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Micro-scale pedestrian streetscapes and physical activity in Hispanic/Latino adults: Results from HCHS/SOL

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ABSTRACT

We examined associations of micro-scale environment attributes (e.g., sidewalks, street crossings) with three physical activity (PA) measures among Hispanic/Latino adults (n = 1776) living in San Diego County, CA. Systematic observation was used to quantify micro-scale environment attributes near each participant's home. Total PA was assessed with accelerometers, and PA for transportation and recreation were assessed by validated self-report. Although several statistically significant interactions between individual and neighborhood characteristics were identified, there was little evidence micro-scale attributes were related to PA. An important limitation was restricted environmental variability for this sample which lived in a small area of a single county.

1. Introduction

The neighborhood built environment has been related to adult physical activity in numerous studies. In general, these studies have shown walkability and its components (i.e., residential density, mixed land use, street connectivity) were associated with more physical activity (Saelens and Handy, 2008; Sallis et al., 2012; Smith et al., 2017; Bauman et al., 2012). Longitudinal studies and evaluations of environmental changes have mainly confirmed cross-sectional findings (The Community Guide, 2021; Kärmeniemi et al., 2018). Although most studies focused on the aforementioned macro-scale community design features of the environment, evidence is accumulating that micro-scale features including details of streets, sidewalks, intersections, aesthetics, and physical disorder (e.g., graffiti) features around one's home may also shape physical activity (Read, 2015). Micro-scale features are believed to affect the experience of being active in that location, and improvements to these characteristics are more feasible than for macro features in terms of cost and time required.

Built environment features may have different impacts on physical activity for different populations. There is limited evidence of variations in patterns of associations between built environment and physical activity across countries, age, sex (Sallis et al., 2020), and socioeconomic status (Engelberg et al., 2016; Thornton et al., 2016; Perez et al., 2017). A population of particular interest is the Hispanic/Latino community in the United States. Hispanic/Latino adults appear to have relatively low leisure-time physical activity (Neighbors et al., 2008; Kakinami et al.,

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2018; Arredondo et al., 2016) and low rates of meeting physical activity guidelines (Arredondo et al., 2016; Troiano et al., 2008). Concomitantly, there are higher rates of inactivity-related cardiometabolic disorders such as obesity and type 2 diabetes among Hispanics/Latino than among non-Hispanic White adults (Schneiderman et al., 2014; Avilés-Santa et al., 2017; Isasi et al., 2015; Centers for Disease Control and Prevention, 2020). Evidence of micro-scale neighborhood environment correlates of physical activity in areas with large Hispanic/Latino populations could be useful in advocating for interventions to provide more activity-supportive environments for Hispanic/Latino residents.

There are few studies of the relation of micro-scale features to physical activity among Hispanic/Latino adults. A study in Kansas found more Hispanic/Latino adults met physical activity guidelines when they had sidewalks in their neighborhoods (Fields et al., 2013), but sidewalk presence was not related to meeting guidelines in a different study of Hispanic/Latina women (Voorhees and Young, 2003). In the Kwarteng et al. multiethnic study with a large proportion of Hispanic/Latino residents, having sidewalks in good condition in neighborhoods was positively related to physical activity for the entire sample, but indicators of physical disorder (e.g., vacant lots, litter) were more related to physical activity among non-Hispanic Whites (Kwarteng et al., 2014). Another multi-ethnic study supported Kwarteng et al.'s (Kwarteng et al., 2014) finding that quantity and quality of sidewalks was positively related to physical activity, but Mama et al. (2015) additionally reported significant results for lighting and having a buffer (e.g., planted strip) between the street and sidewalk. Although Silfee et al. (2016) found (macro-level) walkability was positively related to meeting physical activity guidelines, neighborhood aesthetics (a micro-scale variable) was not. In a study of Hispanic/Latina women, socioeconomic status was an environmental moderator, such that favorable aesthetics was related to leisure-time physical activity only among lower-income women, and better sidewalk maintenance was related to more leisure-time physical activity only among higher-income women (Perez et al., 2017). Sidewalk maintenance and neighborhood aesthetics were related to adult Latinas' outdoor physical activity only among subgroups defined by neighborhood social environment variables (e.g., safety from crime and social cohesion) (Perez et al., 2016). Thus, the design of micro-scale neighborhood environments appears to be relevant for Hispanic/Latino adults' physical activity, but further study is needed to develop a consensus about the most important features of micro-scale neighborhood environments and how associations may differ across subgroups of Hispanics/Latino residents.

Some ecological models of physical activity are based on hypotheses about associations of built environment features with specific domains of physical activity. Examples are aesthetics are more likely to be related to recreation physical activity, and sidewalk presence and quality may be more related to active transport (Sallis et al., 2006). Few prior studies of micro-scale environment features and physical activity examined measures of recreation, transport, and total physical activity, but the present study fills a gap by including all three types of physical activity measures. Prior studies with Hispanics/Latinos reported social environment variables interacted with micro-scale environment features in explaining physical activity (Perez et al., 2016, 2017), so the present study evaluated neighborhood income as a moderator of micro-scale feature associations with physical activity. It is possible other demographic variables could serve as effect modifiers, so we went beyond prior studies of Hispanics/Latinos by exploring the potential moderators of age, sex, neighborhood walkability, and work status.

The aim of the present study was to investigate associations of Micro-scale Audit of Pedestrian Streetscapes (MAPS) subscales and total scores with accelerometer-assessed total MVPA (moderate-to-vigorous intensity physical activity), self-reported recreation physical activity, and self-reported walking and bicycling for transport in a population-based sample of Hispanic/Latino adults living in San Diego County, California. A secondary goal was to explore multiple socio-demographic variables as potential effect modifiers. Because prior studies have identified racial/ethnic and socioeconomic status disparities in micro-scale features (Engelberg et al., 2016; Thornton et al., 2016; Franzini et al., 2010; Lovasi et al., 2009; Neckerman et al., 2009), this could be an important confounder. Thus, we compared mean values for each MAPS variable across tertiles of neighborhood socioeconomic deprivation, in addition to using this variable as a covariate.

We hypothesized that (a) MAPS scores representing greater safety from traffic and crime, and more favorable aesthetics, would be positively associated with all three physical activity measures, and (b) the MAPS active transport score would be positively associated with walking and bicycling for transport. Effect modification of micro-scale feature associations with physical activity by age group, sex, macro-level walkability, neighborhood socioeconomic deprivation, and work status were considered exploratory analyses.

2. Methods

2.1. Participants and procedures

Participants for the current study were recruited from the Study of Latinos Community and Surrounding Areas (SOL CASAS); an ancillary study to the Hispanic Community Health Study/Study of Latinos (HCHS/SOL) in San Diego County, CA. The HCHS/SOL is a prospective cohort study of self-identified Hispanic/Latino adults from four large US cities (Bronx, NY, Chicago, IL, Miami, FL, and San Diego, CA). Participants were recruited using a stratified two-stage area probability sampling design (LaVange et al., 2010; Sorlie et al., 2010). HCHS/SOL participants living in San Diego were invited to participate in SOL CASAS if they could walk at least one block unassisted (Gallo et al., 2019). The present analyses used data from HCHS/SOL Visit 2, which occurred in 2014–2017. Of 2,520 HCHS/SOL participants screened 88 (3.5%) were ineligible, 161 (6.4%) declined participation, and 495 (19.6%) did not attend the study visit, leading to 1,776 enrolled participants (70.5% enrollment rate) in SOL CASAS. These participants were spread throughout 195 census tracts out of 627 tracts in the county. Within the 195 tracts there was a mean of 19 participants and median of 3 (std 28).

2.2. Measures

Demographics. Participants reported their age, sex (female or male), birthplace (born in US 50 states or DC, yes/no), number of years living in the US, education (at least high school diploma or not), and annual household income ($\geq$\$30K or $<$\$30K).

Micro-scale neighborhood features. We used the abbreviated version of the Micro-scale Audit of Pedestrian Streetscapes (MAPS) tool (Millstein et al., 2013; Cain et al., 2017) to conduct systematic observational audits of the street blocks and street crossings along a 0.25 to 0.44-mile route from each participant's approximate home address (a random 2-digit number was added or subtracted from the actual address) toward the nearest commercial cluster, approximating a likely walking route. The route selection method was systematic, using Google Maps, and all the routes were created by an experienced staff member who developed the methods, implemented them in several prior studies, and has trained investigators on the protocol. A cluster was at least two commercial destinations, access was determined by the street network, and major barriers such as restricted access highways were considered in selecting the commercial cluster and likely route. Observing a sample of the environment at the beginning of a likely walking route is an efficient method of estimating each participant's micro-scale environment.

This abbreviated version of MAPS included 60 items assessing features such as the presence and quality of sidewalks, street crossings, bicycle facilities, landscaping, buildings, and lighting. Some items were scored for the entire route, some were scored for each street segment, and some items assessed street crossings. Most individual items rating the presence of a feature were scored on a 0–2 scale (none, 1, or >1) or

0–1 scale (none or ≥1), with higher scores indicating a more physical activity-supportive environment.

A "street surveillance" subscale for each street segment was newly developed by the investigators for SOL CASAS to represent features that might facilitate social interaction/cohesion or neighbors "watching out for" each other. The four new items assessed two types of street lighting, percent of residences with front windows, and front porches/stoops.

MAPS has documented good inter-rater reliability with both in-person (Millstein et al., 2013) and online (Phillips et al., 2017) observation modes, the latter of which was used in SOL CASAS, using 2017 imagery from Google Street View and Google Earth. We used the four validated MAPS subscales and three overall/composite scores for the current analyses, plus the new "street surveillance" subscale. Only summary scores were analyzed because items are inter-correlated, and we expect broader multi-item summary scores to better represent patterns of attributes likely to be related to physical activity. Summary scores have tended to have higher inter-rater observer reliabilities (Lovasi et al., 2009) and associations with physical activity than single items or short construct-specific subscales (Cain et al., 2017). A list of variable names and descriptions is provided in Table 1. MAPS data were not collected for 96 participants (5.4%) because addresses could not be geo-located or online images were not available.

Macro-scale neighborhood features. SOL CASAS also collected GIS-based measures of the macro-scale neighborhood environment within an 800-m circular buffer around each participant's home address. These were used as covariates and explored as potential moderators in present analyses. We computed a walkability index score based on a sum of z-scores among indicators of residential density, retail density, and intersection density (Frank et al., 2010). Neighborhood socioeconomic deprivation was defined using principal components analysis of nine indicators from the 2013–2017 American Community Survey covering education, employment, and income, all with greater values indicating lower socioeconomic conditions (i.e., higher deprivation). Full details on macro variable calculation, data sources, and how data were joined to participants can be found in the SOL CASAS protocol paper (Gallo et al., 2019).

Accelerometer-based physical activity. SOL CASAS participants were asked to wear an Actical accelerometer (version B-1; model 198-0200-03; Philips Respironics®, Bend, OR) on their hip for one week during waking hours (Evenson et al., 2015). We processed the Actical data using 1-min epochs, with the Choi algorithm (e.g., consecutive zero counts for at least 90 min, allowing for time intervals with nonzero counts lasting up to 2 min) to define non-wear periods (Choi et al., 2011). Only days with ≥10 h wear time and participants with ≥3 such days were included in present analyses. MVPA was defined as ≥1535 counts/minute (Colley et al., 2011; Colley and Tremblay, 2011). Overall MVPA minutes/day for each participant were calculated by taking the average of these values across valid wear days.

Self-reported physical activity. Participants completed the Global Physical Activity Questionnaire (GPAQ), a reliable measure for culturally diverse contexts, to assess transport and recreation MVPA (Bull et al., 2009). Participants self-reported frequency and duration, in a typical week, of engaging for at least 10 min continuously in transport-related (i.e., walking and cycling for transport) and recreation-related (e.g., walking/cycling for recreation) physical activity. Average minutes/day of transport and recreation MVPA were used in present analyses.

Statistical analyses. Unweighted and weighted descriptive statistics were calculated in IBM SPSS Statistics 24 and regression analyses in Mplus version 7.4. The complex samples analyses accounted for the stratified sampling design, clustering of participants within census tracts, and sampling weights. The weights were trimmed to handle extreme values and calibrated to the 2010 US Census according to age, sex, and Hispanic/Latino background to support generalization of the results to the underlying population in the selected areas (LaVange et al., 2010). The number of participants with missing data for ≥1 variable in the analyses was 244 (13.7%) for models examining accelerometer-based total MVPA, 177 (10.0%) for models investigating transportation MVPA, and 237 (13.3%) for models examining recreation MVPA. Inverse probability weights (IPW) were used to account for the missingness due to non-adherence to the Actical protocol (Evenson et al., 2015). The final weight was a product of the IPW and sampling weight. Maximum likelihood robust estimation was used to account for missing data in covariates in all statistical models. The final analytic sample included 1776 participants.

We conducted linear regression models to investigate associations of MAPS variables (independent variables) with the three physical activity dependent variables (accelerometer-based total MVPA, self-reported transport MVPA, self-reported recreation MVPA). Reported MVPA

Table 1
List of micro-scale pedestrian streetscapes variable names and descriptions, SOL CASAS

Variable name	Possible range	Description
Subscales		
Route positive streetscape elements	0 to 8	A composite score representing the presence of transit stops (0–2), driveways (>5 = 0; 0–5 = 1), building overhangs (0–1), trash bins (0–1), benches (0–1), bicycle racks (0–1), traffic calming (0–1).
Route overall aesthetics and social subscale	−5 to 3	Positive aesthetics and social subscale - negative aesthetics and social subscale
Overall positive crossing characteristics	0 to 11	A composite score representing the presence of crosswalk amenities (e.g., marked crosswalk) (0–5), curb ramps (0–2), and crossing signals (0–4).
Segment street surveillance	0 to 8	A composite score representing the presence of high (car-oriented) streetlights (0–2) and low (pedestrian-oriented) streetlights (0–2), and the proportion of the segment with street level windows (0–25% = 0; 26–75% = 1; 76–100% = 2) and stoops/porches (0–25% = 0; 26–75% = 1; 76–100% = 2).
Segment sidewalks	0 to 7	A composite score representing the presence of sidewalks (0–2), width of sidewalks (0–3), continuity of sidewalks (0–1), and absence of trip hazards (0 or 1 = 1; >1 = 0).
Overall scales		
Overall positive street segment	0 to 33	A composite score representing the presence of buffers between the street and sidewalk (0–2), presence of a marked bicycle lane (0–2), tree coverage (0–5), building setback from sidewalk (0–3, with shorter distances receiving a higher score), building height (0–3, with taller buildings receiving a higher score), ratio of the building height to road width + setback (0–3, with the middle values receiving a higher score than the extreme values), and the surveillance (0–8) and sidewalk (0–6) subscales.
Overall micro-scale positive for active transportation	0 to 52	Route positive streetscape elements subscale + Overall positive street segment subscale + Overall positive crossing characteristics subscale
Overall micro-scale positive	0 to 55	Route positive streetscape elements subscale + Route positive aesthetics and social subscale + Overall positive street segment subscale + Overall positive crossing characteristics subscale

Note: A 0–1 response scale typically represents whether the feature was absent (0) or present (1); a 0–2 response scale typically represents whether the feature was absent (0) or whether 1 (1) or >1 (2) were present.

variables were natural log transformed due to non-normal distributions, and corresponding regression coefficients and standard errors were exponentiated to facilitate their interpretation as percent differences in MVPA for a 1 SD difference in the independent variable. The five MAPS subscales were investigated together in the same model, whereas each MAPS composite was tested in a separate model. All independent variables were standardized (z-scored) to facilitate comparison of coefficients across variables. Models were adjusted for participant age, sex, annual household income category, US born (yes/no), years living in the US, neighborhood walkability, and neighborhood socioeconomic deprivation. Models investigating overall MVPA were additionally adjusted for accelerometer wear time.

We tested interactions between the overall micro-scale positive composite and continuous variables for 1) participant age, 2) participant sex, 3) neighborhood walkability, and 4) neighborhood income in relation to each MVPA outcome to identify potential moderators. Interactions with a P value < 0.05 were plotted. This p-value was selected over a more conservative p-value for probing interactions because power to detect interactions is lower than for detecting main effects (McClelland and Judd, 1993), and we sought to minimize risk for Type II error when investigating potential moderation (or effect modification). To investigate whether micro-scale features were associated with neighborhood socioeconomic status, mean values for each MAPS variable were compared across tertiles of neighborhood socioeconomic deprivation. Lastly, distributions of the MAPS variables were compared between SOL CASAS and a previous study (Cain et al., 2017) to gauge the level of variability these measures exhibited in SOL CASAS.

3. Results

Descriptive statistics for the study population and measures are presented in Table 2. The population had a mean age of 46.1 years, 53.3% were female, and mean accelerometer-based total MVPA was 20.6 min/day. A comparison of distributions in the MAPS variables between SOL CASAS and previous studies conducted in Baltimore, MD, Seattle/King County, WA, and San Diego, CA regions (Cain et al., 2017) are presented in Table 3. Standard deviations were much larger in the previous study than in SOL CASAS for five of the seven variables investigated.

No micro-scale subscales or composites were significantly associated with accelerometer-based total MVPA (Table 4). The micro-scale route positive streetscape elements subscale had a marginal positive association with self-reported transportation MVPA (Table 4) (B = 0.15, SE = 0.07, P = 0.06). No other micro-scale subscales and no micro-scale composites were significantly associated with self-reported transportation MVPA. No micro-scale subscales or composites were significantly associated with self-reported recreation MVPA (Table 4), though marginally significant associations were observed for route positive streetscape elements (B = 0.15, SE = 0.08, P = 0.10), overall micro-scale positive for active transportation (B = 0.16, SE = 0.08, P = 0.08), and overall micro-scale positive (B = 0.16, SE = 0.09, P = 0.09) in relation to self-reported recreation MVPA.

We found some evidence of effect modification on the association of micro-scale positive composites on MVPA by a few neighborhood- and individual-level characteristics (Table 5). Greater values on the overall micro-scale positive composite were associated with slightly less accelerometer-based total MVPA among those living in neighborhoods with lower socioeconomic deprivation, and more accelerometer-based total MVPA among those living in neighborhoods with greater socioeconomic deprivation (Fig. 1a). Greater values on the overall micro-scale positive composite were not associated with self-reported recreation MVPA among women, but this composite was associated with substantially more self-reported recreation MVPA among men (Fig. 1b). Finally, greater values on the overall micro-scale positive composite were associated with greater self-reported recreation MVPA among employed individuals but associated with slightly less self-reported recreation MVPA among those not employed (Fig. 1c).

The comparison of micro-scale variables across tertiles of neighborhood socioeconomic deprivation revealed differences for two of the micro-scale subscales and two composites (Table 6). Neighborhoods with greater socioeconomic deprivation had more route positive

Table 2
Sociodemographic characteristics, physical activity, and MAPS variables, SOL CASAS (N = 1776)

	n	Weighted mean (SE) or %	Unweighted mean (SD) or %
Sociodemographic variables			
Age (at time of CASAS clinic visit), years	1776	46.1 (0.7)	55.3 (12.8)
Female	1776	53.3%	67.5%
Born in US	1776	31.6%	19.3%
High school diploma or greater	1776	74.1%	65.7%
Annual household income ≥$30k	1720	55.7%	47.0%
Employed	1764	62.6%	54.2%
Physical activity variables			
Accelerometer-based total MVPA, min/day	1622	20.6 (1.4)	16.4 (23.0)
Self-reported transportation MVPA, min/day[a]	1629	2.5 (1.1)	2.5 (4.8)
Self-reported recreation MVPA, min/day[a]	1688	7.7 (1.1)	5.4 (6.3)
Micro-scale pedestrian streetscape subscales			
Route positive streetscape elements	1680	3.4 (0.1)	3.4 (1.9)
Route overall aesthetics and social	1680	1.0 (0.1)	1.1 (1.1)
Overall positive crossing characteristics	1680	2.3 (0.1)	2.2 (1.6)
Segment surveillance	1680	2.1 (0.1)	2.1 (0.9)
Segment sidewalks	1680	3.8 (0.03)	3.9 (0.7)
Micro-scale pedestrian streetscape composites			
Overall positive street segment	1680	6.0 (0.1)	6.0 (1.6)
Overall micro-scale positive for active transportation	1680	11.6 (0.2)	11.4 (3.2)
Overall micro-scale positive	1680	13.9 (0.2)	13.8 (3.4)

Min = minutes; MVPA = moderate to vigorous physical activity; n = sample size (number of participants); SD = standard deviation; SE = standard error.
[a] Geometric means, SEs, and SDs are reported.

Table 3
Distribution of micro-scale pedestrian streetscape variables between studies

	SOL CASAS (N = 1776)		Cain et al. results from studies of 3 US regions (N = 3677) (Cain et al., 2017)	
Variable name	Possible range	Mean (SD)	Possible range	Mean (SD)
Subscales				
Route positive streetscape elements	0 to 8	3.4 (1.9)	0 to 9	2.2 (1.5)
Route overall aesthetics and social subscale	−5 to 3	1.1 (1.1)	−3 to 3	1.2 (1.5)
Overall positive crossing characteristics	0 to 11	2.2 (1.6)	0 to 10	2.6 (3.1)
Segment surveillance	0 to 8	2.1 (0.9)	n/a	n/a
Segment sidewalks	0 to 7	3.9 (0.7)	0 to 6	2.9 (1.6)
Composites				
Overall positive street segment	0 to 33	6.0 (1.6)	0 to 25	6.4 (2.7)
Overall micro-scale positive for active transportation	0 to 52	11.4 (3.2)	0 to 77	14.4 (6.9)
Overall micro-scale positive	0 to 55	13.8 (3.4)	0 to 47	13.4 (4.9)

Table 4
Associations between micro-scale pedestrian streetscapes and accelerometer-based MVPA (min/day), SOL CASAS (N = 1776)

	Accelerometer-based total MVPA[a]		Self-reported transportation MVPA		Self-reported recreation MVPA	
MAPS subscales	B (SE)	P	B (SE)	P	B (SE)	P
Route positive streetscape elements (z score)	−0.42 (1.06)	0.693	0.15 (0.07)	0.063	0.15 (0.08)	0.099
Route overall aesthetics and social (z score)	0.36 (1.32)	0.784	−0.05 (0.06)	0.416	0.09 (0.11)	0.350
Overall positive crossing characteristics (z score)	−0.18 (0.77)	0.813	−0.05 (0.07)	0.532	0.01 (0.08)	0.939
Segment surveillance (z score)	0.30 (1.09)	0.781	0.03 (0.06)	0.588	0.06 (0.07)	0.416
Segment sidewalks (z score)	0.83 (1.20)	0.492	0.05 (0.06)	0.398	0.08 (0.09)	0.382
MAPS composites (tested individually)						
Overall positive street segment (z score)	1.13 (1.11)	0.304	0.02 (0.06)	0.737	0.11 (0.08)	0.174
Overall micro-scale positive for active transportation (z score)	0.13 (0.93)	0.885	0.07 (0.06)	0.232	0.16 (0.08)	0.081
Overall micro-scale positive (z score)	0.30 (0.99)	0.759	0.06 (0.06)	0.356	0.16 (0.09)	0.090

MAPS = microscale audit of pedestrian streetscapes; MVPA = moderate to vigorous physical activity; B = unstandardized regression coefficient, minutes per day of accelerometer-based total MVPA; SE = standard error.
All models adjusted for participant age, sex, annual household income, US born, years living in the US, neighborhood walkability and neighborhood socioeconomic deprivation.
[a] Additionally adjusted for mean hours/day of wear time, number of valid wear days, and proportion of wear days that were weekdays.

streetscape elements and higher scores on the overall micro-scale positive and overall micro-scale positive for active transportation composites, as compared to neighborhoods with lower socioeconomic deprivation. The route overall aesthetics and social subscale had similar values in the low- and high-deprivation neighborhoods, and lower values in the medium-deprivation neighborhoods.

4. Discussion

In this study of Hispanic/Latino adults in San Diego County, little evidence was found for significant associations of neighborhood micro-scale environment features with three validated physical activity measures. Micro-scale environment features are believed to indicate the extent to which streetscapes, including sidewalks, street crossings, and aesthetics are designed for the safety and comfort of pedestrians. For the accelerometer-assessed total MVPA outcome, no MAPS summary variables were even marginally significant. In a previous study with MAPS-Abbreviated, the positive street segment score and overall microscale positive score were significantly related to total MVPA among older adults (Cain et al., 2017). Other studies, based on a variety of microscale measures and populations, found significant associations with accelerometer-assessed MVPA (Read, 2015; Perez et al., 2017; Hawkesworth et al., 2018), suggesting present results may not be typical. Possible explanations for the present lack of association with MVPA are discussed below.

The self-reported active transport association with the route positive streetscape scale was marginally significant. Previous studies reported transport physical activity was related to sidewalk characteristics and aesthetics (Read, 2015; Hoehner et al., 2005), and Lanza and colleagues (Lanza et al., 2020) found microscale summary scores were related to higher light rail use, which is considered active transportation. Though the present study found only one marginally significant model out of 24 tested for the active transport outcome, and the marginal result could be spurious, it is worth examining what was covered in the route positive streetscape score. The items were related to active transport amenities (transit stops, bike racks), comfort (benches, overhangs that provide shade, trash bins), and safety (traffic calming), so they have face validity for being relevant to active transport.

Several of these amenities in the route positive streetscape score are expected to be relevant for active recreation as well. Interestingly, marginally positive associations of the MAPS route positive streetscape score also were found for recreation MVPA, in addition to the composite scales that included the route positive streetscape score (i.e., overall micro-scale positive score and overall micro-scale positive for active transportation score). Recreation physical activity has been infrequently studied in relation to micro-scale features, but Hoehner and colleagues (Hoehner et al., 2005) found this outcome was positively related to observed “attractive features” which could be considered an aesthetics variable. Given the weak but repeated evidence of association of micro-scale features with two physical activity measures in the present study, it is important to determine whether the association of positive streetscape features with physical activity can be replicated in other studies with Hispanic/Latino adults.

A related unexpected finding was that the same three MAPS variables

Table 5
Investigation of moderators of associations between the overall micro-scale positive composite and MVPA (min/day), SOL CASAS (N = 1776)

	Interaction tests									
	Age and Micro-scale Interaction (z score)		Sex and Micro-scale Interaction (Female = 0, Male = 1)		Walkability and Micro-scale Interaction (z score)		Neighborhood Deprivation and Micro-scale Interaction (z score)		Work Status and Micro-scale Interaction (Unemployed = 0; Employed = 1)	
Outcomes[a]	B (SE)	P	B (SE)	P	B (SE)	P	B (SE)	P	B (SE)	P
Accelerometer-based total MVPA[b]	0.83 (0.82)	0.313	−0.61 (1.02)	0.548	0.20 (0.84)	0.817	2.19 (0.88)	0.012	−1.62 (2.10)	0.440
Self-reported transportation MVPA[c]	−0.03 (0.06)	0.637	−0.04 (0.06)	0.484	0.01 (0.06)	0.863	0.03 (0.05)	0.569	−0.90 (0.16)	0.566
Self-reported recreation MVPA[c]	−0.12 (0.07)	0.094	0.21 (0.07)	0.003	−0.16 (0.09)	0.085	0.01 (0.10)	0.899	0.40 (0.14)	0.005

MAPS = microscale audit of pedestrian streetscapes; MVPA = moderate to vigorous physical activity; B = unstandardized regression coefficient for the interaction term; SE = standard error.
[a] Adjusted for participant age, sex, annual household income, US born, years living in the US, neighborhood walkability, and neighborhood socioeconomic deprivation.
[b] Additionally adjusted for mean hours/day of wear time, number of valid wear days, and proportion of wear days that were weekdays.
[c] The dependent variable was natural log transformed and regression coefficients were exponentiated, interpretable as percent difference.

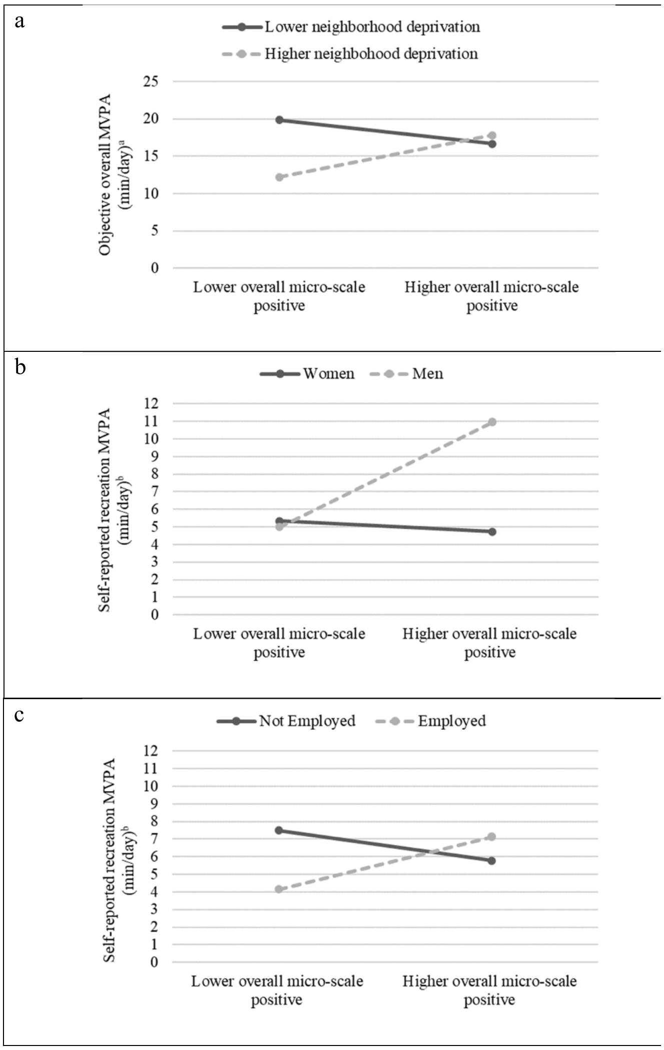

Fig. 1. Plots of significant moderators of associations between the overall micro-scale positive composite and MVPA, SOL CASAS (N = 1776). Min = minutes; MVPA = moderate to vigorous physical activity; Lower = 1 standard deviation below mean; Higher = 1 standard deviation above mean. All models were adjusted for participant age, sex, annual household income, US born, years living in the US, neighborhood walkability, deprivation.
The circles in each plot reflect the mean value in the MVPA variable for each combination of independent variables (i.e., low-low, low-high, high-low, high-high).
[a]Additionally adjusted for mean hours/day of wear time, number of valid wear days, and proportion of wear days that were weekdays.
[b]Geometric rather than arithmetic means are reflected.

that were marginally related to recreation MVPA all had their highest (most favorable) scores in the highest-deprivation neighborhoods. This is a pattern of "positive disparities" in micro-scale features such as transit stops, trash bins, benches, bike racks, and traffic calming. One would expect these features to be more common in more-urban (as opposed to suburban) neighborhoods that also happened to be lower-income in the present study. A prior study using MAPS found the direction of association of neighborhood income to MAPS scores varied across jurisdictions and likely reflected local historical trends and policies (Engelberg et al., 2016). Thus, inequities in micro-scale features that might facilitate physical activity cannot be assumed and should be assessed in each study location.

Present results were different from the only previous study of associations of MAPS-Abbreviated scores with physical activity outcomes of which we are aware, providing an important comparison. The prior study with a mostly non-Hispanic White sample from two US regions found many MAPS-Abbreviated scores were significantly related to reported walking for transportation, including all the MAPS composite variables (Cain et al., 2017). By contrast, no significant associations with reported active transportation were seen in the SOL CASAS population. In the prior study, only the aesthetics and street surveillance scores were related to recreation physical activity, supporting the idea of domain-specific environmental correlates of physical activity (Cain et al., 2017) In SOL CASAS analyses, there was a trend for two overall micro-scale scores, but no association of the aesthetics and social score with recreation physical activity. The prior study did not have accelerometer data for adults, so no comparisons across studies can be made for total MVPA.

Differences between the studies that could explain the discrepant results include race/ethnicity of samples, distribution of socioeconomic status, geographic locations, physical activity patterns, and built environments. Though none of these can be ruled out as explanations, we believe the most likely reason for the contrasting results is built environment differences. In this respect, the biggest difference in results was the general lack of significant associations in present SOL CASAS analyses, compared to a range of few significant results (recreation physical activity) to several (accelerometer-assessed MVPA), to many significant associations (active transportation) in the Cain et al. (2017) paper that were documented across multiple age groups.

It is important to note that the variability of MAPS-Abbreviated scores was much less in the present study than in the Cain et al. (2017) study, as shown in Table 3. For example, 99% of SOL CASAS participants had sidewalks in their immediate neighborhoods. It is a basic statistical principle that low variability leads to underestimates of true associations. Thus, we believe the concentration of SOL CASAS participants in a limited geographic area of a single region led to the limited variability. By contrast, the studies from which the data were drawn for the Cain et al. (2017) analyses were intentionally designed to maximize variability in both built environments (i.e., walkability) and participant socioeconomic status. As stated in the Introduction, the modest number of prior studies examining micro-scale environment associations with physical activity in (substantially) Hispanic/Latino adult samples produced inconsistent results. So it is notable that five of the prior studies were conducted in a single region (though sometimes in multiple communities) (Perez et al., 2017; Fields et al., 2013; Voorhees and Young, 2003; Kwarteng et al., 2014; Silfee et al., 2016), and only three studies were conducted in more than one region (Mama et al., 2015; Perez et al., 2016; Franzini et al., 2010). Because of this geographic limitation of present analyses, we encourage further study of the relation of micro-scale streetscape attributes to physical activity among Latino/Hispanic adults, ideally recruited from geographically diverse areas.

Another notable difference between the current study and prior research is the relatively low level of socioeconomic status of the SOL CASAS population. As we have reported previously, nearly one third of the HCHS/SOL San Diego population had yearly household incomes ≤$20,000/year, and 28% had less than a high-school education (Gallo et al., 2019). The block groups where SOL CASAS participants resided were also higher in socioeconomic deprivation (and showed less variability in deprivation), relative to all block groups in San Diego County (Gallo et al., 2019). Individuals with lower SES may have less choice about activity patterns–for example, they may rely on walking and public transport because they do not have cars–and this may reduce the salience of micro-level factors.

Prior analyses in SOL CASAS examined neighborhood socioeconomic deprivation and macro-level neighborhood environment features in relation to activity patterns and health. We found that walkability, residential density, and retail density were positively associated with active transportation, but only retail density was associated with overall device-measured MVPA (Carlson et al., 2022). These associations persisted with control for neighborhood deprivation. Other analyses

Table 6
Distribution of MAPS variables across low, medium, and high neighborhood socioeconomic deprivation, SOL CASAS (N = 1776)

	Observed mean (SD)			Estimated mean (SE)			
	Low Deprivation (1)	Medium Deprivation (2)	High Deprivation (3)	Low Deprivation (1)	Medium Deprivation (2)	High Deprivation (3)	Significant differences ($p < 0.05$)
MAPS subscales							
Route positive streetscape elements	2.79 (1.80)	3.52 (1.79)	3.73 (1.92)	2.83 (0.21)	3.55 (0.19)	3.90 (0.21)	1 < 2 < 3
Route overall aesthetics and social	1.25 (0.98)	0.88 (1.20)	1.15 (1.01)	1.23 (0.11)	0.62 (0.17)	1.10 (0.11)	1 > 2
Overall positive crossing characteristics	2.07 (1.48)	2.27 (1.59)	2.19 (1.58)	2.13 (0.11)	2.42 (0.15)	2.33 (0.15)	NONE
Segment surveillance	2.00 (0.89)	2.12 (0.81)	2.16 (0.89)	2.02 (0.07)	2.08 (0.09)	2.23 (0.10)	NONE
Segment sidewalks	3.80 (0.75)	3.85 (0.72)	3.91 (0.56)	3.88 (0.04)	3.80 (0.07)	3.86 (0.05)	NONE
MAPS composites							
Overall positive street segment	6.05 (1.73)	5.80 (1.55)	6.19 (1.56)	6.14 (0.20)	5.71 (0.19)	6.21 (0.16)	NONE
Overall micro-scale positive for active transportation	10.74 (3.27)	11.50 (3.13)	12.07 (3.07)	10.91 (0.34)	11.56 (0.38)	12.40 (0.33)	1 < 3, 2 < 3
Overall micro-scale positive	13.13 (3.44)	13.73 (3.33)	14.47 (2.27)	13.29 (0.38)	13.57 (0.46)	14.78 (0.35)	1 < 3, 2 < 3

SD = standard deviation; SE = standard error.
The low, middle, and high deprivation groups, based on tertiles, had a mean of 8.98%, 18.12%, 24.55% of households below poverty line (Colley et al., 2011), respectively.

showed that neighborhood socioeconomic deprivation predicted adverse changes in body mass index and diabetes status (Gallo et al., 2022), and both neighborhood socioeconomic deprivation and social disorder related to hypertension risk over six years (Savin et al., 2022), over and above individual socioeconomic status. Walkability was not related to these health outcomes (Gallo et al., 2022; Savin et al., 2022). Thus, neighborhood walkability was related to physical activity, but this effect did not translate into health differences. In contrast, adverse neighborhood social environmental features predicted a deterioration of cardiometabolic health over time. It is possible micro-level built environmental features have a smaller role that is difficult to detect in the context of restricted ranges and/or the overarching impact of adverse individual and neighborhood social conditions.

4.1. Effect modification findings

Of the 15 interactions examined, only three were significant, providing weak evidence of moderating effects that might explain the general lack of hypothesized main effects in associations of MAPS variables with physical activity. Only the overall micro-scale positive score, the main MAPS summary score, was examined for interactions. For the total MVPA outcome, there was a significant interaction of overall micro-scale positive with neighborhood deprivation. In high-deprivation (low-income) neighborhoods, the overall micro-scale positive score was positively related to MVPA, suggesting pedestrian design could be particularly beneficial in low-income neighborhoods. The inverse association between the overall micro-scale positive score and MVPA in low-deprivation (higher-income) neighborhoods was unexpected and difficult to explain. In interactions with sex, the overall micro-scale positive score was related to higher MVPA only among males, with no association among females. This apparent sex-specific recreation MVPA effect should be followed up in subsequent studies. The association between higher scores on the overall micro-scale positive composite and lower self-reported recreation MVPA for unemployed individuals was unexpected. However, the positive association between the overall micro-scale composite score and recreation MVPA among employed adults suggests pedestrian-friendly design may be particularly beneficial to those who are likely to spend most of their working hours outside the neighborhood.

Prior studies with substantially Hispanic/Latino samples examined interactions of micro-scale variables with demographic and social environment variables in explaining physical activity. In one study, there was no main effect of sidewalk variables regarding physical activity, but several interactions were found between microscale features and social environments, such as crime safety (Perez et al., 2016). Two studies reported microscale variables either interacted with participant weight status (Read, 2015), or were part of complex pathways of influence on physical activity that involved weight status (Mama et al., 2015). Repeated findings of significant interactions of micro-scale variables with personal and social environment variables suggest a complex pattern of influences on physical activity that should continue to be examined in studies based on multilevel ecological models (Sallis et al., 2006).

4.2. Strengths and limitations

Among study strengths were a large sample of Hispanic/Latino (primarily Mexican heritage) adults, multiple physical activity outcomes using both accelerometers and validated self-reports, use of a well-studied streetscape observation measure that was adapted in minor ways for the population, analyses that systematically controlled for a wide range of variables, and exploration of interactions between micro-scale environment variables and demographics. A potential limitation was minor temporal mismatch between the dates of Google imagery that was used for online MAPS observations and dates of physical activity measures, but the vast majority of the photos were taken within a year of Visit 2 measures (around 2017). Analysis of only broad summary scores of micro-scale environments could be viewed as a limitation, because individual items could have revealed additional significant associations. However, conceptually, we expected broader patterns of micro-scale attributes to be more strongly related to physical activity than single items and construct-specific subscales. Inter-observer reliabilities (Millstein et al., 2013) and associations with physical activity (Cain et al., 2017) in prior studies generally supported this expectation. Moreover, analysis of >60 items would have likely led to spurious findings.

Observation of only a limited sample of streetscapes starting from each participant's home address was a study limitation driven by the time-consuming nature of the coding and could have missed the most common walking path. The burdensome nature of the data collection has limited the growth of literature on micro-scale features. However, use of artificial intelligence, machine learning, and visual computing is likely to dramatically change the nature of such data collection. Recent papers have demonstrated the utility of automated assessment of streetscape greenery (Yang et al., 2021) and multiple streetscape features (Wang et al., 2022) in explaining physical activity of diverse samples. A short version of MAPS has been automated, with encouraging validity results (Koo et al., 2022). In the near future investigators may be able to use the new technologies to create detailed assessments of micro-scale environmental features for whole neighborhoods and cities.

As explained above, an important limitation was the restricted range of environmental variability, largely because the study was conducted in a small portion of a single county. Another important limitation was the very low levels of reported recreation MVPA and transport MVPA, further reducing power to detect associations. Although previous HCHS/SOL papers have reported higher means for time spent in active transport and active recreation (Arredondo et al., 2016), the present paper reports geometric rather than arithmetic means for these variables, due to their non-normal distributions. The physical activity measures did not reveal the location of the activity, even though it was expected micro-scale features would be most related to physical activity in and around the neighborhood. We recommend investigators of future studies to incorporate global positioning satellite (GPS) measures that would allow geolocation of physical activity. The present study only assessed micro-scale environments near the home, but it would also be valuable to conduct measures around other commonly visited places, such as worksites and shopping areas.

5. Conclusion

Voluminous evidence supports the importance of designing communities that support physically active lifestyles (Saelens and Handy, 2008; Sallis et al., 2012; Smith et al., 2017; Bauman et al., 2012; The Community Guide, 2021; Kärmeniemi et al., 2018), but few studies on this topic were conducted with Hispanic/Latino populations. The present study was intended to build on a small literature with mixed results regarding micro-scale built environment features such as sidewalks, street crossings, and aesthetics. The primary findings indicated none of the micro-scale environment scores had significant associations with any of the three physical activity outcomes while adjusting for demographics, macro-scale walkability, and neighborhood socioeconomic deprivation. However, marginal associations of streetscape characteristics with recreation MVPA and transport MVPA justify further study of micro-scale environment features and physical activity among Hispanics/Latinos. It is possible that limited variability in the environment variables and low levels of reported recreation MVPA and transportation MVPA seriously reduced power to detect associations. Some previous studies of environments and physical activity were designed to maximize variability in environments and socioeconomic status (e.g. Sallis et al., 2009), and we encourage investigators to ensure higher levels of neighborhood variability in future studies to examine associations between built environment attributes and physical activity among under-studied Hispanic/Latino populations.

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Data statement

HCHS/SOL data are publicly available through biolincc - https://biolincc.nhlbi.nih.gov/studies/hchssol/. SOL CASAS data will be posted on this site in the future.

Declaration of competing interest

JFS: Rails-to-Trails Conservancy, Board of Directors; AARP, Advisory Board for Livability Index. All other authors have no conflicts to declare.

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