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Active living environments mediate rural and non-rural differences in physical activity, active transportation, and screen time among adolescents

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ABSTRACT

Disparities in physical activity-related behaviors among rural and non-rural adolescents are important to consider given the relatively recent concerns surrounding the health of rural populations. Differences in rural and non-rural environments may facilitate or hinder physical activity opportunities. The purpose of this study is to examine differences between non-rural and rural adolescents' moderate-to-vigorous physical activity (MVPA), screen time, and active transportation, including the mediating role of neighborhood resources. Data came from 1,128 adolescents (207 rural, 18%) aged 12–17 years old and their parents living in the United States in the 2014 Family Life, Activity, Sun, Health, and Eating (FLASHE) study. Counterfactual mediation models were used to compare MVPA and screen time (linear regression) and active transit (log-binomial regression) among rural and non-rural adolescents, adjusting for demographics and health and measuring the mediating influence of neighborhood resources for PA. In adjusted models, rural adolescents engaged in less MVPA at school compared to non-rural adolescents (B = −1.14 min/day, p = 0.031) while no difference was found in MVPA at home or on weekends. Rural adolescents had less screen time (B = −2.1 min/day, p = 0.036) than their non-rural peers and were less likely to report active transit trips than non-rural adolescents (OR = 0.66, p = 0.016). Much of the differences in MVPA (70%) and active transit (54%) were mediated by differences in neighborhood resources. Improving the neighborhood resources in rural areas may encourage adolescents to be more active. This includes providing physical activity resources in rural areas such as sidewalks, bike lanes, greenways, playgrounds, fitness facilities, and parks/green space.

1. Introduction

Differences in physical activity (PA) and sedentary behaviors among rural and non-rural adolescents remains unclear. While some studies indicate adolescents living in rural areas have significantly lower PA levels compared to those in urban areas (Moore et al., 2013), others have shown higher PA levels among rural adolescents or no difference (Euler et al., 2019; Machado-Rodrigues et al., 2014; Moore et al., 2014). Similar mixed results are seen among studies examining sedentary behavior or physical inactivity (Liu et al., 2008; Smith et al., 2018). However, most studies focused on specific regions of the United States, with one exception that used a large national dataset of parent-reported adolescent PA (Liu et al., 2008). Despite conflicting findings, there is reason to believe that differences might exist between rural and non-rural adolescents, given the differences which exist between adults in rural compared to non-rural areas with these health behaviors and related health conditions (Matthews et al., 2017).

Rural-urban disparities in PA-related behaviors are important to consider given the relatively recent concerns surrounding the health of rural populations (Hartley, 2004). The concept of active living incorporates an ecological framework that recognizes the environments in which people live (i.e., home, neighborhoods, schools, workplaces) influences PA-related behaviors (Sallis et al., 2006). Subsequently, differences in rural and non-rural environments may facilitate or hinder PA opportunities (Moore et al., 2013). For example, adolescents in rural areas may be less likely to engage in active transport (e.g., walking, biking from place-to-place) as distance is a key barrier (Su et al., 2013; Chillón et al., 2014). Active transport has been found to be associated with healthy levels of PA and fitness in youth (Henriquez-Neto et al., 2020) and adolescents living in non-rural areas may be more likely to engage in active transport due to shorter distances to places of interest such as school, parks/greenways and friends' homes. Alternately, rural areas may provide suitable environments for active transport due to decreased traffic concerns (Su et al., 2013). In addition, it has been

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reported that urban populations may have benefited from prevention initiatives at a higher rate than rural populations due to the greater investment in non-rural areas (Hartley, 2004). Availability of resources that promote PA, such as parks, trails, playgrounds, and fitness facilities may be lacking in rural areas (Committee on Environmental Health, 2009). Thus, if the environment mediates the relationship between living in a rural area and engaging in less PA or more sedentary behavior, enhancing resources in rural areas could be an effective strategy to reduce place-based differences.

The purpose of the current study is to explore differences in non-rural and rural adolescents' PA levels, active transportation, and screen time. Specifically, the study seeks to answer the following research questions: 1) Do differences exist in self-reported PA levels, screen time, and active transport behaviors among non-rural and rural adolescents; 2) Do differences exist in the active living environments of rural and non-rural settings and does this mediate the relationship between rural residence and outcomes?

2. Methods

2.1. Data source

This study is a secondary data analysis of the Family Life, Activity, Sun, Health, and Eating (FLASHE) Study. FLASHE was a cross-sectional study conducted in 2014 by the National Cancer Institute to examine correlates of preventive behaviors associated with cancer among a nationally representative sample of United States parent-adolescent dyads (National Cancer, 2014). Parent-adolescent dyads were eligible to participate if the parent was over 18 years old and was currently living at least 50% of the time with at least one child between 12 and 17 years old. In the case of more than one adolescent meeting the inclusion criteria, only one adolescent per household was randomly selected to participate. A total of 5,027 dyads were invited and 1,945 chose to participate (38.7% response rate) (National Cancer, 2019). Approval for the current study was obtained from the authors' university institutional review board.

2.2. Measures

2.2.1. Rural residence (Exposure)

Urban-rural classification was determined from 2010 Census data categorized by the National Center for Education Statistics (NCES) urban-centric categories (National Center for Education Statistics, 2020). For the current study, the NCES categories were dichotomized with the categories of city, suburb, and town combined to represent non-rural and the category of rural (Census-defined rural territory outside of an urbanized area or urban cluster).

2.2.2. Physical activity, screen time, and active transportation (Outcomes)

The primary outcome variables of adolescents' MVPA, screen time, and active transportation were obtained using the Youth Activity Profile (YAP) (Saint-Maurice and Welk, 2014). The YAP has been validated for use in large-scale research studies (Saint-Maurice et al., 2017). The YAP estimates adolescents' daily minutes of MVPA in school, out-of-school, and on weekends by asking about activity levels in each domain during the past week. It defines physical activities as "things that involve a lot of walking, running or moving around' and includes examples like biking, dancing, sports, and outdoor play. MVPA was estimated directly and a dichotomous variable was calculated to indicate whether or not adolescents met the recommended 60 min of MVPA per day. Screen time is estimated by asking adolescents to estimate the amount of time in the past week they spent watching TV, playing video games, using the computer, and a cell phone. Active transportation is estimated as the number of active trips to/from school (only for adolescents enrolled in school) or the number of active trips to/from a job, friend's house, or an event/activity. For this study, a dichotomous variable was created to indicate whether or not adolescents made any active trips in the past week.

2.2.3. Active living environment (Mediator)

The PA environments where adolescents lived were assessed by variables that asked about the availability and use of PA equipment/resources in the home and neighborhood. Dichotomous variables were created to indicate whether adolescents had PA equipment (i.e., bicycle, basketball hoop, sports equipment, skateboard/scooter, weight lifting equipment, cardio equipment, active gaming, and exercise videos or DVDs) available for them to use in their home, yard, or apartment complex and whether they had access to resources (i.e., indoor recreation or exercise facility, school recreation facilities, bike/hiking/walking trails or paths, basketball courts or playing fields, and public parks) in their neighborhood, defined as the area within a 10–15 min walk from their home. To evaluate whether the active living environment mediates the relationship between rural residence and PA, variables were created to indicate the number of PA resources available to each adolescent at home (range: 0–8) or in their neighborhood (range: 0–5) by summing the number of yes responses in each category. Respondents were required to answer >70% of the items to calculate a summed score. Higher numbers represent an environment that is more conducive to/supportive of active living.

2.2.4. Covariates

FLASHE includes variables that estimate the distance from home to school for each adolescent by using the reported home and school addresses. The street network distance was used as a measure of the distance from home to school.

Adolescents self-reported their age, sex, general health, weight and height (to calculate and classify BMI), year in school, type of school attended (public, private, home school, another type of school). One parent in the household self-reported their education level and annual household income as measures of the adolescents' socioeconomic position.

2.3. Sample

The adolescent and parent datasets were merged which resulted in 1,661 matched dyads. Adolescents were excluded who were home-schooled (n = 102; 6.1%) because in-school versus out-of-school differences in PA were explored. Adolescents were also excluded whose distance from home to school was greater than 50 miles (n = 6; 0.4%) since these students may have been attending a residential school and because they were outliers in the dataset as well as adolescents who could not be classified as living in a rural or non-rural area (n = 80; 4.8%) and those who were missing information about any of the outcomes (MVPA, screen time, or active trips; n = 219; 13.2%). Finally, adolescents missing information on any of the covariates included in regression models (n = 126; 7.6%) were excluded. The final analytic sample included 1,128 adolescents (67.9% of original 1,661). Included and excluded adolescents were similar in age, sex, general health, BMI category, household income, parent education, and distance from home to school. Excluded participants were more likely to live in a rural area and less likely to attend a public school than included participants.

2.4. Data analysis

The characteristics of rural and non-rural adolescents were described and t-tests were used to compare means for quantitative variables (i.e., age, network distance from home to school, MVPA and screen time) and chi-square tests to compare proportions for categorical variables (all other measures). The counterfactual approach to mediation analysis was used to explore whether the built environment, measured as neighborhood resources, influenced the relationship between rural residence and each outcome (Valeri and VanderWeele, 2013). This approach included

an interaction term between rural residence and the hypothesized mediator – neighborhood resources – in each model. Based on the causal diagrams (directed acyclic graphs created using DAGitty Textor et al., 2016), age, sex, general health, public school attendance, and household SES (parent-reported household income and parent education level) were adjusted for as exposure-outcome confounders and distance from home to school as a potential confounder between neighborhood resources (mediator) and the outcomes. Separate linear regression models were used to estimate the difference between rural and non-rural adolescents in MVPA at school, at home, and on the weekends. Similarly, linear regression was used to estimate differences in screen time between rural and non-rural adolescents. Log-binomial regression was used to estimate the prevalence ratio (Barros and Hirakata, 2003) of taking any active trips for rural versus non-rural respondents, adjusting for age, public school attendance, household SES, and distance from home to school. (model convergence was unachievable with sex and general health in the model that included the exposure-mediator interaction term.) All analyses were conducted using Stata version 13.1, and mediation analyses were conducted using the paramed command (Emsley and Liu, 2013).

Both the total effect of rural residence on each PA-related outcome was reported, adjusting for potential confounding variables, and the controlled direct effect (CDE), which estimates the average effect of rural residence on the outcomes when the active living environment characteristics were the same across the population; specifically, the effect when the environment was at the level observed in non-rural areas was estimated (Valeri and VanderWeele, 2013). The natural effects were also reported, which are useful for understanding the relative importance of the neighborhood environment as a mechanism between rural residence and PA outcomes. Specifically, the natural direct effect (NDE) was reported, representing how much change in the outcomes we might expect for rural versus non-rural adolescents if the environment was commensurate with a non-rural area, and the natural indirect effect (NIE), or the amount by which living in a rural area would impact the outcome if the environment was changed from what was observed in rural areas to what was observed in non-rural areas. Finally, these estimates were used to calculate the percent of the effect of rural residence on PA that is mediated by the environment by dividing the NIE by the total effect (the natural log of these estimates were used for the log-binomial models).

Table 1
Characteristics of rural and non-rural adolescents, Family Life, Activity, Sun, Health, and Eating (FLASHE) Study, 2014.

Variable	Category	Rural Adolescents (N = 207) %	Non-rural Adolescents (N = 921) %	P-value[1]
Sex	Female	50.2	51.3	0.79
	Male	49.8	48.8	
Age	12	12.6	12.5	0.99
	13	20.8	20.1	
	14	15.0	16.4	
	15	18.4	17.6	
	16	19.3	20.2	
	17	14.0	13.3	
School level	Middle	39.3	39.7	0.93
	High	60.7	60.3	
School type	Public	91.8	89.8	0.38
	Private or another type of school	8.2	10.2	
Health status	Excellent, very good, or good	95.2	94.3	0.60
	Fair or poor	4.8	5.8	
BMI category	Underweight (<18.5)	6.8	3.7	0.24
	Healthy (18.5–24.9)	64.7	67.4	
	Overweight or obese (≥25.0)	27.1	26.8	
	Missing	1.5	2.1	
Parent's highest level of education[2]	Less than high school	1.5	1.2	0.02
	High school degree or GED	21.7	14.4	
	Some college	36.7	34.3	
	4-year college degree or higher	40.1	50.1	
Annual household income[2]	Less than $100,000	86.5	76.1	0.001
	$100,000 or more	13.5	23.9	

[1] P-value based on chi-square test comparing percentage of rural adolescents to non-rural adolescents in each category.

[2] "Parent" refers only to the parent who responded to the survey. These variables were reported by the parent; all others were reported by the adolescents themselves.

3. Results

Eighteen percent of adolescents included in the study lived in a rural area. Rural and non-rural adolescents were similar except that adolescents living in rural areas had lower household income and parents with lower levels of education than their non-rural peers (Table 1). The mean age in both groups was 14.5 years ($p = 0.97$). Adolescents living in rural areas lived, on average, about twice as far from school as non-rural adolescents (7.0 [SD = 5.6] versus 3.6 [SD = 4.1] miles, respectively, $p < 0.001$).

The PA-related resources available to adolescents at home did not differ substantially between rural and non-rural (Table 2). Rural adolescents were significantly less likely to report having a skateboard or scooter than non-rural adolescents (43% versus 57%, $p = 0.001$), but access to other types of equipment and total number of resources available were similar. However, in terms of neighborhood resources, rural adolescents had significantly less access than their non-rural counterparts. In all five areas assessed, rural adolescents were significantly less likely to report a given resource and had significantly fewer neighborhood access points, on average, than non-rural adolescents (1.3 versus 2.4 neighborhood resources, $p < 0.001$).

All adolescents included in the study met the recommendations for daily PA. No differences were found in the reported levels of MVPA among rural and non-rural adolescents, whether at school, at home, or on the weekends (Table 3). Rural adolescents averaged significantly less screen time, on average, than non-rural adolescents (277 versus 279 min per day, $p = 0.04$). Rural adolescents were significantly less likely than their non-rural counterparts to engage in active transportation in the past week (16% versus 30%, $p < 0.001$).

In adjusted mediation models (Table 4), rural residence was significantly associated with lower MVPA at school, screen time, and prevalence of active transportation among adolescents (marginal total effects: $B = -1.14$, $p = 0.031$ for MVPA at school, $B = -2.08$, $p = 0.036$ for MVPA out of school on weekdays, and $PR = 0.66$, $p = 0.016$ for active transit). Neighborhood resources were an important mediator of the total effect of rural residence on PA outcomes. The NIE for MVPA at school and out-of-school on weekdays were both negative and statistically significant ($B = -0.80$, $p = 0.007$ and $B = -0.57$, $p = 0.035$, respectively), indicating lower PA among rural adolescents through the pathway of neighborhood resources. Similarly, the PR for active transportation indicated significantly less active transit among rural adolescents through the neighborhood resources pathway ($PR = 0.80$, $p = 0.005$). The study estimates that 21% of the effect of rural residence on screen time, 54% of the effect on active transportation, and 70.2% of the effect on MVPA at school is mediated through neighborhood resources. After accounting for confounding and mediation, there was no direct effect of living in a rural area on any of the outcomes (p-values for CDE estimates ranged from 0.08 to 0.58).

Table 2
Physical activity-related resources available to adolescents at home or in their neighborhoods by rural and non-rural status, Family Life, Activity, Sun, Health, and Eating (FLASHE) Study, 2014.

Variable	Category	**Rural Adolescents** (N = 207)	**Non-rural Adolescents** (N = 921)	P-value
Resources at home, in yard, or in apartment complex	Bicycle (not stationary)	69.1%	76.6%	0.05[1]
	Basketball hoop	56.0%	54.9%	0.62[1]
	Sports equipment like balls, racquets, bats and sticks	73.9%	71.9%	0.70[1]
	Skateboard or scooter	**42.5%**	**56.8%**	**0.001**[1]
	Weight lifting equipment	49.3%	52.1%	0.62[1]
	Cardio equipment like tread-mills, stationary bicycles, step climbers, elliptical machines, rowing machines, etc.	50.2%	50.7%	0.79[1]
	Active gaming like Wii or Xbox Kinect	72.5%	73.4%	0.92[1]
	Exercise videos or DVDs	44.4%	51.7%	0.12[1]
	Total home resources *Mean (SD)*	4.6 (2.0)	4.9 (2.1)	0.06[2]
Resources in neighborhood (within 10–15 min walk from home)	Indoor recreation or exercise facility (public or private)	**14.0%**	**31.2%**	**<0.001**[1]
	School with recreation facilities open to the public	**15.5%**	**29.8%**	**<0.001**[1]
	Bike/hiking/walking trails, paths	**39.6%**	**52.4%**	**0.001**[1]
	Basketball courts, running track/other playing fields (like soccer, football, softball, tennis, skate park etc.)	**27.5%**	**55.7%**	**<0.001**[1]
	Public park	**35.8%**	**69.1%**	**<0.001**[1]
	Total neighborhood resources*Mean (SD)*	**1.3 (1.5)**	**2.4 (1.5)**	**<0.001**[2]

Bold font indicates statistically significant differences.
Note: Responses were missing for some items in the resources at home category; <2% of responses were missing for each resource. All respondents had a total score since, at most, a respondent did not answer 2 items.
[1] P-value based on chi-square test comparing percentage of rural and non-rural adolescents with resource.

[2] P-value based on *t*-test comparing mean number of resources for rural and non-rural adolescents.

Table 3
Physical activity, screen time, and active transportation among rural and non-rural adolescents, Family Life, Activity, Sun, Health, and Eating (FLASHE) Study, 2014.

Variable	Category	**Rural Adolescents** (N = 207)	**Non-rural Adolescents** (N = 921)	P-value
Minutes per day of MVPA	At school *Mean (SD)*	55.5 (11.5)	56.9 (13.2)	0.18[1]
	At home, weekday *Mean (SD)*	57.7 (10.7)	57.7 (10.6)	0.99[1]
	Weekend *Mean (SD)*	104.0 (20.3)	104.4 (19.5)	0.79[1]
Minutes per day of screen time	Total *Mean (SD)*	**276.6 (12.7)**	**278.6 (13.2)**	**0.04**[1]
Active transportation in the past week	Any trip to school (students) or to a job, friend's house, or activity/event (non-students)	**15.5%**	**30.2%**	**<0.001**[2]

MVPA: Moderate to vigorous physical activity.
[1] P-value based on *t*-test comparing mean minutes per day of physical activity or screen time for rural and non-rural adolescents.

[2] P-value based on chi-square test comparing percentage of rural and non-rural adolescents engaging in active transportation.

4. Discussion

The current study found that rural adolescents engaged in fewer MVPA minutes at school than their non-rural counterparts, however no difference was found in MVPA minutes at home and on the weekend. This effect was largely the result of differences in rural and non-rural environments rather than rural residence *per se*. Previous research comparing non-rural and rural adolescent MVPA has found mixed results, although most of these studies have been conducted in one region of the United States (Moore et al., 2013, 2014; Euler et al., 2019; Machado-Rodrigues et al., 2014). The current study reports data collected from a national study of adolescent MVPA. Similarly, data collected from 1999 to 2006 using a nationally representative sample revealed no difference in PA between rural and non-rural adolescents (Liu et al., 2012). Contrary to the current study, a study of Midwest children showed non-rural children were less active than rural children with the difference being most pronounced during school lunch period (Joens-Matre et al., 2008). Though no difference was found in time spent in physical education between non-rural and rural adolescents in the current study, it is possible that differences in policies and structure of non-rural and rural physical education curriculum could account for higher levels of PA in non-rural schools (Joens-Matre et al., 2008). Alternatively, the difference in MVPA at school could be explained by differences in active transportation, which predominantly included transit to or from school (Burns et al., 2019).

A recent review of the literature confirms these conflicting results, suggesting that the varied ways in which studies define rural and the methods of collecting PA data may account for mixed results (McCormack and Meendering, 2016). Of the 16 studies conducted in the United States comparing the PA of rural and non-rural youth, only three cross-sectional studies used accelerometry or pedometry to measure PA objectively. Furthermore, 10 different definitions of rural were utilized in the studies.

Rural adolescents in the current study were also found to take fewer active transit trips than their non-rural counterparts. As with MVPA at school, this effect was predominantly mediated by differences in the environment (54%). To our knowledge, no studies have compared active transportation between non-rural and rural adolescents in the United States, however, this finding is consistent with studies in Canada that have found that the majority of MVPA among urban youth is from commuting by walking, biking, or some other active means (Rainham et al., 2012). Further support is provided by studies using objectively measured PA and objectively measured built environment showing that urban settings have more positive features related to being active than

Table 4
Association between rural residence and physical activity, screen time, and active transportation among adolescents based on mediation analysis regression models, Family Life, Activity, Sun, Health, and Eating (FLASHE) Study, 2014.

Physical Activity-Related Outcome	Domain	Controlled direct effect (CDE)	Natural Direct Effect (NDE)	Natural Indirect Effect (NIE)	Marginal Total Effect (TE)	Proportion Mediated
		Estimate (95% CI) *p-value*	Estimate (95% CI) *p-value*	Estimate (95% CI) *p-value*	Estimate (95% CI) *p-value*	Estimate (95% CI) *p-value*
Moderate to Vigorous Physical Activity, Minutes Per Day[1]	At school	−0.34 (−1.52, 0.84) *0.58*	−0.34 (−1.01, 0.82) *0.57*	**−0.80 (−1.37, −0.22) *0.007***	**−1.14 (−2.17, −0.11) *0.031***	70.2%
	Out of school, weekdays	1.01 (−1.11, 2.13) *0.077*	1.00 (−0.11, 2.11) *0.076*	**−0.57 (−1.10, −0.04) *0.035***	0.43 (−0.54, 1.40) *0.38*	NR
	Weekends	1.01 (−1.95, 4.00) *0.50*	0.99 (−1.94, 3.92) *0.51*	−1.17 (−2.55, 0.20) *0.095*	−0.18 −2.74, 2.37) *0.89*	NR
Screen time, Minutes per Day[1]	Overall average	−1.65 (−3.92, 0.62) *0.15*	−1.66 (−3.89, 0.58) *0.15*	−0.43 (−1.46, 0.60) *0.42*	**−2.08 (−4.03, −0.14) *0.036***	20.7%
Active Transportation[2]	Any (to school or work or other)	0.78 (0.57–1.08) *0.13*	0.82 (0.59–1.12) *0.22*	**0.80 (0.69–0.94) *0.005***	**0.66 (0.47–0.92) *0.016***	53.7%

Proportion mediated calculated as NIE/TE*100 for linear regression models and as ln(NIE)/ln(TE) for log-binomial regression models . This value is only reported when the NIE and NDE are in the same direction; otherwise, it is not reported (NR).

[1] Linear regression used to model outcome and linear regression used to model relationship between neighborhood environment and outcome. Reported estimates are Bs, representing difference in minutes of MVPA or screen time per day associated with rural residence. Covariates include: interaction between rural residence and neighborhood environment, age, sex, general health, public school attendance, parent-reported household income and parent education level, distance from home to school.

[2] Log-binomial regression used to model outcome and linear regression used to model relationship between neighborhood environment and outcome. Reported estimates are prevalence ratios (PRs), representing the relative prevalence of rural compared to Non-rural adolescents taking any active transportation trips in the past week. Covariates include: interaction between rural residence and neighborhood environment, age, public school attendance, parent-reported household income and parent education level, distance from home to school.

rural settings (i.e., walkability, street connectivity, land-use mix) (Frank et al., 2005). Rural environments (e.g., safe routes to school, parks) may explain rural adolescents making fewer active trips than their non-rural peers. Therefore, establishing safe greenways, sidewalks, and bike lanes in rural areas may encourage adolescents to make more active trips (Committee on Environmental Health, 2009). Furthermore, a possible explanation for rural adolescents' engaging in less MVPA at school may be due to rural adolescents taking fewer active transit trips to/from school.

Rural adolescents in the current study had less screen time than their non-rural counterparts, though the absolute difference was small. This is supported by several large cross-sectional studies that found the amount of time adolescents living in more urbanized areas spent in sedentary behaviors (i.e., watching TV, playing video games, using the computer) to be greater than those living in less urbanized areas (Carson et al., 2011) with urban adolescents from low socioeconomic status families having the highest likelihood of increased screen time (Nelson et al., 2006). However, other studies have found conflicting results with several finding no difference between adolescents living in urban vs rural areas (Liu et al., 2012; Davis et al., 2011) or that rural adolescents engage in more sedentary behaviors than their urban peers (Lutfiyya et al., 2007). The difference in this study did not appear to be attributable to either rural residence or the built environment since only the total effect was significant and not the CDE, NDE, and NIE.

Non-rural neighborhoods had more resources available such as indoor recreation facilities, playing fields, parks, and trails/paths for biking and walking. Almost half of rural adolescents reported that no resources for PA were available in their neighborhoods within a 15-minute walk and about a quarter reported there being only one neighborhood resource available. However, it should be noted that rural populations may perceive the acceptable distance of resources to be further away than urban populations. Neighborhood resources were an important mediator of MVPA, including at school, which may be due to the broader neighborhood environment being reflective of resources available at school; explaining the resulting association. Future studies assessing school-based resources would help clarify whether built environment differences at school indeed mediate the relationship. No difference was found between non-rural and rural adolescents in the PA equipment available at home with a majority of non-rural and rural adolescents reporting at least five different equipment items available. Studies have shown that aspects of the rural environment may hinder PA among children and adolescents and promote sedentary behaviors, although the impact may be greater for children than adolescents (McGrath et al., 2015). Among these environmental features are less access to public transportation, parks and green spaces, exercise facilities, and community recreation centers along with fewer and lower quality sidewalks in rural areas compared to urban (Hill, 2005; Tremblay and Willms, 2003).

4.1. Limitations

To our knowledge, the current study is the first to compare participating in active transportation between U.S. non-rural and rural adolescents and also the first to examine non-rural-rural differences in PA, active transport, and screen time together using a national dataset. However, there are some limitations. This was a cross-sectional study of a national sample of U.S. adolescents. While we expect that the temporal ordering was in place – i.e., that adolescents lived in a rural area before their reported PA patterns were established, it is possible that their parents selected where to live based on availability of PA-related amenities and opportunities for active transit. Also, while the sample was nationally representative, adolescents reported higher overall levels of PA and came from families with slightly higher levels of income than would be representative of all U.S. adolescents and therefore the results should be taken within this context. Although included and excluded dyads had similar demographic characteristics, rural adolescents were more likely to be excluded making it possible this, combined with the relatively low response rate of the survey, could have resulted in a sample that does not represent all adolescents living in rural areas. The fact that all adolescents in the study reported 60 min or more of daily MVPA is concerning, although other commonly used self-report measures have similarly been found to overestimate MVPA when validated by accelerometer (Saint-Maurice et al., 2017). However, this study was designed to compare MVPA rather than provide estimates of prevalence. Additionally, the definitions and dichotomous nature of non-rural and rural used may have impacted the results and should be considered

when comparing across studies. Studies that have compared the PA of urban and rural youth have used numerous definitions of rurality (McCormack and Meendering, 2016). Future research should seek to standardize how we compare rural and non-rural while maintaining the rural-to-urban spectrum given the vast differences that exist in between these two extremes.

5. Conclusions

Although absolute differences in MVPA at school and screen time between non-rural and rural adolescents were small, evidence suggests that these behaviors may track over time from youth to adulthood (Hayes et al., 2019). Therefore, small differences in minutes of MVPA and screen time may impact health across the lifespan. Understanding environmental and social factors that influence sedentary behaviors and school MVPA of non-rural and rural adolescents may help refine approaches to improve these behaviors. Providing opportunities to increase school-related MVPA in rural school districts such as physical education or after-school sports may increase total daily MVPA. Additionally, more attention to the built environment may be needed to bring rural adolescents' MVPA and active transit patterns in line with their non-rural peers. Specifically, providing resources for adolescents living in rural areas to increase school PA and active transportation include quality sidewalks, bike lanes, greenways, school facilities such as playgrounds and athletic fields.

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Richard W. Christiana: Conceptualization, Methodology, Project administration, Writing - original draft, Writing - review & editing. **Erin D. Bouldin:** Conceptualization, Methodology, Data curation, Formal analysis, Writing - original draft, Writing - review & editing. **Rebecca A. Battista:** Conceptualization, Writing - original draft, Writing - review & editing.

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.

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