64	0.0084
	Town	1.78	0.41	4.39	<0.0001
Effect for DBP Model: F(5, 53 166)=4.84, *p*=0.0002					
Intercept		56.28	1.00	56.46	<0.0001
Student age		0.99	0.08	11.74	<0.0001
Student race (referent: white)	Asian	−0.47	0.58	−0.81	0.4173
	Bi-racial	0.51	0.25	2.06	0.0396
	Black	1.34	0.26	5.17	<0.0001
	Hispanic	0.60	0.49	1.23	0.2193
	Other	0.28	0.62	0.45	0.6533
Student gender (referent: male)	Female	−0.34	0.08	−4.16	<0.0001
Mother's education (referent: some high school)	Eighth grade or less	0.55	0.33	1.65	0.0992
	High school	−0.10	0.17	−0.57	0.5708
	Some college	−0.27	0.17	−1.58	0.1151
	College	−0.31	0.18	−1.73	0.0834
	Graduate school	−0.50	0.22	−2.25	0.0243
RUCC category (referent: rural)	Large metro	2.76	0.83	3.34	0.0008
	Mid-sized metro	1.38	0.37	3.79	0.0002
	Small metro	0.88	0.38	2.34	0.0192
	Non-metro urban	1.27	0.40	3.18	0.0015
	Town	1.34	0.33	4.09	<0.0001
Effect for LDL-C Model: F(5, 44 915)=13.72, *p*<0.0001					
Intercept		113.57	2.87	39.60	<0.0001
Student age		−2.17	0.25	−8.80	<0.0001
Student race (referent: white)	Asian	−0.51	1.67	−0.31	0.7579
	Bi-racial	0.26	0.70	0.37	0.7123
	Black	0.57	0.74	0.77	0.4386
	Hispanic	−1.15	1.37	−0.84	0.4018
	Other	−1.51	1.78	−0.85	0.3958
Student gender (referent: male)	Female	−1.44	0.24	−6.10	<0.0001
Mother's education (referent: some high school)	Eighth grade or less	0.14	1.01	0.14	0.8888
	High school	0.73	0.50	1.46	0.1445
	Some college	0.08	0.51	0.16	0.8734
	College	−0.86	0.52	−1.65	0.0998
	Graduate school	−0.05	0.64	−0.08	0.9399
RUCC category (referent: rural)	Large metro	1.99	1.72	1.16	0.247
	Mid-sized metro	5.68	0.83	6.82	<0.0001
	Small metro	2.74	0.85	3.23	0.0012
	Non-metro urban	2.26	0.90	2.49	0.0126
	Town	1.12	0.76	1.46	0.1429

Table 2: cont'd

Effect for TC Model: F(5, 45 077)=10.76, *p*<0.0001					
Intercept		188.75	3.20	58.97	<0.0001
Student age		−2.53	0.28	−9.18	<0.0001
Student race (referent: white)	Asian	3.67	1.87	1.96	0.0502
	Bi-racial	0.50	0.79	0.63	0.5309
	Black	0.56	0.83	0.68	0.4964
	Hispanic	0.34	1.54	0.22	0.8252
	Other	−1.47	2.00	−0.73	0.463
Student gender (referent: male)	Female	−2.11	0.27	−7.95	<0.0001
Mother's education (referent: some high school)	Eighth grade or less	0.32	1.13	0.28	0.777
	High school	0.89	0.56	1.59	0.1114
	Some college	0.18	0.57	0.32	0.7453
	College	−0.42	0.58	−0.72	0.4696
	Graduate school	0.74	0.72	1.03	0.3028
RUCC category (referent: rural)	Large metro	1.20	1.55	0.77	0.439
	Mid-sized metro	1.58	0.81	1.95	0.051
	Small metro	1.15	0.81	1.41	0.1587
	Non-metro urban	−2.46	0.87	−2.83	0.0047
	Town	−1.61	0.75	−2.15	0.0317
Effect for log TRIG Model: F(5, 44 970)=4.09, *p*=0.001					
Intercept		3.96	0.06	67.59	<0.0001
Student age		0.04	0.01	7.57	<0.0001
Student race (referent: white)	Asian	0.03	0.03	0.75	0.4546
	Bi-racial	−0.09	0.01	−6.16	<0.0001
	Black	−0.20	0.02	−13.42	<0.0001
	Hispanic	0.01	0.03	0.37	0.7081
	Other	−0.05	0.04	−1.31	0.1919
Student gender (referent: male)	Female	0.11	0.00	22.79	<0.0001
Mother's education (referent: some high school)	Eighth grade or less	0.01	0.02	0.48	0.6347
	High school	−0.02	0.01	−1.63	0.1037
	Some college	−0.05	0.01	−4.65	<0.0001
	College	−0.07	0.01	−6.64	<0.0001
	Graduate school	−0.07	0.01	−5.55	<0.0001
RUCC category (referent: rural)	Large metro	−0.06	0.03	−1.93	0.0539
	Mid-sized metro	0.00	0.02	0.26	0.7981
	Small metro	−0.03	0.02	−1.96	0.0503
	Non-metro urban	0.01	0.02	0.53	0.5988
	Town	0.02	0.01	1.05	0.2951

BMI, body-mass index. DBP, diastolic blood pressure. GED, General Educational Development test. HDL-C, high-density lipoprotein cholesterol. LDL-C, low-density lipoprotein cholesterol. RUCC, Rural–Urban Continuum Codes. SBP, systolic blood pressure. SE, standard error. TC, total cholesterol. TRIG, triglycerides.

HDL-C: Significant type 3 test of fixed effects for RUCC, F(5, 44 984)=17.66, *p*<0.0001; race, F(5)=28.29, *p*<0.0001; gender, F(1)=370.55, *p*<0.0001; maternal education, F(5)=22.55, *p*<0.0001; and student age, F(1)=53.31, *p*<0.0001. Large metro (mean=54.78), rural (mean=54.13) and small metro (mean=53.17) areas had the best (highest) HDL as compared to mid-sized metro (mean=50.82), non-metro urban (mean=51.0), and urban areas (mean=51.65, all adjusted *p*<0.05).

SBP: Significant type 3 test of fixed effects for RUCC, F(5, 53 224)=6.06, *p*<0.0001; race, F(5)=6.69, *p*<0.0001; gender, F(1)=39.15, *p*<0.0001; maternal education, F(5)=6.77, *p*<0.0001; and student age, F(1)=327.95, *p*<0.0001. Rural areas (mean=106.92) had significantly lower SBP than mid-sized metro (mean=108.75), and urban (mean=108.70) areas (all adjusted *p*<0.05). Small metro (mean=107.40) was also significantly less than mid-sized metro and urban areas (all adjusted *p*<0.05). Non-metro urban (mean=108.23) and large metro (mean=108.44) areas were not significantly different than other areas.

DBP: Significant type 3 test of fixed effects for RUCC, F(5, 53 166)=4.84, *p*=0.0002; race, F(5)=6.38, *p*<0.0001; gender, F(1)=17.28, *p*<0.0001; maternal education, F(5)=3.08, *p*=0.009; and student age, F(1)=137.73, *p*<0.0001. Rural (mean=67.22) had significantly lower means than urban (mean=68.55), large metro (69.98), non-metro urban (mean=68.49), and mid-sized metro (mean=68.60) areas (all adjusted *p*<0.05). Small metro (mean=68.10) was not significantly different than other areas.

Log TRIG: Significant type 3 test of fixed effects for RUCC, F(5, 44 970)=4.09, *p*=0.001; race, F(5)=42.49, *p*<0.0001; gender, F(1)=519.45, *p*<0.0001; and maternal education, F(5)=20.77, *p*<0.0001. Town (mean=4.36) was significantly larger than small metro (mean=4.32) area (adjusted *p*=0.0014). No differences were found among large metro (mean=4.28), mid-sized metro (mean=4.35), non-metro urban (mean=4.35), or rural (mean=4.35) areas.

LDL-C: Significant type 3 test of fixed effects for RUCC, F(5, 44 915)=13.72, *p*<0.0001; student age, F(1)=77.5, *p*<0.0001; gender, F(1)=37.27, *p*<0.0001; and maternal education, F(5)=4.77, *p*=0.0002; but not race (*p*=0.81). Mid-sized metro (mean=94.37) presented with higher LDL than rural (mean=88.70), urban (89.81), small metro (mean=91.43), and non-metro urban (mean=90.95) areas, and small metro was also significantly larger than rural (all adjusted *p*<0.05). Large metro (mean=90.69) was not significantly different than other areas.

TC: Significant type 3 test of fixed effects for RUCC, F(5, 45 077)=10.76, *p*<0.0001; student age, F(1)=84.23, *p*<0.0001; gender, F(1)=63.17, *p*<0.0001; and maternal education, F(5)=2.91, *p*=0.013; but not race (*p*=0.81). Mid-sized metro area (mean=162.35) and small metro (mean=161.91) presented with higher TC over non-metro urban (mean=158.3) and urban (mean=159.15) areas (all adjusted *p*<0.0001). No differences were found with large metro (mean=161.97), small metro (mean=161.91) or rural (mean=160.77) areas.

Discussion

The study's findings directly counter previous literature connecting more rural locations to CVD risk factors, particularly obesity[10,12-14]. The authors instead note particularly poor outcomes in mid-sized metro areas in the Appalachian state of West Virginia, using clustered analysis techniques, representative sample, and adjusting for individual-level covariates. The mid-sized metro areas include counties in metro areas having a population density of 250 000 to 1 million, which is an urban/metropolitan area according to the binary urban/rural or metropolitan/non-metropolitan classification system. Specifically, mid-sized metro and urban areas presented with the highest average BMI% above ideal for age and gender among fifth-grade participants in the state, the lowest HDL-C, and highest mean DBP, LDL-C, TC, and log-transformed TRIG levels. In contrast, the rural areas (population density <2500) tended to have among the best outcomes for certain CVD risk factors, including LDL-C, HDL-C, and BP.

Although the authors note that rural areas have better outcomes compared to other regions in West Virginia, these regions continue to have high CVD risk compared to other regions in the nation[23]. It is also noted that large metro areas generally presented with some of the best outcomes in the state, perhaps most consistent with previous research. However, large metro also presented the highest average DBP. This may be an artifact of only one region in West Virginia being considered large metro: the eastern panhandle of West Virginia, a distal suburb of Washington DC. Again, an examination of intervening mechanisms is needed.

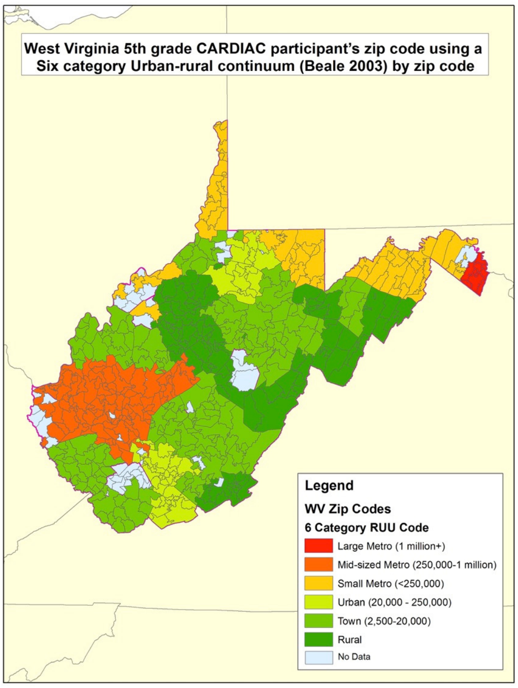

Figure 1: ArcGIS map of Coronary Artery Risk Detection In Appalachian Communities fifth-grade participants

Although not a focal point of this article, examination of the covariates also yields some interesting findings. Female students generally had improved outcomes over males, except for HDL-C and log TRIG. This may be due to lower cholesterols occurring with puberty at younger ages in females. As maternal education increased, outcomes consistently improved on average. Although the majority of the state of West Virginia is white, this study notes worse outcomes in terms of BMI, SBP and DBP for other racial groups, but surprisingly improved outcomes such as HDL-C and log TRIG among all other racial groups.

Limitations include use of cross-sectional data, limiting any type of causal inference. Beale RUCC codes were from 2003, so more recent zip codes added since 2003 could not be included in this analysis. Additionally, Beale RUCC codes are based on county-level data, which limits within-county conclusions. Also, the authors could not explore mechanisms for the associations between geographic locations and CVD risk outcomes in this particular study. Despite these limitations, these results add to the literature in terms of presenting data representative of the generally rural Appalachian region with appropriate statistical modeling techniques and individual-level covariate inclusion. Furthermore, this study used the RUCC classification system and aims to overcome some of the potential limitations of a broad binary classification system that fails to account for some of the variances present in areas that have a population greater than 2500 but are either adjacent to a metro area (small metro) or not adjacent to a metro area (non-metro urban). Results themselves were counter to the authors' prior hypotheses, suggesting the relationship between rurality and CVD risk factors to be more complex than previously supposed. The study adds to the understanding of the differences in geographic CVD risk factors distribution in the Appalachian region of West Virginia. Future research is needed to identify the factors associated with the differences observed. This can lead to potential interventions geared specially in geographic areas where the risk factors are significantly higher.

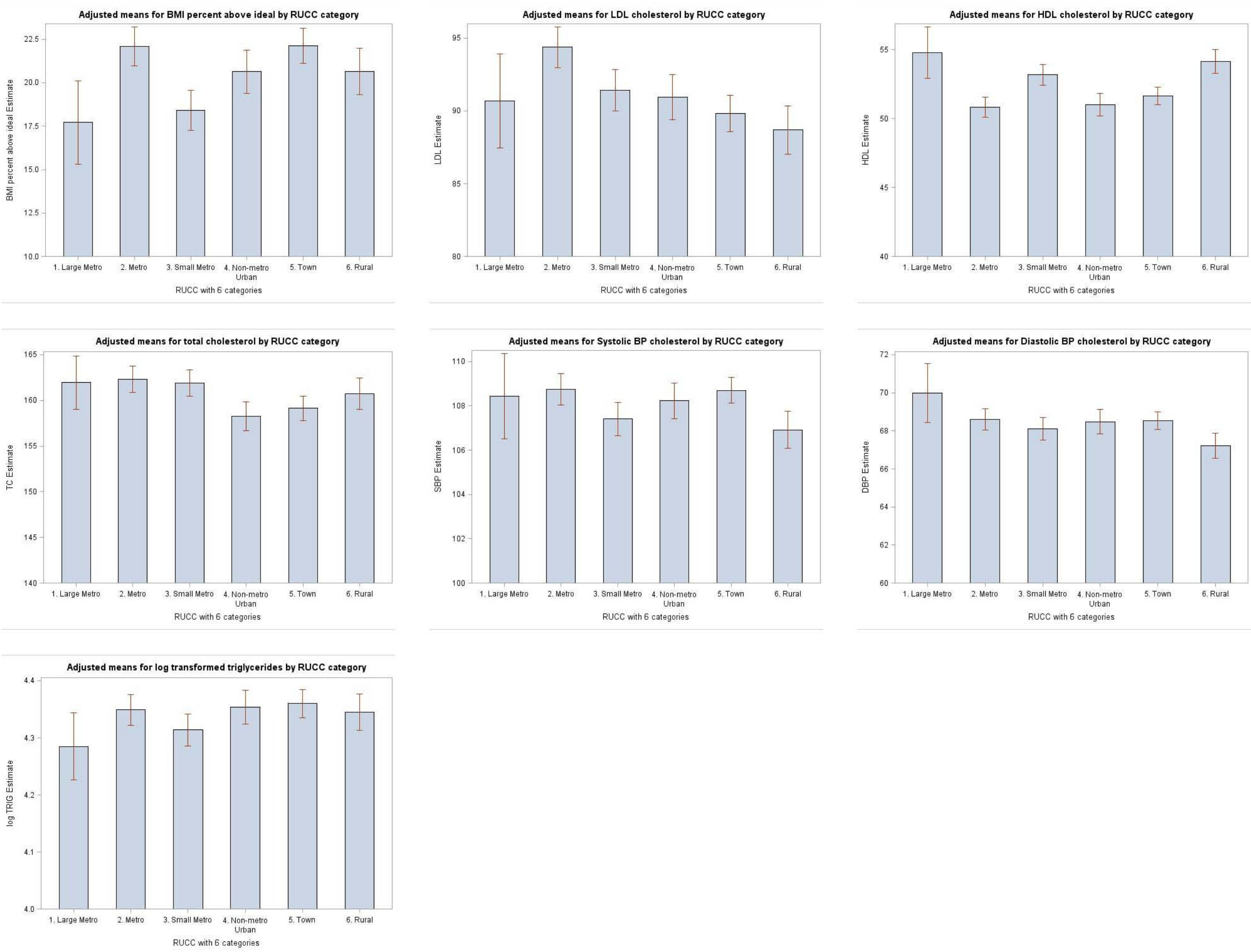

Figure 2: Least square adjusted means for study outcomes by Rural–Urban Continuum Codes category

Conclusions

In general, mid-sized metro areas presented with the worst CVD risk factors outcomes in children and adolescents in the Appalachian state of West Virginia. This data contradicts previous literature suggesting a straightforward link between rurality and cardiovascular risk factors. Future research should include a longitudinal design and explore some of the mechanisms between cardiovascular risk factors and rurality.

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