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Association of neighborhood Walk Score with accelerometer-measured physical activity varies by neighborhood socioeconomic status in older women

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ABSTRACT

The built environment can influence physical activity behavior. Walk Score is a widely used measure of the neighborhood built environment to support walking. However, studies of the association between Walk Score and accelerometer-measured physical activity are equivocal and no studies have examined this relationship among older adults. We analyzed data from a large, diverse sample of women (n = 5650) with a mean age of 79.5 (SD = 6.7) at time of accelerometry wear in the Women's Health Initiative Objective Physical Activity Cardiovascular Health Study in the United States to examine associations between neighborhood Street Smart Walk Score (SSWS) and accelerometer-measured physical activity. Participants wore triaxial accelerometers for seven days and SSWS was determined from home addresses. 67 % of the sample lived in "car-dependent" locations (SSWS 0–49 out of 100); only 3 % lived in "walker's paradise" locations (SSWS 90–100). The multivariable model indicated an association between SSWS and accelerometer-measured physical activity (steps/day) in the total sample. The association varied by neighborhood socioeconomic status; in high socioeconomic status neighborhoods, higher SWSS was associated with greater steps per day, while no significant association between SWSS and physical activity was observed in low socioeconomic neighborhoods. This study should catalyze furtherresearch regarding the utility of SSWS in determining neighborhood walkability for older women across different neighborhood settings and suggests other built environment factors must be considered when determining walkability. Future studies should examine what factors influence walkability and develop age-relevant methods to assess and characterize neighborhood walkability.

1. Introduction

A substantial and expanding body of research demonstrates the influence of built environmental features on physical activity among children and adults. (Kärmeniemi et al., 2018; Smith et al., 2017) However, much less is known about the influence of these features on older adults' physical activity behavior. The characteristics most commonly examined relate to walkability, since walking is the most common form of physical activity (U.S. Department of Health and Human Services, 1996) and because of its relevance across all age,

Abbreviations: ANOVA, analysis of variance; BMI, body mass index; METs, metabolic equivalent of task; OPACH, Objective Physical Activity and Cardiovascular Health; SWSS, Street Smart Walk Score; WHI, Women's Health Initiative.

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gender, race, and ethnicity groups. (Eyler et al., 2003; Reis et al., 2008) Walkability is typically assessed based upon the availability of destinations that could be accessed within "walking" distance (maximum of one mile radius and often much smaller distances) around a person's home, such as schools, libraries, stores/markets, parks, and restaurants. (Hajna et al., 2013; Rundle et al., 2019) It usually also includes safety features such as the presence of sidewalks; street block or street segment lengths; and/or traffic speed or "traffic calming" features (e.g. speed bumps) and sometimes aesthetic features. (Wang and Yang, 2019).

Walk Score is a measure of the neighborhood built environment to support walking as part of a healthy lifestyle and has been increasingly utilized in the study of walkability due to its accessibility, international scale, and continually updated data. (Score, 2020) A recent systematic review found mixed evidence supporting the validity of Walk Score in determining neighborhood walkability. (Hall and Ram, 2018) In this review of 42 studies, it was found that the validity of Walk Score varied depending on sociodemographic factors (age, gender, and cultural context) and walking type (purposive vs leisure), and concluded that other factors may need to be considered when evaluating the walkability of the physical activity environment. Furthermore, very few studies have looked at the relationship between Walk Score and objectively measured physical activity (e.g., via accelerometer). In those studies, five found a positive relationship between Walk Score and overall walking. (Camhi et al., 2019; Chudyk et al., 2017; Gell et al., 2015; Hajna et al., 2015; Han et al., 2018; Duncan et al., 2016; Hwang et al., 2016) A few studies looked at the relationship between Walk Score and objectively measured moderate and vigorous physical activity. One U.S. study, conducted in youth, found an inverse association between Walk Score and accelerometer-measured physical activity; the authors noted the negative influence of crime may outweigh the association with neighborhood walkability on physical activity in this area. (Pitts et al., 2013) A study with about 150 rural US women found that Walk Score was generally not associated with moderate and vigorous physical activity, (Lo et al., 2019) while a US study with a national cohort of over 4000 adults found those who lived in areas with higher Walk Scores performed more moderate and vigorous physical activity. (Twardzik et al., 2019) Previous studies that have thus far examined the relationship between Walk Score and objectively measured physical activity have methodological weakness such as sample sizes of <300 (Camhi et al., 2019; Chudyk et al., 2017; Gell et al., 2015; Han et al., 2018; Hwang et al., 2016; Koohsari et al., 2019; Lo et al., 2019; Pitts et al., 2013; Duncan et al., 2016) and/or studied specialized populations such as hemodialysis patients, (Han et al., 2018) adults with mobility disabilities, (Gell et al., 2015) or youth. (Pitts et al., 2013).

The findings in previous studies bring into question the utility of Walk Score as a predictor of physical activity, particularly in older women, as none of the previous studies have examined the relationship between neighborhood walkability and objective physical activity with older women. Examining this relationship in older women is particularly important given the fact that walking is a preferred form of physical activity for older women (Reitlo et al., 2018; Li et al., 2017) and can lower the risk of developing cardiovascular disease, even when initiated at older ages. (Bassuk and Manson, 2010) The purpose of this study was to examine associations between neighborhood Walk Score and objective physical activity behavior in older adult women using data from a large, diverse sample of older women in the Women's Health Initiative (WHI) Objective Physical Activity and Cardiovascular Health Study (OPACH) study. Because there is often a positive relationship between socioeconomic status and physical activity, (McNeill et al., 2006) we also examined the relationship between Walk Score and physical activity by neighborhood socioeconomic status in this large, diverse sample of older women.

2. Methods

2.1. Study population

The sample consisted of participants from the WHI OPACH Study. Study procedures have been published previously. (LaCroix et al., 2017) The WHI is an ongoing nationwide prospective study of postmenopausal women in the United States. WHI enrollment data was collected between 1993 and 1998. From 2012 to 2013, participants in the WHI Extension Study Medical Records Cohort were invited to participate in a home visit for the Long Life Study. In-person visits were conducted with 7875 participants. All ambulatory participants were invited to further enroll in the OPACH study. For the OPACH study, participants wore a triaxial accelerometer (Actigraph GT3X +) for one week. At a walking speed of 5 km per hour, waist-worn Actigraph accelerometers have a step count error of about 1.5 %. (Chow et al., 2017) Participants also completed a physical activity questionnaire at OPACH enrollment between 2012 and 2014. 7058 women were enrolled in the OPACH study, of whom 6126 of these provided adherent accelerometer data (≥4 days out of 7 for ≥ 10 awake hours of accelerometer wear per day). Of the 6126 participants with adherent wear, 5650 also had walkability data and were included in this analysis. All participants were non-institutionalized at the time of the study and were able to walk at least 10 min without assistance. Participants provided consent and the study protocol was approved by the Institutional Review Board at the WHI Coordinating Center at the Fred Hutchinson Cancer Research Center.

2.2. Walkability data

Walk Score is a reliable, popular, up-to-date online tool that is commonly used by the public and for research purposes. (Score, 2020) Walk Score ranges from 0 to 100 with lower scores indicating locations that are most car-dependent and higher scores indicating most walkable. Categories are as follows: 0–49: car-dependent; 50–69: somewhat walkable; 70–89: very walkable; 90–100: walker's paradise. The "Classic" Walk Score algorithm uses straight-line "crow flies" distance to the closest amenity within each of their five core categories (educational, retail, food, recreational, and entertainment), whereas the "Street Smart" Walk Score (SSWS) algorithm uses the actual, shortest walking route distance to those amenities. From there, a value for each amenity is calculated using a combination of the distances weighted by facility priority type and a distance decay function. Amenities within a 5-minute walk (0.25 miles) are given maximum points and the decay function is used to give points to more distant amenities, with no points given after a 30-minute walk (1.5 miles). All WHI participant addresses were geocoded (Whitsel et al., 2006) and matched SSWS values.

2.3. Accelerometer-measured physical activity

Information about accelerometer data collection and data processing has been previously published. (LaCroix et al., 2017) Briefly, the accelerometer was placed at the iliac crest and secured with a belt. Women were asked to wear the accelerometer for seven days during both waking and sleeping hours, except when bathing or swimming. The accelerometer did not provide any feedback to participants about their physical activity.

A calibration study was conducted and determined accelerometer count cutpoints that best distinguished physical activity intensity in older adults. (Evenson et al., 2015) Variables used from the OPACH Study include those summarizing total, light intensity, and moderate/vigorous intensity physical activity, and total sedentary time and daily steps while the accelerometer was worn. Specifically, total sedentary time was defined as the average number of minutes per day of 15-second epochs having triaxial vector magnitude acceleration counts <19. Light intensity physical activity, defined as movements with energy expenditure measured by indirect calorimetry between 1.6 and 2.9 metabolic equivalents (METs), was computed as the mean number of minutes per day of 15-second epochs having vector magnitude counts between 19 and 518 per day; moderate/vigorous physical activity intensity (≥3.0 METs) was computed as the mean number of minutes per day of 15-second epochs with vector magnitude counts of at least 519. All physical activity measures were averaged over all days with awake wear time of at least 10 h, and all such days were included in the analysis.

2.4. Neighborhood socioeconomic status

Neighborhood socioeconomic status was an index of six variables at the census tract level: percent of adults older than 25 years with less than a high school education, percent of males employed, percent of households with income levels below the poverty line, percent of households receiving public assistance, percent of female-headed households (no adult male present) with children, and median household income. This composite measure was identified through confirmatory factor analysis (Shih et al., 2011) and has been demonstrated to be an important neighborhood-level predictor of health outcomes. (Shih et al., 2011; Bird et al., 2009; Dubowitz et al., 2012) The neighborhood socioeconomic status composite variable was scaled to range from 0 to 100 for census tracts; higher scores indicate more affluent tracts. We assigned the neighborhood socioeconomic status based on participant residence at baseline.

2.5. Covariates

Potential confounders were selected based on previous literature. Individual demographic factors were obtained from WHI questionnaires and included age, race/ethnicity, years of education, income, marital status, and habitation (e.g., living alone). Behavioral and social support factors were obtained from WHI questionnaires and included self-rated health status and current smoking status. Psychosocial and physical health factors and outcomes were obtained from WHI questionnaires and included menopausal hormone therapy use; depressive symptoms; number of falls in past 12 months; activities of daily living disability; physical function; history of treated diabetes, hypertension, coronary heart disease, congestive heart failure, arthritis, total cancer, chronic obstructive pulmonary disease, or history of hip fractures in those ≥ 55 years. A summary score was developed to reflect the presence and number of the above comorbidities. (Rillamas-Sun et al., 2016).

2.6. Statistical analysis

Descriptive statistics by SSWS were used to describe demographics and other characteristics. The one-to-one relationship between SSWS and baseline characteristics was evaluated by Pearson's chi-square test for categorical variables and by ANOVA F test for continuous variables.

Multiple linear regression with covariate adjustment was used to estimate the level of accelerometer-measured physical activities by SSWS and the difference in physical activities when comparing a higher SSWS category (e.g., somewhat walkable, very walkable, walker's paradise) to the reference category (car-dependent). The linear regression model included the following covariates: age (continuous), race/ethnicity, smoking, alcohol, self-reported general health, number of comorbidities, physical function (continuous), and awake wear time (continuous). The main analysis was then stratified by neighborhood socioeconomic status (high socioeconomic status N = 2513, low socioeconomic status N = 2511). Three participants with daily steps > 50,000 were excluded in the steps modeling. All statistical tests were two-sided, with the level of significance set to 0.05. Analyses were performed with SAS statistical software version 9.4 (SAS Inc, Cary, NC).

3. Results

The analytic sample included 5650 participants with a mean age of 62.6 (SD = 6.8) years at WHI enrollment (1993–1998) and mean age of 79.5 (SD = 6.7) at OPACH accelerometry wear. Over half of the sample (67.2 %) lived in a "car-dependent" location; only 2.8 % lived in a "walker's paradise" location, based on the SSWS score. This pattern was consistent across four OPACH baseline age strata (63–69, 70–79, 80–89, 90–99, p = 0.06) but varied by race/ethnicity ($p < 0.0001$): the percentage of respondents living in car-dependent locations was higher among White than Black and Hispanic respondents (74.9 %, 58.4 %, and 61.7 % respectively). There was an inverse relationship between neighborhood socioeconomic status and SSWS ($p < 0.0001$). There was no evidence to suggest an association between BMI and SSWS (p = 0.60) or an association of self-reported physical activity level and sedentary behavior with SSWS at OPACH baseline (p = 0.08 and p = 0.20, respectively). For clinical risk factors, history of diabetes, hypertension, and number of chronic conditions were strongly related to SWSS (p = 0.0003, p = 0.04 and p = 0.005, respectively), but not for the other factors in Table 1.

The multivariable model indicated a statistically significant association between SSWS and accelerometer-measured steps among the analytic sample, in which participants living in a "walker's paradise" location recorded more steps per day (p = 0.002, Table 2). There also seemed to be patterns whereby participants living in a "walker's paradise" spent more hours in sedentary time, less time on light activities, and less time in total activities (moderate/vigorous activities plus light activities). The association between SSWS and physical activity varied by neighborhood socioeconomic status. Among those living in low socioeconomic status neighborhoods, there was no association between SSWS and physical activity (Table 3). In contrast, among high neighborhood socioeconomic status (Table 3), higher SSWS (i.e., less car-dependent) was significantly positively related to increased steps per day (p = 0.0001). In high socioeconomic status neighborhoods, participants in walker's paradise locations had 1175.9 extra steps per day compared to participants in car-dependent locations (CI: 665.6–1686.2, trend p = 0.02).

4. Discussion

Our study showed a relationship between Walk Score and accelerometer-measured steps per day that varied based upon neighborhood setting and degree of walkability. A previous national cohort study also found a significant positive relationship between Walk Score and objectively measured physical activity across adults aged 45–94, and that the association did not differ by age. (Twardzik et al., 2019) In contrast, in a small study of older adults, Hirsch and colleagues found limited relationships between neighborhood destinations and objectively measured physical activity. (Kim et al., 2020).

Previous studies have found that, even after adjustment for individual socioeconomic status, lower neighborhood socioeconomic status is associated with lower levels of leisure time physical activity. (Gerber et al., 2011; Boone-Heinonen et al., 2011) Neighborhood socioeconomic status and walkability were inversely related in our study. This indicated that many neighborhoods that scored higher on Walk Score were in urban areas where safety from traffic and crime may be a concern. Supporting this notion, we observed a positive association between Walk Score and accelerometer-measured physical activity in higher socioeconomic neighborhoods. Certain neighborhoods may be less likely to have issues with crime and traffic and the populations that live there may be less likely to have chronic conditions or mobility issues, may have better access to and utilization of primary/preventive medicine advice that promotes walking, and may have more leisure time. Similarly, Pitts et al. reported an inverse association between moderate-to-vigorous physical activity and Walk Score in a population of youth where Walk Score was also positively associated with crime. (Pitts et al., 2013) They posited the negative effects of crime may explain the lack of an association between Walk Score and physical activity in their study. Our results build upon this concept and suggest Walk Score, without

Table 1
Baseline characteristics of participants by Street Smart Walk Score (N = 5650).

Characteristics	Total N	Street Smart Walk Score				p
		Car-dependent	Somewhat Walkable	Very Walkable	Walker's Paradise	
		n (%) or n, mean (SD)				
All	5650	3796 (67.2 %)	1069 (18.9 %)	627 (11.1 %)	158 (2.8 %)	
Age [1]						0.06
60–69	502	327 (65.14 %)	105 (20.92 %)	59 (11.75 %)	11 (2.19 %)	
70–79	2293	1494 (65.15 %)	446 (19.45 %)	276 (12.04 %)	77 (3.36 %)	
80–89	2587	1796 (69.42 %)	468 (18.09 %)	263 (10.17 %)	60 (2.32 %)	
90–99	268	179 (66.79 %)	50 (18.66 %)	29 (10.82 %)	10 (3.73 %)	
Race [2]						<0.0001
White	2808	2104 (74.93 %)	449 (15.99 %)	206 (7.34 %)	49 (1.75 %)	
Black	1871	1093 (58.42 %)	400 (21.38 %)	308 (16.46 %)	70 (3.74 %)	
Ethnicity [2]						<0.0001
Hispanic	971	599 (61.69 %)	220 (22.66 %)	113 (11.64 %)	39 (4.02 %)	
Income [2]						0.002
<$20,000	834	523 (62.71 %)	179 (21.46 %)	107 (12.83 %)	25 (3.00 %)	
$20,000-$34,999	1416	933 (65.89 %)	310 (21.89 %)	135 (9.53 %)	38 (2.68 %)	
$35,000-$49,999	1190	815 (68.49 %)	211 (17.73 %)	137 (11.51 %)	27 (2.27 %)	
$50,000-$74,999	1110	748 (67.39 %)	191 (17.21 %)	134 (12.07 %)	37 (3.33 %)	
>=$75,000	863	611 (70.80 %)	138 (15.99 %)	85 (9.85 %)	29 (3.36 %)	
Education [2]						<0.0001
None through high school diploma	1131	766 (67.73 %)	224 (19.81 %)	121 (10.70 %)	20 (1.77 %)	
School after high school	2162	1456 (67.35 %)	436 (20.17 %)	226 (10.45 %)	44 (2.04 %)	
College degree or higher	2324	1553 (66.82 %)	401 (17.25 %)	278 (11.96 %)	92 (3.96 %)	
Living alone [1]	2317	1456(62.84 %)	481(20.76 %)	290(12.52 %)	90(3.88 %)	<0.0001
Marital status [2]						<0.0001
Never married	226	110 (48.67 %)	65 (28.76 %)	39 (17.26 %)	12 (5.31 %)	
Divorced/separated	1110	613 (55.23 %)	260 (23.42 %)	186 (16.76 %)	51 (4.59 %)	
Widowed	966	631 (65.32 %)	181 (18.74 %)	118 (12.22 %)	36 (3.73 %)	
Presently married/living as married	3332	2433 (73.02 %)	559 (16.78 %)	282 (8.46 %)	58 (1.74 %)	
Neighborhood socioeconomic status [3]	5024	3486,74.46 (9.15)	894,71.12 (10.40)	497,69.41 (11.35)	147,67.04 (14.22)	<0.0001
Physical activity level (METs) [1]	5650	3796,417.5 (170.1)	1069,404.1 (166.7)	627,408.5 (163.9)	158,426.6 (179.6)	0.08
BMI [1]						0.60
<25	1741	1163 (66.80 %)	337 (19.36 %)	187 (10.74 %)	54 (3.10 %)	
25–30	1912	1301 (68.04 %)	364 (19.04 %)	200 (10.46 %)	47 (2.46 %)	
>30	1997	1332 (66.70 %)	368 (18.43 %)	240 (12.02 %)	57 (2.85 %)	
Sedentary behavior [1]						0.20
≤6 h/day	1613	1086 (67.33 %)	307 (19.03 %)	182 (11.28 %)	38 (2.36 %)	
>6–8 h/day	1010	708 (70.10 %)	161 (15.94 %)	111 (10.99 %)	30 (2.97 %)	
>8–11 h/day	1260	868 (68.89 %)	231 (18.33 %)	122 (9.68 %)	39 (3.10 %)	
>11 h/day	1093	711 (65.05 %)	220 (20.13 %)	130 (11.89 %)	32 (2.93 %)	
Self-rated health status [1]						0.053
Excellent	530	376 (70.94 %)	89 (16.79 %)	50 (9.43 %)	15 (2.83 %)	
Very good	2162	1479 (68.41 %)	374 (17.30 %)	248 (11.47 %)	61 (2.82 %)	
Good	2019	1354 (67.06 %)	377 (18.67 %)	233 (11.54 %)	55 (2.72 %)	
Fair/Poor	468	294 (62.82 %)	114 (24.36 %)	46 (9.83 %)	14 (2.99 %)	
Smoking now [1]	145	94 (64.83 %)	32 (22.07 %)	14 (9.66 %)	5 (3.45 %)	0.62
Alcohol use [1]						0.23
Never	1927	1281 (66.48 %)	375 (19.46 %)	224 (11.62 %)	47 (2.44 %)	
<1 per week	1784	1213 (67.99 %)	342 (19.17 %)	185 (10.37 %)	44 (2.47 %)	
1 or 2 times per week	545	368 (67.52 %)	89 (16.33 %)	66 (12.11 %)	22 (4.04 %)	
3 or 4 times per week	358	245 (68.44 %)	61 (17.04 %)	41 (11.45 %)	11 (3.07 %)	
5 or 6 times per week	290	197 (67.93 %)	44 (15.17 %)	37 (12.76 %)	12 (4.14 %)	
Every day	297	217 (73.06 %)	47 (15.82 %)	25 (8.42 %)	8 (2.69 %)	
Female hormone use in the past year [1]	347	238 (68.59 %)	58 (16.71 %)	39 (11.24 %)	12 (3.46 %)	0.50
Depressed mood [1]						0.75
0	1600	1080 (67.50 %)	301 (18.81 %)	173 (10.81 %)	46 (2.88 %)	
1–2	1709	1168 (68.34 %)	301 (17.61 %)	199 (11.64 %)	41 (2.40 %)	
3–4	1027	698 (67.96 %)	193 (18.79 %)	103 (10.03 %)	33 (3.21 %)	
5+	687	453 (65.94 %)	133 (19.36 %)	77 (11.21 %)	24 (3.49 %)	
Number of falls in the past 12 months [1]						0.31
None	3848	2611 (67.85 %)	717 (18.63 %)	416 (10.81 %)	104 (2.70 %)	
1 time	1163	777 (66.81 %)	216 (18.57 %)	140 (12.04 %)	30 (2.58 %)	
2 or more times	639	408 (63.85 %)	136 (21.28 %)	71 (11.11 %)	24 (3.76 %)	
Activity of daily living disability (≥1 disability) 1	110	72 (65.45 %)	21 (19.09 %)	17 (15.45 %)	0 (0.00 %)	0.17
History of congestive heart failure [1]	92	57 (61.96 %)	18 (19.57 %)	12 (13.04 %)	5 (5.43 %)	0.38
History of coronary heart disease [1]	571	377 (66.02 %)	121 (21.19 %)	60 (10.51 %)	13 (2.28 %)	0.45
History of stroke [1]	178	130 (73.03 %)	29 (16.29 %)	17 (9.55 %)	2 (1.12 %)	0.28
History of diabetes (use of pills or shots) [1]	1130	721 (63.81 %)	257 (22.74 %)	111 (9.82 %)	41 (3.63 %)	0.0003
History of hypertension [1]	4036	2680 (66.40 %)	794 (19.67 %)	457 (11.32 %)	105 (2.60 %)	0.04
History of arthritis [1]	4094	2747 (67.10 %)	786 (19.20 %)	444 (10.85 %)	117 (2.86 %)	0.64
History of cancer [1]	936	597 (63.78 %)	197 (21.05 %)	117 (12.50 %)	25 (2.67 %)	0.08
History of chronic obstructive pulmonary disease [1]	284	183 (64.44 %)	67 (23.59 %)	25 (8.80 %)	9 (3.17 %)	0.15
History of hip fracture at age ≥ 55 years [1]	122	74 (60.66 %)	27 (22.13 %)	20 (16.39 %)	1 (0.82 %)	0.10
Number of chronic conditions [1]						0.005

(*continued on next page*)

Table 1 (*continued*)

Characteristics	Total N	Street Smart Walk Score				p
		Car-dependent	Somewhat Walkable	Very Walkable	Walker's Paradise	
0	1011	694 (68.64 %)	180 (17.80 %)	105 (10.39 %)	32 (3.17 %)	
1	1965	1335 (67.94 %)	344 (17.51 %)	235 (11.96 %)	51 (2.60 %)	
2	1498	1006 (67.16 %)	286 (19.09 %)	170 (11.35 %)	36 (2.40 %)	
3+	1152	753 (65.36 %)	248 (21v53%)	113 (9.81 %)	38 (3.30 %)	
Morbidity data missing	24	8 (33.33 %)	11 (45.83 %)	4 (16.67 %)	1 (4.17 %)	
Hours accelerometer worn per day	5650	3796,14.78 (1.27)	1069,14.68 (1.32)	627,14.85 (1.35)	158,15.05 (1.38)	0.002
Daily steps from accelerometer	5650	3796,3724 (3258)	1069,3598 (3700)	627,3612 (2200)	158,4366 (2757)	0.04
Sedentary time, hours	5650	3796,9.06 (1.56)	1069,9.06 (1.59)	627,9.13 (1.62)	158,9.23 (1.67)	0.45
Light physical activities, hours	5650	3796,4.84 (1.28)	1069,4.80 (1.32)	627,4.88 (1.29)	158,4.88 (1.31)	0.65
Moderate/vigorous physical activities, hours	5650	3796,0.87 (0.59)	1069,0.82 (0.57)	627,0.84 (0.55)	158,0.94 (0.62)	0.02

Abbreviations: BMI: body mass index, METs: metabolic equivalent of task.

[1] Based on questionnaires collected prior to accelerometry wear (OPACH baseline).

[2] Based on questionnaires collected on WHI baseline.

[3] Based on 2010 U.S. Census data.

Table 2

Multivariate Regression Examining Relationship between Street Smart Walk Scores and Accelerometer-measured Physical Activity (N = 5650) [1.]

	Estimates	Difference	p
Steps per day			0.002
Car dependent	3676.4 (3435.7, 3917.0)		
Somewhat walkable	3639.1 (3383.1, 3895.0)	−37.29 (-161.90, 87.33)	
Very walkable	3632.6 (3360.8, 3904.3)	−43.79 (-199.60, 112.04)	
Walker's paradise	4230.5 (3861.6, 4599.5)	554.15 (257.75, 850.54)	
Trend p			0.17
Sedentary time, hours/day			0.29
Car dependent	9.09 (8.90,9.28)		
Somewhat walkable	9.14 (8.94,9.34)	0.05 (-0.05,0.15)	
Very walkable	9.18 (8.97,9.40)	0.09 (-0.03,0.21)	
Walker's paradise	9.24 (8.95,9.54)	0.15 (-0.08,0.39)	
Trend p			0.053
Time spent on light activities, hours/day			0.13
Car dependent	4.87 (4.71,5.03)		
Somewhat walkable	4.83 (4.66,5.00)	−0.03 (-0.11,0.05)	
Very walkable	4.79 (4.61,4.97)	−0.07 (-0.18,0.03)	
Walker's paradise	4.67 (4.42,4.91)	−0.20 (-0.40,-0.00)	
Trend p			0.03
Time spent on moderate/vigorous activities, hours/day			0.47
Car dependent	0.85 (0.78,0.92)		
Somewhat walkable	0.83 (0.76,0.91)	−0.02 (-0.05,0.02) −0.02(-006,0.03) 0.05(-0.04,0.13)	
Very walkable	0.83 (0.76,0.91)	−0.02 (-0.06,0.03)	
Walker's paradise	0.90 (0.79,1.01)	0.05 (-0.04,0.13)	
Trend p			0.86
Total activities, hours/day			0.29
Car dependent	5.72 (5.53,5.91)		
Somewhat walkable	5.67 (5.47,5.87)	−0.05 (-0.15,0.05)	
Very walkable	5.63 (5.41,5.84)	−0.09 (-0.21,0.03)	
Walker's paradise	5.57 (5.27,5.86)	−0.15 (-0.39,0.08)	
Trend p			0.053

[1] Adjusted for age, race/ethnicity, smoking, alcohol, self-reported health, number of chronic conditions, physical functioning, and wear time.

considering additional contextual factors pertaining to the built environment and the individual, is not associated with physical activity in a given neighborhood. In sum, the findings from our present study also have implications for future research. A better understanding of these additional contextual factors will be important in incorporating design aspects for walkability in less affluent communities. Additionally, development of age-relevant methods to assess and characterize neighborhood walkability are needed to better evaluate the influence that built environment has on physical activity and sedentary behaviors in later life adults.

This study used a large, diverse sample of older community-dwelling adult women to examine the relationship between neighborhood walkability and accelerometer-measured physical activity. While the study has many strengths, it also has some weaknesses. There was high heterogeneity across neighborhood type, and small cell sizes in some cases. Some factors that may influence walking among older women, such as perceptions of safety walking outside, environmental obstacles like busy intersections, and pet ownership, were not captured. Walk Score calculations include destinations within a distance of up to 1.5 miles. For adults older than 75, destinations up to 1.5 miles might not be feasible for travel by walking over this distance. Thus, additional development of walkability measures with shorter distances may be more appropriate for older populations. Also, it may be that older adults are more likely to walk for leisure purposes than utilitarian reasons. We were also unable to disaggregate physical activity that took place indoors from that which took place outdoors, so the amount of activity attributable to walkability is unknown. The multivariate regression examining the relationship between SSWS and physical activity by socioeconomic status was an exploratory analysis, could be subject to multiple testing errors, and would need additional research to confirm the findings.

5. Conclusions

In this study with a large, diverse sample of older women, neighborhood Walk Score was associated with accelerometer-measured physical activity. The association varied by neighborhood socioeconomic status; in high socioeconomic neighborhoods, there was a positive relationship between Walk Score and physical activity, while in low socioeconomic neighborhoods, there was no association between Walk Score and physical activity. This study provides important evidence to suggest that built environment factors and measures beyond SSWS are needed to understand walkability and active living among diverse older women especially those with less socioeconomic advantage. Future studies should examine what factors make a neighborhood walkable for this population, which may be very different from the characteristics of relevance for children and younger adults.

CRediT authorship contribution statement

Rebecca A. Seguin-Fowler: Conceptualization, Writing – original draft. **Andrea Z. LaCroix:** Conceptualization, Writing – review & editing. **Michael J. LaMonte:** Writing – review & editing. **Jingmin Liu:** Writing – review & editing. **Jason E. Maddock:** Writing – original draft. **Chad D. Rethorst:** Writing – original draft. **Chloe E. Bird:** Writing – review & editing. **Marcia L. Stefanick:** Writing – review & editing. **JoAnn E. Manson:** Writing – review & editing.

Table 3
Multivariate Regression Examining Relationship between Street Smart Walk Scores and Accelerometer-measured Physical Activity by Socioeconomic Status [1.]

	High Socioeconomic Status N = 2513 Estimates	Difference	p	Low Socioeconomic Status N = 2511 Estimates	Difference	p
Steps per day			0.0001			0.24
Car dependent	3505.3 (3118.7,3891.9)			3900.8 (3553.8,4247.8)		
Somewhat walkable	3495.9 (3073.9,3918.0)	−9.38 (-212.2,193.5)		3881.1 (3514.5,4247.7)	−19.64 (-194.4,155.15)	
Very walkable	3512.2 (3053.9,3970.4)	6.84 (-274.4,288.10)		3845.9 (3458.1,4233.7)	−54.83 (-268.5,158.87)	
Walker's paradise	4681.2 (4061.1,5301.3)	1175.9 (665.6,1686..)		4258.5 (3767.0,4750.0)	357.77 (-12.18,727.73)	
Trend p			0.02			0.50
Sedentary time, hours/day			0.49			0.44
Car dependent	9.15 (8.84,9.45)			9.10 (8.81,9.39)		
Somewhat walkable	9.18 (8.85,9.51)	0.03 (-0.13,0.19)		9.14 (8.84,9.45)	0.04 (-0.10,0.19)	
Very walkable	9.32 (8.96,9.68)	0.17 (-0.05,0.39)		9.17 (8.85,9.50)	0.07 (-0.11,0.25)	
Walker's paradise	9.09 (8.60,9.58)	−0.06 (-0.46,0.34)		9.33 (8.92,9.75)	0.24 (-0.08,0.55)	
Trend p			0.33			0.13
Time spent on light activities, hours/day			0.24			0.40
Car dependent	4.91 (4.66,5.17)			4.75 (4.51,4.99)		
Somewhat walkable	4.87 (4.60,5.15)	−0.04 (-0.17,0.09)		4.74 (4.49,5.00)	−0.01 (-0.13,0.12)	
Very walkable	4.74 (4.44,5.04)	−0.18 (-0.36,0.01)		4.72 (4.45,4.99)	−0.03 (-0.18,0.12)	
Walker's paradise	4.77 (4.36,5.18)	−0.14 (-0.48,0.19)		4.53 (4.18,4.87)	−0.22 (-0.48,0.04)	
Trend p			0.054			0.22
Time spent on moderate/vigorous activities, hours/day			0.06			0.36
Car dependent	0.80 (0.68,0.91)			0.93 (0.83,1.03)		
Somewhat walkable	0.81 (0.69,0.93)	0.01 (-0.05,0.07)		0.89 (0.78,1.00)	−0.04 (-0.09,0.01)	
Very walkable	0.80 (0.67,0.93)	0.01 (-0.07,0.09)		0.89 (0.77,1.00)	−0.04 (-0.11,0.02)	
Walker's paradise	1.00 (0.82,1.18)	0.20 (0.06,0.35)		0.92 (0.77,1.06)	−0.01 (-0.12,0.10)	
Trend p			0.08			0.17
Total activities, hours /day			0.49			0.44
Car dependent	5.71 (5.41,6.01)			5.68 (5.39,5.97)		
Somewhat walkable	5.68 (5.35,6.01)	−0.03 (-0.19,0.13)		5.64 (5.33,5.94)	−0.04 (-0.19,0.10)	
Very walkable	5.54 (5.18,5.90)	−0.17 (-0.39,0.05)		5.61 (5.28,5.93)	−0.07 (-0.25,0.10)	
Walker's paradise	5.77 (5.28,6.26)	0.06 (-0.34,0.46)		5.44 (5.03,5.86)	−0.24 (-0.55,0.08)	
Trend p			0.33			0.13

[1] Adjusted for age, race/ethnicity, smoking, alcohol, self-reported health, number of chronic conditions, physical functioning, and wear time.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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