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Higher residential and employment densities are associated with more objectively measured walking in the home neighborhood

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ABSTRACT

Introduction: Understanding where people walk and how the built environment influences walking is a priority in active living research. Most previous studies were limited by self-reported data on walking. In the present study, walking bouts were determined by integrating one week of accelerometry, GPS, and a travel log data among 675 adult participants in the baseline sample of the Travel Assessment and Community study at Seattle, Washington in the United State.
Methods: Home neighborhood was defined as being within 0.5 mile of each participants' residence (a 10–min walk), with home neighborhood walking defined as walking bout lines with at least one GPS point within the home neighborhood. Home neighborhood walkability was constructed with seven built environment variables derived from spatially continuous objective values (SmartMaps). Collinearity among neighborhood environment variables was analyzed and variables that were strongly correlated with residential density were excluded in the regression analysis to avoid erroneous estimates. A Zero Inflated Negative Binomial (ZINB) served to estimate associations between home neighborhood environment characteristics and home neighborhood walking frequency.
Results: The study found that more than half of participants' walking bouts occurred in their own home neighborhood. Higher residential density and job density were the two neighborhood walkability measures related to higher likelihood and more time walking in the home neighborhood, highest tertile residential density (22.4–62.6 unit/ha) (coefficient = 1.43; 95% CI 1.00–2.05) and highest tertile job density (12.4–272.3 jobs/acre) (coefficient = 1.62; 1.10–2.37).
Conclusions: The large proportion of walking that takes place in the home neighborhood highlights the importance of continuing to examine the impact of the home neighborhood environment on walking. Potential interventions to increase walking behavior may benefit from increasing residential and employment density within residential areas.

1. Introduction

Regular, moderate-intensity physical activity (e.g. brisk walking, dancing) can reduce the risk of cardiovascular diseases, diabetes, colon and breast cancer, depression, and other chronic diseases or disorders (World Health Organization (WHO), 2012).

However, it is estimated that 60-80% of the world's population does not meet PA recommendations of at least 150 min of

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moderate-intensity aerobic PA per week (World Health Organization (WHO), 2009). Among moderate-intensity types of PA, walking is a popular, convenient, and low cost or free form of PA that can be incorporated into everyday life and sustained across the lifespan (Morris and Hardman, 1997; Ogilvie et al., 2007; Siegel et al., 1995). These characteristics have made the promotion of walking a promising public health strategy to counter physical inactivity trends (Eyler et al., 2003).

In places dominated by cars or other forms of motorized transport, walking has become a location-dependent activity that concentrates in relatively small, neighborhood-sized areas (Rappaport and Seidman, 2000). Accordingly, research on the contribution of walking to physical activity has examined neighborhood-level determinants of walking (Brownson et al., 2005; Kawachi and Berkman, 2003). To date, most of this research has focused on the walkability of the residential neighborhood, based on the hypothesis that people's place of residence exerts the most influence on walking behavior. However, little is known about where people actually walk, even though without this information, it is difficult to examine the potential influences of the built environment (BE) on walking behavior.

Studies seeking to find out where people walk have been limited by their use of self- reported walking data. Self-report walking data are only modestly accurate (Lee et al., 2011; Rzewnicki et al., 2003) and transportation surveys focusing on motorized trips tend to underreport walking trips (Stopher and Greaves, 2007). Further, self-reported walking measures often do not provide information on where walking occurs. If they do, they may be biased by inter- and intra-participant variations in the definition of neighborhood (e.g., different people considering the size of their neighborhood to be different).

Identifying where individuals are walking potentially allows for a better understanding of the built environment factors that impact walking. Measuring neighborhood walkability requires capturing the many characteristics of the BE that could support or limit walking. Unlike many prior studies that have examined the relation between an individuals' home neighborhood environment and their overall walking or physical activity, examining the more specific relationship between an individuals' home neighborhood environment and their walking within that environment is critical. This precision will better inform interventions to promote walking in residential areas. Further, many studies have used composite indices that combine measures of BE characteristics to reduce measurement error, collinearity and over-adjustment. Examples include a walkability index (Norman et al., 2013) and a sprawl index (Ewing et al., 2008). These composite indices were demonstrated in some studies to be more correlated with physical activity outcome than single BE variables because they capture the combination impact of many BE variables and minimize the spatial collinearity (Brownson et al., 2009). However, such indices are typically developed and standardized and thus are specific for only a given geographic location (e.g., a certain metropolitan area), thus introducing methodological concerns about validity, reliability, and generalizability. For intervention purposes, composite indices can also be of limited use because they do not identify the specific BE components that have a high potential to be modified to affect walking. Hence, simple measures of individually observable variables might be more, or at least equally, effective in characterizing environments for walkability than composite indices (Lee and Moudon, 2006). However, methodological concerns regarding the measurement of walkability also occur when associations between individual neighborhood BE characteristics and walking ignore the fact that BE variables are highly correlated (Feng et al., 2010; Huang et al., 2015). These methodological limitations may therefore lead to erroneous estimates, large standard errors, and spurious significant results due to multicollinearity.

This study fills a gap by using objective data on the frequency, duration, and location of walking in a large urban population to explore how home neighborhood built environment factors are associated with walking in the neighborhood.

2. Methods

2.1. Participants

Participants in this analysis are from the baseline sample of the Travel Assessment and Community study (TRAC) examining the impact of a new light rail system on PA. Participants were selected to reside proximal (case) or distal (control) from future light rail stops, but to be living within the same county (Seattle/King County, WA) and living in areas with similar built environments (defined by residential density, housing type, home values, bus transit access, and availability of proximate neighborhood services) and census-based demographic characteristics (household income and race/ethnicity). Households in eligible areas were contacted using address and phone information from marketing companies. Eligible participants needed to be 1) 20 + years old, 2) able to complete the travel log and survey in English, and 3) able to walk unassisted for at least 10 min. Participants gave consent and the study was approved by the Seattle Children's Research Institute Institutional Review Board. At least one valid assessment day was available for 701 participants. Of these, 18 were excluded because they did not have at least one valid day with GPS coverage totaling 3 + minutes; eight other participants were excluded because they did not complete the attitudinal/demographic survey.

2.2. Data collection

Eligible and interested participants were mailed an accelerometer (Actigraph GT1M), portable GPS device (GlobalSat DG-100), and a 7-day paper travel log. Participants were also provided a written or on-line (based on their preference) attitudinal and demographic survey to complete. Soon after receiving these materials, participants were contacted by study staff to review procedures (e.g., how to wear the devices; how to charge the GPS device nightly) and asked to wear the accelerometer and GPS concurrently for seven days during waking hours and to complete the travel log for these days. Accelerometer data were aggregated to 30-second epochs and GPS devices were set to collect data at 30-second intervals. Participants mailed back the devices and travel log (and survey if in written form) in a pre-paid envelope (Saelens et al., 2014). Socio-demographic data on participants' age, sex, household income, race/ethnicity, and highest level of education came from the survey as well as height and weight from which body mass index (BMI) was calculated.

2.3. Activity data processing

Physical activity (PA) was divided into walking and non-walking activity bouts following a process by which accelerometer data were integrated with GPS and travel log information. The process is described elsewhere (Huang et al., 2017; Hurvitz et al., 2014; Kang et al., 2013). In summary, PA bouts of ≥ 7 min of accelerometer counts > 500 per 30-second epoch, with a 2 min tolerance of lower accelerometer counts, were considered to be physical activity. Bouts were classified as walking bouts based on GPS speeds (2-6 km/h) and/or temporal overlap with trips in the travel diary. Operationally, walking bout lines were walking bouts with at least two GPS points.

In the present analysis, a valid day had at least one place record in the travel diary and accelerometer wearing time of ≥ 8 hours. Accelerometer periods of ≥ 20 min with continuous zero values were considered non-wearing times (Troiano and Freedson, 2010). An assessment day may or may not have had GPS data. The final sample consisted of 675 participants and 4,494 person-days (mean = 6.7 days/person; SD = 1.7).

2.4. Home neighborhood and outcome

Home neighborhood was defined by a 0.5 mile (833 meters, or 10 min walking) radius around the home location, which was geocoded using ArcGIS 10.0. Fig. 1 shows the geographic distribution of home locations and walking bout lines. Note that for data anonymity home location points shown on the figure have been randomly shifted a small distance from their actual geocoded locations to avoid being identified from the map.

The outcome of the analysis was the number of walking bout lines in the home neighborhood. Walking bout lines with at least one GPS point falling within the 0.5 mile buffer around the home location were classified as home neighborhood walking. Because the frequency and duration of daily walking bout lines in the home neighborhood were so highly correlated (r = 0.87), only daily walking frequency was used in the analyses.

2.5. Neighborhood walkability data and measures

Neighborhood walkability was captured with seven built environment variables, which had previously been associated with overall physical activity and walking (Saelens and Handy, 2008; Stewart et al., 2016). Residential density and job density were measures from the neighborhood composition domain (Ewing et al., 2008; Feng et al., 2010; Forsyth et al., 2007; Papas et al., 2007). They were complemented by residential property values, which represented neighborhood socioeconomic status (SES) (Moudon et al., 2011a; Rehm et al., 2012). The number of parks (Feng et al., 2010; Papas et al., 2007) and fitness facility density (Moore et al., 2013) measured neighborhood environment support for physical activity. The transportation environment domain related to walking included street intersection and sidewalk density measures (Block et al., 2011; Feng et al., 2010).

Neighborhood BE values were derived from SmartMaps, which were created using focal raster processing in ArcGIS (Hurvitz and Moudon, 2012). First, the study area parcel characteristics were translated into a 30 meter by 30 meter grid, previously shown to represent urban and suburban parcels with sufficient spatial fidelity (Moudon et al., 2011b). The buffer around each grid cell was defined within an 833 meter radius (a 10 min walking distance). The mean value of the environmental variables was calculated for each grid cell using the ArcGIS (version 10.0) Spatial Analyst Extension. BE variables were thus converted to a continuous function at each grid point, and then linked spatially to each study participant's geocoded home address for analyses.

2.6. Analyses

Summary statistics were calculated for participants' walking activity and the seven home neighborhood BE variables. ANOVA was used to compare neighborhood environment variables between participants with at least one walking bout line anywhere versus those with at least one walking bout line in the home neighborhood versus those without any walking bout line in the home neighborhood, during the assessment period.

Multicollinearity in the seven home neighborhood environment variables was examined and variables correlated greater than 0.7 were excluded from the regression models. Variable exclusion criterion was based on measurement accuracy and significance as reported in the literature. Conditional indexes and variance decomposition proportions (Belsley, 1991) as well as regression collinearity diagnostic procedures were also implemented to confirm the exclusion by using correlation coefficients.

Two regression models examined walking frequency in the home neighborhood in relation to home neighborhood environment adjusting for socio-demographic characteristics. First, a zero-inflated negative binomial (ZINB) regression was run for the entire sample, which included participants with no walking bout during the assessment period. This regression model takes into account a high number of zeros (i.e., no walking) and over-dispersed distribution in the outcome variable. A likelihood ratio test for over-dispersion in count data was used to compare the log-likelihoods of a negative binomial regression model and a Poisson regression model (Cameron and Trivedi, 1998). A Vuong's non-nested hypothesis test was also used to compare zero-inflated count models with their non-zero-inflated analogs, i.e. zero-inflated negative-binomial versus ordinary negative-binomial (Vuong, 1989). Both tests (tested but not shown in the result section) justified the use of negative zero-inflated negative binomial regression to model daily

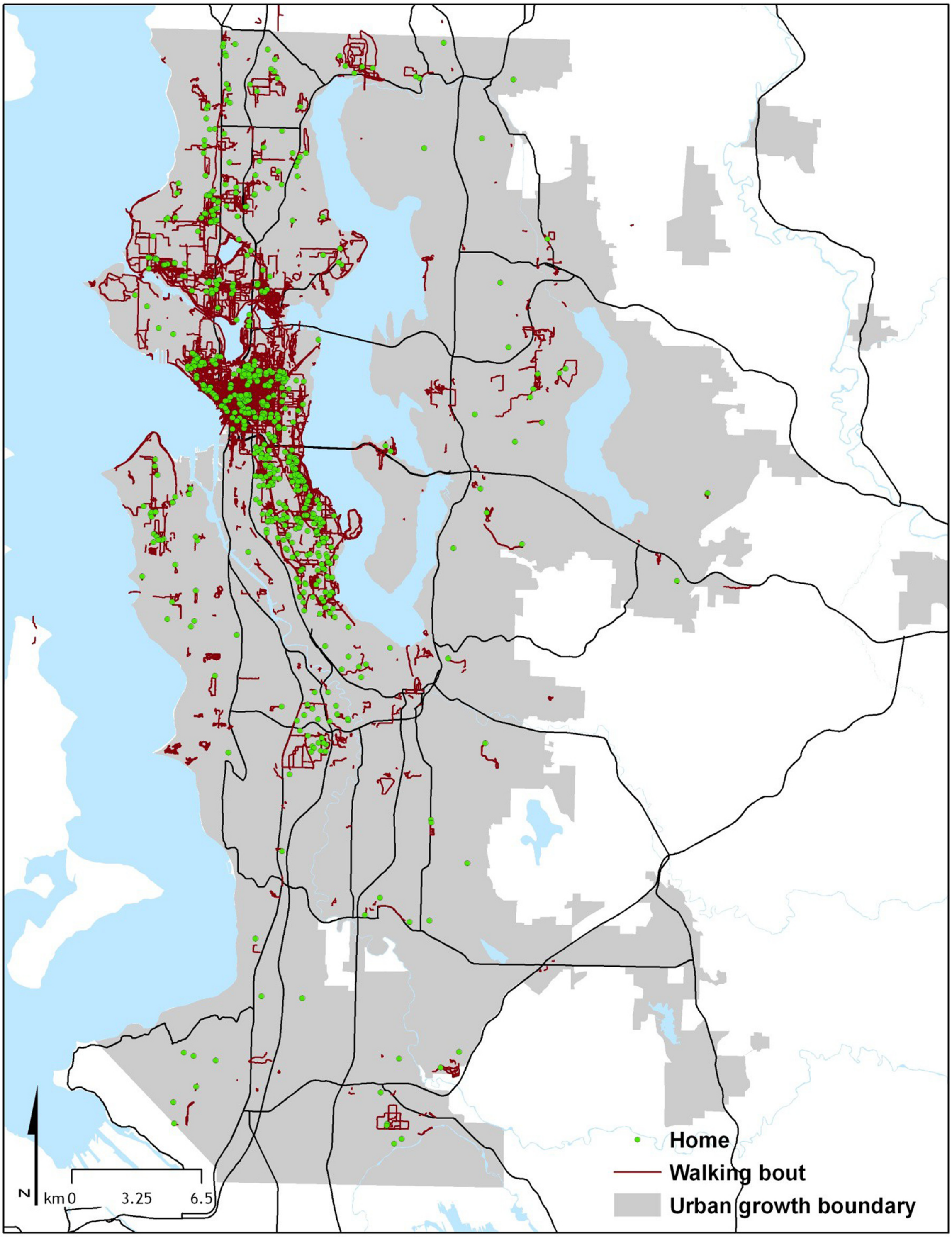

Fig. 1. The geographic distribution of participants' homes and walking bout lines.

walking bout frequency for the entire study sample.

Second, a negative binomial regression was carried out for the sample who had at least one walking bout anywhere during the assessment period, thus excluding those who did not have any walking bout lines during assessment period.

Table 1
Descriptive Characteristics of Study Sample.

	All (n = 675)		Participants > 0 walking bout line anywhere (n = 605)		Participants with > 0 walking bout line in their home neighborhood (n = 497)		Participants with > 0 walking bout lines, but with none in the home neighborhood (n = 108)		
	Mean / Percent	SD	Mean / Percent	SD	Mean / Percent	SD	Mean / Percent	SD	p-value
Gender									
Male	36.9%		38.8%		38.4%		32.8%		
Female	63.1%		61.2%		61.6%		67.2%		
Age									
18–39	21.7%		22.0%		23.6%		16.4%		
40–65	63.5%		64.9%		62.4%		66.7%		
> 65	14.8%		13.1%		14.0%		17.0%		
Race									
Hispanic or non-white	20.4%		19.2%		18.5%		25.7%		
Non-Hispanic White	79.6%		80.8%		81.5%		74.3%		
Education									
Less than college graduate	29.6%		27.4%		26.3%		39.1%		
College graduate	70.4%		72.6%		73.7%		60.9%		
Weight status									
BMI < 25	48.5%		50.0%		52.9%		35.6%		
BMI = 25–30	30.1%		29.7%		28.8%		33.8%		
BMI > 30	21.4%		20.3%		18.3%		30.6%		
Home neighborhood walking Bout lines									
Daily walking bout count	0.7	(0.8)	0.8	(0.8)	1.0	(0.8)	0.0	(0.0)	
Daily walking bout duration (minutes)	12.0	(15.3)	13.4	(15.6)	16.3	(15.8)	0.0	(0.0)	
Neighborhood environment									
Residential density (unit/ha)	20.1	(14.3)	20.7	(14.4)	22.2	(14.9)	14.3	(10.1)	< 0.001
Residential property value (1000)	247.3	(81.8)	249.8	(83.7)	251.2	(84.1)	236.3	(74.2)	0.027
Job density (jobs/acre)	32.8	(61.8)	34.3	(63.1)	38.9	(66.5)	15.9	(41.7)	< 0.001
Street intersection density (count/acre)	214.0	(74.3)	216.6	(74.4)	221.9	(75.6)	191.8	(65.9)	< 0.001
Sidewalk length (km/ha)	150.8	(80.7)	154.7	(80.0)	161.4	(78.7)	121.1	(79.0)	< 0.001
Fitness (count/acre)	5.5	(5.0)	5.7	(5.0)	6.2	(5.1)	3.7	(4.0)	< 0.001
Park count	6.2	(3.6)	6.4	(3.6)	6.6	(3.6)	5.3	(3.6)	< 0.001

3. Results

The majority of the sample was female, between the ages of 40 and 65, non-Hispanic White, with a college education, and nearly half were of healthy weight status. Nearly 90% of the participants had at least one walking bout during the assessment period.

The density plot of GPS coverage of walking bout lines (Appendix - Figure A) shows that 90% of the walking bout lines had a GPS coverage of more than 50% of their duration. In terms of walking frequency, the total number of walking bout lines for the study population was 5,628, of which 3,192 (57%) were at least partially in participants' home neighborhoods. In terms of duration, 63% of time spent walking occurred in home neighborhoods. Across the whole sample, the average daily count of walking bout lines per person in the home neighborhood was 0.7 (compared to a total number of daily walking bout lines of 1.2) and the daily walking duration per person in the home neighborhood was 12 min across all assessment days (compared to 18.5 total average daily minutes walking).

Comparing home neighborhood attributes, all neighborhood environment variables were significantly higher among those participants who had at least one walking bout in the home neighborhood versus those who had no walking bout lines in the home neighborhood (Table 1). Examination of the relationships among neighborhood environment variables led to the exclusion of street intersection density, sidewalk density, and fitness facility density from the subsequent regression analyses to avoid multicollinearity (Appendix - Table A). These variables can be linearly predicted from residential density (correlation coefficient > 0.70).

The neighborhood environment covariates remaining in the models: residential density, residential property value, job density, and the number of parks, were classified into tertile ranges to aid in the interpretation of model results and to take into account their possible non- linear relationship with the outcomes (Table 2).

Table 2
Tertile ranges of neighborhood environment variables (n = 675).

	Low tertile	Medium Tertile	High tertile
Residential density (unit/ha)	2.5–10.6	10.6–22.4	22.4–62.6
Residential property value ($1000)	100–205	205–259	259–873
Job density (jobs/acre)	0–3.7	3.7–12.4	12.4–272.3
Park (count)	0–4	4–8	8–19

The negative binomial part in the ZINB for the entire study population yielded four variables, gender, weight status, residential and job density, which were significantly associated with having more walking bout lines in the home neighborhood (Table 3). Walking bout lines in the home neighborhood were 23% higher for males than for females, and 45% lower for obese participants than those of normal weight. There were 43% more walking bout lines within the home neighborhood among those living in high tertile residential density neighborhoods than for those living in low tertile residential density neighborhoods. Similarly, for those living in high tertile job density neighborhoods, there were 60% more walking bout lines than for those living in low tertile job density neighborhoods. It should be noted that the binomial with logit link part of the model is only used to explain the excessive zeros in the outcome and narrow down the confidence interval in the negative binomial part.

The negative binomial regression of the subpopulation who had at least one walking bout anywhere during the assessment period showed that gender was no longer significantly related to more frequent walking in the neighborhood. Among walkers, the odds of having more neighborhood walking bout lines continued to be lower for obese participants (Table 4). Also, the effect of residential density and job density on walking frequency was stronger for this subpopulation.

Table 3
ZINB Results (Outcome: Number of walking bout lines per day in the home neighborhood) (n =675).

	exp(β)	**Confidence interval**
Negbin with log link		
Male *	1.23	(1.03, 1.48)
Age40-65	1.13	(0.92, 1.40)
Age > 65	1.24	(0.91, 1.67)
Non-Hispanic white	0.84	(0.66, 1.07)
Income50-100K	0.98	(0.79, 1.21)
Income > 100k	0.91	(0.70, 1.19)
College graduate	1.06	(0.85, 1.31)
Weight status-Overweight	0.87	(0.70, 1.08)
Weight status-Obese ***	0.55	(0.43, 0.71)
Residential density-Medium	1.22	(0.93, 1.60)
Residential density-High*	1.43	(1.00, 2.05)
Property value-Medium	1.12	(0.87, 1.44)
Property value-High	0.92	(0.69, 1.23)
Jobs density-Medium	1.18	(0.91, 1.54)
Jobs density-High *	1.62	(1.10, 2.37)
Park count-Medium	0.89	(0.71, 1.13)
Park count-High	0.84	(0.64, 1.12)
Binomial with logit link		
Male	0.71	(0.29, 1.73)
Age40-65	2.27	(0.40, 12.87)
Age > 65	4.51	(0.64, 31.73)
Non-Hispanic white	0.57	(0.24, 1.33)
Income50-100K	1.04	(0.44, 2.45)
Income > 100k	0.68	(0.18, 2.58)
College graduate	0.68	(0.31, 1.52)
Weight status-Overweight	1.78	(0.63, 5.00)
Weight status-Obese	2.30	(0.81, 6.56)
Residential density-Medium	0.91	(0.34, 2.41)
Residential density-High	0.15	(0.01, 1.72)
Property value-Medium	0.92	(0.37, 2.26)
Property value-High	0.35	(0.08, 1.66)
Jobs density-Medium	1.11	(0.41, 2.99)
Jobs density-High	0.79	(0.13, 4.78)
Park count-Medium	0.77	(0.31, 1.91)
Park count-High	1.28	(0.33, 4.93)

Note: *p value < 0.05, ** p value < 0.01, *** p value < 0.001

Table 4
Negative Binomial Regression For Participants with at Least One Walking Bout (Outcome: Number of Walking bout lines per Day in the Home Neighborhood) (n = 605).

	exp(β)	Confidence interval
Male	1.19	(0.99, 1.42)
Age40–65	1.01	(0.82, 1.25)
Age > 65	1.14	(0.84, 1.53)
Non-Hispanic white	0.89	(0.71, 1.11)
Income50-100K	0.96	(0.78, 1.17)
Income > 100k	0.88	(0.69, 1.13)
College graduate	1.05	(0.86, 1.29)
Weight status-Overweight	0.84	(0.69, 1.03)
Weight status-Obese ***	0.53	(0.42, 0.67)
Residential density-Medium	1.23	(0.98, 1.54)
Residential density-High**	1.61	(1.14, 2.26)
Property value-Medium	1.16	(0.92, 1.45)
Property value-High	1.04	(0.82, 1.31)
Jobs density-Medium	1.19	(0.94, 1.50)
Jobs density-High **	1.68	(1.17, 2.42)
Park count-Medium	0.92	(0.73, 1.15)
Park count-High	0.83	(0.63, 1.08)

Note: *p value < 0.05, ** p value < 0.01, *** p value < 0.001

4. Discussion

Using more objective measures of walking frequency and location, this study confirms the findings from prior studies about the influence of the home neighborhood environment on walking activity. Within this urban adult sample of walkers and non-walkers, more than half of the walking occurred at least in part within ½ mile of their home. Of the participants who walked (> 0 walking bout), 82% had at least one walking bout in their home neighborhood (833 m or 0.5 mile buffer around their residence) during the assessment period of 7 days. Also, people who walked in their neighborhoods walked more overall frequently than those who did not: they had an average of 1.6 total walking bout lines per day versus 0.6 for those who did not walk in their neighborhood. At the individual level, the frequency of walking in the neighborhood was significantly associated with only two sociodemographic characteristics, being male and having a lower BMI. The association with gender was no longer significant in the model considering only those who walked.

Higher residential and employment density were associated with more walking in the neighborhood (Duncan et al., 2014, 2012; Forsyth et al., 2007; Saelens and Handy, 2008).While the association was significant for the entire population (of walker and non-walkers) (p > 0.05), it was stronger for the subpopulation of walkers (p > 0.01). In this study, the lowest bound of the highest tertile of residential density (gross density of 22 units/ha) was equivalent to a neighborhood where connected or row houses are dominant, which suggests that compact single-family housing and apartments should be considered as walking-friendly housing forms. Furthermore, finding that high job density is associated with more walking in a residential neighborhood indicates that walking-supportive neighborhoods may intermix residential and employment uses. Neighborhood areas combining residential and employment uses may also encourage walking because they typically have a higher accessibility to local retail and services, a higher level of transit service, higher parking costs, and correspondingly lower automobile ownership rates (Cervero, 2006; Frank and Pivo, 1994). This is consistent with recent recommendations to implement interventions that encourage combining changes in various aspects of the built and transportation environment in order to support more walking and other physical activity (Community Preventive Services Task Force, 2016). As the present study revealed that only highest tertile of employment density in home neighborhood was significantly associated with more walking, suggesting that the lower employment densities which can be found in low-rise office parks or big-box commercial/retail areas would not promote walking activities.

More specifically, the study confirms that residential and employment densities are the primary aspects of the home neighborhood environment that are related to more walking. Past research found that higher residential density, greater street connectivity, greater number and variety of destinations, and mixed land use in residential neighborhoods defined walkability and were associated with more walking (Coogan et al., 2009; Duncan et al., 2010; McConville et al., 2011; Saelens and Handy, 2008). The present study demonstrates that residential density is highly correlated with other built environment constructs herein including street intersection and sidewalk density, as well as with the density of fitness facilities. These results suggest that measuring residential and employment density may be sufficient to assess the walkability of a neighborhood. This finding could help future research by reducing the number of variables needed to be examined. Furthermore, it could help bypass methodological issues, as analyses adding other neighborhood characteristics to these two variables likely engender issues of multicollinearity, which can lead to erroneous estimates of coefficients, large standard errors, and potentially spurious significant results.

There is a caveat to these findings: in this study, residential and employment densities were calculated using fine-grained, parcel-level data, which may not be obtainable in all settings. Studies based on coarser census data have used composite indices of the neighborhood environment (e.g., the walkability index (Norman et al., 2013)) and the sprawl index (Ewing et al., 2008) to circumvent the issue of multicollinearity. However, composite indices cannot be used to design policy interventions or to test specific hypothesizes (Feng et al., 2010) because of the inability to identify specific attributes of environment that are modifiable and have the highest potential to change behaviors. Hence, if fine-grained data are available, it is preferable to use such simple measures of individually observable variables as residential and employment density (Lee and Moudon, 2006). This study shows that these two variables are effective in characterizing environments for walkability.

The study outcome combined utilitarian walking and recreational walking because the ultimate public health goal is to promote all types of walking. A recent publication using the same the Travel Assessment and Community study (TRAC) data showed that 87.4% of walking was utilitarian and 12.6% recreational and that recreational walking was not associated with the presence of recreational land uses (Kang et al., 2017).

The study has limitations. First, the sample was drawn from only one U.S. metropolitan region, restricting the generalizability of findings. For example, it could be that there are other areas or regions (e.g., rural areas) in which the examined built environment variables are not as highly correlated or wherein walking behavior is related to different built environment variables. This cross-sectional study prevents inference of causal relationship between walking and walkability. Being part of a large study investigating the impact of light rail on travel behavior and physical activity, participants in this study had more transit access than the general local or U.S. population. Given the limited range of the built environments included in the present analysis, it was not appropriate to examine interactions between the various built environmental variables in relation to walking behavior. Also, using circular rather than street-network buffers to define neighborhoods could ignore the uneven accessibility of local land uses based on the structure of local street network. Finally, while walking in the home neighborhood was objectively measured, missing GPS data may have resulted in inexact estimates of home neighborhood walking bout lines.

5. Conclusion

Objective measures of walking show that walking takes place most frequently in the home neighborhood. People who walk in the neighborhood also have more overall walking compared to those who do not walk in their neighborhood. Higher densities of both residential and employment uses in the home neighborhood effectively define levels of walkability associated with higher levels of walking in home neighborhoods. These two density measures are correlated with high street intersection and sidewalk density. The study confirms the importance of past research focusing on the impact of home neighborhood walkability on walking and indicates that efforts to increase development density in residential neighborhoods will help promote more walking.

Acknowledgments

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Appendix

See Fig A1 and Table A1.

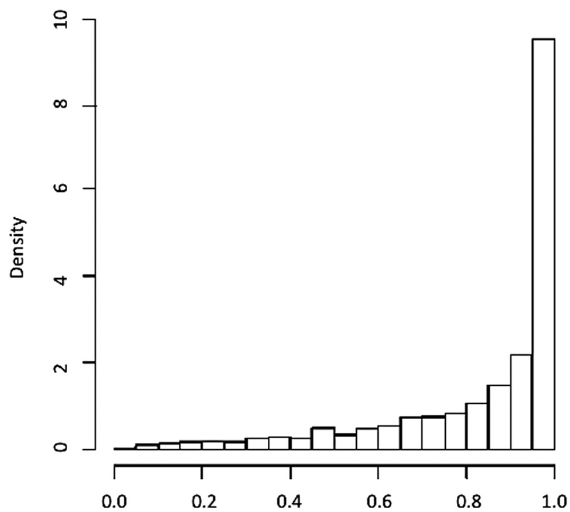

Fig. A1. Walking bout GPS coverage ratio.

Table A1
Correlation matrix of BE variables.

	Residential density	Residential property value	Job density	Street intersection density	Sidewalk length	Fitness count	Park count
Residential density	1.00	-0.28	0.62	0.78	0.75	0.80	0.38
Residential property value	-0.28	1.00	-0.13	-0.13	-0.02	-0.23	0.14
Job density	0.62	-0.13	1.00	0.73	0.45	0.77	0.27
Street intersection density	0.78	-0.13	0.73	1.00	0.84	0.77	0.48
Sidewalk length	0.75	-0.02	0.45	0.84	1.00	0.70	0.46
Fitness count	0.80	-0.23	0.77	0.77	0.70	1.00	0.32
Park	0.38	0.14	0.27	0.48	0.46	0.32	1.00

Note: Shaded cells have a correlation coefficient > 0.70

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