



## A novel method to map community- and neighborhood-level access to rural physical activity built environments in the United States

Eydie N. Kramer-Kostecka<sup>a,\*</sup>, Amanda L. Folk<sup>b</sup>, Sarah Friend<sup>c</sup>, Brian Coan<sup>d</sup>, Len Kne<sup>d</sup>, Jennifer Beaudette<sup>e</sup>, Daheia J. Barr-Anderson<sup>b</sup>, Jayne A. Fulkerson<sup>c</sup>

<sup>a</sup> School of Public Health, Division of Epidemiology and Community Health, University of Minnesota, 420 Delaware St. S.E, Minneapolis, MN 55455, United States

<sup>b</sup> School of Kinesiology, University of Minnesota, 209 Cooke Hall, 1900 University Ave SE, Minneapolis, MN 55455, United States

<sup>c</sup> School of Nursing, University of Minnesota, 5-140 Weaver-Densford Hall, 308 Harvard Street SE, Minneapolis, MN 55455, United States

<sup>d</sup> U-Spatial, Research Computing, University of Minnesota, 420 Blegen Hall, 269 19th Ave. S Minneapolis, MN 55455, United States

<sup>e</sup> Minneapolis Heart Institute Foundation, 920 E 28th St #100, Minneapolis, MN 55407, United States

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### ABSTRACT

Physical activity (PA) built environments may support PA among rural youth and families. In the United States (U.S.), differences between rural and urban PA built environments are assessed using coarse scale, county-level methods. However, this method insufficiently examines environmental differences within rural counties. The present study uses rural-specific geospatial mapping techniques and a fine scale, within-rural grouping strategy to identify differing levels of access to the PA built environment among a rural sample. First, PA infrastructure variables (parks, sidewalks) within a rural region of the Midwest U.S. were mapped. Then, households (N = 112) of participants in the NU-HOME study, a childhood obesity prevention trial, were categorized to community-level and neighborhood-level PA built environment groups using two access indicators; Rural-Urban Commuting Area (RUCA) codes and Walk Scores<sup>®</sup>, respectively. Finally, households were categorized to new groups that combined community-level RUCA codes and neighborhood-level Walk Scores<sup>®</sup> to indicate the diverse ways in which rural families might access PA built environments, including by vehicle travel and pedestrian commuting. Household access to PA infrastructure (per geospatial proximity and density analyses), parent perceptions of the PA environment, and child PA were examined across the new combined access groups. All measures of household access to PA infrastructure significantly differed by group ( $p < .0001$ ). Several parent PA perceptions differed by group; child PA did not. The present study provides future researchers with innovative strategies to map and examine how access to the PA built environment differs within a rural area. Due to the public availability of the access indicators used (RUCA codes, Walk Scores<sup>®</sup>), study methods can be replicated.

### 1. Introduction

In the United States (U.S.), many youth fail to meet physical activity (PA) recommendations (Katzmarzyk, 2016) and may not achieve the substantive health benefits associated with PA (Janssen and LeBlanc, 2010). Although a myriad of factors contribute to activity levels among youth (Craggs, 2011; Heath, 2012; Sterdt et al., 2014), the built environment (i.e., collective availability of human-made structures and facilities in one's environment) is one such factor known to affect PA. In general, greater access to PA infrastructure (e.g., sidewalks, parks, recreational facilities) is thought to facilitate PA. Previous studies have used Geographic Information Systems (GIS) to plot PA infrastructure

and a positive relationship between youth PA and access to the PA built environment has been established (McCrorie et al., 2014; McGrath et al., 2015; Dowda, 2007; Rodríguez, 2012; Norman, 2006; Ding, 2011; Sallis, 2018). However, less is known with regard to rural PA built environments, including whether rural youth and families report varying levels of access to PA infrastructure and differing PA perceptions and behaviors.

While rural definitions widely vary, this study will adopt a rural-urban framework based on a variety of inputs, including population density and vehicle commuting flows. For example, using these inputs, a rural region may be conceptualized as an area that is sparsely populated with most residents commuting outward for work and recreation. In the

\* Corresponding author.

E-mail address: [krame640@umn.edu](mailto:krame640@umn.edu) (E.N. Kramer-Kostecka).

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U.S., rural families report limited access to PA infrastructure compared to their urban counterparts (Frost, 2010; Kegler, 2014; Umstadt Meyer, 2016) and PA disparities between rural and urban youth are evident (Moore, 2013; Rainham, 2012). Although it is plausible that PA infrastructure is unequally distributed within rural regions, current literature has not fully addressed whether access to the PA built environment differs by degree of rurality.

Built environments can be examined using either coarse or fine scales. Coarse scale approaches use a wide lens to assess differences between rural and urban regions, such as geographic sub-divisions of U.S. states (e.g., counties, parishes, boroughs). For example, the Childhood Obesogenic Environment Index (COEI) utilizes a coarse scale to assess environmental supports of healthful eating and PA at the county level in the U.S. (Kaczynski, 2020). However, it is difficult to determine variance within rural regions using coarse scale, county-level assessments. Alternatively, researchers and practitioners might consider using fine scale assessments to examine how access to the PA built environment varies within the proximal areas in which rural families live, work, and play – such as their neighborhoods and communities.

Fine scale approaches examine PA built environments with a narrow lens, such as with neighborhood- and community-level assessments. Neighborhood-level assessments examine areas near households where families can access PA infrastructure through pedestrian active commuting (e.g., walking, biking). Youth PA is associated with the neighborhood-level PA built environment (van Loon et al., 2014). Community-level assessments examine areas that are more distal yet still connected to households; a vehicle may be needed to access PA infrastructure at the community level. For research conducted in the U.S., community membership is determined based on which specified postal code (e.g., ZIP Code) or census tract is associated with the home address. In rural areas, ZIP Codes and census tracts can be quite large, encompassing both the more densely populated town as well as the less populated surrounding farmland. It is possible that some rural families with the same ZIP Code or census tract have access to multiple parks or recreational facilities within walking distance of their home while others have few and must access PA infrastructure via vehicle travel. Therefore, it may be useful to characterize the different ways in which rural residents can feasibly access PA infrastructure when assessing rural PA built environments, including by neighborhood-level pedestrian and community-level vehicle pathways.

Additionally, objective environmental assessments should incorporate rural-specific mapping and geoanalyzing procedures. Past GIS analyses reveal that rural areas have comparatively less sidewalk coverage than urban areas (Janssen and Rosu, 2012). Rural sidewalk networks should be mapped to determine if sidewalk access differs by rurality. Community facilities, such as schools and places of worship, should also be mapped since rural families report using these spaces to be active (Hansen, 2015). However, families may lack full access to schools and places of worship and therefore it is advisable to determine which community facilities have easily accessible, outdoor PA amenities onsite (e.g., sports fields, playgrounds). Importantly, PA among youth may be seasonally restricted if all PA amenities are located outside or in unsheltered areas (Kegler, 2012; Oreskovic, 2012; Jones, 2009; Button, 2021) and it is possible that rural areas have few funds available for indoor recreational facilities (e.g., community centers). Thus, it is important to use geospatial tools to determine facility locations and attributes (e.g., indoor gyms, outdoor swimming pools).

The present study aims to provide health promotion and prevention professionals with a rural-specific geospatial toolkit to identify differences among rural PA built environments, especially those located in the U.S. This roadmap may inform future public health policy by identifying which rural areas experience inequitable access to PA infrastructure. The present study will fill gaps in the literature by:

- (1) Presenting GIS strategies to comprehensively map PA infrastructure (sidewalks, parks, community and recreational facilities) within a rural region;
- (2) Applying a fine scale grouping strategy to examine rural families' access to the PA built environment at community and neighborhood levels;
- (3) Assessing how household access to PA infrastructure, parent-reported perceptions of the PA built environment, and child PA differ by community- and neighborhood-level PA built environment access groups.

## 2. Methods

### 2.1. Rural sample and study variables

This study presents descriptive findings from a secondary assessment and geospatial analysis of the PA built environments of participants of the rural NU-HOME study, a childhood obesity prevention randomized controlled trial (RCT); eligibility criteria, enrollment and study procedures have been previously described (Fulkerson, 2021; Fulkerson, 2022). Participant households – the primary geospatial reference unit – were located within a multi-county area in the Midwest region of the U.S. Families were eligible to participate in the NU-HOME study if they lived within a 50-mile radius two intervention hub communities; these communities (New Ulm and Sleepy Eye, Minnesota) were classified as rural based on their ZIP Code (see Section 2.3.1. for rural classifications). Parent-child dyads (N = 114) enrolled in two cohorts; baseline data, including home addresses, were collected in the summer of 2017 (Cohort 1) or 2018 (Cohort 2). Prior to participant recruitment, the study received approval from the University of Minnesota Institutional Review Board (IRB) (1509S78583) and the Quorum Review IRB (803161-27), the external IRB contracted by Allina Health.

A subsample of NU-HOME participants who had valid geospatial data (N = 112) were identified for the current study. Participants' home address ZIP Codes were associated with ten rural communities. One household listed a post office address, rather than a home address, and one household was classified as urban per the associated ZIP Code; both were excluded from analyses. Parents (mean age:  $38.0 \pm 5.4$  years) and children (mean age:  $8.9 \pm 1.1$  years) were predominantly female and racially and ethnically homogenous (white, non-Hispanic). Most households (72.3 %) reported no public assistance or free-reduced lunch; in the U.S., public assistance and free-reduced price school lunches are often used as indicators of lower socioeconomic status.

Geospatial methods were used to plot PA infrastructure within the participants' built environments, including all sidewalk networks, city parks, and community and recreational facilities that were located within a 1600-meter buffer of the ten rural communities. Regional trails and parks outside of city boundaries were also mapped. Parent perceptions of access to safe walking/biking routes and free or low-cost recreational facilities were captured via a survey and child moderate-vigorous PA levels (MVPA; minutes/day) were assessed using Actigraph GT3X accelerometers (see study variables, Table 1).

### 2.2. Mapping and geospatial analysis

Research team members partnered with U-Spatial – a nationally recognized unit that serves and drives a fast-growing need for expertise in GIS, remote sensing, and spatial computing across the University of Minnesota – to geocode and analyze geospatial features. All mapping procedures were completed using Esri ArcGIS Pro 2.3 (ArcGIS), Esri Business Analyst 10.7.1, and Google Earth Pro software (summer 2020). First, home addresses were securely geocoded using ArcGIS software and verified by research team members. Next, a 9-county region (1.5 million hectares) surrounding the ten rural communities, all participant households, and pedestrian active commuting buffers was examined to capture geospatial data relevant to the families' PA built environments.

**Table 1**  
Study variable characteristics.

Variables not Derived from Geographic Information Systems (GIS)			
Variable	Data Procurement	Survey Questions or Instrument Characteristics	
Safe bike/walk	Parents self-reported PA perceptions at study baseline data collection; surveys	The following 5 survey items were summed to create the “Safe Bike/Walk” variable: Item 1: There are safe places for my family to walk near where we live, such as roads with little traffic, wide roads to accommodate vehicles and walkers, or walking trails; Item 2: There are safe places for my family to bicycle near where we live, such as special lanes, separate paths or trails, or shared use paths; Item 3: I feel it is safe for my family to walk near where we live; Item 4: I feel it is safe for my family to bicycle near where we live; Item 5: I often see people being physically active near where I live, doing things like walking, jogging, cycling, or playing sports and active games. Item response options: 1 = Strongly disagree; 2 = Somewhat disagree; 3 = Somewhat agree; 4 = Strongly agree; Don't know/Not sure = recorded as missing; Full sample Cronbach alpha = 0.86; Range 5–20	
Free/low-cost physical activity (PA) facilities	Parents self-reported PA perceptions at study baseline data collection; surveys	The following survey item was used to create the “Free/Low-Cost PA Facilities” variable: Item: There are free or low cost recreation facilities near where we live such as parks, walking trails, bike baths, rec enters, playgrounds, and public swimming pools etc. Item Response Option: 1 = Strongly disagree, 2 = Somewhat disagree, 3 = Somewhat agree, 4 = Strongly agree; Don't know/Not sure = recorded as missing; Range 1–4	
Child moderate-vigorous PA (MVPA)	Children were fitted with activity monitors for 1-week at baseline data collection; Actigraph GT3X accelerometers	Accelerometry data were valid if the activity monitors were worn for > 8 hrs/days for 3 days Evenson cut points (Evenson, 2008) for children were used to classify physical activity intensities: sedentary (0–100), light (101–2295), moderate (2296–4011), and vigorous ( $\geq 4012$ ) Total physical activity included counts above 100 and moderate-to-vigorous physical activity included counts above 2296	
Variables Derived from GIS			
Variable	Data Procurement	GIS Tool, Analysis	Rural Characteristics, Mapping Considerations
Participant households	Home addresses were obtained from study baseline surveys; and then geocoded <sup>1</sup> to create point data by the geospatial analyst	ArcGIS; home addresses were the reference data for all GIS analyses	Households with post office box addresses and those that were considered urban using ZIP Code-associated Rural-Urban Commuting Area (RUCA) codes were excluded from geospatial analyses ( $n = 2$ )
Sidewalk connectivity	Using GIS and aerial imagery, the geospatial analyst digitized lines over visible sidewalk networks and generated nodes at intersections	ArcGIS; aerial imagery Density <sup>2</sup> analysis; Summarize Nearby <sup>3</sup> tool	Sidewalk connectivity within the rural region was measured by examining the number of intersecting sidewalk networks (i.e., nodes)
Paved trail	Using GIS, the geospatial analyst retrieved trail inventory line data from authoritative repositories	ArcGIS; Proximity <sup>4</sup> analysis; Closest Facility <sup>5</sup> tool with elevation layer	A single paved trail network was located within the rural region, this network was primarily linear with no intersections
Road connectivity	Using GIS, the geospatial analyst retrieved road inventory line and node data from verified repositories	ArcGIS; Density analysis; Summarize Nearby tool	Road connectivity within the rural region was measured by examining the number of intersecting sidewalk networks (i.e., nodes)
Parks, city and regional	Research staff verified addresses and PA amenities using Esri Business Analyst and aerial imagery; using GIS, the geospatial analyst generated polygonal feature data representing park boundaries	ArcGIS; Google Earth Pro; Density and Proximity analyses; Closest Facility, Summarize Nearby, and Spatial Join <sup>6</sup> tools	Rural community stakeholders and multiple research team members who were familiar with the rural setting identified the list of parks City, county, and state parks varied by stage of development and presence or absence of outdoor PA amenities, such as playgrounds or sports fields
Community facility	Research staff verified addresses and PA amenities using Esri Business Analyst and aerial imagery; using GIS, the geospatial analyst generated point data representing the facility entrance	ArcGIS; Google Earth Pro; Density and proximity analyses; Closest Facility and Summarize Nearby tools	Rural community stakeholders and multiple research team members who were familiar with the rural setting identified the list of community and indoor and outdoor recreational facilities Community facilities included schools and places of worship with outdoor PA amenities on the property (e.g., onsite playgrounds or sports fields); community facilities were considered separate from recreational facilities due to the potential for differences in entry fees and/or public accessibility
Indoor recreational facility			Indoor recreational facilities included bowling alleys, community gyms, and indoor skating rinks that were accessible year-round
Outdoor recreational facility			Outdoor recreational facilities included golf courses and swimming pools that were seasonally unavailable

**Notes.**

<sup>1</sup> Geocode: a process that takes an address or other geospatial attribute (e.g., street address, ZIP Code, city) and assigns a latitude and longitude to the location so it can be mapped.

<sup>2</sup> Density: an analysis tool that measures the number and spatial relationships of features within a specified location; for example, XX number of parks within a 1600-meter network buffer of a participant's home address.

<sup>3</sup> Summarize Nearby: a tool that summarizes features within a defined buffer around a location; when measuring the density of parks or other polygonal features, the Summarize Nearby tool was combined with the Spatial Join tool to aggregate the number of features in each buffer area.

<sup>4</sup> Proximity: an analysis tool that measures the distance between two specific locations; for example, the shortest network route between a participant's home address and the nearest park.

<sup>5</sup> Closest Facility: a tool that measures the proximity of the nearest feature of interest to a specified location based on the most direct travel route; for example, the distance between a participant's home address and the nearest park with an elevation layer applied to account for walking distance on non-level terrain.

<sup>6</sup> Spatial Join: a process of applying attributes from one or more layers to target features that intersect on the map.

A research team member and stakeholders from the rural communities identified a list of specific PA infrastructure within the selected rural region, including city and regional parks, community facilities (e.g., schools, places of worship) with outdoor PA amenities onsite, and indoor and outdoor recreational facilities. Infrastructure addresses were verified with Esri Business Analyst and the locations and presence of PA amenities on community facility properties were independently verified by two research staff using aerial imagery tools (Google Earth Pro Street View and Placemark). Next, the tabular data with spatial references (e.g., street address, city, ZIP Code) were geocoded using ArcGIS software. Geospatial analysts retrieved road, sidewalk, and trail inventory data from city and county GIS departments and plotted network intersections using ArcGIS software. All geospatial features were represented in a vector data model (e.g., points, lines and polygons), allowing for efficient editing and spatial analysis of individual thematic layers as needed (Table 1). Research team members familiar with the rural setting identified issues with the data during these mapping processes.

Two ArcGIS Network Analysis (Esri ArcGIS Pro 2.3) tools, proximity and density, were utilized to determine household access to PA infrastructure within the built environment. Proximity analysis output measured the distance in meters between participant households and the nearest geospatial feature of interest using road networks and pedestrian walking estimations. Density analysis output measured the number of geospatial features of interest within a specified geographic area (i.e., buffer) surrounding the participant households. Consistent with previous studies conducted with rural children, a 1600-meter network buffer was selected for all density analyses (van Loon, 2014; Jones, 2009).

### 2.3. Fine scale grouping

A fine scale grouping strategy was used to examine household access to the PA built environment at community and neighborhood levels. Participant households were grouped at the community level to characterize families' access to PA infrastructure via vehicle travel and at the neighborhood level to characterize access to PA infrastructure via pedestrian active commuting. Community- and neighborhood-level groups were then combined to assess the differing levels at which rural families could access PA infrastructure using both vehicle and pedestrian pathways.

#### 2.3.1. Community-level groups

Households were grouped by ZIP Code-associated Rural-Urban Commuting Area (RUCA) codes to determine community-level access to PA infrastructure. In the U.S., numeric RUCA codes (1–10 scale) are predominantly used to classify rural–urban differences based on the population density, urbanization, and daily commuting patterns of given ZIP Code or census tract areas (U.S. Department of Agriculture (USDA), 2020). In “core” communities, most residents commute inward; in “commuting” communities, most residents commute outward for work and recreation (U.S. Department of Agriculture (USDA), 2020; University of Washington, 2020). RUCA 4 and 5 ZIP Code areas encompass at least one core community (population: 10,000–49,999) with commuting flows going into RUCA 4 and out of RUCA 5 communities. RUCA 7 ZIP Code areas encompasses at least one core community (population: 2500–9999) with inward commuting flows. Isolated rural (RUCA 10) ZIP Code areas encompass commuting communities with outward commuting flows.

Using ZIP Code-associated RUCA codes that are freely accessible on the U.S. Department of Agriculture (USDA) webpage and rural-centric terminology, households were designated as being located in “Large Rural” (RUCA 4, 5), “Small Rural” (RUCA 7), or “Isolated Rural” (RUCA 10) groups (U.S. Department of Agriculture (USDA), 2020; University of Washington, 2020). If RUCA codes accurately distinguished household access to PA built environments at the community level, one would expect similarities between the two Large Rural (RUCA 4, 5) groups and differences between the Large Rural and Small/Isolated Rural (RUCA 4,

5 vs RUCA 7, 10) groups.

#### 2.3.2. Neighborhood-level groups

Households were separately grouped by Walk Scores® to determine neighborhood-level access to PA infrastructure. Walk Scores® estimate household access to neighborhood amenities (e.g., grocery stores, schools, parks, recreational facilities) (Walk Score®, 2021; Carr et al., 2011), have been validated as reliable measures of neighborhood walkability in general populations (Carr et al., 2010; Duncan, 2011), and adequately assess walkable amenities in rural areas (Lo, 2019). Walk Scores® associated with participant households were retrieved by using a publicly accessible website ([www.walkscore.com](http://www.walkscore.com)). Households were assigned to “Less Walkable” (score of 0–24; almost all errands require a car) and “More Walkable” (score of 25+; at least a few amenities within walking distance) groups according to established Walk Score® cut points (Walk Score, 2021). If Walk Scores® accurately distinguished household access to PA built environments at the neighborhood level, one would expect a difference between the Less Walkable and More Walkable (Walk Scores® 0–24 vs Walk Scores® 25+) groups.

#### 2.3.3. New rural PA built environment access groups

Households were assigned to new rural PA built environment access groups by combining the fine scale indicators of community- and neighborhood-level access to PA infrastructure: RUCA codes and Walk Scores®, respectively (Fig. 1a). Groups were expected to represent varying levels of access to the rural PA built environment via both vehicle travel and pedestrian active commuting (Fig. 1b). For example, households located in large rural communities (RUCA 4, 5) with high neighborhood walkability (Walk Scores® 25+) were expected to have the greatest level of access to PA infrastructure and were assigned to the “Most Access” group (Group 1). Households located in small or isolated rural communities (RUCA 7, 10) with low neighborhood walkability (Walk Score® 0–24) were expected to have comparatively less access to PA infrastructure and were assigned to the “Least Access” group (Group 4).

*Data Analysis.* Household access to PA infrastructure, parent perceptions of the PA environment, and child MVPA were examined descriptively by the community- and neighborhood-level (Table 2) and the new rural PA built environment access groups (Table 3). Analysis of variance (ANOVA) and multiple pairwise comparisons were used to explore group differences in study variables among among the new combined access groups using Fisher's exact tests for categorical data and *t*-tests for continuous data (Table 3). Statistical analyses were performed using SAS 9.4 (Cary, NC) and the alpha level for statistical significance was set at  $p < .01$  given the multiple comparisons.

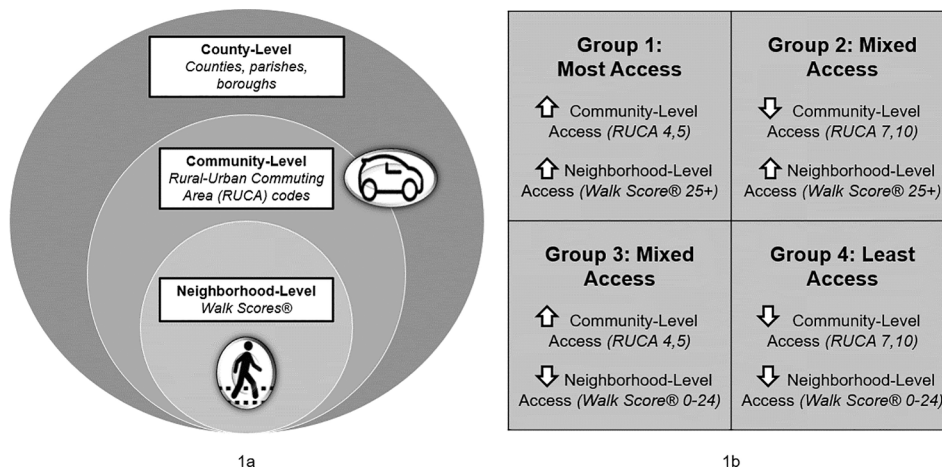
## 3. Results

### 3.1. Mapping and geospatial analysis

In the rural communities examined, most PA infrastructure was located outdoors. Aerial imagery indicated that the largest rural community (RUCA 4) had the most PA infrastructure compared to all other communities within the selected rural region. Sidewalk networks differed across the ten rural communities with some large rural (RUCA 5) communities having sparser sidewalk connectivity than some small/isolated rural (RUCA 7, 10) communities (Fig. 2a). Google Earth Pro imagery revealed that some rural schools or places of worship had more outdoor PA amenities onsite than some rural parks (Fig. 2b).

### 3.2. Community- and neighborhood-level groups

Fine scale assessments revealed that the rural PA built environments varied (see Table 2). When grouped at the community level only, household access to PA infrastructure and parent perceptions of safe access to walking/biking routes differed across the four RUCA categories



**Fig. 1.** 1a. Coarse scale assessments examine access to physical activity (PA) built environments with a wide lens and may identify access differences between rural and urban regions (e.g., counties). Fine scale assessments examine access to PA built environments with a narrow lens and may identify access differences within rural communities and neighborhoods via vehicle and pedestrian pathways. 1b. Combining community- and neighborhood-level access indicators (RUCA codes; Walk Scores®) may identify differing levels of access to the PA built environment, including "most access" and "least access" areas.

but not necessarily as would be expected by RUCA designation. For example, households assigned to one of the Large Rural groups (RUCA 5) had the least access to PA infrastructure compared to all other groups. When grouped at the neighborhood level only, households with Walk Scores® of 25+ had comparatively greater access to PA infrastructure and more favorable parent PA perceptions and child MVPA than households with Walk Scores® of 0–24.

**3.3. New rural PA built environment access groups**

When households were assigned to groups that combined community- and neighborhood-level access indicators, all proximity and density measures of household access to PA infrastructure significantly differed by group ( $p < .0001$ ). Multiple pairwise comparisons revealed that household access to PA infrastructure significantly differed across many of the paired groups (Table 3). Group 1: Most Access (RUCA 4/5; Walk Score® 25+) and Group 2: Mixed Access (RUCA 7/10; Walk

**Table 2**

Descriptive statistics of household access to physical activity (PA) infrastructure, parent PA perceptions, and child moderate-vigorous PA by separate community- and neighborhood-level access groups.

	Rural Sample N = 112	Community-Level				Neighborhood-Level	
		Large Rural RUCA <sup>1</sup> 4 n = 70	Large Rural RUCA 5 n = 9	Small Rural RUCA 7 n = 22	Isolated Rural RUCA 10 n = 11	More Walkable Walk Score® <sup>2</sup> 25+ n = 57	Less Walkable Walk Score® 0–24 n = 55
<b>Proximity,<sup>3</sup> mean (SD)</b>							
Paved Trail	12.6 (13.5)	4.7 (4.6)	22.8 (8.9)	25.0 (7.8)	28.4 (23.2)	10.6 (13.7)	14.4 (13.1)
Park, city and regional	3.0 (4.8)	1.8 (3.0)	7.6 (6.0)	3.8 (6.7)	5.6 (6.1)	0.4 (0.3)	5.7 (5.8)
Community facility	4.1 (6.1)	3.2(4.6)	8.6 (10.1)	4.1 (7.1)	6.9 (6.8)	1.7 (3.7)	6.7 (7.0)
Indoor recreational facility	7.0 (8.7)	3.9 (4.9)	23.0 (5.9)	5.2 (7.9)	13.8 (8.7)	2.2 (4.0)	11.3 (8.9)
Outdoor recreational facility	7.5 (7.0)	6.2 (4.5)	17.9 (5.4)	4.8 (6.3)	10.0 (9.6)	3.5 (2.1)	11.1 (7.2)
<b>Density,<sup>4</sup> mean (SD)</b>							
Sidewalk connectivity	536.4 (494.2)	745.3 (496.0)	4.9 (9.7)	330.5 (216.3)	53.5 (73.0)	860.3 (405.2)	200.6 (325.8)
Road connectivity	406.2 (294.1)	500.4 (289.6)	48.3 (48.1)	357.3 (230.3)	196.8 (193.4)	634.4 (150.4)	169.6 (205.8)
Park, city and regional	4.3 (3.53)	5.2 (3.5)	0.2 (0.4)	4.5 (3.0)	1.5 (2.0)	6.9 (2.4)	1.6 (2.3)
Community facility	2.2 (1.9)	2.3 (1.8)	0.2 (0.4)	2.6 (1.7)	1.9 (2.3)	3.3 (1.4)	1.0 (1.6)
Indoor recreational facility	0.7 (0.8)	0.8 (0.8)	0 (0)	1.1 (0.8)	0.2 (0.4)	1.2 (0.7)	0.2 (0.6)
Outdoor recreational facility	0.2 (0.5)	0.1 (0.3)	0 (0)	0.6 (0.7)	0.6 (0.8)	0.4 (0.6)	0.1 (0.3)
<b>Parent PA Perceptions &amp; Child PA, mean (SD)</b>							
Safe bike/walk <sup>5</sup>	16.4 (3.4)	16.7 (3.0)	11.0 (4.1)	18.4 (1.5)	15.4 (3.7)	17.5 (2.3)	15.2 (4.0)
Free/low-cost PA facilities <sup>6</sup>	3.4 (0.8)	3.5 (0.7)	2.6 (0.9)	3.6 (0.5)	3.4 (0.9)	3.5 (0.7)	3.3 (0.8)
Child MVPA <sup>7</sup>	42.6 (20.5)	44.5 (20.9)	34.3 (20.9)	39.4 (17.4)	43.2 (23.3)	43.6 (22.6)	41.5 (18.1)

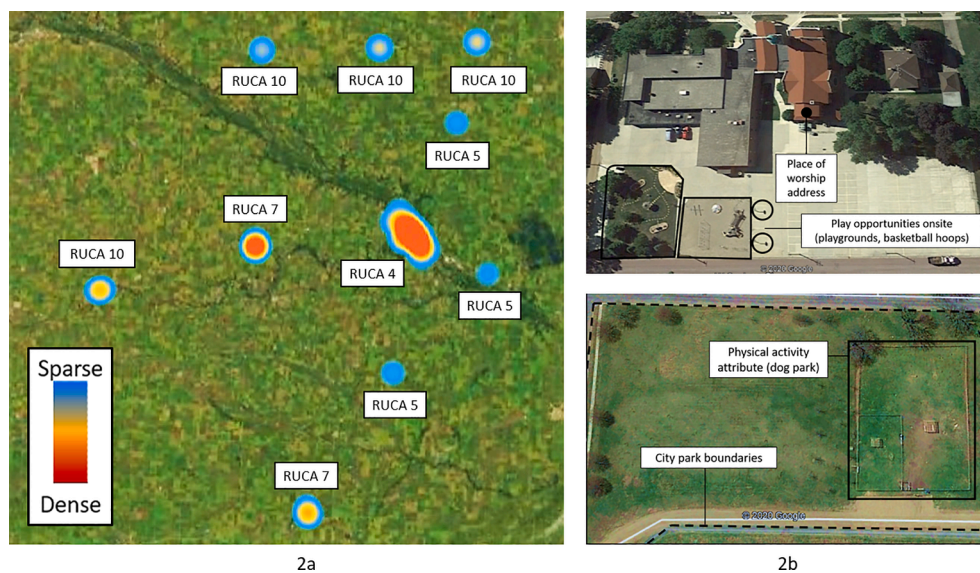
Notes.  
<sup>1</sup> RUCA (Rural-Urban Commuting Area): a code associated with participant ZIP Code areas; RUCA codes characterize community-level population density and vehicle commuting routes with higher numerical codes indicating a greater degree of rurality.  
<sup>2</sup> Walk Score®: a score associated with participant home addresses; Walk Scores® estimate neighborhood-level walkability with a higher score indicating greater access to walkable amenities.  
<sup>3</sup> Proximity: the distance of a pedestrian network route between a participant's home address and a built PA feature of interest; unit = kilometers.  
<sup>4</sup> Density: a measure of the built PA features of interest available within a 1600-meter network buffer of a participant's home address; unit = counts.  
<sup>5</sup> Safe bike/walk: parent self-reported perceptions of access to safe biking and walking opportunities at study baseline; range of 5–20 with higher scores being more favorable; n = 100 survey responses.  
<sup>6</sup> Free/low-cost PA facilities: parent self-reported perceptions of access free or low-cost recreational facilities at study baseline; range of 1–4 with higher scores being more favorable; n = 101 survey responses.  
<sup>7</sup> Child MVPA: child participation in moderate-vigorous PA as measured by accelerometry at study baseline; units = minutes/day; n = 108 valid accelerometer wear times.

**Table 3**

Group differences in household access to physical activity (PA) infrastructure, parent PA perceptions, and child moderate-vigorous PA by combined community- and neighborhood-level access groups.

	Group 1: Most Access RUCA <sup>1</sup> 4,5 Walk Score® <sup>2</sup> 25+ n = 39	Group 2: Mixed Access RUCA 7,10 Walk Score® 25+ n = 18	Group 3: Mixed Access RUCA 4,5 Walk Score® 0–24 n = 40	Group 4: Least Access RUCA 7,10 Walk Score® 0–24 n = 15	Group Difference p-value
<b>Proximity,<sup>3</sup> mean (SD)</b>					
Paved Trail	3.1 (1.2) <sup>b,c,d</sup>	26.9 (14.4) <sup>a,c</sup>	10.3 (9.6) <sup>a,b,d</sup>	25.3 (15.1) <sup>a,c</sup>	<0.0001
Park, city and regional	0.4 (0.3) <sup>c,d</sup>	0.4 (0.2) <sup>c,d</sup>	4.4 (4.7) <sup>a,b,d</sup>	9.1 (7.2) <sup>a,b,c</sup>	<0.0001
Community facility	1.7 (3.6) <sup>c,d</sup>	1.7 (4.1) <sup>c,d</sup>	5.8 (6.6) <sup>a,b</sup>	9.1 (7.8) <sup>a,b</sup>	<0.0001
Indoor recreational facility	1.7 (0.8) <sup>c,d</sup>	3.3 (7.0) <sup>c,d</sup>	10.4 (9.2) <sup>a,b</sup>	13.8 (7.8) <sup>a,b</sup>	<0.0001
Outdoor recreational facility	4.5 (1.7) <sup>c,d</sup>	1.4 (0.8) <sup>c,d</sup>	10.6 (7.0) <sup>a,b</sup>	12.8 (7.9) <sup>a,b</sup>	<0.0001
<b>Density,<sup>4</sup> mean (SD)</b>					
Sidewalk connectivity	1,077.2 (276.7) <sup>b,c,d</sup>	390.4 (167.1) <sup>a,d</sup>	255.1 (361.3) <sup>a</sup>	55.3 (120.9) <sup>a,b</sup>	<0.0001
Road connectivity	707.8 (94.1) <sup>b,c,d</sup>	475.4 (124.9) <sup>a,c,d</sup>	196.5 (222.7) <sup>a,b</sup>	97.9 (132.5) <sup>a,b</sup>	<0.0001
Park, city and regional	7.4 (2.4) <sup>c,d</sup>	5.6 (2.0) <sup>c,d</sup>	1.9 (2.5) <sup>a,b</sup>	0.9 (1.8) <sup>a,b</sup>	<0.0001
Community facility	3.1 (1.5) <sup>b,c,d</sup>	3.7 (0.7) <sup>a,c,d</sup>	1.2 (1.6) <sup>a,b</sup>	0.7 (1.4) <sup>a,b</sup>	<0.0001
Indoor recreational facility	1.1 (0.8) <sup>c,d</sup>	1.3 (0.7) <sup>c,d</sup>	0.3 (0.6) <sup>a,b</sup>	0.3 (0.6) <sup>a,b</sup>	<0.0001
Outdoor recreational facility	0.1 (0.3) <sup>b</sup>	0.9 (0.6) <sup>a,c,d</sup>	0.0 (0.2) <sup>b</sup>	0.2 (0.6) <sup>b</sup>	<0.0001
<b>Parent PA Perceptions &amp; Child PA, mean (SD)</b>					
Safe bike/walk <sup>5</sup>	17.1 (2.4) <sup>c</sup>	18.5 (1.7) <sup>c</sup>	15.0 (4.2) <sup>a,b</sup>	15.8 (3.5)	0.002
Free/low-cost PA facilities <sup>6</sup>	3.6 (0.8)	3.6 (0.5)	3.3 (0.8)	3.4 (0.9)	0.375
Child MVPA <sup>7</sup>	44.2 (24.6)	42.4 (18.3)	42.6 (17.1)	38.8 (20.8)	0.863

**Notes.**  
 Multiple pairwise comparison statistical significance set at  $p < .01$ .  
<sup>a</sup> statistically significant mean differences from Group 1.  
<sup>b</sup> statistically significant mean differences from Group 2.  
<sup>c</sup> statistically significant mean differences from Group 3.  
<sup>d</sup> statistically significant mean differences from Group 4.  
<sup>1</sup> RUCA (Rural-Urban Commuting Area): a code associated with participant ZIP Code areas; RUCA codes characterize community-level population density and vehicle commuting routes with higher numerical codes indicating a greater degree of rurality.  
<sup>2</sup> Walk Score®: a score associated with participant home addresses; Walk Scores® estimate neighborhood-level walkability with a higher score indicating greater access to walkable amenities.  
<sup>3</sup> Proximity: the distance of a pedestrian network route between a participant’s home address and a built PA feature of interest; unit = kilometers.  
<sup>4</sup> Density: a measure of the built PA features of interest available within a 1600-meter network buffer of a participant’s home address; unit = counts.  
<sup>5</sup> Safe bike/walk: parent self-reported perceptions of access to safe biking and walking opportunities at study baseline; range of 5–20 with higher scores being more favorable;  $n = 100$  survey responses.  
<sup>6</sup> Free/low-cost PA facilities: parent self-reported perceptions of access free or low-cost recreational facilities at study baseline; range of 1–4 with higher scores being more favorable;  $n = 101$  survey responses.  
<sup>7</sup> Child MVPA: child participation in moderate-vigorous PA as measured by accelerometry at study baseline; units = minutes/day;  $n = 108$  valid accelerometer wear times.



**Fig. 2.** 2a. A sparsity-density heat map illustrates that sidewalk intersection density varies across rural communities, as defined by Rural-Urban Commuting Area (RUCA) codes. 2b. Aerial imagery reveals that some rural community facilities offer more onsite physical activity amenities and play opportunities (two playgrounds, a basketball court and two hoops ) than do some rural parks (dog park).

Score® 25+) appeared to have the greatest access to PA infrastructure per proximity and density output. Group 3: Mixed Access (RUCA 4/5; Walk Score® 0–24) and Group 4: Least Access (RUCA 7/10; Walk Score® 0–24) appeared to have the least access. Parent perceptions of safe access to walking/biking routes differed across groups ( $p = .002$ ) and were most favorable in groups with Walk Scores® higher than 24 (Groups 1 and 2). Parent perceptions of access to free and low-cost PA facilities did not differ across groups. Child daily MVPA did not differ across groups.

#### 4. Discussion

The present study examined the PA built environments of a rural sample using geospatial mapping and a fine scale grouping strategy to plot and identify within-rural differences in families' access to the PA built environment. Our study findings demonstrate the need for finer grained, rather than traditional coarse scale or county-level, assessments of rural PA built environments. We examined differences in rural families' access to PA infrastructure at the community level using RUCA codes and at the neighborhood level using Walk Scores®. To determine how multiple commuting modalities (e.g., vehicle, pedestrian) could affect access to rural PA built environments, we combined the community- and neighborhood-level access groups. The following research takeaways may be utilized as a translational roadmap for future health promotion and prevention specialists interested in promoting PA among rural youth and families.

Important insights were gleaned from the mapping and geospatial analysis procedures. Rural play opportunities existed outside of traditional park boundaries, with outdoor PA amenities often located on school and place of worship properties. Although previous research demonstrates that community facility sites are often used as alternative locations for PA in rural areas with limited access to parks (Hansen, 2015; Kegler, 2012; Oreskovic, 2012), it is worth noting that some schools and places of worship are privately (Davison and Lawson, 2006) owned institutions and thus onsite PA equipment may not be publicly accessible. Therefore, community facilities and parks should have distinct geospatial attributes to allow for easy data differentiation and independent analysis.

The use of separate GIS layers for indoor and outdoor recreational facilities is also advised. In rural regions with few indoor recreational facilities and distinct seasonal shifts, community members may experience compounded PA barriers (Hansen, 2015; Jones, 2009; Button, 2021). For example, outdoor swimming pools and youth sports fields may become unusable during the winter months in colder climates, and rural communities may lack the city revenue required to construct or maintain indoor athletic complexes. In these situations, it is useful for environmental researchers to have indoor/outdoor GIS layers to identify seasonal factors that affect PA among rural families.

Our study findings provide evidence that rural communities are distinct entities and that rural classification systems “matter” when mapping PA built environments. However, RUCA codes do not appear to accurately distinguish household access to PA infrastructure when used as a stand-alone indicator of community-level access. Prior to completing the geospatial analysis, the research team expected that levels of access would align with RUCA ZIP Codes. For example, households located in large rural communities (RUCA 4, 5) were expected to have greater access to PA infrastructure as compared to households in small or isolated rural communities (RUCA 7, 10). However, the RUCA 5 group was unexpectedly more akin to RUCA 10 group than to RUCA 4 group.

Previous studies have demonstrated some discordance between rural residents' perception of rurality and RUCA classifications (Onega, 2020) and no associations between RUCA community types and youth PA were found in a mixed urban and rural sample (Kasehagen, 2012). Importantly, the RUCA classification system characterizes degree of rurality primarily based on vehicle commuting flows within community “cores”

or between “commuting” communities (U.S. Department of Agriculture (USDA), 2020; University of Washington, 2020). This may in part explain the differences seen between the two Large Rural (RUCA 4 vs 5) groups. The RUCA 4 group was comprised of a single core community with relatively dense PA infrastructure. The RUCA 5 group included multiple commuting communities that had relatively sparse PA infrastructure, yet were centrally located around and in close driving proximity to the RUCA 4 community. It is plausible that families living in under-resourced rural regions, such as the RUCA 5 communities, travel to nearby larger or more developed communities to access PA infrastructure. In these instances, RUCA codes may serve as an adequate indicator of community-level access to the PA built environment by means of vehicle travel.

Relatedly, Walk Scores® may be an adequate indicator of neighborhood-level access to the PA built environment by means of pedestrian active commuting. In the present study, when households were grouped by neighborhood-level Walk Scores® alone, those assigned to the More Walkable (Walk Score® 25+) group had greater access to PA infrastructure than those assigned to the Less Walkable (Walk Score® 0–24) group. Thus, Walk Scores® seems to accurately characterize rural families' walkable access to PA infrastructure. However, using Walk Scores® as a stand-alone indicator of access to the PA built environment may be problematic since neighborhood-level access does not equate to community-level access. For example, in rural regions in which PA infrastructure is unavailable via pedestrian active commuting (e.g., those living on farmland), it may be important to identify community-level assets which could contribute to PA, such as centrally located regional parks or community centers that are accessible via vehicle travel. Thus, it is advised to combine community- and neighborhood-level indicators of access to comprehensively characterize rural families' access to the PA built environment.

When community- and neighborhood-level access groups were combined to create the new combined access groups, households assigned to Group 4: Least Access (RUCA 7/10; Walk Score® 0–24) were located the furthest away from parks, community facilities, and indoor and outdoor recreational facilities as compared to other groups. Importantly, households in Group 4 were located the greatest distance from PA infrastructure even when compared to a group that also had low neighborhood walkability scores (Group 3: Mixed Access – RUCA 4/5; Walk Score® 0–24). Density of sidewalk and road intersections, parks, and community facilities was also the lowest in Group 4. Taken together, these results provide preliminary evidence that rural youth and families living in RUCA-defined small and isolated rural communities with less walkable neighborhoods may face compounded PA barriers at both the community and neighborhood levels. Targeted policies may be needed to address these compounded barriers.

Child daily MVPA did not significantly differ across the rural PA access groups. These findings align with previous research that suggests that the PA built environment is only one factor that affects youth PA; social environments have also been shown to play an important role (Daniels, 2021; Davison and Lawson, 2006; Sandercock et al., 2010; Ferreira, 2007). Future studies might explore how youth PA relates to multiple levels of the PA environment, including built and social components. The present study provides a framework for future researchers to use fine scale, within-rural, and multi-level environmental assessments to demonstrate variance among rural PA environments. To build upon these findings, the methods used in the present study should be replicated in a larger, more diverse rural sample. Future public health and prevention professionals should identify rural youth and families who have the least access to environmental PA supports to implement rural-specific PA interventions.

This study has several strengths and advances the science related to rural PA environment assessments. Study strengths include mapping PA infrastructure known to be important to rural residents and collaborating with an interdisciplinary team of rural community members, geospatial analysts, and research staff to generate and analyze the GIS

dataset. Findings may inform future research within, and outside of, the U.S. Although RUCA codes and Walk Scores® are most applicable in the U.S., researchers can use our fine scale grouping methods as a framework to identify the unique ways in which rural youth and families access PA built environments in their region. Additionally, there is an exciting opportunity to compare or corroborate our fine scale grouping strategy with other available rural PA built environment assessments, such as the Rural Active Living Assessment (RALA) tools. RALA tools use a combination of subjective and objective instruments to determine the activity friendliness of rural communities based on town-level, program/policy-level, and street-level characteristics (Yousefian, 2010; Robinson, 2014). Therefore, researchers might consider using RALA tools, RUCA codes, and Walk Scores® to comprehensively examine rural PA built environments in the future. International researchers might consider collaborating to develop freely accessible, culturally-relevant, and localized community- and neighborhood-level PA built environment access indicators that are similar to those used in the present study (RUCA codes and Walk Scores®).

Study limitations include analyzing a single rural region with demographically homogeneous participants. It is acknowledged that study findings should be interpreted in context of limitations, including the secondary analysis of an existing dataset that was comprised of baseline data from a relatively small RCT. Future analyses using our fine scale grouping strategy should account for potential clustering of individuals within communities and the effects of community- and neighborhood-level access indicators should be examined separately, to test for interactions between the two. The limited generalizability of our findings and potential for selection bias, confounding, and effect modification must be taken into consideration.

## 5. Conclusion

Rural youth and families in the U.S. may experience varying levels of access to PA built environments across the rurality spectrum. Our fine scale grouping strategy combined community- and neighborhood-level indicators of access to PA infrastructure and demonstrated differences in rural families' access to the PA built environment via vehicle travel and pedestrian active commuting. Study methods can be replicated to examine PA built environments in other rural regions in the U.S. due to the publicly accessible nature of the input data used to create the fine scale groups (community-level access: RUCA codes; neighborhood-level access: Walk Scores®). Those outside the U.S. may benefit from this framework by determining how rural families access PA built environments in their geographic region via pedestrian and vehicle pathways. Findings may inform future policies and interventions to promote PA in rural areas. Public health funding should support rural families whose communities and neighborhoods lack PA infrastructure and development projects should aim to diminish structural barriers to facilitate PA opportunities within rural PA built environments.

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## 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 will be made available on request.

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