Preventive Medicine Reports 29 (2022) 101960

Contents lists available at ScienceDirect

Preventive Medicine Reports

journal homepage: www.elsevier.com/locate/pmedr

Exploring differences in adolescent BMI and obesity-related behaviors by urban, suburban, and rural status

Brittany M. Kirkpatrick[a,*], Maryam Yuhas[b], Jamie M. Zoellner[a]

[a] University of Virginia, Department of Public Health Sciences, UVA Cancer Center Research and Outreach Office, 16 East Main Street, Christiansburg, VA 24073, USA

[b] Syracuse University, Department of Nutrition and Food Studies, 558 White Hall, Syracuse, NY 13244, USA

ARTICLE INFO

Keywords:
Adolescents
Body Mass Index
Rural Health
Suburban Health
Urban Health
Risk Factors
Diet
Obesity
Physical Fitness
Socioeconomic Factors

ABSTRACT

Data from the nationally representative 2014 Family Life, Activity, Sun, Health, and Eating (FLASHE) study was examined to identify differences in adolescent Body Mass Index (BMI) and obesity-related behaviors by rurality status (i.e., urban, suburban, rural) while accounting for relevant demographics (i.e., sex, race/ethnicity, household income). This secondary, cross-sectional analysis included 1,353 adolescents. Analyses included descriptive statistics, one-way analysis of variance, Chi-squared tests, and multiple linear regression models (reported significance level $p < 0.05$). Rurality was not associated with BMI when controlling for demographics. However, relative to rural adolescents, suburban adolescents had significantly higher junk food, sugar-sweetened beverages (SSB), sugary food (all $\beta=+0.2$, $p \le 0.001$), and fruit/vegetable intake ($\beta=+0.1$, $p \le 0.05$). Compared to Non-Hispanic White adolescents, Non-Hispanic Black adolescents had significantly higher BMI ($\beta=+4.4$, $p \le 0.05$), total sedentary time ($\beta=+4.1$, $p \le 0.001$), junk food, SSB, and sugary food intake (all $\beta=+0.2$, $p \le 0.05$). Relative to their lower-income household counterparts, adolescents from higher-income households had significantly lower BMI ($\beta = -9.7$, $p \le 0.001$), junk food ($\beta = -0.2$, $p \le 0.05$), and SSB intake ($\beta = -0.5$, $p \le 0.001$). Contrary to literature, rurality was not a significant predictor of adolescent BMI. While suburban status was significantly associated with several diet-related risk factors, it was not in the direction anticipated. Being non-Hispanic Black and from a low-income household had the greatest influence on adolescent BMI. Findings highlight the importance of using a three-category classification for rurality.

1. Introduction

Obesity is a leading public health concern within the United States, including among adolescents with about 20 % being considered obese (Hales, 2017; Sanyaolu et al., 2019). This causes concern as adolescent obesity is predictive of adult obesity and can lead to chronic disease risks (e.g., high blood pressure, impaired glucose tolerance, type 2 diabetes, asthma, joint and musculoskeletal problems, anxiety, depression, low self-esteem, and even some cancers) (Dietz, 1998; Centers for Disease Control and Prevention, 2021a; Centers for Disease, 2021b). Obesity is caused by various and complex interactions among sociodemographic (e.g., race and ethnicity, family household income), behavioral (e.g., diet, physical activity), and environmental factors (e.g., rural residency). For example, obesity prevalence is highest among adolescents who are Hispanic (25.8 %), non-Hispanic Black or African American (22.0 %), and living in lower-income family households (18.9 %). Yet, obesity prevalence is relatively consistent across male and female adolescents (20.4 % and 20.9 %, respectively) (Hales, 2017; Ogden et al., 2018a; Ogden et al., 2018b; Sanyaolu et al., 2019).

In recent years, the influence of rurality on adult obesity-related behaviors and obesity risk has received increased attention noting rural adults are less physically active, have less access to healthy food retailers, higher poverty levels, and greater food insecurity than urban adults (Lundeen et al., 2018); however, these relationships have been relatively understudied in adolescents (Johnson & Johnson, 2015; U.S, 2015). Existing literature identifies that relative to urban adolescents, rural adolescents have higher obesity rates, consume more sugar-sweetened beverages and fewer fruits and vegetables, yet are slightly more physically active (Davis et al., 2011; Johnson & Johnson, 2015; Liu et al., 2012; Rural Health Information, 2020; Singh et al., 2008; U.S, 2015). However, no known studies have examined differences in obesity and obesity-related behaviors among adolescents residing in urban, suburban, and rural regions (Johnson & Johnson, 2015). This is a notable gap, given that suburban regions represent a large cross-section of US with potentially different obesity-related landscapes. Results from the 2017 American Housing Survey showed that 51.8 % of U.S. residents

* Corresponding author at: 16 East Main Street, Christiansburg, VA 24073, USA.

https://doi.org/10.1016/j.pmedr.2022.101960
Received 14 December 2021; Received in revised form 17 August 2022; Accepted 25 August 2022
Available online 30 August 2022

described their neighborhood as suburban (Office of Policy Development and Research, 2017). Suburban neighborhoods, while increasing in racial and ethnic diversity, are still comprised of a majority of non-Hispanic White (68 %) residents, as well as having lower levels of poverty (14 %) compared to urban (17 %) and rural (18 %) neighborhoods (Parker et al., 2018). Using a large nationally representative sample of US adolescents, the objective of this study is to explore differences in adolescent BMI percentile and obesity-related behaviors (e.g., total moderate to vigorous physical activity (MVPA), sedentary time, diet) by urban, suburban, and rural status while also accounting for relevant demographic factors (i.e., sex, race/ethnicity, household income).

2. Methods

2.1. Sample

This study is a cross-sectional and secondary analysis of data collected from the 2014 Family Life, Activity, Sun, Health, and Eating (FLASHE) study sponsored by the National Cancer Institute (Institute, 2020). FLASHE was approved by Institutional Review Boards (IRB) at Westat and the National Cancer Institute; yet, no additional IRB approval was needed for this secondary study. The cross-sectional FLASHE study, administered between April and October 2014, included an internet-based questionnaire administered to adolescents aged 12 to 17 years (mean = 14.5) and their parents (Institute, 2020). This sample was pulled from the Consumer Opinion Panel using balanced sampling to create a sample with distributions that align with the U.S. population on the following demographic characteristics: sex, education, income, age, household size, and region (National Cancer Institute, 2015). Out of the 5,027 invited to participate in FLASHE, this study's sample includes adolescents who returned the physical activity and dietary surveys (n = 1,890). Respondents with incomplete surveys (<50 % completion) (n = 161) or missing values for study variables tested, such as GeoData (n = 154; parent-reported), physical activity (n = 142), diet (n = 37), height and weight (n = 29), or race/ethnicity (n = 14), were excluded, resulting in an analytical sample of 1,353 adolescents. Based on completeness of data, the overall response rate was 26.9 %.

2.2. Rurality classification

Rurality for adolescents was determined using "FLASHE GeoFLASHE Methods Report on alternative approaches to collapsing the urbanicity" (Institute et al., 2018). Traditional variables of zip code and specific location were not provided as part of the FLASHE study to protect confidentiality of participants. Instead, parents were asked to report the street/road for which they and their adolescent lived, as well as the street/road where their adolescent attended school. The data obtained from these questions were used to develop the geographic coding for the publicly available FLASHE dataset which analyses for this study were conducted (Institute et al., 2018). Data was coded into 26 different variables with various measures related to home and school locations. From these variables, the home census tract, which contained home addresses as self-reported by parents, was chosen as the variable to condense and geocode into three categories (i.e., urban/suburban/rural), per FLASHE's alternative approaches to collapsing the urbanicity categories (Institute et al., 2018). Two different neighborhood characteristics classifications were available in FLASHE as a way to define a more appropriate buffer of the home location, including access (e.g., proximity to state-of-the-art medical facilities or other services typically found in larger cities) and context (e.g., likeliness of sidewalks or local recreational areas/parks near adolescent's homes). Initially, rurality and obesity research questions were explored by both neighborhood classifications, yet results and interpretation were remarkably similar. Therefore, only neighborhood context is presented as this buffer related more to the research questions for this study.

2.3. Measures

All measures included in this analysis were adolescent self-reported, except for family household income and address (i.e., rurality), which were parent self-reported (National Cancer Insitute, 2015). Demographic characteristics included variables of sex, age, race/ethnicity, and family household income.

2.3.1. BMI percentile

Parents were asked to report their adolescent's height in feet/inches and weight in pounds (National Cancer Institute, October, 2017). Height was recoded to achieve a continuous variable in centimeters, rounded to 2 decimal places. Weight was recoded to a continuous variable in kilograms, rounded to 2 decimal places. From these two variables, adolescent BMI and BMI percentiles were calculated based on the Centers for Disease Control and Prevention SAS program on computing percentiles (Centers for Disease Control and Prevention, 2022; National Cancer Institute, October, 2017). Adolescent BMI percentiles were also categorized on established obese cut points (>95th percentile) (Centers for Disease Control and Prevention, 2022).

2.3.2. Physical activity

Adolescents reported minutes of moderate-to-vigorous physical activity (MVPA) (i.e., any form of physical activity that gets you moving and breathing harder) at school (5 items), out of school (3 items), and on weekends (2 items), as well as sedentary time out of school (5 items) through several 5-category Likert scale responses (e.g., 0 days of activity to 5 days of activity, no activity to large amount of activity, I didn't really play at all to I played>3 h per day) (National Cancer Institute, October, 2017). Physical activity was evaluated for minutes of activity per day at school, out of school, and on weekends; each variable is expressed in minutes as a composite score and indicates the Youth Activity Profile (YAP) predicted time per day spent in moderate-to-vigorous physical activity (MVPA) (National Cancer Institute, October, 2017). The YAP was designed to estimate minutes of MVPA and sedentary behaviors and was calibrated and validated in adolescents of the FLASHE study (National Cancer Institute, October, 2017; Saint-Maurice et al., 2017). The YAP has been identified as a quality measure to characterize both MVPA and sedentary behaviors in adolescents (National Cancer Institute, October, 2017; Saint-Maurice et al., 2017). Per FLASHE standardized scoring procedures, a total predicted value for MVPA minutes per day was coded as a mean of the sums of each daily value (National Cancer Institute, October, 2017; Saint-Maurice et al., 2017). Sedentary time out of school (i.e., time spent watching TV, playing video games, using the computer, using a cell phone, and sitting during free time) was also used as an evaluation of minutes per day (variable is expressed in minutes and indicates the YAP predicted time per day spent in sedentary behaviors out-of-school).

2.3.3. Diet

Adolescents were asked to report frequency of certain food items consumed within the last 7 days with a six-category response (i.e., never, 1–3 times in the last 7 days, 4–6 times in the last 7 days, 1 time per day, 2 times per day, 3 or more times per day) (National Cancer Institute, October, 2017). Adolescent diet variables included daily frequency of junk food, sugar-sweetened beverages (SSB), sugary foods, fast/convenient foods; daily cup equivalent of fruits and vegetables; and daily ounce equivalent of whole grains. Standardized FLASHE scoring procedures were applied to convert each variable into a daily frequency (i.e., never = 0, 1–3 times in the last 7 days = 0.29, 4–6 times in the last 7 days = 0.71, 1 time per day = 1, 2 times per day = 2, 3 or more times per day = 3) (National Cancer Institute, October, 2017). Specifically, predicted intake estimates were derived from the Risk Factor Assessment Branch of NCI that was applied to the 2009–2010 National Health and

Nutrition Examination Survey dietary screener (National Cancer Institute, October, 2017). Also, fruit and vegetable intake per day was sex-adjusted per current minimum daily intake recommendations (Lange et al., 2021).

2.4. Analyses

IBM SPSS Statistics for Windows, version 27 (IBM, 2021) was used for all analyses. The publicly available dataset from FLASHE received multiple quality checks prior to publication (National Cancer Institute, 2015). Additionally, each variable included in this study was analyzed for outliers using boxplots, histograms, and interquartile range analyses. No outliers were identified. Descriptive statistics, including means and standard deviations (SDs), are reported. One-way analysis of variance (ANOVA) and Chi-square tests were used to assess differences among variables. Multiple linear regression models were used to examine cross-sectional associations among sociodemographic (i.e., sex, race and ethnicity, family household income) and environmental factors (i.e., rural residency) on the continuous dependent variables including adolescent BMI percentile, total MVPA, total sedentary time, junk food intake, SSB intake, sugary food intake, and fruit and vegetable intake. Independent variables were treated as categorical variables, with females, non-Hispanic Whites, lower family household incomes, and rural adolescents used as the reference groups for each respective factor. Beta weights (β) and p values set at $p < 0.05$ were used to interpret statistical significance. Predictor variables were tested for multicollinearity and no multicollinearity was indicated (Keith, 2006).

Finally, visual trends on the intersectionality of rurality and the independent variables are displayed in Supplementary Figures 1 and 2. Due to concerns with small cell sizes, inferential testing was not applied.

3. Results

3.1. Participants

As shown in Table 1, the adolescent (12–17 years old) sample (n = 1,353) was predominately suburban (41.8 %), followed by urban (36.9 %) and rural (21.3 %). This sample also included a relatively even distribution by sex (49.0 % male; 51.0 % female). Participant race and ethnicity was 64.7 % non-Hispanic White, 16.3 % non-Hispanic Black, 9.9 % Hispanic, and 9.1 % other/two or more races. Family household income was predominately greater than $50,000 (59.4 %).

3.2. BMI percentiles

As further illustrated in Table 1, sex and rurality were not significantly associated with BMI percentiles. However; BMI percentiles varied significantly across race/ethnicity and household family income. BMI percentiles were statistically higher among non-Hispanic Blacks as compared to non-Hispanic Whites and Other race/ethnicity ($p < 0.001$). Also, relative to their higher-income counterparts, BMI percentiles were statistically higher among those with a family household income <$50,000 ($p < 0.001$).

In the multiple linear regression model (Table 2), neither rurality status nor sex were significant predictors of BMI percentile. Non-Hispanic Black adolescents showed a significantly higher BMI percentile (β=+4.4, SE = 1.8, p = 0.013) compared with non-Hispanic White adolescents (Table 2). Also, adolescents in higher family household incomes showed lower BMI percentile (β = -9.7, SE = 1.7, p < 0.001) than those living in lower family household incomes. The model accounted for 3.9 % of variance in BMI percentile (F = 7.761, p < 0.001).

Also, the overall adolescent obesity prevalence rate was 12.0 %. As illustrated in Supplementary Figure 1b, obesity prevalence was 13.2 % among urban, 9.7 % among suburban, and 14.2 % among rural adolescents.

Table 1
Differences in BMI percentile by adolescents' rurality status and by demographic factors (n = 1,353).

Variable	n (%)	BMI Percentile Mean (SD)	F-Statistic (p-value)
Rurality			
Urban	499 (36.9 %)	63.3 (28.3)	2.4 (0.091)
Suburban	566 (41.8 %)	59.8 (29.4)	
Rural	288 (21.3 %)	59.5 (29.8)	
Sex			
Male	663 (49.0 %)	61.7 (30.2)	0.7 (0.414)
Female	690 (51.0 %)	60.4 (28.0)	
Race/Ethnicity			
Non-Hispanic White	875 (64.7 %)	59.4 (29.3)[a]	6.4 (<0.001)
Non-Hispanic Black	221 (16.3 %)	68.4 (27.2)[b]	
Hispanic	134 (9.9 %)	62.3 (27.1)[a,b]	
Other	123 (9.1 %)	57.8 (31.5)[a]	
Family Household Income			
< $50,000	549 (40.6 %)	67.1 (27.9)	42.2 (<0.001)
≥ $50,000	804 (59.4 %)	56.8 (29.2)	

[a,b] One-way analysis of variance tests were used to assess if there were any significant differences between the means of the categories Post-hoc analyses were done using the Tukey method. Values without the same superscript letter are significantly different (p < 0.05).

3.3. Physical activity

As shown in Table 3, across all adolescents, total predicted MVPA averaged 73.1 (SD = 13.0) minutes per day; yet, there were no significant differences by rurality status. Predicted sedentary time out of school averaged 278.7 (SD = 13.2) minutes per day and trended slightly lower for rural adolescents (277.2, SD = 12.9) as compared to urban adolescents (279.6, SD = 13.1) ($p = 0.06$).

In the multiple linear regression model, neither rurality nor demographic variables significantly contributed to the model for total MVPA (Table 2). Rurality did not impact sedentary time, yet non-Hispanic Black adolescents had higher amounts of sedentary time (β=+4.1, SE = 0.8, $p < 0.001$) than non-Hispanic White adolescents (overall model $F = 6.586$, $p < 0.001$, $R^2 = 0.034$).

3.4. Diet

As shown in Table 3, rural adolescents were lower consumers of junk food, SSB, and sugary foods in comparison with suburban adolescents, but were not significantly different from urban adolescents (all $p < 0.05$). Intake of cups of fruit/vegetables per day was significantly lower for rural adolescents as compared to both urban and suburban adolescents (p = 0.004). Adolescent dairy and whole-grain intake were not statistically significant based on rurality (both p > 0.05).

As illustrated in multiple linear regression models in Table 2, compared with rural adolescents, suburban adolescents showed consistently higher intake for junk food, SSB intake, and sugary food intake (all β=+0.2, SE = 0.1, $p < 0.001$), and for fruits and vegetables (β=+0.1, SE = 0.0, $p = 0.044$). Yet, contrasts for urban versus rural were not significant. SSB intake was higher among males (β=+0.2, SE = 0.1, $p = 0.005$), but sex was not related to any other dietary variables. Also, relative to non-Hispanic Whites, non-Hispanic Blacks show consistently higher intakes for junk food, SSB, and sugary food (all β=+0.2, SE = 0.1,

Table 2
Regression models to explain adolescent BMI percentile, physical activity, and diet using rurality status and demographics (n = 1353).

		Multiple Linear Regression						
		BMI Percentile	Physical Activity		Diet			
			Total MVPAmin/day	Total Sedentary Time Out of Schoolmin/day	Junk Food Intake [b]serv/day	SSB Intake [b]serv/day	Sugary Food Intake [b]serv/day	Fruit and Vegetable Intake [c]serv/day
		$R^2 = 0.039$*** $F = 7.761$	$R^2 = 0.005$ $F = 1.001$	$R^2 = 0.034$*** $F = 6.586$	$R^2 = 0.016$** $F = 3.098$	$R^2 = 0.043$*** $F = 8.227$	$R^2 = 0.013$* $F = 2.542$	$R^2 = 0.012$* $F = 2.134$
Variables		**β (S.E.)**	**β (S.E.)**	**β (S.E.)**	**β (S.E.)**	**β (S.E.)**	**β (S.E.)**	
Demographic Factors [a]								
Rurality 1	Urban vs Rural	+0.5 (1.1)	−0.6 (0.5)	+0.5 (0.5)	−0.1 (0.1)	−0.1 (0.1)	−0.1 (0.1)	+0.1 (0.0)
Rurality 2	Suburban vs Rural	+1.0 (1.1)	+0.2 (0.5)	+0.3 (0.5)	+0.2 (0.1)***	+0.2 (0.1) ***	+0.2 (0.1)***	+0.1 (0.0)*
Sex	Male vs Female	+1.1 (1.6)	+0.9 (0.7)	+0.9 (0.7)	−0.0 (0.1)	+0.2 (0.1)**	−0.0 (0.1)	0.0 (0.1)
Race and Ethnicity 1	Non-Hispanic Black vs Non-Hispanic White	+4.4 (1.8) *	−0.7 (0.8)	+4.1 (0.8)***	+0.2 (0.1)*	+0.2 (0.1)*	+0.2 (0.1)*	+0.1 (0.1)
Race and Ethnicity 2	Hispanic vs Non-Hispanic White	+0.2 (2.0)	+0.8 (0.9)	−1.8 (0.9)	−0.1 (0.1)	0.0 (0.1)	−0.1 (0.1)	+0.1 (0.1)
Race and Ethnicity 3	Other vs Non-Hispanic White	−2.8 (2.1)	+0.1 (1.0)	−0.7 (1.0)	−0.1 (0.1)	−0.1 (0.1)	−0.1 (0.1)	−0.1 (0.1)
Family Household Income	≥$50,000 vs < $50,000	−9.7 (1.7) ***	−1.5 (0.8)	−1.0 (0.8)	−0.2 (0.1)*	−0.5 (0.1) ***	−0.1 (0.1)	0.0 (0.1)

β: Beta Weight; S.E.: Standard of Error; CI: Confidence Interval; R^2: Squared multiple correlation-denotes the variance explained in the outcome variable by the predictor variables F: statistical significance of R^2; BMI: Body Mass Index; MVPA: moderate to vigorous physical activities; SSB: Sugar-sweetened beverages

[a] All Demographic variables were dummy coded. Sex: female = 0, male = 1; Race and Ethnicity 1: White = 0, Black = 1; Race and Ethnicity 2: White = 0, Hispanic = 1; Race and Ethnicity 3: White = 0, other = 1; Family household income: <$50,000 = 0, ≥$50,000 = 1; Rurality 1: rural = 0, urban = 1; Rurality 2: rural = 0, suburban = 1.

*$P \leq 0.05$.
**$P \leq 0.01$.
***$P \leq 0.001$.

[b] Daily intake frequencies for the items were summed to create scores for each food group, representing their aggregate daily intake for each food group. Those with missing data for any item within a food group did not receive a score for that food group. To deal with potential overestimation, daily intake frequencies for each food group were top-coded. Values were considered overestimates if reported intakes corresponded to z-scores |≥3.29| (i.e., where 99.95 % of scores would fall in a normal distribution). If the reported value corresponded with a z-score |≥3.29|, it was first removed and then the value nearest to it without having a z-score |≥3.29| was imputed in its place.[12].

[c] Scoring algorithms to convert screener responses to estimates of individual dietary intake was developed following scoring procedures for the National Health and Nutrition Examination Survey.[12].

$p < 0.05$), but no significant difference for fruits and vegetables. Contrasts for other races and ethnicities were not significant. Relative to their counterparts, adolescents with a family household income ≥$50,000 reported lower intakes for both junk food (β = -0.2, SE = 0.1, $p = 0.018$) and SSB (β = -0.5, SE = 0.1, $p < 0.001$), but other dietary variables were not significant. All diet models were significant ($p < 0.05$), yet explained a small amount of variance (range 1.2–4.3 %).

4. Discussion

This study examined differences in adolescent BMI percentiles and obesity-related behaviors by urban, suburban, and rural status. While there are some existing reports of urban and rural differences, no known studies have also considered the influence of suburban status among US adolescents (Johnson & Johnson, 2015). We discuss how rural status, in combination with sex, race, ethnicity, and socioeconomic status, support or refute prior obesity-related literature. We intend that the empirically evaluated data, visual trends, and strengths and limitations of this secondary FLASHE analysis will be used to generate rurality hypotheses for future adolescent-focused epidemiological and intervention studies. Importantly, while FLASHE is considered a nationally representative sample of US adolescents, the sample may not explicitly be representative of urban, suburban, and rural regions. However, this FLASHE sample and the US statistics do follow the same general trend for being predominately suburban (41.8 % vs 55.0 %, respectively), followed by urban (36.9 % vs 31.0 %, respectively) and rural (21.3 % vs 14.0 %, respectively). Also, regression models were significant, yet the amount of variance explained by the included variables were low. These points should be considered in the interpretation and application of our findings.

We found rurality status was not significant in the BMI percentile model when controlling for sex, race and ethnicity, and household income. There is only one other known regional study conducted in Georgia that has explored suburban status and found rural adolescents had a higher overweight and obesity prevalence compared to both urban and suburban adolescents (Lewis et al., 2006), while most other studies show higher obesity rates among rural adolescents compared with urban adolescents (Davis et al., 2011; Johnson & Johnson, 2015; Liu et al., 2012; Ogden et al., 2018a; Ogden et al., 2018b; Singh et al., 2008; Thulitha Wickrama, Wickrama, & Bryant, 2006). Thus, our methods and findings highlight that considering suburban status may offer a unique and important insight into differences.

In the linear regression model, family household income significantly predicted adolescent BMI percentile. Current literature notes similar findings, with adolescents from low-income families having higher obesity rates compared with adolescents from higher-income families (Davis et al., 2011; Johnson & Johnson, 2015; Liu et al., 2012; Ogden et al., 2018a; Ogden et al., 2018b; Singh et al., 2008; Thulitha Wickrama, Wickrama, & Bryant, 2006). When evaluating race and ethnicity differences in BMI percentile, non-Hispanic Black adolescents had significantly higher BMI percentiles than non-Hispanic White adolescents, which is consistent with current literature (Davis et al.,

Table 3
Bivariate analyses to determine differences in physical activity and dietary factors by adolescents' rurality status (n = 1353).

	Overall Mean (SD) n = 1353	Urban Mean (SD) n = 499	Suburban Mean (SD) n = 566	Rural Mean (SD) n = 288	F-Stat (P-value)
Activity-related					
Total Predicted MVPA (mins/day)	73.1 (13.0)	72.7 (13.1)	73.1 (12.7)	73.6 (13.5)	0.4 (0.668)
Predicted Sedentary Time Out of School (mins/day)	278.7 (13.2)	279.6 (13.1)	278.5 (12.9)	277.2 (12.9)	2.8 (0.060)
Diet-related					
Junk food incl. some sugary foods (serv/day)	1.9 (1.6)	1.9 (1.4)[a,b]	2.0 (1.9)[a]	1.7 (1.2)[b]	3.6 (0.029)
SSB (serv/day)	1.3 (1.4)	1.3 (1.3)[a,b]	1.4 (1.7)[a]	1.1 (0.9)[b]	3.6 (0.027)
Sugary foods (serv/day)	1.5 (1.3)	1.4 (1.2)[a,b]	1.6 (1.6)[a]	1.3 (1.0)[b]	3.4 (0.034)
Fruit and Vegetables (cups equiv/day)	2.1 (1.0)	2.1 (1.0)[a]	2.1 (1.1)[a]	1.9 (0.8)[b]	5.5 (0.004)
Dairy (cup equiv/day)	1.7 (0.7)	1.7 (0.7)	1.7 (0.8)	1.7 (0.7)	0.2 (0.816)
Whole Grains (oz equiv/day)	0.9 (1.6)	0.8 (1.2)	1.0 (2.2)	0.8 (1.0)	2.2 (0.116)

SD: Standard Deviation; BMI: Body Mass Index; MVPA: moderate to vigorous physical activities; SSB: Sugar-sweetened beverages.
[a,b] One-way analysis of variance tests were used to assess if there were any significant differences between the means of the categories Post-hoc analyses were done using the Tukey method. Values without the same superscript letter are significantly different ($p < 0.05$).

2011; Johnson & Johnson, 2015; Liu et al., 2012; Ogden et al., 2018a; Ogden et al., 2018b; Singh et al., 2008; Thulitha Wickrama, Wickrama, & Bryant, 2006). Collectively, these results suggest that efforts should focus on reaching and intervening with non-Hispanic Black adolescents and those from lower income family households, as these may be more important factors contributing to adolescent obesity than rurality. Of additional interest, the FLASHE sample shows the majority of both rural and urban adolescents came from households <$50,000 annually, and the largest proportion of the suburban sample from a household income ≥$50,000 annually. This suggests that high income may be a likely protective factor for obesity and highlights the importance of defining rurality by not only urban and rural but including suburban as this is an important literature gap that should be explored further.

Contrary to literature, rurality status was not significantly related to MVPA or sedentary time out of school in the bivariate analyses or regression models; yet, these studies do not separate suburban status adolescents (Davis et al., 2011; Johnson & Johnson, 2015; Liu et al., 2012; Rural Health Information, 2020; Singh et al., 2008; U.S, 2015). When also considering demographics, multiple linear regression models revealed higher minutes of sedentary time among non-Hispanic Black adolescents as compared to non-Hispanic White adolescents, which is similar to other literature (Davis et al., 2011; Johnson & Johnson, 2015; Lange et al., 2021; Liu et al., 2012; Rural Health Information, 2020; Singh et al., 2008; U.S, 2015). In sum, our findings highlight the need for more studies to consider suburban status and empirically evaluate the interactions among rurality status and demographics when exploring MVPA and sedentary time in adolescents (Johnson & Johnson, 2015).

In this study, rural adolescents had lower consumption of junk food, SSBs, and sugary foods per day compared to both urban and suburban adolescents, which is contrary to other research findings; however, these studies were limited in comparing rural and urban adolescents as suburban adolescents were often classified into either category and not used as a complete comparative group (Davis et al., 2011; Johnson & Johnson, 2015; Lewis et al., 2006; Liu et al., 2012; Singh et al., 2008). Moreover, while fruit and vegetable intake was statistically significant with rural adolescents consuming less than both suburban and urban adolescents, it was a relatively even distribution across all rurality classifications for fruit and vegetable intake, whereas other studies have shown considerably lower intakes of fruits and vegetables among rural adolescents as compared to urban adolescents (Johnson & Johnson, 2015; Lange et al., 2021). We speculate these discrepancies with past literature exist, in part, due to our three rurality categories. On the contrary, and in alignment with other published studies (Bleich et al., 2018; Johnson & Johnson, 2015), our findings revealed higher intake of SSB intake in males, non-Hispanic Blacks, and adolescents from lower-income households.

Family household income has been established in literature as a strong predictor of health for both adults and adolescents (Eberhardt & Pamuk, 2004; Kim et al., 2021; Long et al., 2018; Parker et al., 2018; Rural Health Research Gateway, 2018). Adolescents from lower-income families have generally poorer outcomes compared to adolescents from higher-income families. This is especially important as rural households report higher percentages of family's living below the federal poverty level each year compared to urban and suburban areas, which is similar in the family household income values we found for this sample (Eberhardt & Pamuk, 2004; Kim et al., 2021; Rural Health Research Gateway, 2018). This low income has multiple disadvantages for rural communities including higher percentages of uninsured individuals, lack of easily accessible transportation, availability of healthcare facilities, and limited access to healthy and affordable foods (Parker et al., 2018; Rural Health Research Gateway, 2018). Research has shown that if socioeconomic variables were controlled these rural outcomes would be relatively similar to both urban and suburban populations (Long et al., 2018). These disadvantages could be additional factors for why the proportion of obesity in rural adolescents was higher in this sample than that of suburban adolescents, despite their differences in obesity-related behaviors.

It is important to note that the overall obesity rate in the FLASHE sample included in our analyses was 12.0 %. This is in contrast to other recent data showing that 20.6 % of all US adolescents (12–19 years old) are obese (Hales, 2017). This raises some questions around representativeness of the FLASHE study sample. Importantly, FLASHE reports oversampling for non-Hispanic Blacks and balancing on sex, census division, household income, household size, and race and ethnicity (National Cancer Institute, 2015). Yet, study participants also had higher family socioeconomic status in comparison to the US population (Hales, 2017; Ogden et al., 2018a; Ogden et al., 2018b). These differences may be attributed to the FLASHE sample being recruited from the Ipsos Consumer Opinion Panel, where participants were required to have in-house internet connection in 2014 (Institute et al., 2018).

5. Strengths and limitations

The potential concerns around representativeness, as explained above, should be considered and may limit generalizability of our findings. While the FLASHE dataset offers a flexible range of rurality coding on urban/suburban/rural categories with numerous subcategories to identify adolescent's neighborhood (i.e., mixed city/suburb, mixed city/rural, mixed suburb/rural, mixed town/rural, and mixed city/suburb/rural), traditional geographical variables (e.g., zip codes, street addresses, rural–urban commuting area codes, rural–urban continuum codes) are not provided (Institute et al., 2018). This methodological difference somewhat limits comparisons of our findings to other rurality literature and may explain some of the discrepancies with other literature. It is important to note that data from this study is currently 8 years old as data was collected during 2014. Also, data for this study was self-reported and could be subject to self-report bias. Finally, the possibility of unanalyzed confounding variables should be considered, especially given the previously mentioned low variance explained by the models. Despite these limitations, notable strengths of our paper are the inclusion of the suburban identifier in comparison to urban and rural and examining established obesity risk factors.

6. Conclusions and future research

Contrary to literature, rurality was not a significant predictor of adolescent BMI. While suburban status was significantly associated with several diet-related risk factors, it was not in the direction anticipated. Given our findings on rurality that were inconsistent with current literature, several areas for future research are highlighted. More studies are needed to study epidemiology of rural populations, including among adolescents. A future recommendation is to include traditional urban/suburban/rural identifiers data in more adolescent national datasets, including, but not limited to FLASHE. For example, the Youth Risk Behavior Surveillance System (YRBSS) is one of the largest sources of national adolescent health data; however, it does not allow for analyses based on adolescent rurality. If national datasets included traditional urban/suburban/rural identifiers, researchers may be able to get a more complete picture of current public health trends based on rurality for adolescents. In addition, research is needed to explore how rurality may interact with demographic characteristics to influence obesity and overall adolescent health. Finally, given the low amount of variance explained by our models, future research should include other relevant independent variables (beyond rurality and demographic characteristics) when exploring predictors of adolescent obesity and obesity-related behaviors. These future studies could provide key information to develop targeted adolescent obesity interventions.

As adolescent obesity continues to be a leading US public health concern, our study can be used as a foundation to explore how rurality and other sociodemographic factors may influence BMI percentiles and obesity-related behaviors. This study provides insights into differences in adolescent BMI percentiles and obesity risk factors among urban, suburban, and rural areas, as well as further evidence for socioeconomic and racial and ethnic disparities. Given notable discrepancies in our findings compared to prior published literature, it is imperative that future researchers and public health practitioners consider suburban status when examining differences in BMI percentiles, obesity and obesity-related behaviors among adolescents.

Ethical approval

The database was approved through the Institutional Review Board of Westat, the National Cancer Institute Special Studies Institutional Review Board, and the Office of Management and Budget. For this secondary data analysis study, no institutional review board approval was needed. Per the FLASHE methods report, parents provided consent for themselves and their child to participate and adolescents provided assent.

CRediT authorship contribution statement

Brittany M. Kirkpatrick: Conceptualization, Methodology, Data curation, Writing – original draft, Writing – review & editing. **Maryam Yuhas:** Conceptualization, Writing – original draft. **Jamie M. Zoellner:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data is currently publicly available through FLASHE

Acknowledgments

Funding Acknowledgments: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Contributor Acknowledgments: We would like to acknowledge and thank the National Cancer Institute for making the Family Life, Activity, Sun, Health, and Eating (FLASHE) study database publicly available in 2016.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2022.101960.

References

Bleich SN, Vercammen KA, Koma JW, Li Z. Trends in Beverage Consumption Among Children and Adults, 2003-2014 [published correction appears in Obesity (Silver Spring). 2019 Oct;27(10):1720]. *Obesity (Silver Spring)*. 2018;26(2):432-441. doi: 10.1002/oby.22056.

Centers for Disease Control and Prevention. A SAS Program for the 2000 CDC Growth Charts (ages 0 to <20 years). Center for Disease Control and Prevention, U.S. Department of Health & Human Services; 2021. Updated February 18, 2022. Accessed June 15, 2022. https://www.cdc.gov/nccdphp/dnpao/growthcharts/resources/sas.htm.

Centers for Disease Control and Prevention. Adult obesity causes & consequences. Center for Disease Control and Prevention, U.S. Department of Health & Human Services; 2021. Updated March 22, 2021. Accessed March 24, 2021. https://www.cdc.gov/obesity/adult/causes.html.

Centers for Disease Control and Prevention. Childhood obesity causes & consequences. Center for Disease Control and Prevention, U.S. Department of Health & Human Services; 2021. Updated March 19, 2021. Accessed March 24, 2021. https://www.cdc.gov/obesity/childhood/causes.html.

Davis, A.M., Bennett, K.J., Befort, C., Nollen, N., 2011. Obesity and related health behaviors among urban and rural children in the united states: data from the national health and nutrition examination survey 2003–2004 and 2005–2006. J. Pediatr. Psychol. 36 (6), 669–676. https://doi.org/10.1093/jpepsy/jsq117.

Dietz WH. Health consequences of obesity in youth: childhood predictors of adult disease. *Pediatrics*. 1998;101(3 Pt 2):518-525. Accessed March 31, 2021. https://pediatrics.aappublications.org/content/101/Supplement_2/518.long.

Eberhardt, M.S., Pamuk, E.R., 2004. The importance of place of residence: examining health in rural and nonrural areas. Am. J. Public Health 94 (10), 1682–1686. https://doi.org/10.2105/ajph.94.10.1682.

Hales CM, Carroll MD, Fryar CD, Ogden, CL. Prevalence of obesity among adults and youth: United States, 2015–2016. NCHS Data Brief. Published October 2017. Accessed December 10, 2020. https://www.cdc.gov/nchs/data/databriefs/db288.pdf.

IBM Corp. IBM SPSS Statistics for Windows, Version 27. Armonk, NY: IBM Corp.

National Cancer Institute. Family Life, Activity, Sun, Health, and Eating (FLASHE) GeoFLASHE Methods Report. Westat;70 p. Contract No.: HHSN261201200039I. Published March 2018. Accessed October 16, 2020. https://cancercontrol.cancer.gov/sites/default/files/2020-06/geoflashe-methods-report-nci.pdf.

National Cancer Institute. About the FLASHE study. National Cancer Institute, Division of Cancer Control & Population Sciences. Contract No.: HHSN261201200039I. Updated November 19, 2020. Accessed December 16, 2020 https://cancercontrol.cancer.gov/brp/hbrb/flashe-study.

Johnson 3rd, J.A., Johnson, A.M., 2015. Urban-rural differences in childhood and adolescent obesity in the United States: a systematic review and meta-analysis. Child Obes. 11 (3), 233–241. https://doi.org/10.1089/chi.2014.0085.

Keith, T.Z., 2006. Multiple regression and beyond. Pearson Education.

Kim, K.W., Wallander, J.L., Depaoli, S., Elliot, M.N., Schuster, M.A., 2021. Longitudinal associations between parental SES and adolescent health-related quality of life using growth curve modeling. J Child Family Stud. 30 (6), 1463–1475. https://doi.org/10.1007/s10826-021-01970-y.

Lange, S.J., Moore, L.V., Harris, D.M., et al., 2021. Percentage of Adolescents Meeting Federal Fruit and Vegetable Intake Recommendations - Youth Risk Behavior Surveillance System, United States, 2017. MMWR Morb. Mortal. Wkly Rep. 70 (3), 69–74. https://doi.org/10.15585/mmwr.mm7003a1.

Lewis, R.D., Meyer, M.C., Lehman, S.C., et al., 2006. Prevalence and degree of childhood and adolescent overweight in rural, urban, and suburban Georgia. J. Sch. Health 76 (4), 126–132. https://doi.org/10.1111/j.1746-1561.2006.00080.x.

Liu, J.H., Jones, S.J., Sun, H., Probst, J.C., Merchant, A.T., Cavicchia, P., 2012. Diet, physical activity, and sedentary behaviors as risk factors for childhood obesity: an urban and rural comparison. Child Obes. 8 (5), 440–448. https://doi.org/10.1089/chi.2012.0090.

Long AS, Hanlon AL, Pellegrin KL. Socioeconomic variables explain rural disparities in US mortality rates: Implications for rural health research and policy [published correction appears in SSM Popul Health. 2020 Dec 10;12:100714]. *SSM Popul Health*. 2018;6:72-74. doi:10.1016/j.ssmph.2018.08.009.

Lundeen, E.A., Park, S., Pan, L., O'Toole, T., Matthews, K., Blanck, H.M., 2018. Obesity Prevalence Among Adults Living in Metropolitan and Nonmetropolitan Counties - United States, 2016. MMWR Morb. Mortal. Wkly Rep. 67 (23), 653–658. https://doi.org/10.15585/mmwr.mm6723a1.

National Cancer Institute. Family Life, Activity, Sun, Health, and Eating (FLASHE) Study Methodology Report. Westat;35 p. Contract No.: HHSN261201200039I. Published July 2015. Accessed October 16, 2020. https://cancercontrol.cancer.gov/sites/default/files/2020-06/flashe_methods_report.pdf.

National Cancer Institute. Guide for Data Users: The Family Life, Activity, Sun, Health, and Eating Study (FLASHE). U.S. Department of Health and Human Services, National Cancer Institute. Updated October 2017. Accessed October 16, 2020. https://cancercontrol.cancer.gov/sites/default/files/2020-06/flashe-data-users-guide.pdf.

Office of Policy Development and Research (PD&R). The 2017 AHS Neighborhood Description Study. U.S. Department of Housing and Urban Development. Accessed March 17, 2022. https://www.huduser.gov/portal/AHS-neighborhood-description-study-2017.html#summary-tables-tab.

Ogden, C.L., Carroll, M.D., Fakhouri, T.H., et al., 2018a. Prevalence of Obesity Among Youths by Household Income and Education Level of Head of Household - United States 2011–2014. MMWR Morb. Mortal. Wkly Rep. 67 (6), 186–189. https://doi.org/10.15585/mmwr.mm6706a3.

Ogden, C.L., Fryar, C.D., Hales, C.M., Carroll, M.D., Aoki, Y., Freedman, D.S., 2018b. Differences in Obesity Prevalence by Demographics and Urbanization in US Children and Adolescents, 2013–2016. JAMA 319 (23), 2410–2418. https://doi.org/10.1001/jama.2018.5158.

Parker K, Menasce Horowitz J, Brown A, Fry R, Cohn D & Igielnik, R. Demographic and economic trends in urban, suburban and rural communities. Pew Research Center. Published Mar 22, 2018. Accessed June 11, 2021. https://www.pewresearch.org/social-trends/2018/05/22/demographic-and-economic-trends-in-urban-suburban-and-rural-communities/.

Rural Health Information Hub. Rural obesity and weight control. Rural Health Information Hub, U.S. Department of Health and Human Services. Published August 7, 2020. Accessed December 16, 2020. https://www.ruralhealthinfo.org/topics/obesity-and-weight-control.

Rural Health Research Gateway. Rural communities: age, income, and health status. Rural Health Research Recap, University of North Dakota Center for Rural Health. Published November 2018. Accessed June 11, 2021 https://www.ruralhealthresearch.org/assets/2200-8536/rural-communities-age-income-health-status-recap.pdf.

Saint-Maurice, P.F., Kim, Y., Hibbing, P., Oh, A.Y., Perna, F.M., Welk, G.J., 2017. Calibration and Validation of the Youth Activity Profile: The FLASHE Study. Am. J. Prev. Med. 52 (6), 880–887. https://doi.org/10.1016/j.amepre.2016.12.010.

Sanyaolu A, Okorie C, Qi X, Locke J, Rehman S. Childhood and Adolescent Obesity in the United States: A Public Health Concern. *Glob Pediatr Health*. 2019;6:2333794X19891305. doi:10.1177/2333794X19891305.

Singh, G.K., Kogan, M.D., Van Dyck, P.C., Siahpush, M., 2008. Racial/ethnic, socioeconomic, and behavioral determinants of childhood and adolescent obesity in the United States: analyzing independent and joint associations. Ann. Epidemiol. 18 (9), 682–695. https://doi.org/10.1016/j.annepidem.2008.05.001.

Thulitha Wickrama, K.T., Wickrama, K.A., Bryant, C.M., 2006. Community influence on adolescent obesity: Race/ethnic differences. J. Youth Adolesc. 35 (4), 641–651. https://doi.org/10.1007/s10964-006-9050-9.

U.S. Department of Health and Human Services, Health Resources and Services Administration, Maternal and Child Health Bureau. The health and well-being of children in rural areas: a portrait of the nation, 2011-2012. U.S. Department of Health and Human Services. 61 p. Contract No. GS10F0261K. Published April 2015. Accessed December 16, 2020. https://mchb.hrsa.gov/sites/default/files/mchb/Data/NSCH/nsch11-12-health-well-child-rural-apr2015.pdf.