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Associations Between Worksite Walkability, Greenness, and Physical Activity Around Work

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Abstract

This article explores the role of the work environment in determining physical activity gained within and around the workplace. With most adults spending more than half of their waking day at work, the workplace is a promising venue for promoting physical activity. We used a sample of 147 employed women—median age = 53 years old; 42% meeting Centers for Disease Control and Prevention (CDC) physical activity recommendations—wearing a GPS device and accelerometer on the hip for 7 days to assess location and physical activity at minute-level epochs. We analyzed the association between geographic information systems (GIS) measures of walkability and greenness around the workplace and the amount of physical activity gained while in the work neighborhood. Our results showed that working in high walkable environments was associated with higher levels of moderate to vigorous physical activity while at work, and with higher moderate to

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vigorous physical activity gained within the work neighborhood. Increasing walkability levels around workplaces can contribute to increasing physical activity of employees.

Keywords
worksite environment, physical activity, walkability, greenness, accelerometry, global positioning systems

Introduction

Physical inactivity is a widely recognized global health risk (World Health Organization, 2010). Few Americans get an adequate amount of physical activity (PA) with only 10% of adults reaching Centers for Disease Control and Prevention (CDC) PA recommendations (Tucker, Welk, & Beyler, 2011). Lack of PA also contributes to the high prevalence of obesity and overweight persons in the United States (Pate, Taverno Ross, Liese, & Dowda, 2015). Given that most adults spend half of their waking day in their work environment (Hipp et al., 2015), the workplace could be an important venue for the promotion of health and PA (Memish, Martin, Bartlett, Dawkins, & Sanderson, 2017; van Uffelen et al., 2010).

The socio-ecological framework suggests that beyond the individual, environments have important relationships with behavior (Tabak, Hipp, Marx, & Brownson, 2015). Strategies aimed at increasing PA at the same time need to target multiple levels and settings of the ecologic framework, including the worksite (Hipp et al., 2015). Walkable environments, characterized by density, connectivity, and land use diversity (Forsyth, 2015) can increase the amount of active commuting (Frank, Bradley, Kavage, Chapman, & Lawton, 2008), as well as short active trips taken throughout the working day (Forsyth & Oakes, 2014; Gehrke & Welch, 2017). At the same time, working in a natural and aesthetically pleasing environment can foster going out for a walk in the middle of the day, or encourage walking meetings. Thus, the built and natural environment around the workplace can potentially play an important role in promoting healthy behaviors in a typically sedentary venue (Hipp et al., 2015). This potential, however, has been largely understudied (Schwartz, Aytur, Evenson, & Rodríguez, 2009), with the majority of work-centered health promotion initiatives being focused on interventions and structured programs that take place inside the workplace (Gazmararian, Elon, Newsome, Schild, & Jacobson, 2013; Loeppke, Edington, Bender, & Reynolds, 2013; Parry, Straker, Gilson, & Smith, 2013; Quintiliani, Sattelmair, Activity, & Sorensen, 2007; Shrestha, Ijaz, Kt, Kumar, & Cp, 2015). Understanding whether worksite neighborhoods influence walking offers important benefits. Such studies could provide evidence to encourage employers to promote worksites that are pedestrian friendly, located in well-designed green environments, and include programs that support outdoor PA.

Promoting PA while at work is important beyond just meeting PA guidelines. Sedentary behaviors such as sitting for long periods of time (Chau et al., 2013) or in large uninterrupted bouts (Honda et al., 2016) that characterize many workplaces have been found to be particularly harmful, even beyond the effects of physical inactivity (van der Ploeg & Hillsdon, 2017). In the specific case of women, sitting for more than 8 hr/day was associated with a 45% to 65% increased risk of mortality over the next 9 years (Pavey, Peeters, & Brown, 2012). While some negative effects of sedentarism can be compensated for through increases in moderate to vigorous physical activity (MVPA), research shows that this compensation occurs only at very high doses of PA (Ekelund et al., 2016).

PA can be encouraged and sustained through walkable and amenable built and natural environments. In recent years, the role of the residential environment in fostering healthy behaviors has been extensively studied (Brownson, Hoehner, Day, Forsyth, & Sallis, 2009; Parra et al., 2010). Researchers have found that people who live in more walkable environments tend to have lower body mass index (BMI; Brownson et al., 2009; Hoehner, Handy, Yan, Blair, & Berrigan, 2011; Norman et al., 2013), walk more for utilitarian purposes (Jack & McCormack, 2014; Thielman, Rosella, Copes, Lebenbaum, & Manson, 2015; Wasfi, Dasgupta, Eluru, & Ross, 2016), and have higher levels of MVPA (Sundquist et al., 2011) and overall PA (Kondo et al., 2009; Wineman et al., 2014). At the same time, living in greener neighborhoods has been linked with more walking trips (Tilt, Unfried, & Roca, 2007), PA (McMorris, Villeneuve, Su, & Jerrett, 2015; Richardson, Pearce, Mitchell, & Kingham, 2013; Schipperijn, Bentsen, Troelsen, Toftager, & Stigsdotter, 2013), and lower BMI levels (Tilt et al., 2007).

Much less attention, however, has been paid to how the work environment affects behavior, and only a handful of studies have tried to assess whether the built and natural environment around the workplace can also encourage PA (Adams, Bull, & Foster, 2016; Adlakha et al., 2015; Schwartz et al., 2009). Adams et al. (2016) found self-reported perceptions of the built environment around work to be positively correlated with commuter walking in a study set in the United Kingdom. In the U.S. context, Adlakha et al. (2015) found factors such as the presence of bike facilities, interesting things to look at, and crime rates to significantly predict workplace PA, while Forsyth and Oakes (2014) found the attributes of the built environment around work to be associated with walking for transport but not for total PA. Finally, and also in the United States, Schwartz et al. (2009) reported a lack of significant associations between perceived attributes of the built environment around work and average weekday steps measured by accelerometer.

Overall, research on the relationship between the built environment and PA around work has been scarce and its findings have been inconsistent. However, this is an important area of inquiry because different domains and types of activities are associated with specific features of the built and natural environment (Barrington, Beresford, Koepsell, Duncan, & Moudon, 2015). PA gained from different activities—for example, recreation, transportation—are not associated with the same environmental attributes (Van Holle et al., 2012). Thus, PA gained around work may not depend on the same built environment features as PA gained around the home.

Specifically, there is a need to analyze how the work environment contributes to PA gained in the work domain, either inside the workplace or in its vicinities. With notable exceptions reported by Troped, Wilson, Matthews, Cromley, and Melly (2010) and Forsyth and Oakes (2014), previous research has used either subjective measures of built environment or self-reported PA (Yang et al., 2014). Relying exclusively on subjective or self-reported measures may result in intended or unintended bias. Sebastião et al. (2012) found participants generally overestimating their levels of PA, and found these distortions to be particularly high when trying to assess work-related PA. Others have found that people tend to over-report travel times and activity times (Delclòs-Alió, Marquet, & Miralles-Guasch, 2017; Kelly, Krenn, Titze, Stopher, & Foster, 2013).

In addition, active behavior around the workplace should be considered in relation within the set of spatial locations accessed by individuals on any given day, that is, their activity space (Chaix et al., 2012). Even when the research focus is on the environmental determinants of work PA, one should also account for the role that the residential environment plays at determining the behavior throughout the daily activity space (Chaix et al., 2017). Access to a trail next to home might reduce the need for going out for a walk in the middle of the workday. Similarly, an individual living in a nonurban area might not have the possibility of shopping around the home, increasing the need for shopping and making errands around the workplace. In the same way, living in high walkable areas might encourage people to choose transit or active modes of transport over the car, a decision that would also affect the amount of PA gained while moving around work (Foley, Panter, Heinen, Prins, & Ogilvie, 2015). Residential self-selection might encourage healthier and more active people to live in more walkable or greener environments, preferences that would be translated also into their behavior around the workplace (Inagami, Cohen, & Finch, 2007). Because of these factors, the work environment should not be considered in isolation, but in relation to the residential environment. As a final point, and because the associations between the built environment and PA may be influenced by each individual typical levels of PA, it is also important to adjust the statistical analysis to the amount of nonwork-related PA of each participant.

Using geographic information systems (GIS)-based measures of walkability and greenness together with accelerometer-based measures of PA allows us to understand how work environments may support PA during work hours. In this context, this study examines how work environments encourage PA, using accelerometer-based measures of PA along with GIS-based measures of walkability and greenness around the workplace and residence. It is hypothesized as follows:

Hypothesis 1: High levels of walkability around the workplace are associated with higher levels of MVPA.
Hypothesis 2: Working in a greener environment is also associated with higher levels of PA in and around work.
Hypothesis 3: Higher levels of walkability around both home and residence will be more strongly associated with higher MVPA, than walkability around the workplace alone.

Data and Method

Participants and Data Processing

The study used a convenience sample of 353 women living in or near San Diego, CA; Philadelphia, PA; St. Louis, MO; and other parts of the United States (James et al., 2014; Mitchell et al., 2016). The decision to focus on women only responds to the need to develop research and interventions targeted toward specific groups more often affected by inactivity (European Commission, 2017). Data were collected in 2012 and analyzed in 2017 following identical measurement protocols, and all participants provided informed consent. Each study site received its own institutional review board approval. Participants were asked to wear a GPS device and accelerometer for 7 days (Kerr et al., 2017; Mitchell et al., 2016). From the total sample of 353 women, who were between 21 and 75 years old and with self-reported BMI between 21 and 39.9 kg/m^2 (Mitchell et al., 2016), we selected only full-time employees with geolocated work and home addresses (n = 147, Table 2). Unemployed participants (n = 9), part-time workers (n = 55), participants who worked from home (n = 24), or participants lacking a valid home and work address were excluded.

Accelerometer data processing. Data from 7-day hip-accelerometer tracking provided estimates of energy expenditure. Participants wore hip accelerometers (ActiGraph GT3X+) for a minimum of 10 waking hours per day, to be included in the analysis. A cut point of >1,040 counts per minute was used to define MVPA, with sedentary behavior defined as <100 counts per minute (Meseck et al., 2016). In all, 10-s count data were categorized into minutes spent in sedentary, light, moderate, and vigorous activity. GPS data were collected using the QStarz BT-Q1000X device. Accelerometer and GPS data were merged using PALMS software (James et al., 2016).

Location processing. We refined the geolocation of work and home addresses using the centroid of all GPS points accumulated within a 400-m buffer of the self-reported home and worksite addresses. This process created a more accurate location of the actual worksite and residence, based on where the participants spent most of their work or home time, and it avoided basing our analysis on potentially misplaced street addresses. All geospatial analyses were performed using ArcGIS 10.3 software.

Measures

PA. To define PA that occurred around the workplace, we used a 40- to 400-m radial donut buffer around the work address. A 400-m buffer is commonly used to represent the reachable area in a short trip (<10-min walk; Berrigan et al., 2015). Circular buffers were used instead of network linear buffers to reduce missing data due to GPS-related errors (James et al., 2014). Similar to Troped et al. (2010), we categorized all points registered within less than 40 m of the workplace to be worksite PA. All points made between 40 m and 400 m of the workplace were categorized as PA gained while in the worksite neighborhood. MVPA recorded while at work and MVPA recorded while in the work neighborhood (40-400 m radial donut buffer) were computed and used as dependent variables. Both measures were standardized by the number of hours spent at work by each participant.

Walkability. Two different measures assessed walkability of the environment. As walkability indexes composed of aggregated density, connectivity, and land use mix values are commonly used in environmental studies (Brown et al., 2009; Frank et al., 2006; Frank et al., 2010), we calculated a walkability index based on data from the Smart Location Database developed by the U.S. Environmental Protection Agency (EPA; Ramsey & Bell, 2014). This database includes nationwide census block group level data. We then used *Z* scores of gross population density, street intersection density, and land use entropy to calculate a walkability index at the census block group level and then used a 400-m buffer around the workplace and the residence to estimate an average walkability score.

The second measure of walkability focused exclusively on destination access, and was obtained through the Walkscore© algorithm. Walkscore© data have also been used extensively in research and walkability studies (Forsyth, 2015; Hirsch, Winters, Ashe, Clarke, & McKay, 2016; Langlois, Wasfi, Ross, & El-Geneidy, 2016) and is a measure of density of economic activity based on Google map distance to desirable destinations such as stores, restaurants, or public transport. Despite incorporating in its most recent versions some measure of urban attributes—such as block sizes—Walkscore© is mainly determined by the number of facilities that are within a reachable distance of an address. Walkscores© were obtained for each participant's work and residential address.

These two separate indices correspond with two different approaches to measuring land use mix within walkability indices: the first one uses a land use entropy index and the second one uses a destination-based approach (Manaugh & Kreider, 2013). Areas with a high mix of land use score higher on the entropy index, but as discussed by Brown et al. (2009) using only an entropy index, obscure the contribution of the separate land use categories to the walkability score. In fact, entropy is a measure of the balance between land uses that treats all land uses equally without always recognizing that some land uses are more correlated with walking (Dovey & Pafka, 2017). On the contrary, destination-based measures such as Walkscore© also have conceptual and measurement limitations, often revolving around the assumption that all destinations are valued equally across population groups (Brown et al., 2009; Dovey & Pafka, 2017). Because of that, Walkscores© often correlate with walkability index values, but with the two measures being focused on different aspects of walkability that is not always the case (Manaugh & El-Geneidy, 2011).

Greenness. The Normalized Difference Vegetation Index (NDVI) served as the measure of greenness. NDVI is a commonly used measure of vegetation in epidemiological studies (Balseviciene et al., 2014; McMorris et al., 2015) and captures the degree of vegetation derived from satellite imagery. For this study, we used data from the Moderate-Resolution Imaging Spectroradiometer (MODIS) from NASA's Terra satellite, collected in 2012 to approximate the time of data collection. NDVI values range from −1 and +1; higher values represent greener areas (Almanza, Jerrett, Dunton, Seto, & Ann Pentz, 2012). An average greenness score of the area contained within a 400-m radial buffer was obtained both for residential and workplace addresses following a common procedure in greenspace environmental research (Tilt et al., 2007).

Statistical Analysis

To examine associations between walkability and greenness of the work environment and MVPA gained while in the work neighborhood, we used multilevel linear regression models. The models accounted for the nested structure of the data, with minute-level PA locations set within days and within participants. We regressed each of the environment variables on PA. Because PA variables were highly positively skewed, multivariate analyses were performed using Box-Cox transformed variables. The models controlled for age, children in the household, income, work–home distance of each participant and leisure PA, and incorporated each study site as a random effect. We adjusted for socioeconomic variables such as age or income, as lower socioeconomic position is often correlated with occupational sitting, car ownership—and time spent inside it—or time spent in other sedentary activities such as watching TV (Stamatakis, Coombs, Rowlands, Shelton, & Hillsdon, 2014; van der Ploeg & Hillsdon, 2017). We also adjusted for having children, as the presence of children in the household introduces time constraints and out-of-work obligations that might alter participants' behavior. Finally, we adjusted for the amount of nonwork-related PA of each participant to account for any personal preferences toward PA that might affect the relationships between environment and PA around work (van der Velde, Savelberg, Schaper, & Koster, 2015). Two measures of PA served as dependent variables in the different models: total MVPA while at work, and total MVPA gained while in the work neighborhood. For each measure of PA, the association with walkability and greenness around work and around residence was tested independently.

Aiming not to analyze work PA in a vacuum, but rather as PA integrated into the possibilities and opportunities of each participant's daily activity behavior, we not only tested how the work environment was associated with work PA but also the associations between the residential environment and work PA. Both work and home are the "daily life centers" on which adults spend a great amount of time (Perchoux, Chaix, Cummins, & Kestens, 2013) and that are considered important at shaping daily behavior. Because of that we also tested the effect of the interaction between work and home walkability, and work and home greenness for the two measures of PA. Testing the interaction between work and home environmental conditions responds to the possibility that particular healthy behaviors, such as walking and biking to work, might depend on having a minimum threshold of walkability at both ends of the commuting trip (Christiansen et al., 2016). Conversely, participants living in highly walkable environments might see their behavior constrained by a very low walkability around the workplace. All statistical analyses were conducted SPSS v. 24 (SPSS Inc., Chicago, Illinois, USA).

Results

Correlation between the walkability index and destination access (Table 1) was strong but not complete both around work (r = .7; p = .001) and around the home (r = .69; p = .001). Greenness was negatively correlated with both measures of walkability in the work neighborhoods and the residential neighborhoods. Correlations, however, were moderate to low. Work walkability and home walkability were moderately correlated only, meaning that the environmental conditions around home and around work varied substantially.

The average age of the participants was 55.3 years old (SD = 7.9), and they accumulated an average of 5.7 hr of PA per day (SD = 1.65). Overall, 42.2% of the sample achieved the daily amount of PA recommended by the CDC. The distribution of the sample (Table 2) showed several significant differences in the number of hours spent at work per group, with the 40- to 49-year-old group (M = 44.4, SD = 30.3), those with a high school diploma or less (M = 49.5, SD = 21.8), and those with income below <US$50.000 ($M$ = 52.5, SD = 28.3) being associated with working more hours per week. Participants with a “high school degree or less” obtained higher levels of Total PA (M = 14.5, SD = 13.7) in the work vicinity. The average distance between home and work was 9.44 miles (SD = 9.10).

In Table 3, Model 1 examines the associations between the environment and MVPA while in the workplace, while Model 2 examines the associations between the environment and MVPA gained while in the work neighborhood. Both models are adjusted by age, the presence of children in the household, income, distance between home and work, and the amount of nonwork-related PA gained by each participant.

The amount of MVPA gained while at work (Table 3, Model 1) was positively associated with walkability around the workplace (coefficient = 0.067; p = .007), but not with the destination accessibility (coefficient = 0.004, p = .127). Work MVPA was negatively associated with greenness around the workplace (coefficient = −0.003, p = .002). The environment around the home was also positively associated with the overall MVPA gained while at work, with both the walkability around the home (coefficient = 0.091, p = .016) and its associated Walkscore© (coefficient = 0.023, p = .03) being found significant.

Table 1. Correlations Between Main Environmental Variables Near Home and Work.

	Work environment			Home environment		
	1.1	1.2	1.3	2.1	2.2	2.3
Work environment						
1.1 Walkability	—	.7**	−.44**	.39**	.48**	−.18*
1.2 Destination access	.7**	—	−.49**	.33**	.42**	−.20*
1.3 Greenness	−.44**	−.49**	—	−.29**	−.27**	.62**
Home environment						
2.1 Walkability	.39**	.33**	−.29**	—	.69**	−.31**
2.2 Destination access	.48**	.42**	−.27**	.69**	—	−.35
2.3 Greenness	−.18*	−.2*	.62**	−.31**	−.35	—

*$p < .05$. **$p < .01$.

The amount of MVPA gained only while in the work neighborhood (defined as between 40 and 400 m from work) (Table 3, Model 2) was also positively associated with walkability around the workplace (coefficient = 0.065; p = .041). Destination accessibility (Walkscore©) was also found positively associated with MVPA gained around work (coefficient = 0.006; p = .047). While greenness around the workplace was negatively associated with MVPA (coefficient = −0.003; p = .004), walkability around the home was also positively associated with MVPA gained in work surroundings. High levels of greenness around the home slightly diminished the negative impact of greenness around the workplace. Finally, all the interactions were significant, with the combination of work–home walkability (coefficient = 0.128; p = .002) and Walkscores© (coefficient = 0.001; p = .033) being indicative of greater MVPA gained, and the combination of work–home greenness showing a negative effect (coefficient = −0.001; p = .006).

Discussion

Using accelerometer-measured PA, GPS-based location data, and GIS measures of walkability and greenness, we tested associations between the built and natural environment and MVPA gained within and around the workplace. With U.S. adults spending a great deal of time in workplace environments, the neighborhoods around these workplaces may be important locations to encourage PA.

Table 2. Sample Characteristics and Amount of Time Recorded in Work Vicinity.

	Total sample		Hours/week at work			Hours/week of Total PA in work vicinity			Hours/week of MVPA in work vicinity		
	n	%	*M*	*SD*	*p*[a]	*M*	*SD*	*p*[a]	*M*	*SD*	*p*[a]
Age					.028			.127			.437
<40	10	6.8	37.12	16.13		10.1	10.4		0.6	0.6	
40-49	27	18.4	44.40	30.34		6.2	7.0		0.5	0.9	
50-59	74	50.3	35.03	19.14		7.4	8.1		0.5	0.6	
60+	36	24.5	28.59	13.73		4.6	4.2		0.3	0.3	
Children living in the household					.852			.678			.587
Yes	38	25.9	35.13	20.00		6.5	7.4		0.5	0.7	
No	109	74.1	35.86	23.43		7.1	7.6		0.4	0.5	
Married or living with partner					.568			.817			.126
Yes	106	72.1	33.73	18.17		6.4	6.9		0.6	0.8	
Other	41	27.9	35.93	21.86		6.8	7.6		0.4	0.5	
Education					.035			<.001			.279
High school or less	13	8.8	49.54	21.83		14.5	13.7		0.6	1.1	
College	74	50.3	33.84	20.44		6.3	6.6		0.4	0.4	
Graduate degree	60	40.8	34.06	20.34		5.4	5.4		0.5	0.7	
Income					<.001			.465			.836
<US$50,000	23	15.6	52.51	28.26		8.4	10.9		0.5	0.9	
US$50,000-US$69,000	24	16.3	30.04	11.97		7.6	6.1		0.6	0.6	
>US$70,000	75	51.0	32.15	17.84		6.3	6.9		0.5	0.6	

Note. PA = physical activity; MVPA = moderate to vigorous physical activity.
[a]Test: ANOVA, between groups.

Table 3. Adjusted Mixed-Effects Models: Linear Associations of Environmental Attributes With PA (All Kinds) and MVPA Gained While at Work Neighborhood.

	Model 1: Total MVPA while at work			Model 2: Total MVPA neighborhood		
	Coefficient	*p*	95% confidence interval	Coefficient	*p*	95% confidence interval
Workplace environment						
Walkability index	0.067	0.007**	[0.012, 0.124]	0.065	0.041*	[0.003, 0.128]
Walkscore	0.004	0.127	[–0.001, 0.011]	0.006	0.047*	[–0.001, 0.013]
NDVI	−0.003	0.002**	[–0.005, –0.001]	−0.003	0.004**	[–0.006, –0.001]
Home environment						
Walkability index	0.091	0.016*	[0.017, 0.165]	0.017	0.002**	[0.006, 0.027]
Walkscore	0.023	0.030*	[0.002, 0.043]	0.006	0.060	[0.000, 0.012]
NDVI	0.000	0.361	[0.000, 0.000]	−0.007	0.137	[–0.016, 0.002]
Work–home interactions						
Walkability index	0.006	0.003**	[0.002, 0.010]	0.128	0.002**	[0.048, 0.209]
Walkscore	0.001	0.011**	[0.000, 0.001]	0.001	0.033*	[0.000, 0.006]
NDVI	0.000	0.266	[0.000, 0.001]	0.000	0.006*	[0.000, 0.000]

Note. Regression coefficients are adjusted for participant's age, having children, income, work–home distance, amount of nonwork PA. PA = physical activity; MVPA = moderate to vigorous physical activity; NDVI = Normalized Difference Vegetation Index.
*$p < .05$. **$p < .01$.

Our hypothesis of the existence of a positive relationship between walkability and work PA was confirmed. Results showed that working in high walkable environments was associated with higher levels of MVPA while at work, and with higher MVPA gained within the work proximity. These associations were even stronger when participants both worked and lived in walkable places. Results also validate the idea that having good destination accessibility around work (expressed through Walkscore©) is associated with higher MVPA gained in the work neighborhood. Living in a high destination accessibility area, however, was not found associated with MVPA around the work neighborhood.

Previous research by Adams et al. (2016), Schwartz et al. (2009), and Yang et al. (2014) found that environments perceived as walkable around the workplace were associated with commuter walking. Using a 1,040 counts per minute cutpoint meant that walking was included within our definition of MVPA, which allowed us to confirm the reported associations obtained using subjective measures of the built environment. Forsyth and Oakes (2014), however, found only weak associations between the work neighborhood built environment and PA outcomes. To the best of our knowledge, this is the first study analyzing the effects of the work neighborhood using both a land use based and a destination-based walkability measure. Our results seem to suggest a stronger association between the walkability index—land use–based measure—and PA. These results, however, do not completely contradict Brown et al. (2009) who found destination access around the home to be a better predictor than entropy in determining a health outcome—BMI. Our study focused on PA gained around the workplace, not around the residence, and our walkability index was composed not only of a land use entropy measurement but also a connectivity and population density measurement. Interestingly, neither work MVPA nor MVPA within the work neighborhood were significantly associated with destination accessibility. This might mean that the morphology and general urban layout of the environment around the workplace might play a more relevant role than the availability of specific locations.

Our second hypothesis, regarding a positive relationship between greenness around the workplace and work MVPA, was refuted by our results. Greenness around work seemed to be negatively associated with total MVPA while at work and around work, although living in high greenness residential areas slightly diminished the negative impact of green workplaces. These findings regarding greenness resemble those reported by Troped et al. (2010) who also found greenness around home and work to be consistently negatively associated with MVPA. This is contrary to the literature that generally associates access to green spaces, with higher opportunities to engage in active behavior (Costigan, Veitch, Crawford, Carver, & Timperio, 2017;

Joseph & Maddock, 2016). On that matter, our results must be considered within the workplace context, and within a time of the day that usually does not include any space for recreational activities that could potentially be encouraged by the presence of greenspaces. Another greenness characteristic to consider is whether the greenspaces were well maintained, aesthetically pleasing, or perceived to be safe, aspects that have been found to be important in other studies involving women (Roman & Chalfin, 2008). That said, we hypothesized that greener workplace surroundings would be associated with more walking while at work, for example, taking a break for a walk outside or participating in a walking meeting. In addition, measures of greenness such as NDVI are commonly negatively correlated with measures of urbanity in the built environment. In this case, this correlation was weak but significant, meaning that within our sample, those who worked in a highly green environment were often also working in a low walkable environment.

Finally, results from the adjusted models also suggest the combination of both work and home environment to be more powerful at explaining PA than the workplace environment alone. Interactions involving both work and home walkability or work and home greenness showed stronger associations with work-MVPA than individual relationships. This confirmed our third and last hypothesis, and at the same time highlights the need not to treat environmental associations in isolation. Almanza et al. (2012) also found a difference of magnitude in the interaction effect when they included the environment and greenness around home in their study of children's PA. In our case, the interaction may be in part a result of residential and workplace self-selection, with more active individuals choosing to live and work in more walkable or greener environments. Alternatively, these findings might be the result of the home environment being decisive in shaping attitudes and habits regarding PA, shaping a set of behaviors that are then extended to the work environment. Finally, it may be that the environmental conditions found in one area of an individual activity space (i.e., home) might affect behavior in other parts of the activity space (i.e., workplace). The most obvious example of such a dynamic would be high walkability around both the residence and the workplace enabling people to more often use active modes of transport within their daily life. Other examples might include spatial compensation changes by which the lack of opportunities to engage in PA around either home/work might trigger a compensating change on the amount of PA gained while in other areas of the activity space.

Strengths

Our study avoids the "Residential Effect Fallacy," recently described by Chaix et al. (2017). The fallacy arises when one assumes that residential exposures are the only ones to which the individual is exposed to, or when all the environments to which the individual is exposed, share the same environmental characteristics. Both of these two processes may lead to an overestimation of the neighborhood effects (Kramer & Raskind, 2017). In our case, the fact that the work environment was only moderately correlated with the residential environment diminishes the risk of our analysis being overestimated. The weak spatial autocorrelation between work and home environments in our sample contrasts with Chaix et al.'s findings when analyzing the Paris Ile-de-France region and may be a result of highly different geographical study areas. At the same time that we avoid the "Residential Effect Fallacy," by taking into account the exposures from both the work and residential environment, we acknowledge that residential locations are not the sole places where individuals experience health-relevant exposures, and thus that there are other spaces where we can intervene to provide opportunities for PA. Our results also reinforce the need for studying environmental determinants of PA going beyond static measures of exposure (James et al., 2017). In addition to exploring more context-specific PA beyond the home environment, future research will have to address the relationship between the environment and PA within a more dynamic approach inside the activity space of an individual (Perchoux et al., 2013), while avoiding selective mobility bias (Perchoux, Chaix, Brondeel, & Kestens, 2016).

The high specificity of our sample—which was solely comprised of women—is a strength of this study. Associations between environmental attributes and individual behavior or characteristics such as PA, obesity, or cardiometabolic risk have been found to be stronger among women (Leal & Chaix, 2011). Women have been also found to benefit specifically from shorter bouts and lighter PA levels (Xue et al., 2012). In that sense, our study offers important practical lessons about the relationship between the environment and women's PA while at work.

This study also benefited from using GIS-based measures of the environment, GPS measures of location, and objective PA measured with accelerometer. The combination of objective GIS, GPS, and accelerometer measures reduces recall and perception bias, increases accuracy, and puts this study into what is been labeled as the spatial energetics discipline (James et al., 2016): the incorporation of high-spatiotemporal resolution data on location and time matched accelerometry measures to examine how space, time, and environmental characteristics are linked to health behaviors. Collectively, focusing both on workplace and home environments separately reduced problems such as residential self-selection bias and residential socioeconomic status (SES) segregation that often appear in studies assessing the relationship between environment and residence locations (Moore et al., 2013). Self-selection bias occurs when individuals choose to live in environments that best align with their PA preferences (McCormack, 2017), leading, for example, to more active people clustering in more walkable neighborhoods, because they like to walk. In our study, while we retain some of this self-selection bias, it is likely that the work environment is less affected by the self-selection, as people tend to choose their job based on factors other than their the worksite environment. Our study also benefited from having participants located throughout the United States, in diverse work and residential environments. Finally, incorporating two different measures of walkability, one based on the morphology of the urban fabric—walkability index—and the other based on destination accessibility—Walkscore©—provided a more detailed and nuanced view of the relationship between PA and environmental attributes.

Limitations

This study is not without limitations. The most important one concerns the adequacy of using a 400-m buffer around the workplace as a suitable measure of what constitutes the functional workplace environment. While we acknowledge the problems associated with using a radial buffer as small as 400 m (James et al., 2014), we also consider it to be a proper scale to analyze the set of short activities that are often fulfilled during work hours. It seems clear that in the future, continuous measures of PA and the environment will have to be developed and analyzed not exclusively around specific locations such as the residence or the workplace but along the whole activity space of each participant (Berrigan et al., 2015). Additional limitations relate to the fact that the accuracy of environmental measures could not be ground-truthed and from the fact that the total amount of MVPA gained while at work was not very high. Finally, the analysis was not able to control for the mode of transportation to work; however, only 10% of the sample used active modes of transport on their commute.

Conclusion

Overall, this study used objective measures of the environment and accelerometer-measured PA to find that walkability around the workplace is associated with higher amounts of MVPA gained in the workplace and within the workplace neighborhood. It also found a negative association between greenness and MVPA gained both inside the workplace and within the workplace neighborhood. The fact that walkability was significantly associated with work MVPA but not destination accessibility reveals that not all attributes of the built environment might affect PA behaviors in the same way, and exposes the need of further research on the subject. Similarly, the use of NDVI as the measure of greenness may not capture the complete set of nature-related opportunities around the workplace. As such, future research should incorporate other measures of greenness that might complement NDVI on a finer scale.

These findings have public health implications as they suggest that locating workplaces in walkable environments can have positive outcomes in terms of employees' PA. Our findings can contribute to increasing the viability of the workplace neighborhood as a relevant venue of daily PA. Associations between work environment and PA will also have to be considered in combination with the specific PA gains that might derive from programs and activities within the workplace (Hipp et al., 2017; Hipp et al., 2015; Yang et al., 2014). Future research should explore the potential for designing work-based PA interventions that exploit the benefits of the built and natural environment around the workplace.

Declaration of Conflicting Interests

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References

Adams, E. J., Bull, F. C., & Foster, C. E. (2016). Are perceptions of the environment in the workplace "neighbourhood" associated with commuter walking? *Journal of Transport & Health*, *3*, 479-484. doi:10.1016/j.jth.2016.01.001

Adlakha, D., Hipp, J. A., Marx, C., Yang, L., Tabak, R., Dodson, E. A., & Brownson, R. C. (2015). Home and workplace built environment supports for physical activity. *American Journal of Preventive Medicine*, *48*, 104-107. doi:10.1016/j.amepre.2014.08.023

Almanza, E., Jerrett, M., Dunton, G., Seto, E., & Ann Pentz, M. (2012). A study of community design, greenness, and physical activity in children using satellite, GPS and accelerometer data. *Health & Place*, *18*, 46-54. doi:10.1016/j.healthplace.2011.09.003

Balseviciene, B., Sinkariova, L., Grazuleviciene, R., Andrusaityte, S., Uzdanaviciute, I., Dedele, A., & Nieuwenhuijsen, M. J. (2014). Impact of residential greenness on preschool children's emotional and behavioral problems. *International Journal of Environmental Research and Public Health*, *11*, 6757-6770. doi:10.3390/ijerph110706757

Barrington, W. E., Beresford, S. A. A., Koepsell, T. D., Duncan, G. E., & Moudon, A. V. (2015). Worksite neighborhood and obesogenic behaviors: Findings among employees in the Promoting Activity and Changes in Eating (PACE) trial. *American Journal of Preventive Medicine*, *48*, 31-41. doi:10.1016/j.amepre.2014.08.025

Berrigan, D., Hipp, J. A., Hurvitz, P. M., James, P., Jankowska, M., Kerr, J., . . . Zenk, S. N. (2015). Geospatial and contextual approaches to energy balance and health. *Annals of GIS*, *21*, 157-168. doi:10.1080/19475683.2015.1019925

Brown, B. B., Yamada, I., Smith, K. R., Zick, C. D., Kowaleski-Jones, L., & Fan, J. X. (2009). Mixed land use and walkability: Variations in land use measures and relationships with BMI, overweight, and obesity. *Health & Place*, *15*, 1130-1141. doi:10.1016/j.healthplace.2009.06.008

Brownson, R. C., Hoehner, C. M., Day, K., Forsyth, A., & Sallis, J. F. (2009). Measuring the built environment for physical activity. State of the science. *American Journal of Preventive Medicine*, *36*(4, Suppl.), S99-S123.e12. doi:10.1016/j.amepre.2009.01.005

Chaix, B., Duncan, D., Vallée, J., Vernez-moudon, A., Chaix, B., Duncan, D., & Benmarhnia, T. (2017). The "Residential" effect fallacy in neighborhood and health studies: Formal definition, empirical identification, and correction. *Epidemiology*, *28*, 789-797. doi:10.1097/EDE.0000000000000726

Chaix, B., Kestens, Y., Perchoux, C., Karusisi, N., Merlo, J., & Labadi, K. (2012). An interactive mapping tool to assess individual mobility patterns in neighborhood studies. *American Journal of Preventive Medicine*, *43*, 440-450. doi:10.1016/j.amepre.2012.06.026

Chau, J. Y., Grunseit, A. C., Chey, T., Stamatakis, E., Brown, W. J., Matthews, C. E., . . . van Der Ploeg, H. P. (2013). Daily sitting time and all-cause mortality: A meta-analysis. *PLoS ONE*, *8*(11), e80000. doi:10.1371/journal.pone.0080000

Christiansen, L. B., Cerin, E., Badland, H., Kerr, J., Davey, R., Troelsen, J., . . . Sallis, J. F. (2016). International comparisons of the associations between objective measures of the built environment and transport-related walking and cycling : IPEN adult study. *Journal of Transport & Health*, *3*, 467-478. doi:10.1016/j.jth.2016.02.010

Costigan, S., Veitch, J., Crawford, D., Carver, A., & Timperio, A. (2017). A cross-sectional investigation of the importance of park features for promoting regular physical Activity in parks. *International Journal of Environmental Research and Public Health*, *14*(11), 1335. doi:10.3390/ijerph14111335

Delclòs-Alió, X., Marquet, O., & Miralles-Guasch, C. (2017). Keeping track of time: A smartphone-based analysis of travel time perception in a suburban environment. *Travel Behaviour & Society*, *9*, 1-9. doi:10.1016/j.tbs.2017.07.001

Dovey, K., & Pafka, E. (2017). What is functional mix? An assemblage approach. *Planning Theory & Practice*, *18*, 249-267. doi:10.1080/14649357.2017.1281996

Ekelund, U., Steene-Johannessen, J., Brown, W. J., Fagerland, M. W., Owen, N., Powell, K. E., . . . Lee, I. M. (2016). Does physical activity attenuate, or even eliminate, the detrimental association of sitting time with mortality? A harmonised meta-analysis of data from more than 1 million men and women. *The Lancet*, *388*, 1302-1310. doi:10.1016/S0140-6736(16)30370-1

European Commission. (2017). *Physical activity at the workplace . Literature review and best practice case studies: A final report to the European Commission*. Luxemburg: Publications Office of the European Union.

Foley, L., Panter, J., Heinen, E., Prins, R., & Ogilvie, D. (2015). Changes in active commuting and changes in physical activity in adults: A cohort study. *International Journal of Behavioral Nutrition and Physical Activity*, *12*, Article 161. doi:10.1186/s12966-015-0323-0

Forsyth, A. (2015). What is a walkable place? The walkability debate in urban design. *Urban Design International*, *20*, 274-292. doi:10.1057/udi.2015.22

Forsyth, A., & Oakes, J. (2014). Workplace neighborhoods, walking, physical activity, weight status, and perceived health. *Transportation Research Record: Journal of the Transportation Research Board*, *2452*, 98-104. doi:10.3141/2452-12

Frank, L., Bradley, M., Kavage, S., Chapman, J., & Lawton, T. (2008). Urban form, travel time, and cost relationships with tour complexity and mode choice. *Transportation*, *35*, 37-54. Retrieved from http://link.springer.com/article/10.1007/s11116-007-9136-6

Frank, L., Sallis, J. F., Conway, T. L., Chapman, J. E., Saelens, B. E., & Bachman, W. (2006). Many pathways from land use to health: Associations between neighborhood walkability and active transportation, body mass index, and air quality. *Journal of the American Planning Association*, *72*, 75-87. doi:10.1080/01944360608976725

Frank, L., Sallis, J. F., Saelens, B. E., Leary, L., Cain, K., Conway, T. L., & Hess, P. M. (2010). The development of a walkability index: Application to the Neighborhood Quality of Life Study. *British Journal of Sports Medicine*, *44*, 924-933. doi:10.1136/bjsm.2009.058701

Gazmararian, J. A., Elon, L., Newsome, K., Schild, L., & Jacobson, K. L. (2013). A randomized prospective trial of a worksite intervention program to increase physical activity. *American Journal of Health Promotion*, *28*, 32-40. doi:10.4278/ajhp.110525-QUAN-220

Gehrke, S. R., & Welch, T. F. (2017). The built environment determinants of activity participation and walking near the workplace. *Transportation*, *44*, 941-956. doi:10.1007/s11116-016-9687-5

Hipp, J. A., Dodson, E. A., Lee, J. A., Marx, C. M., Yang, L., Tabak, R. G., . . . Brownson, R. C. (2017). Mixed methods analysis of eighteen worksite policies, programs, and environments for physical activity. *International Journal of Behavioral Nutrition and Physical Activity*, *14*, Article 79. doi:10.1186/s12966-017-0533-8

Hipp, J. A., Reeds, D. N., van Bakergem, M. A., Marx, C. M., Brownson, R. C., Pamulapati, S. C., & Hoehner, C. M. (2015). Review of measures of worksite environmental and policy supports for physical activity and healthy eating. *Preventing Chronic Disease*, *12*(5), 140410. doi:10.5888/pcd12.140410

Hirsch, J. A., Winters, M., Ashe, M. C., Clarke, P. J., & McKay, H. A. (2016). Destinations that older adults experience within their GPS activity spaces: Relation to objectively measured physical activity. *Environment and Behavior*, *48*, 55-77. doi:10.1177/0013916515607312

Hoehner, C. M., Handy, S. L., Yan, Y., Blair, S. N., & Berrigan, D. (2011). Association between neighborhood walkability, cardiorespiratory fitness and body-mass index. *Social Science & Medicine*, *73*, 1707-1716. doi:10.1016/j.socscimed.2011.09.032

Honda, T., Chen, S., Yonemoto, K., Kishimoto, H., Chen, T., Narazaki, K., . . . Kumagai, S. (2016). Sedentary bout durations and metabolic syndrome among working adults: A prospective cohort study. *BMC Public Health*, *16*, Article 888. doi:10.1186/s12889-016-3570-3

Inagami, S., Cohen, D. A., & Finch, B. K. (2007). Non-residential neighborhood exposures suppress neighborhood effects on self-rated health. *Social Science & Medicine*, *65*, 1779-1791. doi:10.1016/j.socscimed.2007.05.051

Jack, E., & McCormack, G. R. (2014). The associations between objectively-determined and self-reported urban form characteristics and neighborhood-based walking in adults. *International Journal of Behavioral Nutrition and Physical Activity*, *11*, Article 71. doi:10.1186/1479-5868-11-71

James, P., Berrigan, D., Hart, J. E., Aaron Hipp, J., Hoehner, C. M., Kerr, J., . . . Laden, F. (2014). Effects of buffer size and shape on associations between the built environment and energy balance. *Health & Place*, *27*, 162-170. doi:10.1016/j.healthplace.2014.02.003

James, P., Hart, J. E., Hipp, J. A., Mitchell, J. A., Kerr, J., Hurvitz, P. M., . . . Laden, F. (2017). GPS-based exposure to greenness and walkability and accelerometry-based physical activity. *Cancer Epidemiology, Biomarkers & Prevention*, *26*, 525-532. doi:10.1158/1055-9965.EPI-16-0925

James, P., Jankowska, M., Marx, C., Hart, J. E., Berrigan, D., Kerr, J., . . . Laden, F. (2016). "Spatial energetics": Integrating data from GPS, accelerometry, and GIS to address obesity and inactivity. *American Journal of Preventive Medicine*, *51*, 792-800. doi:10.1016/j.amepre.2016.06.006

Joseph, R. P., & Maddock, J. E. (2016). Observational park-based physical activity studies: A systematic review of the literature. *Preventive Medicine*, *89*, 257-277. doi:10.1016/j.ypmed.2016.06.016

Kelly, P., Krenn, P., Titze, S., Stopher, P. R., & Foster, C. (2013). Quantifying the difference between self-reported and global positioning systems-measured journey durations: A systematic review. *Transport Reviews*, *33*, 443-459. doi:10.1080/01441647.2013.815288

Kerr, J., Marinac, C. R., Ellis, K., Godbole, S., Hipp, J. A., Glanz, K., . . . Berrigan, D. (2017). Comparison of accelerometry methods for estimating physical activity. *Medicine & Science in Sports & Exercise*, *49*, 617-624. doi:10.1249/MSS.0000000000001124

Kondo, K., Lee, J. S., Kawakubo, K., Kataoka, Y., Asami, Y., Mori, K., . . . Akabayashi, A. (2009). Association between daily physical activity and neighborhood environments. *Environmental Health and Preventive Medicine*, *14*, 196-206. doi:10.1007/s12199-009-0081-1

Kramer, M. R., & Raskind, I. (2017). Is a person's place in the home (neighborhood)? *Epidemiology*, *28*, 798-801. doi:10.1097/EDE.0000000000000725

Langlois, M., Wasfi, R. A., Ross, N. A., & El-Geneidy, A. M. (2016). Can transit-oriented developments help achieve the recommended weekly level of physical activity? *Journal of Transport & Health*, *3*, 181-190. doi:10.1016/j.jth.2016.02.006

Leal, C., & Chaix, B. (2011). The influence of geographic life environments on cardiometabolic risk factors: A systematic review, a methodological assessment and a research agenda. *Obesity Reviews*, *12*, 217-230. doi:10.1111/j.1467-789X.2010.00726.x

Loeppke, R., Edington, D., Bender, J., & Reynolds, A. (2013). The association of technology in a workplace wellness program with health risk factor reduction. *Journal of Occupational and Environmental Medicine*, *55*, 259-264. doi:10.1097/JOM.0b013e3182898639

Manaugh, K., & El-Geneidy, A. (2011). Validating walkability indices: How do different households respond to the walkability of their neighborhood? *Transportation Research Part D: Transport and Environment*, *16*, 309-315. doi:10.1016/j.trd.2011.01.009

Manaugh, K., & Kreider, T. (2013). What is mixed use? Presenting an interaction method for measuring land use mix. *Journal of Transport and Land Use*, *6*(1), 63-72. doi:10.5198/jtlu.v6i1.291

McCormack, G. R. (2017). Neighbourhood built environment characteristics associated with different types of physical activity in Canadian adults. *Health Promotion and Chronic Disease Prevention in Canada*, *37*, 175-185. doi:10.24095/hpcdp.37.6.01

McMorris, O., Villeneuve, P. J., Su, J., & Jerrett, M. (2015). Urban greenness and physical activity in a national survey of Canadians. *Environmental Research*, *137*, 94-100. doi:10.1016/j.envres.2014.11.010

Memish, K., Martin, A., Bartlett, L., Dawkins, S., & Sanderson, K. (2017). Workplace mental health: An international review of guidelines. *Preventive Medicine*, *101*, 213-222. doi:10.1016/j.ypmed.2017.03.017

Meseck, K., Jankowska, M. M., Schipperijn, J., Natarajan, L., Godbole, S., Carlson, J., . . . Kerr, J. (2016). Is missing geographic positioning system data in accelerometry studies a problem, and is imputation the solution? *Geospatial Health*, *11*, 157-163. doi:10.4081/gh.2016.403

Mitchell, J. A., Godbole, S., Moran, K., Murray, K., James, P., Laden, F., . . . Glanz, K. (2016). No evidence of reciprocal associations between daily sleep and physical activity. *Medicine & Science in Sports & Exercise*, *48*, 1950-1956. doi:10.1249/MSS.0000000000001000

Moore, K., Diez Roux, A. V., Auchincloss, A., Evenson, K. R., Kaufman, J., Mujahid, M., & Williams, K. (2013). Home and work neighbourhood environments in relation to body mass index: The Multi-Ethnic Study of Atherosclerosis (MESA). *Journal of Epidemiology & Community Health*, *67*, 846-853. doi:10.1136/jech-2013-202682

Norman, G. J., Carlson, J. A., O'Mara, S., Sallis, J. F., Patrick, K., Frank, L., & Godbole, S. V. (2013). Neighborhood preference, walkability and walking in overweight/obese men. *American Journal of Health Behavior*, *37*, 277-282. doi:10.5993/AJHB.37.2.15

Parra, D. C., Gomez, L. F., Sarmiento, O. L., Buchner, D., Brownson, R., Schimd, T., . . . Lobelo, F. (2010). Perceived and objective neighborhood environment attributes and health related quality of life among the elderly in Bogotá, Colombia. *Social Science & Medicine*, *70*, 1070-1076. doi:10.1016/j.socscimed.2009.12.024

Parry, S., Straker, L., Gilson, N. D., & Smith, A. J. (2013). Participatory workplace interventions can reduce sedentary time for office workers—A randomised controlled trial. *PLoS ONE*, *8*(11), e78957. doi:10.1371/journal.pone.0078957

Pate, R. R., Taverno Ross, S. E., Liese, A. D., & Dowda, M. (2015). Associations among physical activity, diet quality, and weight status in U.S. adults. *Medicine & Science in Sports & Exercise*, *47*, 743-750. doi:10.1249/MSS.0000000000000456

Pavey, T. G., Peeters, G. G., & Brown, W. J. (2012). Sitting-time and 9-year all-cause mortality in older women. *British Journal of Sports Medicine*, *49*, 95-99. doi:10.1136/bjsports-2012-091676

Perchoux, C., Chaix, B., Brondeel, R., & Kestens, Y. (2016). Residential buffer, perceived neighborhood, and individual activity space: New refinements in the definition of exposure areas–The RECORD Cohort Study. *Health & Place*, *40*, 116-122. doi:10.1016/j.healthplace.2016.05.004

Perchoux, C., Chaix, B., Cummins, S., & Kestens, Y. (2013). Conceptualization and measurement of environmental exposure in epidemiology: Accounting for activity space related to daily mobility. *Health & Place*, *21*, 86-93. doi:10.1016/j.healthplace.2013.01.005

Quintiliani, L., Sattelmair, J., Activity, P., & Sorensen, G. (2007). *The workplace as a setting for interventions to improve diet and promote physical activity*. Dalian, China: World Health Organization.

Ramsey, K., & Bell, A. (2014). *Smart location database: Version 2.0*. Washington, DC: Environmental Protection Agency.

Richardson, E. A., Pearce, J., Mitchell, R., & Kingham, S. (2013). Role of physical activity in the relationship between urban green space and health. *Public Health*, *127*, 318-324. doi:10.1016/j.puhe.2013.01.004

Roman, C. G., & Chalfin, A. (2008). Fear of walking outdoors. A multilevel ecologic analysis of crime and disorder. *American Journal of Preventive Medicine*, *34*, 306-312. doi:10.1016/j.amepre.2008.01.017

Schipperijn, J., Bentsen, P., Troelsen, J., Toftager, M., & Stigsdotter, U. K. (2013). Associations between physical activity and characteristics of urban green space. *Urban Forestry & Urban Greening*, *12*, 109-116. doi:10.1016/j.ufug.2012.12.002

Schwartz, M. A., Aytur, S. A., Evenson, K. R., & Rodríguez, D. A. (2009). Are perceptions about worksite neighborhoods and policies associated with walking? *American Journal of Health Promotion*, *24*, 146-151. doi:10.4278/ajhp.071217134

Sebastião, E., Gobbi, S., Chodzko-Zajko, W., Schwingel, A., Papini, C. B., Nakamura, P. M., . . . Kokubun, E. (2012). The International Physical Activity Questionnaire-long form overestimates self-reported physical activity of Brazilian adults. *Public Health*, *126*, 967-975. doi:10.1016/j.puhe.2012.07.004

Shrestha, N., Ijaz, S., Kukkonen-Harjula, KT., Kumar, S., & Nwankwo, CP. (2015). Workplace interventions for reducing sitting at work (Review). *Cochrane Library*. doi:10.1002/14651858.CD010912.pub2

Stamatakis, E., Coombs, N., Rowlands, A., Shelton, N., & Hillsdon, M. (2014). Objectively-assessed and self-reported sedentary time in relation to multiple socioeconomic status indicators among adults in England: A cross-sectional study. *BMJ Open*, *4*(11), e006034. doi:10.1136/bmjopen-2014-006034

Sundquist, K., Eriksson, U., Kawakami, N., Skog, L., Ohlsson, H., & Arvidsson, D. (2011). Neighborhood walkability, physical activity, and walking behavior: The Swedish Neighborhood and Physical Activity (SNAP) study. *Social Science & Medicine*, *72*, 1266-1273. doi:10.1016/j.socscimed.2011.03.004

Tabak, R. G., Hipp, J. A., Marx, C. M., & Brownson, R. C. (2015). Workplace social and organizational environments and healthy-weight behaviors. *PLoS ONE*, *10*(4), e0125424. doi:10.1371/journal.pone.0125424

Thielman, J., Rosella, L., Copes, R., Lebenbaum, M., & Manson, H. (2015). Neighborhood walkability: Differential associations with self-reported transport walking and leisure-time physical activity in Canadian towns and cities of all sizes. *Preventive Medicine*, *77*, 174-180. doi:10.1016/j.ypmed.2015.05.011

Tilt, J. H., Unfried, T. M., & Roca, B. (2007). Using objective and subjective measures of neighborhood greenness and accessible destinations for understanding walking trips and BMI in Seattle, Washington. *American Journal of Health Promotion*, *21*(4, Suppl.), 371-379. doi:10.4278/0890-1171-21.4s.371

Troped, P. J., Wilson, J. S., Matthews, C. E., Cromley, E. K., & Melly, S. J. (2010). The built environment and location-based physical activity. *American Journal of Preventive Medicine*, *38*, 429-438. doi:10.1016/j.amepre.2009.12.032

Tucker, J. M., Welk, G. J., & Beyler, N. K. (2011). Physical activity in U.S. adults: Compliance with the physical activity guidelines for Americans. *American Journal of Preventive Medicine*, *40*, 454-461. doi:10.1016/j.amepre.2010.12.016

van der Ploeg, H. P., & Hillsdon, M. (2017). Is sedentary behaviour just physical inactivity by another name? *International Journal of Behavioral Nutrition and Physical Activity*, *14*, Article 142. doi:10.1186/s12966-017-0601-0

van der Velde, J. H., Savelberg, H. H., Schaper, N. C., & Koster, A. (2015). Moderate activity and fitness, not sedentary time, are independently associated with cardio-metabolic risk in U.S. adults aged 18-49. *International Journal of Environmental Research and Public Health*, *12*, 2330-2343. doi:10.3390/ijerph120302330

Van Holle, V., Deforche, B., Van Cauwenberg, J., Goubert, L., Maes, L., Van de Weghe, N., & De Bourdeaudhuij, I. (2012). Relationship between the physical environment and different domains of physical activity in European adults: A systematic review. *BMC Public Health*, *12*, Article 807. doi:10.1186/1471-2458-12-807

van Uffelen, J. G. Z., Wong, J., Chau, J. Y., van der Ploeg, H. P., Riphagen, I., Gilson, N. D., . . . Brown, W. J. (2010). Occupational sitting and health risks: A systematic review. *American Journal of Preventive Medicine*, *39*, 379-388. doi:10.1016/j.amepre.2010.05.024

Wasfi, R. A., Dasgupta, K., Eluru, N., & Ross, N. A. (2016). Exposure to walkable neighbourhoods in urban areas increases utilitarian walking: Longitudinal study of Canadians. *Journal of Transport & Health*, *3*, 440-447. doi:10.1016/j.jth.2015.08.001

Wineman, J. D., Marans, R. W., Schulz, A. J., van der Westhuizen, D. L., Mentz, G. B., & Max, P. (2014). Designing healthy neighborhoods: Contributions of the built environment to physical activity in Detroit. *Journal of Planning Education and Research*, *34*, 180-189. doi:10.1177/0739456X14531829

World Health Organization. (2010). *Global recommendations on physical activity for health*. Geneva, Switzerland. Retrieved from http://www.who.int/dietphysicalactivity/factsheet_recommendations/en/index.html

Xue, Q.-L., Bandeen-Roche, K., Mielenz, T. J., Seplaki, C. L., Szanton, S. L., Thorpe, R. J., . . . Fried, L. P. (2012). Patterns of 12-year change in physical activity levels in community-dwelling older women: Can modest levels of physical activity help older women live longer? *American Journal of Epidemiology*, *176*, 534-543. doi:10.1093/aje/kws125

Yang, L., Hipp, J. A., Adlakha, D., Marx, C. M., Tabak, R. G., & Brownson, R. C. (2014). Choice of commuting mode among employees: Do home neighborhood environment, worksite neighborhood environment, and worksite policy and supports matter? *Journal of Transport & Health*, *2*, 212-218. doi:10.1016/j.jth.2015.02.003

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