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Does the social environment moderate associations of the built environment with Latinas' objectively-measured neighborhood outdoor physical activity?

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A B S T R A C T

Favorable perceptions of the built and social neighborhood environment may promote outdoor physical activity (PA). However, little is known about their independent and interactive effects on neighborhood-specific outdoor PA. We examined associations of perceived built and social neighborhood environment factors, and their interactions, with objectively-measured neighborhood outdoor moderate-to-vigorous physical activity (MVPA) among a sample of Latina women in San Diego, CA. Analyses included baseline data collected in 2011-2013 from 86 Latinas with ≥2 days of combined accelerometer and global positioning system data and complete survey measures. We examined objective neighborhood outdoor MVPA within 500-meter home buffers. Generalized linear mixed models examined associations of 3 perceived built (e.g., sidewalk maintenance) and 3 social environmental (e.g., safety from crime) factors with engaging in any daily neighborhood outdoor MVPA. Models tested interactions between the built and social environmental factors. Although the perceived neighborhood environmental factors were not significantly related to daily neighborhood outdoor MVPA, we found 2 significant interactions: perceived sidewalk maintenance x safety from crime ($p = 0.05$) and neighborhood aesthetics x neighborhood social cohesion ($p = 0.03$). Sidewalk maintenance was positively related to daily neighborhood outdoor MVPA only among Latinas that reported low levels of safety from crime. Neighborhood aesthetics was positively related to daily neighborhood outdoor MVPA only among Latinas with high neighborhood social cohesion. Findings suggest several built and social environmental factors interact to influence Latinas' neighborhood outdoor MVPA. Interventions are needed targeting both built and social neighborhood environmental factors favorable to outdoor PA in the neighborhood.

1. Introduction

Latinos are less likely than non-Latinos to engage in recommended levels of physical activity (PA) (U.S. Department of Health and Human Services, Office of Disease Prevention and Health Promotion; U.S. Department of Health and Human Services, 2008). In addition, compared to Latino men, Latina women report less leisure-time PA (15 vs. 30 min/day) and transportation-related PA (28 vs. 37 min/day) (Arredondo et al., 2016). One possible explanation for Latinas' low PA levels may be linked to perceptions that their neighborhood environment is not conducive to PA. Compared to residents of predominantly White neighborhoods, those living in neighborhoods with a higher racial/ethnic minority composition are more likely to evaluate their environments as being less safe, less comfortable (e.g., worse sidewalk conditions), and less pleasurable for outdoor PA (Franzini et al., 2010). Nevertheless, there is also evidence that Latinos tend to live in areas with high access to destinations near their homes (Franzini et al., 2010). Understanding the built and social environmental factors associated with outdoor PA in the neighborhood may help inform interventions to promote Latinas' PA (Hallal et al., 2005; Bedimo-Rung et al., 2005).

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Favorable perceived environmental factors are positively associated with PA (Ding and Gebel, 2012; Owen et al., 2000; Mama et al., 2015). Among Latinas, positive associations have been reported between perceived neighborhood aesthetics and leisure-time PA, as well as having access to destinations near the home and transportation PA (e.g., walking/cycling) (Perez et al., 2016a). Perceived neighborhood environmental factors are also positively related to objective PA (Mama et al., 2015; Saelens et al., 2003). However, one study involving Latinas in San Diego reported no associations between perceived environmental factors and objective PA (Perez et al., 2016a). Authors noted that the lack of association could have been because accelerometry is not specific to the home neighborhood. A more explicit link between PA and the neighborhood environment can be examined using simultaneous accelerometer-global positioning system (GPS) monitoring (Troped et al., 2010; Jankowska et al., 2015).

Furthermore, examining the interactive effects of built and social environmental factors may help us understand important nuances. Some studies suggest neighborhoods with higher proportions of Latino residents may be more walkable but have worse social environments, including lower perceptions of safety and less collective efficacy (i.e., social cohesion among neighbors and their willingness to intervene for the common good) (Franzini et al., 2010; Sampson et al., 1997; Lovasi et al., 2009; Foster and Giles-Corti, 2008). Residents of less socially-cohesive neighborhoods are less likely to walk for exercise than those living in more cohesive neighborhoods (Echeverría et al., 2008). Thus, despite living in neighborhoods with walkable urban form, adverse social environmental factors may inhibit Latinos' PA. Studies are needed that evaluate the interactions between built and social environmental factors in relation to neighborhood-specific PA (Ding and Gebel, 2012; Giles-Corti and Donovan, 2003).

This study aimed to test interactions among perceived built and social environmental factors in relation to Latinas' objectively-measured neighborhood outdoor PA. We hypothesized that perceived social environmental factors moderate associations of perceived built environmental factors with objectively-measured neighborhood outdoor PA, with positive associations expected only among those with favorable perceived social environments.

2. Methods

2.1. Participants and procedures

Participants were churchgoing Latinas (18-65 years) participating in *Fe en Acción* [Faith in Action], a two-group cluster randomized controlled trial to promote PA in San Diego, California. Participants completed anthropometric measurements and a survey in Spanish or English, and were asked to wear an accelerometer for 7 days. This study used baseline data only, which were collected between May 2011 and September 2013. In addition, from June 2012 through January 2013, global positioning systems (GPS) devices were distributed along with the accelerometer to integrate both sources of objective data for use in the geospatial research tool called the Personal Activity and Location Measurement System (PALMS) (Center for Wireless and Population Health Systems, University of California San Diego) and to evaluate these data in specific contexts (e.g., neighborhood). The Institutional Review Boards of San Diego State University and the University of California, San Diego approved this study.

The sampling and recruitment procedures for the sub-study involving the GPS are the same as for the main trial (Arredondo et al., 2015). In brief, research staff recruited 16 Catholic churches from two Major Statistical Areas (MSA) with large concentrations of Latino residents (San Diego Association of Governments (SANDAG) Data Warehouse, 2010). MSA's are aggregations of census tracts. Participant eligibility criteria were: 18 to 65 years of age, attended church at least 4 times/month, and reported no barriers to attending intervention activities or any health condition that could impede PA. Furthermore, women were eligible if they reported low activity on two screeners (Taylor-Piliae et al., 2006; Smith et al., 2005) (e.g., no PA or mostly light PA during leisure-time and work) and engaged in < 250 min/wk of accelerometer-based MVPA to allow for inclusion of participants most in need of a PA intervention.

Due to challenges in recruiting participants willing to wear both the accelerometer and GPS devices, researchers terminated the sub-study after recruitment of 4 churches. From these 4 churches, 203 women met the inclusion criteria and were invited to participate in the main trial. Participation was voluntary and participants could withdraw from the study at any time. Research assistants (RA) contacted the 132 women that signed an informed consent form. The GPS was optional and participants that agreed to wear the accelerometer but not the GPS were still invited to participate in the main trial. For the present study, we only analyzed data from participants that had complete survey, accelerometer, and GPS data. Reasons for dropping participants from analysis are depicted in Fig. 1. Because early in the data-cleaning phase, study staff noted that several participants had fewer days of GPS data compared to the accelerometer, possibly due to missing GPS signal or noncompliance with wearing or charging the GPS, we decided to reduce the wear time criteria for the analytical sample (≥2 valid days with ≥8 valid hours/day). The final analytical sample was 86 participants (range: 15-28 participants/church).

2.2. PA and spatial measures

Participants were asked to wear a GT3X accelerometer (Actigraph, Pensacola, FL) and a QStarz BT-Q1000XT GPS device (Qstarz International Co., Taipei, Taiwan, ROC) attached to an elastic belt worn over the hip on opposite sides for 7 days. Participants were instructed to charge the GPS each night, wear the devices during waking hours, and remove them only for sleep and water activities (e.g., bathing). ActiLife software version 6 (Actigraph, Pensacola, FL) was used to initialize accelerometers at 1-second epochs and Qstarz software (Qstarz International Co., Taipei, Taiwan, ROC) was used to initialize the GPS devices at 15-second epochs. We collected data at the maximum resolution (1 second epoch) that still allowed for 7 days of data collection. Using ActiLife, we reintegrated the data from 1-second to 15-second epochs to match the GPS epoch length. We used 15-second epochs to reduce misclassification error of PA estimates (e.g., minutes classified as light vs. MVPA) (Gabriel et al., 2010) and allow for greater precision in location detection and collection of data over the number of days required (Kerr et al., 2011) for the main trail (≥5 days, with ≥1 weekend day, and ≥10 hrs/day). Up to 2 re-wears were allowed if non-compliance was noted. Non-wear time was defined as ≥60 consecutive minutes of zero count values.

2.2.1. Data processing

The accelerometer and GPS 15-second epoch files were uploaded into PALMS, a web-based tool that integrates data from both devices. Details of the data processing steps can be found in the PALMS User Guide (Center for Wireless and Population Health Systems, 2011). PALMS synchronized the time-stamped files from both devices and merged them into one file for calculations and analysis. PALMS functions used for this study include indoor/outdoor detection (based on signal-to-noise ratio - SNR), location detection, and activity intensity. We defined MVPA as ≥2020 counts/min (Troiano et al., 2008). The SNR, which represents the strength of the signal from the satellites, was used to classify epochs as occurring indoors or outdoors, with outdoor time defined as SNR >225 (Lam et al., 2013).

2.2.2. Minutes of MVPA in the neighborhood buffer

Using ArcGIS (Esri, Redlands, CA), participants' home addresses were geocoded and plotted on a shapefile of San Diego County (San Diego Association of Governments (SANDAG) Data Warehouse, 2010). A 50-meter radial buffer was created around the geocoded address.

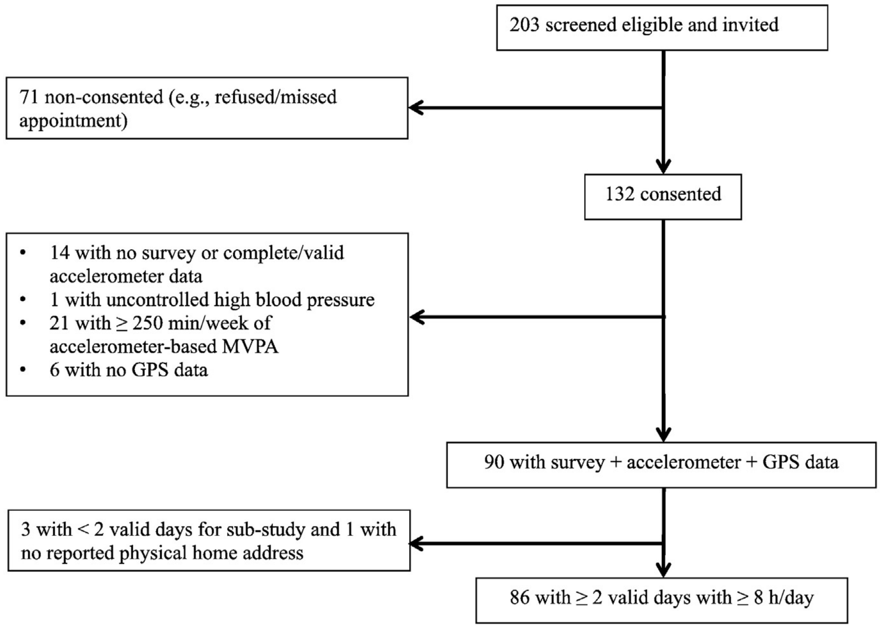

Fig. 1. Reduction of the study analytical sample. *Fe en Acción*, 2011-2013, San Diego, CA.

We also used a 500-meter street network buffer to represent the neighborhood around the home, which was chosen to be on the smaller end of buffer sizes (Adams et al., 2014) because of the low PA levels and thus potentially lower mobility of the sample. Non-walkable routes such as freeways were excluded from the street network buffer. The combined GPS-accelerometer data were linked to the participant buffer shapefiles. Data at the minute level were coded as 1 = '1 minute' or 0 = 'no minutes' in the neighborhood buffer. Because the focus of the present study was on neighborhood outdoor PA, the PA variable excluded activity in the home and any activity marked as taking place indoors (as per the SNR cut-off). Data were aggregated at the day-level for subsequent analysis. Due to the skewed distribution and low sample median for daily minutes of neighborhood outdoor MVPA, we created a binary variable categorizing participants as spending no versus any time in MVPA in the neighborhood buffer.

2.3. Perceived neighborhood environment

Prior to data collection, bilingual RAs reviewed the Spanish-translated versions of the perceived neighborhood environment items to ensure conceptual and linguistic equivalence with the English versions. Items used in this study included relevant built and social environmental factors identified in a focus group involving 25 churchgoing Latinas in San Diego (Martinez et al., 2009). Perceived built environmental factors included neighborhood aesthetics, sidewalk maintenance, and access to recreational facilities. Perceived social environmental factors included safety from traffic, safety from crime, and neighborhood social cohesion. Higher scores on each variable were indicative of more favorable neighborhood perceptions.

Items from the Abbreviated Neighborhood Environment Walkability Scale (NEWS-A) (Saelens et al., 2003) assessed neighborhood aesthetics (4 items such as "trees along the streets and attractive buildings/homes), safety from traffic (1 item), and safety from crime (2 items). Response options ranged from 1 = 'strongly disagree' to 5 = 'strongly agree.' We reverse coded negative statements and computed mean scores for aesthetics and safety from crime.

Items from the US Determinants of Exercise in Women Phone Survey (U.S. Determinants of Exercise in Women Phone Survey, 2012) assessed sidewalk maintenance (1 item) and access to recreational facilities (1 yes/no item). The sidewalk maintenance item was only asked to participants who reported having sidewalks in their neighborhood. Response options ranged from 1 = 'not at all maintained' to 4 = 'very well maintained.'

Neighborhood social cohesion was assessed using the 6-item Neighborhood Social Cohesion Scale (Seidman et al., 1995) (e.g., "I feel like I fit in with the people in my neighborhood"). Response options ranged from 1 = 'not at all true' to 3 = 'very true.' We reverse coded negative statements and computed a mean score (Seidman et al., 1995).

2.4. Participant characteristics

Demographic characteristics were assessed using questions from the 2005 Behavioral Risk Factor Surveillance System (BRFSS) questionnaire (Centers for Disease Control and Prevention (CDC), 2005) and included age, years living in the US, number of vehicles and adults living in the household, country of birth, employment status, monthly household income, education, and marital status. Household income was dichotomized using the median split of $2000/month, which translates to an annual income of about $24,000. Weight and height measures were collected by trained RAs following standard protocols (NHANES, 2005). Measurements were taken twice and averaged.

2.5. Data analyses

Socio-demographic, objective PA, and perceived neighborhood environmental characteristics were examined at the participant-level (N = 86). Chi-square or student t-tests examined differences in these characteristics by the outcome. Models examining the environment-PA associations and interactions were performed at the day-level (N = 494 days, n = 86 participants). When including all independent variables and covariates, the sample was reduced to 422 days due to missing data points for some of the variables. All continuous environmental variables were standardized to have a mean of 0 and standard deviation of 1. Generalized linear mixed-effects models with binomial distributions (Logistic models) were fitted to estimate associations of the 6 environmental variables with engaging in any daily neighborhood outdoor MVPA (yes/no). We also performed the analyses using a negative binomial error distribution to approximate the continuous distribution of the outcome and obtained similar results as the Logistic models; however, examination of the residuals showed that the negative binomial model did not offer the best fit.

To account for the nesting of the data (days within participants), participant ID was included as a random effect. With only 4 churches included in the analysis, clustering effects by the churches were not observed; nevertheless, we included church as a fixed effect to account for differences between the 4 churches. Models were adjusted for covariates found to be significantly correlated with neighborhood outdoor MVPA, including age, vehicle access, and employment status. The years of residence in the US variable was also related to the outcome but due to its high correlation with age, we only controlled for age. Although neighborhood total wear time was significantly correlated with neighborhood outdoor MVPA, we found low variability in neighborhood total wear time minutes within participant clusters (intraclass correlation = 0.54), suggesting high collinearity with the random effect participant ID, thus we did not include it in the model. Total wear time and time spent at home were not correlated with neighborhood outdoor MVPA and therefore not included. Additional models were fitted testing interactions for the 3 built X 3 social environment variables. A backwards elimination approach tested the significance of the interactions, starting with a full model with all 9 interactions. Interactions not significant at the $p<.10$ level were removed first, followed by those not significant at the .05 level. Using the model regression coefficients, significant interactions were plotted using templates developed by Dawson (Dawson). All statistical analyses were performed in SAS version 9.4 (SAS Institute Inc., Cary, North Carolina).

3. Results

The sample mean age was 45 years (Table 1). Most participants were born in Mexico (86%), employed (68%) and of low socio-economic status. Chi-square tests or student t-tests showed no significant differences on demographic variables between women excluded from the analyses and the analytical sample. There were also no significant differences between the two groups on the perceived environmental variables with the exception of safety from crime. The excluded women reported lower perceived safety from crime (mean $\pm$ SD = 2.7 $\pm$ 1.4) than the analytical sample (3.8 $\pm$ 1.2).

Overall, the mean total wear time was 797 min/day, with substantially more activity occurring in the home compared to the neighborhood (Table 1). Chi-square tests or student t-tests revealed that women who engaged in no versus any neighborhood outdoor MVPA did not differ significantly based on the socio-demographic variables, with the exception of years living in the US (those with no activity reported a longer residence in the US than those with any activity). Consistent with study criteria, the sample had low MVPA, with a mean of 12 min/day in MVPA (range: 1-33 min/day) and a median of 0.18 min/day of neighborhood outdoor MVPA (IQR = 2.1). In general, ratings were favorable for the neighborhood environmental factors (Table 1). Results showed a marginally significant association between neighborhood social cohesion and neighborhood outdoor MVPA (OR = 1.66, 95% CI = 0.96, 2.88) (Table 2). The models with the interactions found two statistically significant interaction terms: sidewalk maintenance x safety from crime ($p = 0.05$) and neighborhood aesthetics x neighborhood social cohesion ($p = 0.03$) (Table 2). Sidewalk maintenance was positively associated with engaging in any daily neighborhood outdoor MVPA only among participants with low perceived safety from crime (Fig. 2). Neighborhood aesthetics was positively associated with engaging in any daily neighborhood outdoor MVPA only among those with high neighborhood social cohesion (Fig. 3).

4. Discussion

As hypothesized, associations of perceived built environment with objectively-measured neighborhood outdoor MVPA differed by perceived social environment characteristics. Perceived neighborhood aesthetics was positively related to neighborhood outdoor MVPA among those with high neighborhood social cohesion. However, contrary to our expectations, perceived sidewalk maintenance was positively related to neighborhood outdoor MVPA among those with *low* levels of safety from crime. To our knowledge this is one of the first studies to examine associations of and interactions between perceived built and social environmental factors in relation to objectively-measured neighborhood outdoor MVPA among Latinas.

Participants spent a median of 9.5 min in MVPA/day, which is similar to the 8.2 median daily minutes among a predominantly African American and Latino female sample (Zenk et al., 2011). Just over half of participants (56%) had any outdoor MVPA in the neighborhood buffers. This reflects the study criteria to recruit less active Latinas. Participants with no neighborhood outdoor MVPA likely had higher levels of acculturation as noted by the higher number of years living in the US compared to those with any neighborhood outdoor MVPA. Other studies show lower levels of PA among Latinos with higher acculturation levels (Marquez and McAuley, 2006; Ham et al., 2007), including a previous *Fe en Acción* study (Perez et al., 2016b). The low levels of neighborhood outdoor MVPA in our sample may also be explained by a greater

Table 1
Descriptive characteristics of Latinas (18-65 years), CA, *Fe en Acción*, 2011-2013, San Diego, CA.

Characteristic	Neighborhood outdoor MVPA: None (n = 38) mean (SD) or %	Neighborhood outdoor MVPA: Any (n = 48) mean (SD) or %	Overall (N = 86) mean (SD) or %
Participant characteristics			
Age (years)	46.4 (10.3)	44.5 (8.5)	45.4 (9.3)
Years living in the US [a]	24.5 (11.1)	19.1 (8.0)	21.5 (9.8)
Vehicle access (# vehicles/adult in household)	0.8 (0.3)	0.7 (0.4)	0.7 (0.4)
Born in Mexico	86.5%	85.1%	85.7%
Employed	79.0%	59.6%	68.2%
Monthly household income < $2,000	60.5%	60.0%	60.2%
Less than high school completed	51.4%	60.4%	56.5%
Married or living as married	70.3%	77.1%	74.1%
Overweight or obese	89.5%	81.3%	84.9%
Objective physical activity			
Valid wear days	5.8 (0.9)	5.7 (0.9)	5.7 (0.9)
Total wear time (min/d)	808.1 (86.0)	787.8 (79.0)	796.7 (82.3)
Home total wear time (min/d)	363.7 (159.2)	418.0 (169.2)	394.0 (166.1)
Neighborhood total wear time (min/d), median (IQR) [a]	4.7 (4.3)	12.7 (20.2)	7.3 (12.3)
Total MVPA (min/d) [a]	10.0 (8.3)	14.3 (8.2)	12.4 (8.5)
Neighborhood outdoor MVPA (min/d), median (IQR) [a]	0 (0)	1.5 (3.1)	0.18 (2.1)
Perceived built environment [b]			
Neighborhood aesthetics (range: 1-5)	3.1 (1.0)	3.1 (1.2)	3.1 (1.1)
Sidewalk maintenance (range: 1-4) [c]	3.5 (0.7)	3.4 (0.7)	3.4 (0.7)
Has access to recreational facilities in the neighborhood	86.8%	85.1%	85.9%
Perceived social environment [b]			
Neighborhood social cohesion (range: 1-3)	2.4 (0.4)	2.5 (0.3)	2.5 (0.4)
Safety from traffic (range: 1-5)	3.5 (1.3)	3.7 (1.3)	3.6 (1.3)
Safety from crime (range: 1-5)	3.8 (1.2)	3.8 (1.3)	3.8 (1.2)

IQR = Interquartile range; MVPA = moderate-to-vigorous physical activity.
[a] Groups are significantly different at $p<0.05$.
[b] Higher scores indicative of more favorable evaluation.
[c] Item was only asked to those reporting having sidewalks in their neighborhood (n = 79 women).

Table 2
Multivariate associations of neighborhood environment factors with engaging in any neighborhood outdoor MVPA among Latinas (N = 422 days, n = 86 women). *Fe en Acción*, 2011-2013, San Diego, CA.

Neighborhood characteristic	Odds ratio [b]	95% CI	*p*-value
Initial model without interactions			
Built environment			
Has access to recreational facilities in the neighborhood	0.43	0.08, 2.20	0.31
Aesthetics [a]	0.83	0.48, 1.43	0.50
Sidewalk maintenance [a]	1.15	0.65, 2.02	0.63
Social environment			
Safety from traffic [a]	0.99	0.52, 1.89	0.98
Safety from crime [a]	0.83	0.45, 1.53	0.54
Neighborhood social cohesion [a]	1.66	0.96, 2.88	0.07
Model with significant interactions			
Built environment			
Has access to recreational facilities in the neighborhood	0.35	0.06, 1.92	0.23
Aesthetics [a]	0.85	0.49, 1.47	0.55
Sidewalk maintenance [a]	1.30	0.75, 2.27	0.35
Social environment			
Safety from traffic [a]	0.99	0.52, 1.91	0.99
Safety from crime [a]	0.75	0.40, 1.39	0.36
Neighborhood social cohesion [a]	2.22	1.19, 4.16	0.01
Sidewalk maintenance x safety from crime	0.53	0.28, 1.00	**0.05**
Neighborhood aesthetics x neighborhood social cohesion	2.04	1.07, 3.86	**0.03**

MVPA = moderate-to-vigorous physical activity.
[a] Variable is standardized to have a mean = 0 and standard deviation = 1.
[b] Generalized linear mixed effects models with binary distribution, accounting for participant clustering effects. Model is adjusted for participant age, church site, vehicle access, and employment status.

proportion of time being spent at work or in the home. Our data showed that the total wear time in the home buffer was substantially higher than the total wear time in the neighborhood buffer.

Among the few studies that have examined moderators of PA, none have used objective measures of outdoor PA. One study tested interactions of the built environment with perceptions of crime and safety variables in relation to accelerometer-based MVPA and self-report walking and found inconsistent patterns (Bracy et al., 2014). Our study adds to research on the influence of social environmental factors on built environment-PA associations by providing more support for interactions; however, findings were not straight-forward.

Sidewalk maintenance was inversely related to neighborhood outdoor MVPA only among those with higher perceived safety from crime. This finding contradicts our hypothesis that at favorable levels of perceived sidewalk maintenance, neighborhood outdoor MVPA would be greater among Latinas with higher perceived safety from crime than those perceiving lower safety. Although evidence linking sidewalk maintenance with PA has been limited, one study involving over 1,000 adults from two cites of high/low walkability also found an unexpected inverse relationship between sidewalk maintenance and self-report transportation-related PA (Hoehner et al., 2005). The authors attributed this contradictory finding to possible neighborhood income effects. Less maintained sidewalks were likely concentrated in lower-income areas where residents walked/bicycled for transportation despite sidewalk conditions (Hoehner et al., 2005). Because individual- and neighborhood-level income measures demonstrate poor agreement (Southern et al., 2005), examination of the effects of neighborhood income independent of individual household income is important. Although we did not measure neighborhood income, participants that perceived less maintained sidewalks may have lived in lower-income neighborhoods where those that perceived greater safety from crime did more activity outside in their neighborhood, including necessity-driven behaviors like transportation PA, than those reporting less safety. In contrast, higher-income neighborhoods may have had better maintained sidewalks and residents reporting less safety from crime may have spent more active time outside in their neighborhoods and thus were more aware of crime than those not spending much time outside. Some evidence indicates that individuals who spend more time outdoors may be more aware and/or more critical of their environments (Adams et al., 2009). Overall, our finding suggests that both safety from crime and sidewalk conditions may be important environmental targets for promoting neighborhood outdoor PA among Latinas.

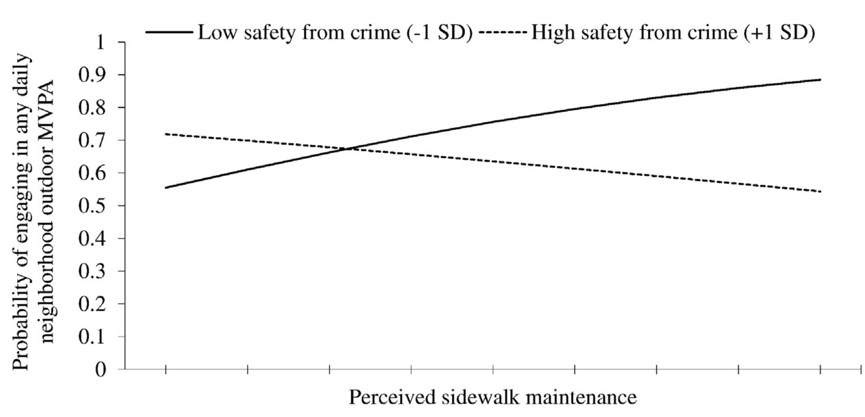

Fig. 2. Interaction between perceived sidewalk maintenance and safety from crime on objectively-measured neighborhood outdoor moderate-to-vigorous physical activity (MVPA) among participants. *Fe en Acción*, 2011-2013, San Diego, CA.

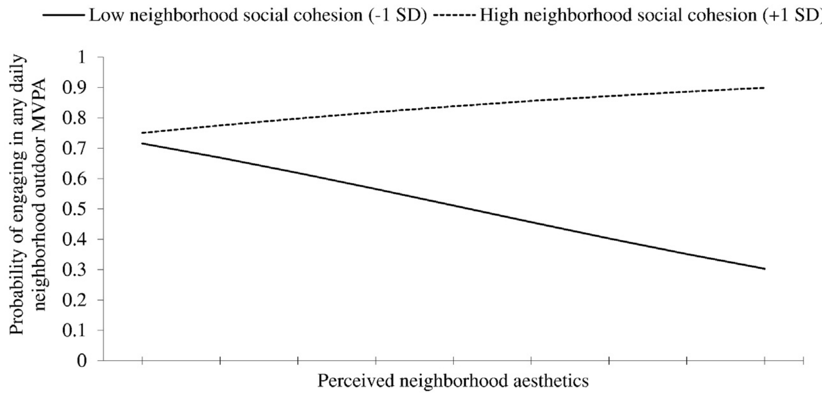

Fig. 3. Interaction between perceived neighborhood aesthetics and neighborhood social cohesion on objectively-measured neighborhood outdoor moderate-to-vigorous physical activity (MVPA) among participants. *Fe en Acción*, 2011-2013, San Diego, CA.

The interaction between neighborhood aesthetics and neighborhood social cohesion suggests that neighborhood aesthetics are positively related to neighborhood outdoor MVPA only among Latinas with higher neighborhood social cohesion. Participants that reported higher neighborhood social cohesion may have spent more time outside in their neighborhood to engage with neighbors or to be physically active. In turn, being outside may have made them more aware of their surroundings (presence of trees, landscaping, etc.) (Adams et al., 2009). It is also possible that pleasant neighborhood aesthetics encouraged women to be outside to engage with neighbors or PA. Improving neighborhood social cohesion may be a promising approach for promoting outdoor PA among Latinas. Multilevel interventions led by *promotoras* (community health workers) from participants' own neighborhoods, for example, have improved Latinas' neighborhood social cohesion and PA (Martinez et al., 2012).

4.1. Limitations and Strengths

There was limited variability in PA among the sample given our inclusion criteria. Perceptions of the neighborhood environment may have had limited variability since participants reported living close to one of the 4 participating churches. Insufficient variability in participant and neighborhood characteristics limits the external validity of study findings. Low variability in the perceived neighborhood environment scores may have also resulted in null associations with neighborhood outdoor MVPA. Nevertheless, findings are relevant to Latinas in the US given less than half of them meet PA recommendations (U.S. Department of Health and Human Services, Office of Disease Prevention and Health Promotion). Another limitation is that the cut-point used to detect neighborhood outdoor MVPA has only been validated in one study (Lam et al., 2013). Additional studies are needed to validate the indoor/outdoor detection cut-offs. Our use of only one buffer size may not be representative of what participants perceived as their 'neighborhood,' yet there has not been a clearly established buffer size for the neighborhood; 500 meters has been used in other studies (Adams et al., 2014; Bracy et al., 2014). We did not objectively assess the neighborhood environment, which is important when considering neighborhood environment-PA associations. We did not create a cumulative environmental index, which would provide an indication of overall neighborhood walkability; this was beyond the scope of this paper. Also, data collection with accelerometer and GPS measures was complex, with recruitment of participants to wear both devices being a challenge, and the data processing and complexity of the data requiring the involvement of highly-trained and knowledgeable staff.

With the exception of the access to recreational facilities variable, built and social environmental characteristics examined in this study are more relevant to outdoor rather than indoor activity. This study is innovative in that it focused on objective outdoor MVPA in the neighborhood. While the sample size was small, modeling neighborhood outdoor MVPA at the day level added statistical power.

Our study is among the first to examine objectively-measured neighborhood outdoor MVPA and to test for interactions between perceived built and social environmental factors among a sample of Latinas. Thus, to elicit stronger recommendations for interventions, additional studies are needed to confirm our findings. In particular, prospective studies can test whether improvements to neighborhood social environmental factors can facilitate Latinas' neighborhood outdoor PA.

Conflicts of interest

The authors declare that there are no conflicts of interest.

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References

Adams, M.A., Ryan, S., Kerr, J., et al., 2009. Validation of the Neighborhood Environment Walkability Scale (NEWS) items using geographic information systems. J. Phys. Act. Health 6 (Suppl. 1), S113–S123.

Adams, M.A., Frank, L.D., Schipperijn, J., et al., 2014. International variation in neighborhood walkability, transit, and recreation environments using geographic information systems: the IPEN adult study. Int. J. Health Geogr. 13, 43.

Arredondo, E.M., Haughton, J., Ayala, G.X., et al., 2015. Fe en Acción/Faith in Action: Design and implementation of a church-based randomized trial to promote physical activity and cancer screening among churchgoing Latinas. Contemp. Clin. Trials 45 (Part B): 404–415. http://dx.doi.org/10.1016/j.cct.2015.09.008.

Arredondo, E.M., Sotres-Alvarez, D., Stoutenberg, M., et al., 2016. Physical activity levels in U.S. Latino/Hispanic adults: Results from the Hispanic Community Health Study/Study of Latinos. Am. J. Prev. Med. 50 (4):500–508. http://dx.doi.org/10.1016/j.amepre.2015.08.029.

Bedimo-Rung, A.L., Mowen, A.J., Cohen, D.A., 2005. The significance of parks to physical activity and public health: a conceptual model. Am. J. Prev. Med. 28 (2 Suppl. 2), 159–168.

Bracy, N.L., Millstein, R.A., Carlson, J.A., et al., 2014. Is the relationship between the built environment and physical activity moderatred by perceptions of crime and safety. Int. J. Behav. Nutr. Phys. Act. 11 (1), 24.

Center for Wireless and Population Health Systems, 2011. Personal Activity Location Measurement System User Guide. https://ucsd-palms-project.wikispaces.com/file/view/PALMS%20USERGUIDE%20FINAL%2011-21-11.pdf/277913422/PALMS%20USERGUIDE%20FINAL%2011-21-11.pdf (Accessed February 1, 2015).

Center for Wireless and Population Health Systems, University of California San Diego, i. Personal Activity and Location Measurement System (PALMS)http://ucsd-palms-project.wikispaces.com/ (Accessed February 1, 2015).
Centers for Disease Control and Prevention (CDC), 2005. Behavioral Risk Factor Surveillance System Questionnaire. http://www.cdc.gov/brfss/annual_data/pdf-ques/2005brfss.pdf Accessed January 10, 2015.
Dawson, J., d. Interpreting interaction effectshttp://www.jeremydawson.co.uk/slopes.htm (Accessed June 30, 2015).
Ding, D., Gebel, K., 2012. Built environment, physical activity, and obesity: What have we learned from reviewing the literature? Health Place 18 (1), 100–105.
Echeverría, S., Diez-Roux, A.V., Shea, S., Borrell, L.N., Jackson, S., 2008. Associations of neighborhood problems and neighborhood social cohesion with mental health and health behaviors: The Multi-Ethnic Study of Atherosclerosis. Health Place 14 (4), 853–865.
Foster, S., Giles-Corti, B., 2008. The built environment, neighborhood crime and constrained physical activity: an exploration of inconsistent findings. Prev. Med. 47 (3), 241–251.
Franzini, L., Taylor, W., Elliott, M.N., et al., 2010. Neighborhood characteristics favorable to outdoor physical activity: Disparities by socioeconomic and racial/ethnic composition. Health Place 16 (2), 267–274.
Gabriel, K.P., McClain, J.J., Schmid, K.K., et al., 2010. Issues in accelerometer methodology: the role of epoch length on estimates of physical activity and relationships with health outcomes in overweight, post-menopausal women. Int. J. Behav. Nutr. Phys. Act. 7, 53.
Giles-Corti, B., Donovan, R.J., 2003. Relative influences of individual, social environmental, and physical environmental correlates of walking. Am. J. Public Health 93 (9), 1583–1589.
Hallal, P.C., Azevedo, M.R., Reichert, F.F., Siqueira, F.V., Araújo, C.L., Victora, C.G., 2005. Who, when, and how much?: Epidemiology of walking in a middle-income country. Am. J. Prev. Med. 28 (2), 156–161.
Ham, S.A., Yore, M.M., Kruger, J., Heath, G.W., Moeti, R., 2007. Physical activity patterns among Latinos in the United States: putting the pieces together. Prev. Chronic Dis. 4 (4), A92.
Hoehner, C.M., Brennan Ramirez, L.K., Elliott, M.B., Handy, S.L., Brownson, R.C., 2005. Perceived and objective environmental measures and physical activity among urban adults. Am. J. Prev. Med. 28 (2 Suppl. 2), 105–116.
Jankowska, M.M., Schipperijn, J., Kerr, J., 2015. A framework for using GPS data in physical activity and sedentary behavior studies. Exerc. Sport Sci. Rev. 43 (1), 48–56.
Kerr, J., Duncan, S., Schipperijn, J., 2011. Using global positioning systems in health research: a practical approach to data collection and processing. Am. J. Prev. Med. 41 (5), 532–540.
Lam, M.S., Godbole, S., Chen, J., et al., 2013. Measuring time spent outdoors using a wearable camera and GPS. Paper presented at: *Proceedings of the 4th International SenseCam & Pervasive Imaging Conference*. Association for Computing Machinery, New York, NY.
Lovasi, G.S., Hutson, M.A., Guerra, M., Neckerman, K.M., 2009. Built environments and obesity in disadvantaged populations. Epidemiol. Rev. 31, 7–20.
Mama, S., Diamond, P., McCurdy, S., Evans, A., McNeill, L., Lee, R., 2015. Individual, social, and environmental correlates of physical activity in overweight and obese African American and Hispanic women: a structural equation model analysis. Prev. Med. 2, 57–64.
Marquez, D.X., McAuley, E., 2006. Gender and acculturation influences on physical activity in Latino adults. Ann. Behav. Med. 31 (2), 138–144.
Martinez, S.M., Arredondo, E.M., Perez, G., Baquero, B., 2009. Individual, social, and environmental barriers to and facilitators of physical activity among Latinas living in San Diego County: Focus group results. Fam. Community Health 32 (1), 22–33.
Martinez, S.M., Arredondo, E.M., Roesch, S., 2012. Physical activity promotion among churchgoing Latinas in San Diego, California: Does neighborhood cohesion matter? J. Health Psychol. 18 (10), 1319–1329.
NHANES Anthropometry Procedures Manual 2005http://www.cdc.gov/nchs/data/nhanes/nhanes_09_10/BodyMeasures_09.pdf (Accessed January 10, 2015).
Owen, N., Leslie, E., Salmon, J., Fotheringham, M.J., 2000. Environmental determinants of physical activity and sedentary behavior. Exerc. Sport Sci. Rev. 28 (4), 153–158.
Perez, L.G., Slymen, D., Sallis, J.F., Ayala, G.X., Elder, J.P., Arredondo, E.M., 2016a. Interactions between individual and environmental factors on Latinas' physical activity. J. Public Health http://dx.doi.org/10.1093/pubmed/fdw061.
Perez, L.G., Chavez, A., Marquez, D.X., Soto, S.C., Haughton, J., Arredondo, E.M., 2016b. Associations of acculturation with self-report and objective physical activity and sedentary behaviors among Latinas. Health Educ. Behav. http://dx.doi.org/10.1177/1090198116669802.
Saelens, B.E., Sallis, J.F., Black, J.B., Chen, D., 2003. Neighborhood-based differences in physical activity: an environment scale evaluation. Am. J. Public Health 93 (9), 1552–1558.
Sampson, R.J., Raudenbush, S.W., Earls, F., 1997. Neighborhoods and violent crime: a multilevel study of collective efficacy. Science 277, 918–924.
San Diego Association of Governments (SANDAG) Data Warehouse, 2010s. http://www.sandag.org (Accessed May 1, 2015).
Seidman, E., Allen, L., Aber, J.L., et al., 1995. Development and validation of adolescent-perceived microsystem scales: social support, daily hassles, and involvement. Am. J. Community Psychol. 23 (3), 355–388.
Smith, B.J., Marshall, A.L., Huang, N., 2005. Screening for physical activity in family practice: evaluation of two brief assessment tools. Am. J. Prev. Med. 29 (4), 256–264.
Southern, D.A., McLaren, L., Hawe, P., Knudtson, M.L., Ghali, W.A., APPROACH Investigators, 2005. Individual-level and neighborhood-level income measures: agreement and association with outcomes in a cardiac disease cohort. Med. Care 43 (11), 1116–1122.
Taylor-Piliae, R.E., Norton, L.C., Haskell, W.L., et al., 2006. Validation of a new brief physical activity survey among men and women aged 60-69 years. Am. J. Epidemiol. 164 (6), 598–606.
Troiano, R.P., Berrigan, D., Dodd, K.W., Masse, L.C., Tilert, T., McDowell, M., 2008. Physical activity in the United States measured by accelerometer. Med. Sci. Sports Exerc. 40 (1), 181–188.
Troped, P.J., Wilson, J.S., Matthews, C.E., Cromley, E.K., Melly, S.J., 2010. The built environment and location-based physical activity. Am. J. Prev. Med. 38 (4), 429–438.
U.S. Department of Health and Human Services, 2008. 2008 Physical Activity Guidelines for Americans. US Department of Health and Human Services, Office of Disease Prevention and Health Promotion, Rockville, MD, pp. 21–28.
U.S. Department of Health and Human Services, Office of Disease Prevention and Health Promotion, e. Healthy People 2020http://www.healthypeople.gov/2020/data/SearchResult.aspx (Accessed August 1, 2015).
U.S. Determinants of Exercise in Women Phone Survey, 2012. http://www.midss.ie (Accessed May 1, 2015).
Zenk, S., Schulz, A., Matthews, S., et al., 2011. Activity space environment and dietary and physical activity behaviors: a pilot study. Health Place 17, 1150–1161.