The Cardiovascular Health of Young Adults: Disparities along the Urban-Rural Continuum

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Abstract

U.S. young adults coming of age in the early 21st Century are the first cohort to grow up during the obesity epidemic; justifiably, there is much concern about their cardiovascular health. To date, however, no research has examined the extent to which there are disparities in young adult cardiovascular health across the urban-rural continuum. We examine this topic using data from the National Longitudinal Study of Adolescent to Adult Health. We find that young adults who live in metropolitan core areas exhibit more favorable cardiovascular health than individuals who live in smaller types of communities, and that population density largely accounts for this association. Further, individuals living in more densely populated areas in young adulthood relative to adolescence have better cardiovascular health than those who live in areas similar or less dense than their adolescent residence. Our results strongly suggest that the physical and social features of communities represent important contexts for young adult cardiovascular health.

Introduction

The U.S. obesity epidemic began among adolescents in the mid- to late-1990s (Lee et al. 2011). By the late 2000s, 37% of young adults were obese and another 33% were overweight (Hussey et al. 2015; Harris 2010). The early onset and rapid rise in obesity among young adults will threaten their cardiovascular health and future work lives for decades to come. Rising inequality and the slow pace of economic recovery after the Great Recession has furthermore forced many young adults to return home to live with their parents while they finish advanced educational degrees or find employment (Fry 2013), redistributing many of these young adults to rural areas or in the micropolitan and commuting areas of cities. In our highly stratified society, however, educational and work opportunities remain increasingly concentrated in large cities (Burton et al. 2013). Given these dramatic shifts in the health, social and economic contexts in which young people live,

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it is critically important to understand *young adult cardiovascular health* in the United States and, in particular, how young adult cardiovascular health differs across residential contexts.

We use data from the National Longitudinal Study of Adolescent to Adult Health (Add Health) to take important steps toward better understanding disparities in young adult cardiovascular health in the United States across the urban-rural continuum. We use a measure of "ideal cardiovascular health" developed by the American Heart Association (Lloyd-Jones et al. 2010) that considers body weight, blood pressure, and other indicators of cardiac and vascular health. First, we document patterns of ideal cardiovascular health among young adults across the urban-rural continuum, as well as according to patterns of residential change from adolescence to young adulthood. Second, we specify multivariate models of ideal cardiovascular health to better understand why there are differences in young adult cardiovascular health across the urban-rural continuum. We focus on the population density of the census tract within which individuals live as one potentially important explanation for differences in young adult cardiovascular health across the urban-rural continuum. We also focus on early life and adolescent factors that are predictors of both young adult geography of residence and cardiovascular health, as well as on young adult socioeconomic, social, and family structure factors that may account for cardiovascular health differences across the urban-rural continuum.

We contribute to the understanding of cardiovascular health disparities in several ways. First, research on geographic based health disparities has tended to focus on morbidity, disability, and mortality patterns among the middle-aged and elderly populations (Glasgow et al. 2004), with relatively little attention given to young adults. This is an important oversight because today's young adults face a far different social, economic, and epidemiologic context than young adults in the past. Second, we provide greater detail on the geographic context of young adults' residence through the use of both rural-urban commuting area codes (RUCA) and a measure of neighborhood population density based on census tracts. The RUCA codes and population density are correlated but distinct measures, and population density may be an important explanatory factor for health disparities across the rural-urban continuum. Third, we use high quality, longitudinal, individual-level data to consider geographic context of young adult residence, changes in residential context between adolescence and young adulthood, and cardiovascular health. A longitudinal analysis is particularly important because of the permeability of rural-urban boundaries and selection processes that shape individuals' decisions to move to or stay in different locations as they make the transition to adulthood. Fourth, we identify and assess the extent to which several different sets of explanatory variables account for differences in young adult cardiovascular health across the urban-rural continuum in the United States.

Geography and Adult Health in the United States

Generally, adults who live in rural communities have poorer health than those living in more urban areas (Anderson et al. 2015; Monnat and Pickett 2011). Whereas mortality rates in the mid-20th century were higher in cities than rural areas, this pattern has since reversed (Cossman et al. 2010). Mortality is now higher in rural areas, in large part due to higher rates of heart disease (Cossman et al. 2010; Eberhardt and Pamuk 2004; Fontanella et al. 2015;

Morton 2004; Singh and Siahpush 2013). Health behaviors are also generally worse in rural areas; importantly, obesity and tobacco use are more common in these areas compared to cities (Agunwamba et al. 2016; Befort et al 2012; Rhew et al. 2011; Roberts et al. 2016).

Much of the research focusing on rural health emphasizes less access to health care among adults living in rural areas. Perhaps the most well documented disparity is that health care providers are fewer and farther away in rural areas, compared with urban areas, and rural residents tend to use fewer health care services compared with their urban counterparts (Agency for Healthcare Research and Quality 2014; Caldwell et al. 2016; Hummer et al. 2004; Purnell et al. 2016). Yet health care access is at best only a partial explanation of geographic health disparities (Hartley 2004). Indeed, the economic circumstances of rural residents appears to be an important source of their worse health relative to people living in urban areas (Probst et al. 2011). Shifts in the U.S. economy have moved jobs out of production facilities in rural areas, with cities now offering more and more service, financial, and technology-based employment opportunities. These changes have resulted in fewer employment opportunities for those in rural areas (Burton et al. 2013). The lower economic well-being of people in rural areas may lead to unhealthy stress-related behaviors, such as smoking, illegal drug use (e.g., opiates), alcohol abuse, unhealthy diet, and inactivity, all of which have detrimental consequences for cardiovascular health, even in early adulthood (Pampel et al. 2010; Thoits 2010).

While the documentation of urban-rural health disparities is a fundamental first step, it is important that researchers move beyond an urban-rural dichotomy to better understand more detailed and nuanced measures of geography of residence. Most research examining geographic differences in health uses a simplified operationalization of rural versus urban residential context, which does not acknowledge the connections and blurring between rural and urban spaces (Lichter and Brown 2011). Research taking a more nuanced approach generally demonstrates that health disparities are not based on a simple urban-rural dichotomy. James (2014), for example, reports heterogeneity in mortality rates across non-urban areas of the United States; he finds that areas adjacent to small towns with populations ranging from 2,500 to 19,999 have the highest mortality rates in the United States. Cossman and colleagues (2010) also show that classifying areas as simply urban or rural obscures important heterogeneity in health patterns across U.S. geographic areas. Thus, our analysis incorporates a rural-urban continuum of residence (i.e. RUCA codes) to more comprehensively operationalize the geography of young adult residence.

Differences in cardiovascular health across the urban-rural continuum may in part be explained by the environmental features of communities. In particular, the population density of the local area in which individuals live differs across the urban-rural continuum and may help shape cardiovascular health. More densely populated areas may have greater street connectivity and walkability, and may offer more or better options for increasing physical activity and improving nutrition; access to retail outlets, health care sites, and social services may also be enhanced in densely populated areas (Galea and Vlahov 2005; Saelens et al. 2003). Higher population density may also help facilitate social connections between individuals, which has been shown to exhibit a strong association with cardiovascular health in the United States (Yang et al. 2016). Densely populated areas may also attract young

adults who are highly educated and affluent because educational and high-paid employment opportunities are more plentiful in comparison with less densely populated areas (Burton et al. 2013).

Another potential explanation for differences in young adult cardiovascular health across the urban-rural continuum highlights differences among individuals that may lead them to both live outside of metropolitan cores and/or less densely populated areas and have worse cardiovascular health. Rather than the rural or small city contexts reflecting fewer economic opportunities, the low socioeconomic status of rural and small city residents may be the result of more educated individuals (or those seeking more education) leaving such areas, also known as the "brain drain" (Burton et al. 2013). Similarly, the unhealthy behaviors observed in rural and smaller urban areas may result from individuals who engage in these behaviors also preferring to live in smaller and/or less dense areas. However, little research explores the extent to which geographic health differences may be due to the *composition* of people living in different communities in the United States, and to our knowledge, no research examines cardiovascular health disparities across the urban-rural continuum among young adults.

To summarize, our research questions are as follows:

1. First, does the cardiovascular health of U.S. young adults differ according to the type of urban or rural area within which they live?

2. Second, to what extent does the population density of the area within which individuals live explain young adult differences in cardiovascular health across the urban-rural continuum?

3. Third, to what extent do demographic, socioeconomic, and behavioral compositional factors – measured both during adolescence and young adulthood – explain differences in young adult cardiovascular health across the urban-rural continuum?

4. Finally, do young adults who live in different geographic contexts compared to adolescence (either in terms of the urban-rural continuum or in terms of population density) exhibit better or worse cardiovascular health in young adulthood relative to those who live in similar contexts across the transition to adulthood?

Methods

Data

We use data from the National Longitudinal Study of Adolescent to Adult Health (Add Health). These data are nationally representative, following a cohort of adolescents into young adulthood. The first wave of data (Wave 1) surveyed adolescents ages 12–19 in 1994–1995, with follow-ups one year later (Wave II; 1995–1996), seven years later (Wave III; 2001–2002), and 14 years later (Wave IV; 2008–2009). Each wave of data provides a wealth of information on health, socioeconomic status, and other social circumstances. We focus on cardiovascular health and residential location in Wave IV, when respondents are aged 24–34,

but also consider a number of variables from Wave I to identify factors that are associated with both residential location and young adult cardiovascular health. Our sample includes the 12,252 respondents who participated in Wave IV, have a valid sampling weight, are not pregnant or probably pregnant at the time of the survey, and are not missing on the outcome variable.

Measures

Our outcome measure is a binary indicator of ideal (versus not ideal) cardiovascular health, a concept defined by the American Heart Association (AHA). The AHA introduced ideal cardiovascular health as a tool to monitor and spur efforts to improve cardiovascular health and reduce deaths from cardiovascular diseases and stroke (Lloyd-Jones et al. 2010). It is based on seven indicators that tap into key dimensions of health behavior and health, including body weight, physical activity, smoking, diet, cholesterol, blood pressure, and blood glucose. Subsequent to the initial report identifying the concept of ideal cardiovascular health, a number of studies have demonstrated its strong association with mortality and morbidity (e.g. Dong et al. 2012; Ford et al. 2012; Yang et al. 2012). We operationalize ideal cardiovascular health using AHA guidelines defining ideal health behaviors and health factors (Lloyd-Jones et al. 2010). Based on available data in Add Health, we measure ideal cardiovascular health based on individuals exhibiting six or more of the following: (1) did not smoke in the last 30 days, (2) have a BMI less than 25, (3) had five or more physical activity sessions per week, (4) consume less than four sugar-sweetened beverages per week,[1] (5) have a total cholesterol in the bottom seven deciles and no reports of lifetime hyperlipidemia diagnosis or recent use of an antihyperlipidemic medication in the previous four weeks, (6) have systolic blood pressure less than 120, diastolic blood pressure less than 80, and no reports of lifetime hypertension diagnosis or recent use of antihypertensive medications, and (7) have no report of lifetime diabetic diagnosis or recent use of anti-diabetic medication, and no indication of diabetic or pre-diabetic levels of glucose (fasting glucose less than 100 mg/dl, non-fasting glucose levels less than 200 mg/dl, and HbA1c less than 5.7).[2] Smoking, physical activity, sugar sweetened beverage consumption, and diagnoses were self-reported by respondents. Interviewers measured height and weight used to calculate BMI and blood pressure. Dried blood spots were assayed to determine cholesterol and glucose levels (for details on these protocols and measures see Entzel et al. 2009; Whitsel et al. 2012; Whitsel et al. 2013).

Our main independent variable is the rural-urban commuting area codes (RUCAs) (United States Department of Agriculture 2016), which are linked to the individual records of Add Health. For both Waves I and IV, the Census tract in which the respondent resides is linked to the RUCA code. Wave IV tracts are identified using Census boundaries in the year 2000 and Wave I tracts are based on 1990 Census boundaries. RUCA codes are taken from these same Census files. RUCA categories include: metropolitan area core, metropolitan area high

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[1]The AHA healthy diet components include levels of fruit and vegetable, fish, whole grain, sodium, and sugar-sweetened beverage consumption (Lloyd-Jones et al. 2010). We set the sugar-sweetened beverage threshold based on their definition of no more than 36 ounces per week, assuming that one serving is 12 ounces.

[2]Measures for total cholesterol, blood pressure, and glucose are designed to be as close to AHA guidelines as possible given our available information. For example, Add Health does not provide absolute concentrations for cholesterol given the assay method (Whitsel et al. 2013).

commuting, metropolitan area low commuting, micropolitan area core, micropolitan area high commuting, micropolitan low commuting, small town core, small town high commuting, small town low commuting, and rural areas (Morrill et al. 1999). Appendix Table 1 displays the characteristics of the 10 categories. Because some of the categories have small numbers of respondents, we combine high and low commuting zones for metropolitan, micropolitan, and small town areas. Thus, we end up with seven different RUCA categories. Further information on RUCA codes can be obtained from the USDA (2016). We measure residential change through comparing movement in or out of metropolitan core areas from adolescence (Wave I) to young adulthood (Wave IV), categorizing individuals as having lived in metropolitan core areas at both time points, at neither time point, in adolescence but not young adulthood, and in young adulthood but not adolescence. Because small percentages of individuals live in other types of locations at either Wave I or Wave IV of Add Health, we are unable to examine patterns other than metropolitan core location (versus non-metropolitan core location).

We also consider population density at the neighborhood or Census Tract level, measured as the number of people per square kilometer living in each respondent's residential tract. For Wave IV, population density is identified with American Community Survey five-year estimates (2005–2009) and for Wave I, 1990 Census data provides values for population density. Because the distribution of this variable is skewed, we take the natural log of the value at each wave.[3] We show quartiles of the original population density measure in the descriptive statistics. We also create a measure of change in population density from adolescence to young adulthood. We compare Census tract population density in Waves I and IV, and identify those people who lived in a less dense context over time, those who lived in a more densely populated area over time, and those who remained in a similarly dense area over time. Similarity in density (or stability) is defined as living in an area that was within 223 people/km^2 of the individual's adolescent population density, as this value represents the mean population density increase among those who were at the same location at Waves I and IV. We do not distinguish whether the change in population density is due to residential mobility or changes in the environment. Population density is associated with RUCA; those living in core areas have higher average density than those in commuting or rural areas, but the range of population density for each of the RUCA codes is large. Importantly, the variation in population density is sufficient to allow for simultaneous analysis of both RUCA codes and population density.

We also examine a number of factors that may be associated with both residential location and cardiovascular health in young adulthood. Sociodemographic background factors include interview age, gender, race/ethnicity, and nativity status. Interview age is years of age at time of interview, and gender is a dichotomous variable indicating if the respondent is female.[4] Race/ethnicity is a mutually exclusive categorical variable that identifies individuals as non-Hispanic White, non-Hispanic Black, Hispanic, and other. Other race/ethnicity includes Asian/Pacific Islander, American Indian/Alaska Native, and those

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[3]We tested for threshold values and squared terms to determine non-linear relationships between population density and ideal cardiovascular health, but the logged term produced the best fitting models.
[4]We tested for interactions between residential location and gender, but none were significant.

selecting "other" for race. Nativity status is a variable that includes three categories: respondents and their parents were born in the United States, respondents were born in the United States and their parents were foreign-born, and respondents were foreign born.

Other compositional factors that may explain young adult differences in cardiovascular health along the urban-rural continuum include adolescent socioeconomic status, health and health behaviors, and residential location. Socioeconomic background is operationalized through parent educational attainment and household income-to-needs collected in Wave I. Parent educational attainment is a continuous measure of years of education representing the average years for the mother and father, or the single measure for those with information only for the mother or father. Income-to-needs is the ratio of the reported household income to the U.S. census-defined poverty threshold for that year and household size.

Adolescent health includes BMI, depressive symptoms, smoking status, self-rated health, number of physical activity sessions, and alcohol consumption, all measured in Wave I. BMI is measured the same as young adult BMI, but height and weight are self-reported in adolescence.[5] Depressive symptoms is a continuous, standardized measure combining responses to 19 questions from the Center for Epidemiological Studies – Depression (CES-D) battery. Smoking status is a dichotomous indicator representing whether the respondent reported any smoking in the last 30 days. Self-rated health in adolescence is a five point scale ranging from poor to excellent. Number of physical activity sessions combines together how often the respondent reports participating in activities in the last seven days. Three questions capture a range of activities, such as participation in sports and working out at the gym. Alcohol consumption is a categorical indicator representing alcohol consumption in the previous 12 months. Those reporting no alcohol consumption are compared to those who report usually consuming one drink, two drinks, or more than two drinks during the times they had an alcoholic drink.

A number of indicators measure achieved SES and the social environment in young adulthood, which also represent potential explanations for cardiovascular health differences across the urban-rural continuum. Educational attainment, household income-to-needs, and employment status represent young adult SES. Educational attainment includes categories for less than high school, high school diploma, some college, and college degree or more (referent). Income-to-needs is a continuous measure that is the ratio of the household's total income to the poverty threshold defined by the U.S. Census for each year and household size. Employment status is represented with three categories: full-time employment (30+ hours per week), part-time employment (10–29 hours per week), and unemployed (less than 10 hours per week). We define individuals as having high social integration if they report two or more of the following: being married, having six or more close friends, attending church 12 or more times in the past year, and volunteering in the past year. Those meeting this criterion are coded with a "1" for high social integration, and all others are coded "0". We create a dichotomous measure for young adults who live with children using the Wave IV household roster.

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[5]BMI based on self-reported height and weight is correlated with measured BMI (in adolescence at Wave II) at over .99.

Analytic Approach

We first examine descriptive statistics of ideal cardiovascular health across young adult RUCA codes, young adult population density, movement into or out of metropolitan core areas from adolescence into young adulthood, and changes in population density. Because there are no studies examining the health correlates of a nationally-representative sample of U.S. young adults by residential location, we devote considerable space to describing these patterns. Our logistic regression analysis begins by baseline differences in young adult cardiovascular health across the urban-rural continuum. Subsequently, we add in substantive groups of characteristics (population density, sociodemographic factors, adolescent characteristics, and young adult characteristics) to the models to assess the extent to which they help explain associations between the RUCA measures and ideal cardiovascular health. We do not directly compare results from different logistic regression models, but base our conclusions on general patterns. Variance inflation factor tests produced no evidence of multicollinearity.

All analyses adjust for the complex sampling design to ensure representativeness. We use multiple imputation for those who are missing values on some independent variables to retain the full sample. All independent and dependent variables are used to inform the imputation model. We do not impute values for our outcome variable, ideal CVH, and we have complete information for young adult RUCA codes, young adult population density, adolescent RUCA codes, age, gender, and young adult educational attainment. We impute less than 1% of values for: race/ethnicity, nativity status, adolescent depressive symptoms, adolescent self-rated health, adolescent physical activity, young adult marital status, living with children, young adult employment, and adolescent population density. We impute 2.2% of values for parent education, 23.5% for adolescent income-to-needs, 2.5% for adolescent BMI, 17.9% for adolescent smoking, 1.7% for adolescent alcohol consumption, and 6.6% for young adult income-to-needs.

Results

Descriptive Results

Table 1 displays descriptive statistics. Just 7% of young adults aged 24–32 has ideal cardiovascular health. The average number of ideal indicators for individuals is 3.32, or just under one-half of the maximum of 7. These figures clearly indicate that this young adult cohort has far from ideal cardiovascular health. The percentages of young adults with healthy physical activity (54%), who are nonsmokers (60%), who have ideal blood sugar (62%), and who have ideal cholesterol (65%), while far from 100%, are much higher than the percentages with healthy BMI (33%), who consume few or no sugar-sweetened beverages (29%), and who have ideal blood pressure (29%), for which only one-third or fewer exhibit healthy levels.[6]

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[6]Our rates for BMI and blood sugar are similar to overall percentages of U.S. adults reported by Lloyd-Jones and colleagues (2010). Our measures of physical activity and total cholesterol reflect greater (or healthier) percentages, likely due to variable construction. The percentage of individuals consuming a healthy amount of sugar-sweetened beverages is much higher than the 0.5% of U.S. adults who meet the AHA healthy diet criterion. Rates of nonsmoking and healthy blood pressure are lower for our sample compared to U.S. adults, which may reflect the unique environment and behaviors of the young adult cohort.

Nearly three-quarters (71%) of young adults live in a metropolitan core, with an additional 10% in high or low commuting areas around these cities. Smaller numbers of individuals live in tracts described as micropolitan, small town, or rural. We divide young adult population density into quartiles in Table 1, so each represents roughly one-quarter of young adults. Table 1 also shows changes in residential context from adolescence to young adulthood. The majority of young adults (63%) lived in a metropolitan core in both adolescence and young adulthood. Smaller proportions lived in a metropolitan core in adolescence and a smaller community in adulthood (12%), lived in a smaller community in adolescence and in a metropolitan core during young adulthood (8%), or did not live in a metropolitan core in either adolescence or young adulthood (17%). The largest proportion of individuals (38%) experienced an increase in population density from adolescence to adulthood, though nearly the same amount lived in a place with similar density (36%).

Although levels of ideal cardiovascular health are very low among young adults living in all types of places, there are clear differences across geographic locations. Individuals living in metropolitan cores and denser areas demonstrate the highest proportion with ideal cardiovascular health, as well as the highest average number of ideal cardiovascular health indicators. Rural areas lag well behind, though small town core areas have the lowest percentage of individuals with ideal CVH. The results demonstrate that RUCA codes do not demonstrate a linear relationship with ideal CVH, in line with previous research showing that mortality rates are not graded across rural-urban continuum codes (James et al. 2014). People living in higher density areas in young adulthood also exhibit higher proportions of ideal cardiovascular health. Focusing on changes in the geography of residence across the transition to adulthood, those living in a metropolitan core in young adulthood who lived in a smaller community in adolescence have the highest proportion of individuals with ideal cardiovascular health, followed by those living in metropolitan core areas in both adolescence and young adulthood. The longitudinal approach to population density indicates that ideal cardiovascular health is most common among those who experience increases in density during the transition to adulthood. Young adults in rural and less densely-settled areas in young adulthood suffer a significant cardiovascular health disparity that will likely be revealed in higher rates of mortality in older age and in lower overall life expectancy.

Additional descriptive statistics (Appendix Tables 2 and 3) demonstrate that there are systematic individual differences in many social, economic, behavioral, and health characteristics by both RUCA code of residence and population density. Notably, those living in more dense areas have higher adolescent and young adult SES, and generally better adolescent health and health behaviors.

Multivariate Models of Young Adult Cardiovascular Health by Geography of Residence

Table 2 presents odds ratios and significance levels from logistic regression models predicting ideal cardiovascular health. Model 1 shows that, compared with those residing in metropolitan core areas, young adults living in metropolitan commuting, micropolitan commuting, small town core, and rural areas are significantly less likely to have ideal cardiovascular health. Those living in micropolitan core and small town commuting areas

exhibit no difference in ideal cardiovascular health relative to individuals in metropolitan core areas.

When population density is added in Model 2, only small town core residents have significantly decreased odds of ideal cardiovascular health. With the addition of demographic controls in Model 3, there are no differences in ideal cardiovascular health across the RUCA codes. Population density is a particularly important explanation for young adult differences in cardiovascular health across the urban-rural continuum. Moreover, individuals who live in more densely populated areas are more likely to have ideal cardiovascular health compared to people who live in less densely populated areas. These results remain in subsequent models, with population density attenuating somewhat with the inclusion of additional covariates. For example, the inclusion of young adult educational attainment, income-to-needs, employment status, social integration, and living with children in Model 5 results in a 33 percent reduction in the association between population density and ideal cardiovascular health (compared to Model 4); the associations between education, income, and ideal cardiovascular health are particularly strong. This suggests that the higher socioeconomic status of individuals who live in more densely populated areas is in part responsible for their more favorable young adult cardiovascular health. Nonetheless, young adults who live in higher density areas continue to exhibit significantly higher odds of ideal cardiovascular health, net of background and young adult factors. Figure 1, Panel A displays the predicted probabilities of ideal cardiovascular health for individuals living in the densest, least dense, and average density areas (and otherwise have characteristics equivalent to the referent group or population mean). Although the overall levels of ideal cardiovascular health are low, the relative differences in predicted probabilities are large, with individuals living in the highest density areas in young adulthood exhibiting more than twice the probability of being in ideal cardiovascular health compared with those who living in low density areas.[7]

Table 3 presents models examining the same outcome, ideal cardiovascular health, but now considers residential location patterns of stability and change from adolescence to young adulthood. Compared to individuals who lived in metropolitan core areas in both adolescence and young adulthood, those who did not live in metropolitan core areas in either life stage have 38% reduced odds of ideal cardiovascular health in young adulthood. Further, those who lived in metropolitan core areas as adolescents but who live in smaller communities in young adulthood have 25 percent lower odds of ideal cardiovascular health in young adulthood compared with those who consistently lived in a metropolitan core. These differences do not persist once other variables are considered, and like the previous set of results, population density and demographic characteristics account for the observed differences across the rural-urban continuum categories. Model 2 demonstrates that individuals who live in a more densely populated area in young adulthood compared with their residential context in adolescence have higher odds of ideal cardiovascular health

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[7]The association between the population density of the tract within which individuals live and cardiovascular health appears to be largely driven by those within metropolitan core areas. The association between population density and cardiovascular health is nearly identical in a full model that includes all covariates but constrains the sample to those in metropolitan core areas, but the effect of population density is smaller and nonsignificant for the same model among those not living in metropolitan core areas.

relative to those who remained in a similarly dense area during the transition to adulthood. Adolescent and young adult factors appear to attenuate the association, but those who live in increasingly dense residential areas are 32% more likely to have ideal cardiovascular health, net of all covariates (Model 5).[8]

Discussion

This study seeks to identify the extent to which US young adult cardiovascular health differs across the rural-urban continuum and, if so, what explanations may account for this difference. Our results show that young adults who live in metropolitan core areas (which encompasses 71% of young adults) exhibit better cardiovascular health than young adults who live outside of these core areas. Even more striking, young adults who live in low density areas have worse cardiovascular health than young adults who live in more dense areas. Further, the strong association between the population density of individuals' Census tract and their odds of ideal cardiovascular health explains the association between rural-urban residence and cardiovascular health in our statistical models. The strength of the association between density and cardiovascular health is further bolstered by our examination of residential changes across the transition to adulthood, which shows that individuals who lived in more densely populated areas as they transitioned to adulthood have higher odds of ideal cardiovascular health compared with individuals who lived in similarly dense or less dense areas over time. This finding supports results from other studies demonstrating greater physical activity and reduced BMI among residents of dense or compact areas (e.g. Ewing et al. 2014; Frank et al. 2005; James et al. 2013)

The mechanisms behind the strong association between young adult residence in a densely populated context and cardiovascular health could be compositional in that there are other unobserved factors we have not accounted for that may explain the association. We have controlled for adolescent health behaviors and health factors to help mitigate selection effects, but it could be that there are other factors shaping the migration of healthy young adults to denser areas. This intra-national process could be similar to that in the international migration and health literature, which has shown that immigrants have better health than their US-born counterparts (Hummer et al. 2015). Alternatively, mechanisms underlying the association may be contextual in that it is the physical and social environment in dense areas that promotes health (Sparks 2012), and cardiovascular health in particular. Perhaps most likely, the environments and people within dense areas co-exist in a reciprocal relationship that reinforce certain patterns and behaviors (Cummins et al. 2007). Individuals have preferences and constraints for where they live, including opinions on walkability and proximity to recreation (Berry et al. 2010). Built and social environments may sort these preferences into different lifestyles. Families seek large homes, nice cars, and attractive lawns as a sign of financial well-being and comfort, and as a source of differentiation from those of lower status, such as families living in inner city public housing. Low density neighborhoods make large homes and cars affordable and convenient. These relatively large homes and cars make it easy to obtain, transport, and store large amounts of non-perishable

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[8]Using number of ideal cardiovascular health indicators instead of a yes/no distinction produced no substantive differences in the results.

foods, and in turn, are more comfortable for bigger bodies. Government institutions also support low density neighborhoods with large homes and cars, providing wide roads and free parking, among other comforts (Jackson 2009). In contrast, other individuals may seek out dense areas for their activity, diversity, and vibrancy. These dense areas are marked by public spaces that can be difficult for bigger bodies to navigate (Brewis et al. 2016). Expenses associated with owning a car, driving, and parking in dense areas may incentivize walking, cycling, and use of public transportation, and smaller residences may prevent the acquisition of large amounts of food. Across these different communities, the environments and social and cultural norms can propagate a way of life, with important health consequences.

Prior research has often used a rural-urban distinction to measure lifestyle and health differences across residential areas, but this simple dichotomy obscures the complexity of location in today's increasingly blurred society (Lichter and Brown 2011). The enhanced rural-urban RUCA continuum is a much more refined categorization of residential space, but these rigid categorizations cannot accommodate the blurring, crossing, and shifting of boundaries. Yet, environmental features still distinguish communities and the residents that reside in them from one another. And based on our findings, the population density within which individuals live appears to be a dimension of residential life that is especially important for a set of important health outcomes in early adulthood and, thus, a dimension that cannot be ignored in future work on the topic. Moreover, density is not only a feature of large metropolitan cities but also of smaller cities, small towns, and rural areas, which may make it an important consideration for population health in all types of residential spaces.

As individuals select into different communities and these environments accommodate and encourage different lifestyles, health disparities across contexts may grow. We focus on ideal cardiovascular health here to foreshadow future cardiovascular conditions that today's young adults have yet to experience. For today's young adults whose future health and longevity are threatened by the obesity epidemic, these spatial differences may only become more important in the future. Fairly strong differences across population density may widen as young adults settle into their current locations, raise families, and perpetuate their lifestyles. At the same time, rural-urban interdependence may obscure spatial disparities. Research on health and place will need to consider how boundaries are blurred and traversed to identify salient features of social and physical environments.

Acknowledgments

the Add Health data files is available on the Add Health website (http://www.cpc.unc.edu/addhealth). No direct support was received from grant P01-HD31921 for this analysis.

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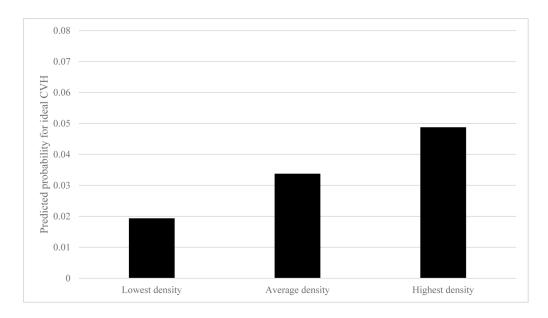
Figure 1. Predicted probabilities of ideal cardiovascular health across young adult population density

Source: Add Health.

N=12, 252.

Notes: Predicted probabilies computed from Table 2, Model 5. Other than population density measures, calculations assume characteristics equivalent to the referent group (for categorical variables) or sample mean (for continuous variables). Analysis adjusts for complex sampling design.

Table 1

Weighted means of young adult ideal cardiovascular health (CVH) across residential location measures

	Population	Ideal CVH (6–7 indicators)	# ideal CVH indicators	BMI<25	5+ physical activity sessions	3 SSB in last week	Not current smoker	Ideal blood sugar	Ideal blood pressure	Ideal cholesterol
								Ideal CVH indicators		
Population		0.07	3.32	0.33	0.54	0.29	0.60	0.62	0.29	0.65
Young adult RUCA										
Metropolitan core	0.71	0.07	3.39	0.34	0.55	0.31	0.62	0.63	0.30	0.64
Metropolitan high/low commuting	0.10	0.06	3.25	0.30	0.52	0.27	0.56	0.64	0.30	0.65
Micropolitan core	0.07	0.06	3.17	0.28	0.50	0.26	0.61	0.59	0.25	0.69
Micropolitan high/low commuting	0.03	0.04	2.99	0.30	0.50	0.16	0.55	0.57	0.28	0.63
Small town core	0.03	0.03	3.15	0.28	0.49	0.25	0.53	0.60	0.32	0.68
Small town high/low commuting	0.02	0.06	3.01	0.31	0.51	0.20	0.52	0.61	0.23	0.64
Rural	0.04	0.04	3.18	0.31	0.54	0.25	0.54	0.62	0.26	0.67
Young adult population density										
<186.06 people/km^2	0.28	0.05	3.16	0.29	0.52	0.25	0.56	0.61	0.28	0.66
186.08 – 955.90 people/km^2	0.26	0.07	3.36	0.33	0.52	0.31	0.62	0.64	0.30	0.63
956.00– 2352.27 people/km^2	0.27	0.07	3.34	0.35	0.54	0.30	0.59	0.63	0.29	0.64
2353+ people/km^2	0.19	0.08	3.49	0.35	0.58	0.31	0.66	0.61	0.32	0.66
Adolescent to young adult RUCA										
Metro core to metro core	0.63	0.07	3.37	0.34	0.55	0.30	0.61	0.63	0.30	0.64
Metro core to other	0.12	0.06	3.26	0.30	0.53	0.28	0.56	0.65	0.28	0.65
Other to metro core	0.08	0.09	3.50	0.36	0.55	0.32	0.66	0.64	0.32	0.65
Other to other	0.17	0.05	3.10	0.29	0.50	0.22	0.57	0.58	0.27	0.67
Adolescent to young adult change in density										
Decreasing	0.25	0.06	3.27	0.30	0.54	0.28	0.61	0.60	0.29	0.65
Stable	0.36	0.05	3.19	0.31	0.52	0.26	0.57	0.62	0.28	0.64
Increasing	0.38	0.09	3.48	0.37	0.56	0.32	0.63	0.64	0.31	0.65

Source: Add Health

Notes: Analysis adjust for complex sampling design. N=12,252

Table 2

Odds ratios for logistic regression models predicting young adult ideal cardiovascular health

	Model 1	Model 2	Model 3	Model 4	Model 5
Young adult RUCA (metro core)					
Metropolitan high/low commuting	0.73 *	0.99	1.12	1.12	1.11
Micropolitan core	0.80	0.94	1.15	1.14	1.28
Micropolitan high/low commuting	0.52 +	0.76	0.88	0.90	0.95
Small town core	0.35 **	0.46 *	0.55	0.60	0.69
Small town high/low commuting	0.75	1.14	1.62	1.95	2.13 +
Rural	0.50 *	0.77	0.95	0.90	0.87
Young adult logged population density		1.10 *	1.17 ***	1.12 **	1.08 *
Age at Wave IV			0.95	1.06 +	1.05
Female			4.22 ***	4.34 ***	3.92 ***
Race/ethnicity (White)					
Black			0.25 ***	0.32 ***	***
Hispanic			0.51 ***	0.86	0.97
Other			0.93	0.88	0.87
Nativity (US born)					
Parents foreign born			0.86	0.88	0.80
Foreign born			1.84 **	1.81 *	1.67 *
Background SES					
Income-needs at Wave I				1.02	1.01
Parent education at Wave I				1.16 ***	1.08 **
Adolescent health (Wave I)					
BMI				0.84 ***	0.84 ***
Depressive symptoms				0.94	1.00
Smoker				0.68 *	0.81
Self-rated health				1.14 *	1.08
Physical activity sessions				1.01	1.00

	Model 1	Model 2	Model 3	Model 4	Model 5
Alcohol consumption (none)					
usually 1 drink				1.03	0.96
usually 2 drinks				0.95	0.85
usually >2 drinks				1.09	1.01
Adolescent residence (Wave I)					
Logged population density				1.00	1.01
RUCA code (metro core)					
Metro/micro high/low commuting				1.20	1.11
Micro core				1.22	1.13
Small town core				0.78	0.67
Small town high commuting				0.91	0.86
Rural area				1.60 *	1.50 *
Young adult factors (Wave IV)					
Educational attainment (BA+)					
<HS					0.37 **
HS					***
Some college					0.53 ***
Income-to-needs					1.04 **
Employed (full-time)					
Not employed					1.14
Part-time					1.12
High social integration					1.28 *
Living with kids					0.91
Constant	0.08 ***	0.04 ***	0.05 **	0.01 ***	0.07 **

Source: Add Health

Notes: Analysis adjust for complex sampling design. Referent is in parentheses. N=12,252

+ p<.10

* p<.05

** p<.01

***
$p < .001$

Table 3

Odds ratios from logistic regression models predicting young adult ideal cardiovascular health

	Model 1	Model 2	Model 3	Model 4	Model 5
Adolescent to young adult RUCA (metro core to metro core)					
Metro core to other	0.75[+]	0.89	0.84	0.90	0.98
Other to metro core	1.27	1.16	1.16	1.06	0.96
Other to Other	0.62[**]	0.71[*]	0.81	1.00	1.06
Change in population density (stable)					
Decreasing		0.96	1.14	1.13	1.06
Increasing		1.48[**]	1.65[***]	1.43[**]	1.32[*]
Age at Wave IV			0.96	1.06[+]	1.05
Female			4.18[***]	4.33[***]	3.93[***]
Race/ethnicity (White)					
Black			0.27[***]	0.34[**]	0.41[***]
Hispanic			0.56[**]	0.91	1.02
Other			0.96	0.92	0.91
Nativity (US born)					
Parents foreign born			0.92	0.90	0.81
Foreign born			1.99[**]	1.85[**]	1.71[*]
Background SES (Wave I)					
Income-needs				1.02[+]	1.01
Parent education				1.16[***]	1.08[**]
Adolescent health (Wave I)					
BMI				0.84[***]	0.84[**]
Depressive symptoms				0.94	1.00
Smoker				0.67[**]	0.81
Self-rated health				1.13[+]	1.08
Physical activity sessions				1.01	1.00
Alcohol consumption (none)					1.00

	Model 1	Model 2	Model 3	Model 4	Model 5
usually 1 drink					0.97
usually 2 drinks					0.85
usually >2 drinks					1.01
<u>Young adult factors (Wave IV)</u>					
Educational attainment (BA+)					
<HS					0.38 **
HS					0.35 ***
Some college					0.53 ***
Income-to-needs					1.05 **
Employed (full-time)					
Not employed					1.14
Part-time					1.13
High social integration					1.27 *
Living with kids					0.89
Constant	0.08 ***	0.06 ***	0.09 **	0.01 ***	0.10 *

Source: Add Health

Notes: Analysis adjust for complex sampling design. Referent is in parentheses. N=12,252

+ p<.10

* p<.05

** p<.01

*** p<.001

Appendix Table 1

RUCA codes with descriptors

Classification	Description
Metropolitan area core	30% of the population is in an urbanized area (urbanized area has population of 50,000 or more)
Metropolitan area high commuting	Primary flow 30% to urbanized area
Metropolitan area low commuting	Primary flow 10–30% to urbanized area
Micropolitan area core	30% of the population is in a large urban cluster (large urban cluster has population of 10,000 to 49,999)
Micropolitan area high commuting	Primary flow 30% or more to a large urban cluster
Micropolitan area low commuting	Primary flow 10–30% to a large urban cluster
Small town core	30% of the population is in a small urban cluster (small urban cluster has population of 2500 to 9,999)
Small town high commuting	Primary flow 30% or more to a small urban cluster
Small town low commuting	Primary flow 10–30% to a small urban cluster
Rural areas	Primary flow is to a tract that is not an urbanized area or an urban cluster

Source: USDA 2014

Appendix Table 2

Weighted means of covariates, across residential location categories in young adulthood (Wave IV)

| | Population | Young adult RUCA | | | | | | | Young adult population density in people/km² | | | |
| | | Metropolitan | | Micropolitan | | Small town | | Rural | <186.06 | 186.08 – 955.90 | 956.00 – 2352.27 | 2353+ |
		core	high/low commuting	core	high/low commuting	core	high/low commuting					
Population		0.71	0.10	0.07	0.03	0.03	0.02	0.04	0.28	0.26	0.27	0.19
Sociodemographics												
Age at Wave IV	28.38	28.38	28.48	28.33	28.25	28.35	28.37	28.43	28.41	28.34	28.34	28.46
Female	0.49	0.49	0.47	0.47	0.52	0.48	0.43	0.49	0.49	0.49	0.49	0.47
Race/ethnicity												
White	0.69	0.64	0.85	0.67	0.81	0.73	0.79	0.85	0.80	0.74	0.65	0.48
Black	0.15	0.15	0.09	0.25	0.13	0.24	0.19	0.12	0.13	0.15	0.16	0.18
Hispanic	0.12	0.16	0.05	0.04	0.04	0.01	0.01	0.01	0.04	0.09	0.15	0.25
Other	0.04	0.05	0.01	0.04	0.03	0.02	0.01	0.01	0.03	0.03	0.04	0.09
Nativity status												
U.S. born and parents	0.87	0.84	0.94	0.95	0.95	0.97	0.99	0.98	0.95	0.90	0.87	0.72
U.S. born												
Parents foreign-born	0.07	0.09	0.03	0.03	0.05	0.03	0.00	0.01	0.03	0.06	0.08	0.16
Foreign-born	0.05	0.07	0.03	0.02	0.01	0.01	0.00	0.01	0.02	0.04	0.05	0.12
Background SES (Wave I)												
Parent education	13.06	13.18	12.86	13.18	12.74	12.38	12.40	12.19	12.76	13.24	13.16	13.07
Income-to-needs	2.90	3.04	2.77	2.52	2.59	2.90	3.00	2.35	2.64	2.93	2.99	3.13
Adolescent health (Wave I)												
BMI	22.56	22.41	22.83	22.67	22.53	23.05	23.69	23.34	22.88	22.34	22.45	22.55
Depressive symptoms	−0.05	−0.05	−0.08	−0.08	0.00	−0.02	−0.15	−0.06	−0.04	−0.08	−0.05	−0.03
Smoker	0.34	0.32	0.39	0.31	0.44	0.38	0.40	0.43	0.40	0.34	0.34	0.26
Self-rated health	3.86	3.88	3.83	3.84	3.87	3.71	3.83	3.77	3.83	3.89	3.86	3.89
Physical activity sessions	5.46	5.53	5.31	5.49	5.14	5.45	5.52	4.83	5.25	5.49	5.44	5.76
Alcohol consumption												
None	0.52	0.52	0.49	0.57	0.50	0.55	0.49	0.50	0.50	0.53	0.52	0.54
usually 1 drink	0.10	0.10	0.09	0.10	0.11	0.08	0.09	0.10	0.09	0.10	0.10	0.11

| | | Young adult RUCA | | | | | | | Young adult population density in people/km² | | | |
| | | Metropolitan | | Micropolitan | | Small town | | | | | | |
	Population	core	high/low commuting	core	high/low commuting	core	high/low commuting	Rural	<186.06	186.08 – 955.90	956.00– 2352.27	2353+
usually 2 drinks	0.08	0.08	0.07	0.10	0.09	0.09	0.06	0.07	0.08	0.08	0.08	0.07
usually >2 drinks	0.30	0.30	0.35	0.23	0.30	0.28	0.36	0.33	0.32	0.30	0.30	0.27
Young adult factors												
Educational attainment												
Less than high school	0.09	0.08	0.10	0.08	0.10	0.12	0.09	0.15	0.10	0.09	0.09	0.07
High school diploma	0.27	0.25	0.32	0.30	0.35	0.39	0.45	0.38	0.35	0.25	0.25	0.24
Some college	0.34	0.34	0.36	0.38	0.37	0.32	0.31	0.28	0.35	0.35	0.35	0.30
College degree or more	0.30	0.33	0.22	0.24	0.17	0.17	0.15	0.20	0.20	0.31	0.31	0.38
Household income-to-needs	3.74	3.97	3.73	3.12	3.03	2.41	2.77	2.73	3.23	3.89	3.78	4.20
Employment												
Unemployed	0.71	0.72	0.73	0.69	0.70	0.61	0.72	0.63	0.68	0.72	0.71	0.72
Part-time	0.09	0.09	0.08	0.08	0.11	0.07	0.09	0.07	0.08	0.09	0.10	0.08
Full-time	0.20	0.19	0.19	0.23	0.19	0.32	0.19	0.31	0.23	0.19	0.19	0.20
High social integration	0.52	0.50	0.54	0.57	0.65	0.57	0.54	0.59	0.56	0.54	0.51	0.45
Living with children	0.46	0.42	0.56	0.54	0.62	0.64	0.56	0.57	0.58	0.47	0.43	0.32

Appendix Table 3

Weighted means of covariates, across transition to adulthood residential location categories

	Population	Adolescent to young adult				Adolescent to young adult change in population density		
		Metro core to metro core	Metro core to other	Other to metro core	Other to other	Decreasing	Stable	Increasing
Population		0.63	0.12	0.08	0.16	0.25	0.36	0.38
Sociodemographics								
Age at Wave IV	28.38	28.40	28.42	28.19	28.37	28.51	28.38	28.30
Female	0.49	0.49	0.46	0.52	0.49	0.48	0.50	0.48
Race/ethnicity								
White	0.69	0.64	0.87	0.69	0.73	0.57	0.77	0.68
Black	0.15	0.14	0.05	0.24	0.24	0.19	0.13	0.14
Hispanic	0.12	0.17	0.06	0.03	0.01	0.18	0.07	0.13
Other	0.04	0.05	0.02	0.05	0.02	0.06	0.03	0.05
Nativity status								
U.S. born and parents U.S. born	0.87	0.83	0.93	0.93	0.97	0.81	0.92	0.86
Parents foreign-born	0.07	0.10	0.03	0.03	0.02	0.10	0.05	0.08
Foreign-born	0.05	0.07	0.03	0.03	0.01	0.08	0.03	0.06
Background SES (Wave I)								
Parent education	13.06	13.10	12.96	13.82	12.59	12.71	12.86	13.47
Income-to-needs	2.90	3.04	3.01	3.00	2.27	2.62	2.73	3.26
Adolescent health (Wave I)								
BMI	22.55	22.47	22.62	21.95	23.12	22.72	22.73	22.29
Depressive symptoms	−0.05	−0.04	−0.11	−0.10	−0.04	−0.03	−0.03	−0.09
Smoker	0.34	0.33	0.40	0.28	0.37	0.33	0.39	0.30
Self-rated health	3.86	3.87	3.87	3.94	3.78	3.83	3.82	3.93
Physical activity sessions	5.46	5.53	5.50	5.53	5.13	5.27	5.40	5.65
Alcohol consumption								
None	0.52	0.52	0.48	0.56	0.55	0.51	0.51	0.54
usually 1 drink	0.10	0.10	0.10	0.10	0.09	0.10	0.09	0.11
usually 2 drinks	0.08	0.08	0.08	0.07	0.09	0.08	0.08	0.07

	Population	Adolescent to young adult				Adolescent to young adult change in population density		
		Metro core to metro core	Metro core to other	Other to metro core	Other to other	Decreasing	Stable	Increasing
usually >2 drinks	0.30	0.30	0.35	0.28	0.27	0.31	0.31	0.28
Young adult factors (Wave IV)								
Educational attainment								
Less than high school	0.09	0.09	0.10	0.04	0.11	0.11	0.11	0.06
High school diploma	0.27	0.26	0.31	0.17	0.37	0.28	0.33	0.22
Some college	0.34	0.34	0.37	0.34	0.33	0.35	0.33	0.34
College degree or more	0.30	0.32	0.22	0.45	0.20	0.26	0.23	0.38
Household income-to-needs	3.74	3.94	3.61	4.22	2.85	3.68	3.38	4.11
Employment								
Unemployed	0.71	0.71	0.71	0.77	0.67	0.70	0.69	0.73
Part-time	0.09	0.09	0.08	0.07	0.08	0.10	0.09	0.08
Full-time	0.20	0.20	0.20	0.16	0.25	0.20	0.23	0.18
High social integration	0.52	0.49	0.54	0.57	0.59	0.50	0.53	0.52
Living with children	0.46	0.42	0.55	0.40	0.58	0.50	0.53	0.38

Source: Add Health.

Notes: Analysis adjust for complex sampling design. N=12,252