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Walkability indices and children's walking behavior in rural vs. urban areas

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ABSTRACT

Purpose: This study described associations between selected walk indices (WI) and walking and physical activity behaviors in rural and urban children.

Findings: WI were higher in urban environments, yet children from rural areas walked for transportation more than children from urban areas. There was a negative correlation between National WI scores and walking for transportation in urban areas, and between the Frank WI scores and walking for exercise in rural areas.

Conclusions: Indices of walkability are not associated with objectively measured physical activity or self-reported walking behavior in children living in rural and urban settings.

1. Introduction

Promotion of physical activity in children and youth has become an important public health priority. This status is reflected in the establishment of U.S. and international physical activity guidelines for school-aged youth, and in the development of an extensive body of knowledge on public health strategies for promoting physical activity in young people(Pate and Dowda, 2019; Piercy et al., 2018; World Health Organization, 2010). Many of the recommended strategies for increasing physical activity in youth have focused on providing community-based physical activity programs, enhancing neighborhood resources such as parks and green spaces, and supporting active transport to school(Lubans et al., 2011; Masoumi, 2017; Pate and Dowda, 2019). Research findings support the efficacy of these approaches, but typically this research has been conducted in urban and suburban areas. Questions have frequently been raised concerning the generalizability of these research findings to children living in rural areas(Masoumi, 2017; McGrath et al., 2015; Sandercock et al., 2010).

Rates of overweight and obesity are greater among U.S. children living in rural areas compared to their urban and suburban counterparts (Johnson and Johnson, 2015). It is well established that low levels of physical activity predispose children to excessive weight gain, but it is not clear that low physical activity is a major factor underlying the higher obesity rates seen in rural children(Psaltopoulou et al., 2019). Previous studies have yielded inconsistent findings. A review by McCormack and Meendering (2016) concluded that differences in physical activity levels between rural and urban environments varied depending on the tool used to measure physical activity. Studies utilizing subjective reports of physical activity showed either no differences or higher levels of physical activity in rural youth, while studies utilizing objective measures showed that urban youth were more physically active than rural youth. Additionally, there are a number of factors that differ between rural and urban environments that are associated with physical activity levels in youth. These include access to parks or other recreation facilities, neighborhood safety, and the availability of resources related to active transportations such as sidewalks and bike lanes (Christiana et al., 2021; Kaczynski et al., 2020). Differences in each of these factors may contribute to the conflicting results seen in this line of research.

Walking is the most common form of physical activity, and in children increased walking through walk-to-school programs increases overall physical activity levels(Larouche et al., 2018; *Vital Signs*, 2012).

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However, the ability of children to walk from home to school and to other destinations is influenced by the nature of the built environment proximal to their residences(Moore et al., 2010; Napier et al., 2011). Walkability is a construct that refers to the ease with which pedestrians can access destinations in a community(Sallis, 2009). Walk Indices (WIs) have been developed to operationalize walkability, and often these indices have been based on the number of amenities in the area, land use, and population density(Duncan, 2013; Frank et al., 2005; US EPA, 2014; Walk Score, 2011). Factors assessed in these indices, such as population density, are typically higher in urban areas, so urban areas may score higher on many indices simply due to the nature of the WI being used. Therefore, it is unclear whether established WIs are relevant in rural areas, and it is not known whether WIs relate to walking behavior and physical activity in children living in rural areas.

The overall goal of the research conducted in this study was to expand the body of knowledge on physical activity behavior in children residing in rural areas. The specific purposes of the study were: 1) to apply selected walk indices to the home environments of a sample of children living in rural areas and to compare those indices to the homes of children living in urban areas; 2) to compare self-reported walking and objectively-measured physical activity behaviors in rural versus urban children; and 3) to describe associations between selected walk indices and walking and physical activity behaviors in rural and urban children. This study was undertaken in a diverse sample of 5th grade children living in a county in South Carolina and in whom physical activity was measured objectively by accelerometry.

2. Materials and methods

2.1. Participants and setting

Data were drawn from the Transitions and Activity Changes in Kids (TRACK) Study, a multi-domain longitudinal study of influences on the changes in children's physical activity as they transition from elementary to middle school(Pate et al., 2019). The present analyses included baseline data on a total of 348 fifth-grade students (166 boys and 182 girls) with a mean age of 10.3 years from one public school district in South Carolina. The sample was about 42% African American, 31% white, 10% Hispanic and 17% other. Slightly over half of the sample had parents with greater than a high school education (Table 1).

The sampling design utilized in this study was reported previously and is summarized here(Taverno Ross et al., 2013). Local school district approval was obtained through meetings with district officials prior to approaching schools. All seven of the elementary schools in the district agreed to participate. Students were invited to participate though recruitment assemblies. Informed consent packets were sent home with the children for their parents or guardians to read, complete, and return; children provided assent before beginning any study procedures. Sixty-four percent of recruited students provided parent consent and child assent, and were representative of age, gender, and race/ethnicity of the students attending schools in the district. The institutional review board at the University of South Carolina (Columbia, SC) approved all protocols.

Table 1
Participant demographics.

Variable	Total Group N = 348	Rural n = 194 (55.57)	Urban n = 154 (44.25)	*P* value
Sex, n (%)				.16
Boys	166 (47.7)	99 (51.03)	67 (43.51)	
Girls	182 (52.3)	95 (48.97)	87 (56.49)	
Age, mean (SD)	10.32 (0.50)	10.30 (0.47)	10.36 (0.53)	.28
Race, n (%)				.05
Black	147 (42.2)	89 (45.88)	58 (37.66)	
White	106 (30.5)	63 (32.47)	43 (27.92)	
Hispanic	36 (10.3)	14 (7.22)	22 (14.29)	
Other	59 (17.0)	28 (14.43)	31 (20.13)	
Parent Education, n (%)				.31
≤ High school	162 (46.6)	95 (48.97)	67 (43.51)	
> High school	186 (53.5)	99 (51.03)	87 (56.49)	

2.2. Measures

Urban/Rural Designation - The 2006 U.S. Census Bureau designations were used to classify whether children lived in urban or rural census blocks(Ratcliffe et al., 2016). In addition to a number of complex criteria, Urban Areas (UA) are defined as housing 50,000 or more persons, while Urban Clusters (UC) are defined as areas containing between 2500 and 50,000 persons. A minimum population density of 500 persons per square mile in areas connected to the center of the UA is required. Urban polygons were determined using one of these procedures, and census blocks that did not meet these requirements were designated as rural.

WIs – Three different WIs were utilized to assess walkability of the areas in which children resided. This included the Walk Score, the Frank Walk Index, and the EPA National Walkability Index.

Walk Score was used to assess neighborhood walkability among TRACK participants("Drive Less. Live More.," n.d.). Each participant's home address was manually entered into the Walk Score site by trained research staff. For each address, the Walk Score algorithm produced a score ranging from 0 to 100 based on the ease of walking to various amenities in the local area. For a given address, an algorithm was used to generate a Walk Score ranking based on distance to various types of amenities (e.g., education, retail stores, food/restaurants, recreation/parks, entertainment). The algorithm used a distance–decay function to generate a score for each type of amenity included in the Walk Score measure. For instance, amenities located closer to a child's home received a higher score than amenities located further away. Scores were summed across each amenity type and normalized to produce the final measure(Carr et al., 2010, 2011; Duncan et al., 2011; Pivo and Fisher, 2011). The percentage of children with a Walk Score of zero was calculated. The distribution of Walk Scores was highly skewed; therefore, a square root transformation was applied to this variable.

The Frank Walk Index was utilized as another measure of walkability. Methods for the development of this measure have been described elsewhere(Frank et al., 2005). The walkability index score for each child's residence was calculated using the formula: Walkability Index score = (6 x z-score of land use mix) + (z-score of net residential density) + (z-score of intersection density). Higher walkability scores reflected more walkable communities.

Each child's place of residence also received a walkability index score based on the EPA National Walkability Index. These scores were based on GIS data provided by the U.S. Environmental Protection Agency's (EPA) Smart Location Database, and were calculated using information on land use mix, street connectivity, and population density of a census block. Scores ranged from 1 to 20, with higher scores reflecting more walkable communities(US EPA, 2014).

Walk for exercise, walk for transportation and total walking behavior - Walking for exercise and transportation were reported on the Physical Activity Choices (PAC) instrument. The PAC was adapted from the Three Day Physical Activity Recall (3DPAR) instrument(Colabianchi et al., 2016; Pate et al., 2003; Saunders et al., 2018; Taverno Ross et al., 2013). Unlike the 3DPAR, which required participants to report engagement in physical activity during specific time blocks, the PAC asked participants to report any participation in a given activity during the past 5 days (e.g., "Between [5 days ago] and today did you do the following activity …''). Walking for exercise and walking for transportation were two of the 49 possible activities reported in fifth grade. Answers for walking for exercise or walking for transportation ranged from 0 to 5. Responses were combined to create a total walking behavior variable that ranged from 0 to 10.

Total PA and sedentary minutes *per* hour – GT1M and GT3X

ActiGraph accelerometers (Pensacola, FL) were utilized to collect objectively-measured physical activity data in 60-s epochs. Monitors were initialized to begin collecting data in the morning on the day following their distribution and were worn on the right hip for the following week. Monitors were removed when the child was sleeping or participating in water-based activities. Non-wear time was defined as any period lasting 1 h or more with consecutive zeros. Non-wear time was recoded as missing. The PROC MI for SAS (Version 9.2, SAS Institute, Inc., Cary, NC) procedure was used to impute missing data, although this was only done for children who wore the monitor on at least 2 days for a minimum of 8 h per day. Total physical activity was operationalized as the number of minutes per hour spent above the light physical activity cutpoint (100 counts/minute), while sedentary behavior was operationalized as the number of minutes per hour below the light physical activity cutpoint(Freedson et al., 2005).

2.3. Analysis

All analyses were conducted using SAS statistical software version 9.4 (SAS Institute Inc., Cary, NC). Descriptive characteristics were calculated for the total sample and for children living in rural and urban environments. T-tests and chi-square tests were used to examine differences in descriptive characteristics between groups.

In order to address the first purpose of the study, mixed model regression analyses were conducted with Walk Score, Frank Walk Index, and National Walk Index entered as the dependent variable in separate analyses, and environment type (rural vs. urban) entered into models as the independent variable. Sex, race/ethnicity, and parent education, which served as a proxy for socioeconomic status, were entered into the model as covariates. Least-square means computed for WIs from the mixed model regression analyses were used to determine if there were differences between children living in rural and urban areas.

Mixed-model and Poisson regression analyses were used to address the second purpose of the study. Objectively-measured physical activity and sedentary behavior levels were entered into mixed-model regression analyses as dependent variables in separate analyses, and environment type (rural vs. urban) was entered into models as the independent variable. The association between rural versus urban designation and self-reported walking behaviors was calculated using Poisson regression analyses. All analyses were adjusted for sex, age, race/ethnicity, and parent education.

Pearson correlation coefficients were utilized to address the third purpose of the study, which was to examine associations between WIs (Frank Walk Index, the square root of the Walk Score and the National Walk Index) and objective and subjective measures of physical activity and walking behaviors. This included the number of days children walked for exercise, the number of days children walked for transportation, the number of times children performed any walking behavior, and total accelerometry-based physical activity minutes per hour. Correlation analyses were conducted in the total sample and were stratified by urban versus rural designation.

3. Results

3.1. Missing data

Of the 348 students participating in the study, 4 were missing Walk Scores as a result of providing inadequate address information. An additional 50 participants did not have Frank WI score due to missing data on one or more components that were not publicly available for their address at the time of data collection. Incomplete PAC questionnaires resulted in missing data regarding participants' walking for exercise ($n = 4$), transportation ($n = 4$), and total walking behavior ($n = 12$). Analyses were completed with all available data, and the number of participants available for each analysis has been listed in the tables below.

3.2. Descriptive characteristics of the sample

Descriptive characteristics can be seen in Table 2. Over half (55.75%) of the sample lived in areas classified as rural. The average Walk Score was 5.3, and 44.8% of the sample had a Walk Score of 0, indicating that no amenities existed within walking distance of a child's home for over 40% of the population. Average scores for the Frank Walk Index and the EPA National Walkability Index were 0.84 and 4.59, respectively. Fig. 1a displays the distribution of National Walkability Index Scores along with the corresponding residences of study participants. Children were physically active for an average of 27.6 min per hour, and sedentary for an average of 32.5 min per hour. Children walked for exercise an average of 1.08 days over a 5-day period, and walked for transportation an average of 1.19 days over a 5-day period. Children walked for exercise and/or transportation an average of 2.23 times.

3.3. Comparing WIs, physical activity and walking behavior in urban versus rural settings

Table 3 presents the estimated mean differences of WIs, physical activity, and sedentary behavior in urban and rural environments based on results of mixed-model regression analyses. Walk Scores and EPA Walkability Index Scores were significantly higher in children living in urban environments compared to children living in rural environments ($P < .001$). Frank Walk Index Scores were not significantly different between children living in urban versus rural environments ($P = .60$). No significant differences were seen in objective measures of total physical activity ($P = .32$) or sedentary behavior ($P = .33$) minutes per hour between children living in urban compared to rural environments.

Table 4 presents results of Poisson regression analyses. There were no significant differences in the number of days children reported walking for exercise ($P = .15$) or their total walking behavior ($P = .34$) between children living in urban versus rural areas. Children who lived in a rural environment walked for transportation significantly more than children living an urban environment ($P = .01$).

3.4. Correlation analyses

Results of correlation analyses for the entire group and by urbanicity are presented in Table 5. A significant negative association was seen between National Walk Index scores and walking for transportation ($R = -.11$, $P > .05$) for the total group. This association was also significant among children living in urban ($R = -0.17$, $P = .01$), but not rural ($R =$

Table 2
Sample characteristics (N = 348).

Variable	
WIs	
Walk score, mean (SD)[a]	5.30 (9.57)
Square root walk score, mean (SD)[a]	1.49 (1.75)
Walk score % zero, n (%)[a]	154 (44.8%)
% Walk score >0, n (%)[a]	190 (55.2%)
Frank Walk index, mean (SD)[b]	0.84 (7.22)
EPA National Walkability Index, mean (SD)	4.59 (2.15)
Accelerometry	
Total PA, minutes/hour, mean (SD)	27.6 (4.5)
Sedentary minutes/hour, mean (SD)	32.5 (4.4)
PA-Reported Walking	
Number of days walked for exercise, mean (SD)[a]	1.08 (1.56)
Number of days walked for transportation, mean (SD) [a]	1.19 (2.13)
Number of times walked for exercise and/or transportation, mean (SD)[c]	2.23 (2.74)

[a] n = 344.
[b] n = 298.
[c] n = 336.

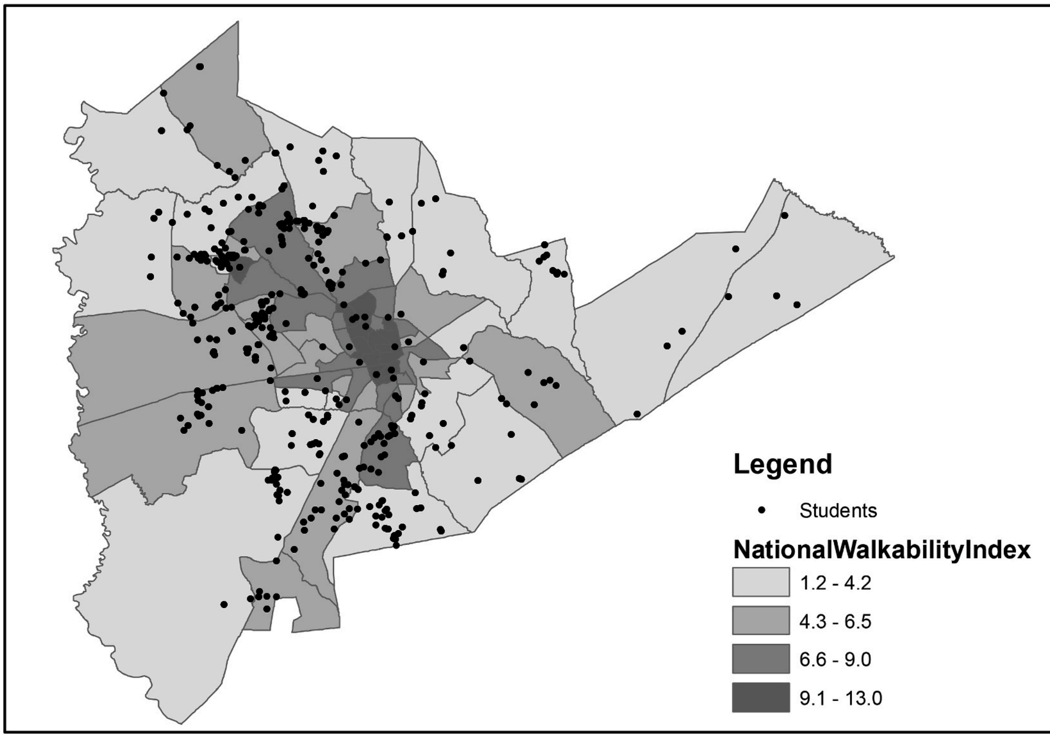

Fig. 1a. National Walkability Index Scores applied to a South Carolina county. Corresponding residences of study participants are displayed.

Table 3
Urban versus rural environment, presented as least square means and standard errors from regression models.

Dependent Variable	N	Rural (n = 194)	Urban (n = 154)	*P* value
Total PA minutes/hour	348	27.73 (0.34)	27.26 (0.36)	.32
Sedentary minutes/hour	348	32.35 (0.34)	32.81 (0.36)	.33
Square root Walk Score	344	0.93 (0.13)	2.26 (0.14)	<.001
EPA National Walkability Index	348	3.77 (0.16)	5.62 (0.17)	<.001
Frank Walk Index	298	0.64 (0.67)	1.09 (0.62)	.60

Note: Adjusted for sex, age, race/ethnicity, and parent education.
N = sample size.

Table 4
Urban versus rural environment, estimate and standard errors from Poisson regression models.

Dependent Variable	N	Estimate	SE	*P* value
Number of days walked for exercise	333			
Rural		−0.16	.11	.15
Urban		Reference		
Number of days walked for transportation	345			
Rural		0.29	.10	.01
Urban		Reference		
Number of times walked for exercise and/or transportation	345			
Rural		0.07	.07	.34
Urban		Reference		

Note: Adjusted for sex, race/ethnicity and parent education.
N = sample size.
SE = standard error.

−0.06 $P = .48$), areas. Correlation analyses for children living in urban areas approached significance for a positive association between Frank Walk Index scores and accelerometry-based total physical activity ($R =$ 0.13, $P = .06$). Correlations between the square root of the Walk Score and walking for transportation ($R = -0.12$, $P = .09$) and accelerometry-based total physical activity ($R = -0.12$, $P = .09$) also approached

Table 5
Pearson correlation coefficients for associations between WIs and measures of physical activity and walking behaviors in the total sample and by urbanicity.

	Walk for Exercise	Walk for Transportation	Exercise and/or Transportation	Total PA mins/hour
Total Group				
Frank Walk Index	-.02 (*n* = 284)	.02 (*n* = 295)	.003 (*n* = 295)	-.07 (*n* = 298)
Square root Walk score	.03 (*n* = 329)	-.03 (*n* = 341)	-.01 (*n* = 341)	.08 (*n* = 344)
National Walk Index	.02 (*n* = 333)	-.11* (*n* = 345)	-.07 (*n* = 345)	-.09 (*n* = 348)
Rural				
Frank Walk Index	-.19* (*n* = 103)	.01 (*n* = 107)	-.11 (*n* = 107)	.02 (*n* = 107)
Square root Walk score	-.10 (*n* = 127)	.07 (*n* = 132)	.002 (*n* = 132)	-.004 (*n* = 132)
National Walk Index	-.09 (*n* = 129)	-.06 (*n* = 134)	-.09 (*n* = 134)	-.14 (*n* = 134)
Urban				
Frank Walk Index	.08 (*n* = 181)	.03 (*n* = 188)	.07 (*n* = 188)	-.13† (*n* = 191)
Square root Walk score	.10 (*n* = 202)	-.12† (*n* = 209)	-.04 (*n* = 209)	-.12† (*n* = 212)
National Walk Index	.07 (*n* = 204)	-.17* (*n* = 211)	-.09 (*n* = 211)	-.02 (*n* = 214)

†$P < .10$.
*$P < .05$.

significance for children living in urban areas. Among children living in rural areas, there was a significant negative association between Frank Walk Index scores and walking for exercise ($R = -0.19$, $P = .05$).

4. Conclusions

A major purpose of the present study was to apply three widely-used indices of walkability to the home environments of children living in rural settings and to compare the resultant scores with those for similar children living in urban settings. Although all of the indices assess walkability, they differ by the formulas used to calculate scores, the factors used to determine scores, and the weight these factors have on the final score. Even with these differences, we found that all three indices yielded lower walkability scores for the children living in rural areas, and the differences were statistically significant for two of the three indices. This finding is consistent with the observations of some previous studies. Large-scale studies in the U.S. have found that rural census tracts, as a group, yielded lower walkability scores than tracts in urban areas(King and Clarke, 2015). Watson et al. (2020) found that, among adults included in the National Health Interview Survey, those living in rural areas scored lower on neighborhood walkability than their counterparts living in urban settings. The present study extends this line of research by examining children, all of whom resided in a single county that has a relatively low overall population density. Even in this setting, walkability scores were markedly lower for children whose homes were in rural areas.

Despite our observation that walkability indices were higher for children living in urban areas, we found no consistent evidence that this was associated with children's walking behavior or overall physical activity. Children living in urban and rural areas did not differ in accelerometer-based physical activity or self-reported walking for exercise. Children in rural areas reported significantly more walking for transportation. These results are consistent with previous studies that suggest differences in physical activity levels between rural and urban environments often vary based on the measure used to assess physical activity(McCormack and Meendering, 2016). Moreover, walk indices were not consistently correlated with physical activity or walking behavior, and the few significant associations were negative in direction and small in magnitude.

Our findings may be explained, in part, by the fact that walkability indices have been developed for application in urban settings. For example, the Walk Index Score by Frank and colleagues was developed using environmental characteristics of Atlanta, GA(Frank et al., 2005). Similarly, the Walk Score penalizes a location depending on the average block length of the area it is located in, with penalty cut-offs developed using block lengths found in major, metropolitan areas like Portland, OR and New York, NY(Walk Score, 2011). The way in which walkability is operationalized by current WIs may not be applicable to rural areas, considering that the characteristics they assess are rarely present in these areas. Results of a study by Whitfield et al. (2019) showed that the existence of multiple environmental characteristics, such as access to sidewalks, shopping, public transit, movie theaters, libraries, churches, and other relaxing places, were associated with greater walking for transportation among urban adults. This was not the case with rural residents. Specifically, sidewalks on most streets and greater access to shops and public transit showed no association with walking for transportation among rural adults(Whitfield et al., 2019). Therefore, WIs should be constructed in a way that accounts for urbanicity in their assessment, considering that some environmental characteristics may only be relevant to walking behaviors in urban or rural communities.

It is well established that overall physical activity in youth is influenced by factors from multiple domains. Walk indices assess one of these elements, the built environment. Personal factors, the social environment, and the physical environment (which includes the natural and built environments) interact in complex ways to affect physical activity in childhood and adolescence, and changes in it over time(Dishman et al., 2017; Graham et al., 2014; Loh et al., 2019; Parker et al., 2019; Pate et al., 2019; Perrin et al., 2016; Schmidt et al., 2019; Sterdt et al., 2014; Wilkie et al., 2018). Similarly, recent work in walking and independent mobility in children highlights the importance of expanding beyond the built environment to include socioeconomic and other social factors(Adkins et al., 2017; Marzi et al., 2018). This becomes even more complex when considering that factors that are correlated with walking for exercise, such as self-efficacy or enjoyment, may differ to those factors that are more strongly correlated with walking for transportation purposes, such as neighborhood safety(Giles-Corti et al., 2009). Accordingly, considering multiple ecological domains may be the most effective approach to promoting physical activity and walking for exercise and transportation in youth.

Our findings may have been influenced by the system used to identify rural and urban settings. The U.S. Census Bureau definition may not be able to capture the complexity of some rural areas, such as communities similar to those studied in the present investigation. For example, small pockets of subdivisions in otherwise rural areas or clustered rural housing may function like an urban area from a walkability perspective. Additional research trajectories based on these data may be well served by creating a metric for the urban-rural dichotomy based on housing density as a surrogate for the urban environment. One methodology this study did not examine is the use of population density based on housing units as a surrogate. Residential housing structures can be obtained from several sources and at scales where they may capture the urban-rural divide more accurately in areas such as those included in this study. Instead of a fixed urban-rural definition, each child's walkability score would incorporate a more refined measure of population and population density that best delineates urban from rural areas based on one of several algorithmic statistical classification techniques. Please see Fig. 1b for more detail.

Strengths of the present study include that it examined three widely-used indices of walkability, included both objectively-measured and self-reported physical activity behaviors, and included relatively large samples of demographically similar children living in rural or urban settings. However, the study is limited by its cross-sectional design and by the demographic nature of the community in which the study was conducted. All participating children resided within a single county situated in a state in the Southeastern United States. Children in the "urban" group resided in a small city that constitutes the county's center for business, cultural activity and education. This representation of "urban" is not similar to that seen in large metropolitan areas. Accordingly, the findings of this study should not be generalized to demographically dissimilar settings, and future studies should address the aims of this investigation in jurisdictions that represent multiple manifestations of urbanicity. Furthermore, accelerometry data collected throughout an entire week did not account for times in which a child may have participated in physical activity outside of his or her immediate home environment.

In summary, two of three walk index scores were significantly higher in children living in urban versus rural settings, and children residing in urban and rural areas did not differ in objectively-measured PA, but rural residents reported more walking for transportation. Walking index scores were not related to objectively-measured PA or walking behavior. Higher walk index scores in urban children should theoretically result in higher self-reported walking in urban children, yet this was not the case, nor were walk index scores associated with objectively-measured PA or self-reported walking in this sample overall or by urbanicity. Walk indices do not appear to work as expected in these settings, which may be due in part to their development in more urbanized areas. Future research should examine approaches to defining and measuring rurality-urbanicity.

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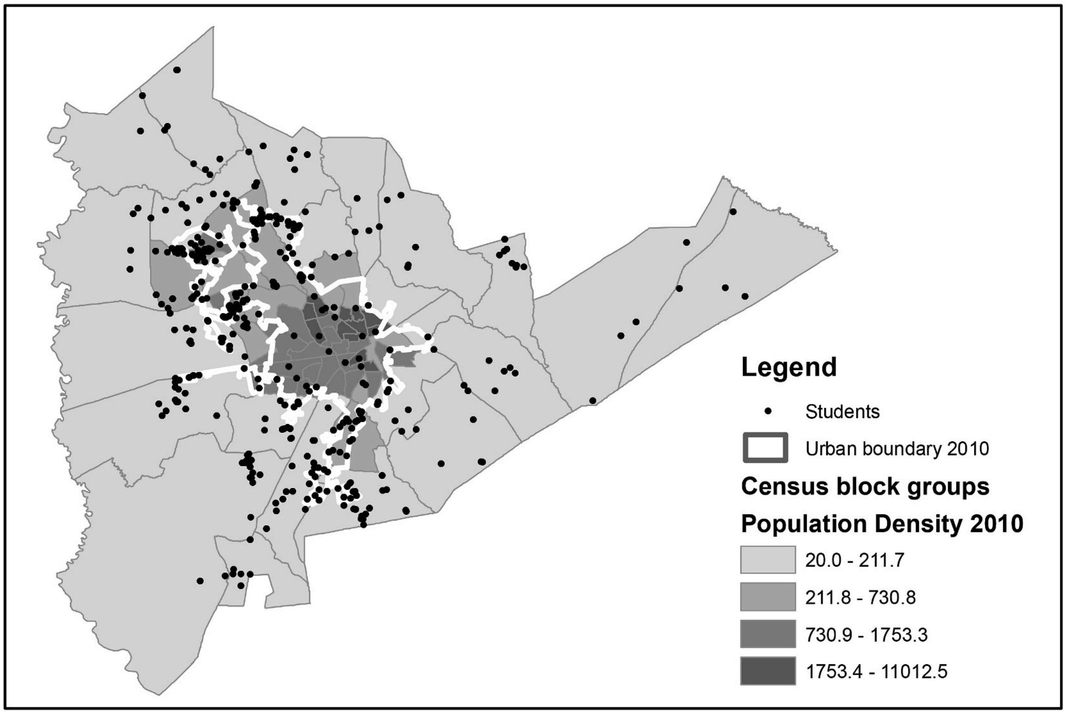

Fig. 1b. Population densities applied to 2010 Census block groups in a South Carolina county. The urban vs. rural boundary is delineated and the corresponding residences of study participants are included.

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Declaration of competing interest

None.

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