Published in final edited form as:

Am J Prev Med. 2016 November ; 51(5): 722–730. doi:10.1016/j.amepre.2016.04.007.

Neighborhood Walkability and Adiposity in the Women's Health Initiative Cohort

Urshila Sriram, MSPH¹, Andrea Z. LaCroix, PhD², Wendy E. Barrington, PhD, MPH³, Giselle Corbie-Smith, MD, MSc⁴, Lorena Garcia, PhD⁵, Scott B. Going, PhD⁶, Michael J. LaMonte, PhD, MPH⁷, JoAnn E. Manson, MD, DrPH⁸, Shawnita Sealy-Jefferson, PhD⁹, Marcia L. Stefanick, PhD¹⁰, Molly E. Waring, PhD¹¹, and Rebecca A. Seguin, PhD¹

¹Division of Nutritional Sciences, Cornell University, Ithaca, New York

²Division of Epidemiology, Family and Preventive Medicine, University of California, San Diego, La Jolla, California

³Department of Psychosocial and Community Health, University of Washington, Seattle, Washington

⁴Departments of Social Medicine, Medicine, and Epidemiology, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina

⁵Department of Public Health Sciences, University of California, Davis, California

⁶Department of Nutritional Sciences, University of Arizona, Tucson, Arizona

⁷Department of Epidemiology and Environmental Health, School of Public Health and Health Professions, State University of New York at Buffalo, Buffalo, New York

⁸Brigham and Women's Hospital, Harvard Medical School, Boston, Massachusetts

⁹Department of Family Medicine and Public Health Sciences, School of Medicine, Wayne State University, Detroit, Michigan

¹⁰Department of Medicine, Stanford Prevention Research Center, Stanford University School of Medicine, Stanford, California

¹¹Department of Quantitative Health Sciences, University of Massachusetts Medical School, Worcester, Massachusetts

Abstract

Introduction—Neighborhood environments may play a role in the rising prevalence of obesity among older adults. However, research on built environmental correlates of obesity in this age group is limited. The current study aimed to explore associations of Walk Score, a validated

Address correspondence to: Rebecca A. Seguin, PhD, Division of Nutritional Sciences, Cornell University, 412 Savage Hall, Ithaca NY 14853. rebeccaseguin@cornell.edu.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

No financial disclosures were reported by the authors of this paper.

measure of neighborhood walkability, with BMI and waist circumference in a large, diverse sample of older women.

Methods—This study linked cross-sectional data on 6,526 older postmenopausal women from the Women’s Health Initiative Long Life Study (2012–2013) to Walk Scores for each participant’s address (collected in 2012). Linear and logistic regression models were used to estimate associations of BMI and waist circumference with continuous and categorical Walk Score measures. Secondary analyses examined whether these relationships could be explained by walking expenditure or total physical activity. All analyses were conducted in 2015.

Results—Higher Walk Score was not associated with BMI or overall obesity after adjustment for sociodemographic, medical, and lifestyle factors. However, participants in highly walkable areas had significantly lower odds of abdominal obesity (waist circumference >88 cm) as compared with those in less walkable locations. Observed associations between walkability and adiposity were partly explained by walking expenditure.

Conclusions—Findings suggest that neighborhood walkability is linked to abdominal adiposity, as measured by waist circumference, among older women and provide support for future longitudinal research on associations between Walk Score and adiposity in this population.

Introduction

Recent U.S. estimates suggest that approximately 71.6% of older adults, defined as people aged 60 years and older, are overweight or obese, and these proportions are continuing to rise.¹ Older women also experience a disproportionately high prevalence of abdominal obesity, defined as a waist circumference >88 cm, as compared with other age or gender groups.² Obesity, particularly abdominal adiposity, may further exacerbate age-related functional decline and the development of chronic illnesses commonly associated with aging.³ Coupled with the rapidly aging population,⁴ these obesity trends will have significant impacts on the healthcare system and older adults’ overall quality of life.

An ecologic perspective suggests that neighborhood environments can contribute to obesity by impacting health-related behaviors such as walking and other forms of physical activity.⁶ This is of particular relevance for older adults who tend to remain in the same communities as they age.⁷ As such, there has been growing interest in built environment features that influence the walkability of a neighborhood, including street connectivity and residential density.⁸ Walking is the most accessible form of physical activity for older adults; several studies have documented associations between neighborhood walkability and physical activity or walking patterns in this age group.^{9–14} Expanding opportunities for walking and physical activity can help older adults achieve or maintain a healthy weight and slow age-related functional decline. Thus, manipulating the built environment to support walking may help improve health outcomes and support older adults aging in place.

Previous research has shown associations between built environmental features and weight outcomes in younger adults.^{15–19} However, research with elderly populations has yielded mixed results.^{7,8,10,20–25} Most of these studies have concentrated on single cities or states, and have used GIS-based built environment attributes to define walkability, such as land use mix, street connectivity, or residential density. GIS-based approaches may have limited

comparability due to a lack of standardized methodology for deriving built environment measures.^{26,27} The cost, time, and expertise required to obtain and process GIS data are additional challenges that limit the use of this approach by public health practitioners and researchers alike.^{26,27}

Walk Score²⁸ is an open-source measure of neighborhood walkability that is known for its accessibility and continually updated data. For a given location, Walk Score combines information on distance to nearby amenities, intersection density, and block length to assign a walkability score ranging from 0 to 100. Unlike traditional GIS-based measures, which require extensive time and resources to produce walkability data, Walk Scores can be easily obtained for geocoded addresses through a publicly available website.²⁹ Accumulating evidence indicates that Walk Score provides a valid measure of built environment features and has good generalizability across a variety of populations and geographic regions.²⁸ Previous studies using Walk Score have primarily examined the relationship between neighborhood walkability and physical activity.^{26,30,31} To the authors' knowledge, only one study has examined obesity as an outcome, in a sample of both middle-aged and older adults, and found that moving to a more walkable area was associated with a decrease in BMI.²⁵ However, these findings have limited generalizability to elderly populations owing to the relatively small and mixed-aged sample size.

To fill these gaps in the existing literature, the current study used cross-sectional data from a large, diverse sample of older women in the Women's Health Initiative (WHI) cohort to examine associations of neighborhood walkability, as measured by Walk Score, with BMI and waist circumference, respectively. A secondary analysis examined whether walking expenditure or total physical activity could account for the relationship between walkability and adiposity.

Methods

Study Population

The sample consisted of participants from the WHI Long Life Study (LLS), an ongoing prospective study of postmenopausal women aged 63–99 years. The LLS enrolled a subset of women from the WHI 2010–2015 Extension Study Medical Records Cohort, which includes all former participants of the WHI hormone trials and all African American and Hispanic women. Eligibility and recruitment details of the main WHI and Extension Studies have been previously published.³² Briefly, women aged ≥63 years from the Medical Records Cohort with available genetic and cardiovascular disease biomarker data were invited to participate in an at-home clinical assessment. Women were excluded if they resided in an institution or were unable or unwilling to provide informed consent. Of the 14,081 women eligible for the LLS, 7,875 successfully completed the at-home visit between March 2012 and May 2013. Visits included a blood draw, physical measurements, and an assessment of physical functional status. All participants provided written informed consent and the study protocol was approved by the IRB at the Fred Hutchinson Cancer Research Center.

Measures

Street Smart (SS) Walk Score²⁸ measures the walkability of a given geographic location based on its distance to nearby amenities within five core categories: education (e.g., schools), retail (e.g., clothing stores), food (e.g., restaurants), recreation (e.g., parks), and entertainment (e.g., movie theaters). SS Walk Score values are assigned using publicly available data from sources such as Google, Education.com, Open Street Map, and the U.S. Census.²⁹

A distance decay function is used to award points to amenities in each category, with destinations within a 0.25-mile radius of the origin receiving maximum points and those outside a 1.5-mile radius receiving no points.²⁹ Categories are weighted to reflect destinations associated with more walking trips and points for each category are summed and normalized to create a score from 0 to 100. Scores are adjusted for street network characteristics, such as block length and intersection density, which facilitate walking by increasing the availability of alternative routes.²⁸ Lower scores indicate locations that are more car-dependent, whereas higher scores indicate those that are more walkable.

Unlike the traditional Walk Score measure, which uses straight-line distances to amenities, SS Walk Score uses street network buffers to estimate the shortest walking route between destinations. The latter measure allows multiple amenities within each category to contribute the overall score, providing a more accurate representation of available choices.²⁶

Updated address information was collected for all LLS participants in 2012. To assign SS Walk Scores, addresses were entered as geographic coordinates and an application programming interface was used to query the Walk Score database through URL calls.²⁹ The Walk Score application programming interface eliminates the need for a website interface, which is especially useful with large data sets.²⁴ To maintain confidentiality of participant addresses, Walk Score values were assigned within the WHI Clinical Coordinating Center and provided to the study team.

The team used SS Walk Scores to classify participants into one of five pre-determined walkability categories²⁸: “very car-dependent” (almost all errands require a car, 0–24), “car-dependent” (few amenities within walking distance, 25–49), “somewhat walkable” (some amenities within walking distance, 50–69), “very walkable” (most errands can be accomplished on foot, 70–89), and “walker’s paradise” (daily errands do not require a car, 90–100).

Anthropometric measurements were made by trained examiners during the LLS in-home visit using standardized methods. BMI was calculated by dividing measured weight in kg by measured height in m². Participants were classified into the following BMI categories based on NIH standards⁵: underweight (<18 kg/m²), normal weight (18.0–24.9 kg/m²), overweight (25.0–29.9 kg/m²), and obese (≥30 kg/m²). Waist circumference in cm was measured at the umbilicus. Abdominal obesity was defined as a waist circumference >88 cm.⁵

Walking expenditure and total physical activity were assessed using the WHI physical activity questionnaire, which has demonstrated good validity and reliability in this

population.^{33,34} Participants were asked to record the weekly frequency, duration, and intensity of walking outside the home (≥ 10 minutes) and other recreational activities. Walking expenditure was estimated in MET hours per week using the following equation: (Frequency of walking episodes [≥ 10 minutes] per week × Minutes per episode × MET level [kcal/kg*hour]) / (60 minutes/hour).³³ MET levels were assigned according to participants' usual walking speed (four levels, 2–5 mph).³³ Total physical activity was defined as the amount of time (in minutes) spent doing any form of recreational physical activity per week.

Information on demographic, medical, and lifestyle factors was obtained through standardized, self-report questionnaires. Sociodemographic factors included age at LLS visit, race/ethnicity (Hispanic, non-Hispanic white, or non-Hispanic black), educational attainment, annual family income, and marital status. Medical and lifestyle factors known to be associated with body weight in this cohort included self-rated health (4-point scale of *fair/poor* to *excellent*), current smoking status, treated diabetes, treated hypertension, and physical function.^{35–37} Physical functioning was assessed using the well-validated RAND 36-item Short-Form Health Survey.³⁸ The ten-item physical function scale reflects the extent to which current health limits the performance of activities ranging from running to bathing. Scale scores vary from 0 to 100 with higher scores reflecting improved physical function.

Statistical Analysis

Analyses were conducted in 2015 using SAS, version 9.4. Participant characteristics were characterized by Walk Score category using means (SDs) for continuous variables, and frequencies (%) for categorical variables. ANOVA or chi-square tests were used to compare demographic characteristics and outcome measures across the five Walk Score categories.

Generalized linear regression models were used to estimate associations between BMI or waist circumference and SS Walk Score (continuous and categorical). Multinomial logistic regression models were used to determine ORs of overweight or obesity, relative to normal weight, associated with continuous or categorical SS Walk Score. Similar models were used to estimate ORs of abdominal obesity (waist circumference >88 cm) associated with SS WalkScore. Continuous SS Walk Score values were rescaled in 10-point increments, to provide meaningful estimates of association between walkability scores and measures of adiposity.

A two-stage process was used to investigate whether associations between neighborhood walkability and adiposity could be explained by total physical activity or walking behavior.³⁹ First, associations between each variable and SS Walk Score were examined using generalized linear regression models. Second, final multivariate linear or logistic regression models were run to include walking expenditure or total physical activity.

All models were adjusted for age at LLS visit, race/ethnicity, educational attainment, annual family income, marital status, self-rated health, current smoking status, treated diabetes, treated hypertension, and physical function. Covariates were selected a priori based on previous analyses of walkability and BMI^{9,20–24} and existing literature on known risk factors for excess weight in this population.^{33–35}

Results

The WHI LLS participants whose addresses could not be geocoded ($n=10$), those with incomplete anthropometric data ($n=117$), and those missing covariate data ($n=1,222$) were excluded from the analysis, resulting in an analytic sample of 6,526 older women. Women who were excluded were more likely to have lower educational attainment, lower income, lower physical function, and be non-Hispanic black. These women were also less likely to be married or living with a partner; however, no differences in age, self-reported health status, or other health indicators were observed (Appendix Table 1). Included participants ranged from age 63 to 97 years at the time of LLS visit, with an overall mean age of 78.7 (SD=6.8) years. The age distribution of participants differed significantly across SS Walk Score categories ($p<0.001$) (Table 1). Participants living in the most walkable areas (“walker’s paradise”) reported the highest average walking expenditures and total physical activity levels ($p<0.001$ for all).

Non-Hispanic whites, married individuals, and high-income earners (\$75,000) were more likely to reside in less walkable areas (“very car-dependent” and “car-dependent”) ($p<0.001$ for all). Residents of the most walkable locations reported the highest educational attainment and were more likely to report excellent health ($p<0.01$ for all). Individuals with treated diabetes were disproportionately located in highly walkable areas, whereas those with lower physical function were more likely to reside in “somewhat walkable” areas ($p<0.05$ for all). No differences in smoking status or treated hypertension were observed across categories of SS Walk Score (Table 1).

Tables 2 and 3 show the associations of walkability with BMI and waist circumference, respectively. There were no significant differences in average BMI or waist circumference across measures of SS Walk Score, after adjusting for sociodemographic, medical history, and lifestyle factors (Model 2, Tables 2 and 3). Every 10-point increase in SS Walk Score was associated with slightly lower odds of being overweight (OR=0.98, 95% CI=0.95, 1.00), but not with overall obesity (Model 2, Table 2). However, the odds of abdominal obesity were 28% lower among residents of the most walkable locations as compared with those living in “very car-dependent” areas (OR=0.72, 95% CI=0.53, 0.99) (Model 2, Table 3).

Secondary analyses showed significant associations of walking expenditure with both continuous and categorical measures of SS Walk Score (Appendix Table 2). Accounting for walking expenditure attenuated all associations between walkability and adiposity (Model 3, Tables 2 and 3). Living in a highly walkable area (“walker’s paradise”) was no longer associated with lower odds of overweight or abdominal obesity.

Although total physical activity was not associated with continuous SS Walk Score, women in “walker’s paradise” areas reported significantly higher levels of total physical activity compared with those living in “very car-dependent” areas (Appendix Table 2). In contrast to walking expenditure, total physical activity did not explain all associations between SS Walk Score and adiposity (Model 4, Tables 2 and 3).

Discussion

Higher neighborhood walkability, as measured by SS Walk Score, was not associated with average BMI or overall obesity in a large, diverse cohort of older U.S. postmenopausal women. However, residents of highly walkable locations were less likely to be abdominally obese than individuals living in less walkable areas, and this association was partially explained by walking expenditure.

The lack of association between SS Walk Score and BMI is consistent with results from a prospective study in older adults in which neighborhood walkability did not explain changes in adiposity, as measured by BMI.²² However, results from other cross-sectional studies have been mixed.^{7,8,10,20,21,23,24} For example, one study in King County, Washington, found that BMI was not significantly lower among older adults in highly walkable neighborhoods.²⁰ By contrast, data from the Senior Neighborhood Quality of Life Study showed that residents of more walkable neighborhoods had lower self-reported BMIs than individuals living in less walkable areas.¹⁰ Possible explanations for this discrepancy include the higher mean age of the present sample (78.6 years), potential lack of comparability between self-reported and measured BMI,⁴⁰ neighborhood socioeconomic differences, or self-selection effects. The concept of “self-selection” suggests that individuals either choose or are limited to an area based on lifestyle preferences and personal circumstances.⁴⁵ Active women may choose to move to more walkable areas as they age, whereas less active or functionally impaired older women may be limited to less walkable locations.

The observed association between abdominal adiposity and neighborhood walkability is supported by research highlighting the better predictive ability of waist circumference in older populations.⁴¹ Although adults tend to deposit more visceral fat as they age, these increases are accompanied by a progressive decline in fat-free mass leading to an overall reduction in body weight. Owing to age-related changes in body composition, BMI tends to underestimate fatness in older individuals.⁴² Given that waist circumference is a more accurate indicator of adiposity in older age groups, this measure may be more sensitive to the effects neighborhood walkability than BMI.

Adjustments for walking expenditure and total physical activity were found to attenuate observed associations between neighborhood walkability and adiposity. The stronger degree of attenuation by walking expenditure provides validation for the SS Walk Score construct, which was designed to measure walkability to nearby destinations. As total physical activity encompasses all forms of physical activity, weaker associations between this measure and walkability were expected. This is consistent with several studies in older adults that found no relationship of walkability with total physical activity.^{9,10} The present preliminary findings suggest that walking expenditure may partly explain the walkability–adiposity relationship; however, more robust mediational analyses are needed. Research in younger adults has identified self-reported transport walking as a partial mediator of this association,⁴³ providing support for continued research among elderly populations.

Strengths of this study include the large sample size, inclusion of women from diverse racial and ethnic backgrounds, and measurement of anthropometric data (BMI and waist

circumference) by trained research personnel. Additionally, SS Walk Score was used to provide an objective, composite assessment of neighborhood walkability that combines access to destinations with street connectivity and density.²⁴ Previous research has shown that composite measures of the built environment are more reflective of walkability than individual measures of land use, population density, or street networks.⁴⁴

Limitations

The cross-sectional design of this study prevents any inference of a causal relationship between adiposity and walkability. Although highly walkable areas may improve health outcomes by increasing opportunities for physical activity, these effects may also be a result of neighborhood self-selection. Thus, highly active older women may opt to reside in more walkable areas, whereas those who are less active may choose or be limited to living in less walkable locations. Though longitudinal studies can address this issue of selection bias, cross-sectional studies that control for residential self-selection are also recommended. Other limitations include a lack of available data on transportation use or driving history. Access to and utilization of motorized transport may influence the relationship with neighborhood walkability and deserves further consideration. Although Walk Score offers multiple advantages, it excludes several important factors that may influence the walkability of a neighborhood. These include the presence of sidewalks, crime levels (a proxy for neighborhood safety), area topography, and weather conditions. Lastly, the analysis was restricted to a specific sample of older women, which limits generalizability to women with different sociodemographic characteristics and elderly men.

Conclusions

Using a publicly accessible, well-validated measure of walkability, this study identified inverse associations with abdominal adiposity, as measured by waist circumference, among older postmenopausal women. These findings support ongoing research on built environment correlates of adiposity in older populations. Future studies examining longitudinal associations and mediational pathways between walkability and adiposity will help inform community planning strategies to promote active living and healthy aging.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

The Women's Health Initiative program is funded by the National Heart, Lung, and Blood Institute (NHLBI), NIH, and U.S. DHHS through contracts HHSN268201100046C, HHSN268201100001C, HHSN268201100002C, HHSN268201100003C, HHSN268201100004C, and HHSN271201100004C. Ongoing research was supported by NIH/NHLBI 5 K01 HL108807-05, NIH KL2TR000160, the President's Council of Cornell Women, Affinito-Stewart Grant (#472626), and the Institute for the Social Sciences, Small Grant (Cornell University). The content of this paper is solely the responsibility of the authors and does not represent the official views of NIH or Cornell University.

References

1. Flegal KM, Carroll MD, Ogden CL, Curtin LR. Prevalence and trends in obesity among U.S. adults, 1999–2008. *JAMA*. 2010; 303(3):235–341. <http://dx.doi.org/10.1001/jama.2009.2014>. [PubMed: 20071471]
2. Ford ES, Maynard LM, Li C. Trends in obesity and abdominal obesity among adults in the United States from 1999–2008. *Int J Obesity*. 2011; 35:736–743. <http://dx.doi.org/10.1038/ijo.2010.186>.
3. Patterson RE, Frank LL, Kristal AR, et al. A comprehensive examination of health conditions associated with obesity in older adults. *Am J Prev Med*. 2004; 27(5):385–390. <http://dx.doi.org/10.1016/j.amepre.2004.08.001>. [PubMed: 15556738]
4. Ortman, JM.; Velkoff, VA.; Hogan, H. An Aging Nation: The Older Population in the United States. Current Population Reports, P25-1140. U.S. Census Bureau; Washington, D.C: 2014.
5. National Heart, Lung, and Blood Institute of NIH. Clinical Guidelines on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults: The Evidence Report. NIH; Bethesda, MD: 1998. NIH publication no. 98-408
6. Papas MA, Alberg AJ, Ewing R, Helzlouer KJ, Gary TL, Klassen AC. The built environment and obesity. *Epidemiological Reviews*. 2007; 29:129–143. <http://dx.doi.org/10.1093/epirev/mxm009>.
7. Vasunilashorn S, Steinman BA, Liebig PS, Pynoos J. Aging in place: Evolution of a research topic whose time has come. *J Aging Res*. 2012:120952. <http://dx.doi.org/10.1155/2012/120952>. [PubMed: 22175020]
8. Saelens BE, Sallis JF, Frank LD. Environmental correlates of walking and cycling: findings from the transportation, urban design, and planning literature. *Ann Behav Med*. 2003; 25(2):80–91. http://dx.doi.org/10.1207/S15324796ABM2502_03. [PubMed: 12704009]
9. Yen IH, Michael YL, Perdue L. Neighborhood environment in studies of health of older adults: a systematic review. *Am J Prev Med*. 2009; 37(5):455–463. <http://dx.doi.org/10.1016/j.amepre.2009.06.022>. [PubMed: 19840702]
10. Frank L, Kerr J, Rosenberg D, King AC. Healthy aging and where you live: community design relationships with physical activity and body weight in older Americans. *J Phys Act Health*. 2010; 7(Suppl 1):S82–S90. [PubMed: 20440017]
11. Kerr J, Norman G, Millstein R, et al. Neighborhood environment and physical activity among older women: Findings from the San Diego Cohort of the Women's Health Initiative. *J Phys Act Health*. 2014; 11(6):1070–1077. <http://dx.doi.org/10.1123/jpah.2012-0159>. [PubMed: 23963780]
12. King AC, Sallis JF, Frank LD, et al. Aging in neighborhoods differing in walkability and income: associations with physical activity and obesity in older adults. *Soc Sci Med*. 2011; 73(10):1525–1533. <http://dx.doi.org/10.1016/j.socscimed.2011.08.032>. [PubMed: 21975025]
13. Carlson JA, Sallis JF, Conway TL, et al. Interactions between psychosocial and built environment factors in explaining older adults' physical activity. *Prev Med*. 2012; 54(1):68–73. <http://dx.doi.org/10.1016/j.ypmed.2011.10.004>. [PubMed: 22027402]
14. Van Holle V, Van Cauwenberg J, Van Dyck D, Deforche B, Van de Weghe N, De Bourdeaudhuij I. Relationship between neighborhood walkability and older adults' physical activity study in seniors (BEPAS Seniors). *Int J Behav Nutr Phys Act*. 2014; 11:110. <http://dx.doi.org/10.1186/s12966-014-0110-3>. [PubMed: 25148845]
15. Sallis JF, Saelens BE, Frank LD, et al. Neighborhood built environment and income: examining multiple health outcomes. *Soc Sci Med*. 2009; 68(7):1285–1293. <http://dx.doi.org/10.1016/j.socscimed.2009.01.017>. [PubMed: 19232809]
16. Frank LD, Andresen MA, Schmid TL. Obesity relationships with community design, physical activity, and time spent in cars. *Am J Prev Med*. 2004; 27(2):87–96. <http://dx.doi.org/10.1016/j.amepre.2004.04.011>. [PubMed: 15261894]
17. Saelens BE, Handy SL. Built environment correlates of walking: a review. *Med Sci Sports Exerc*. 2008; 40(7 Suppl):S550. <http://dx.doi.org/10.1249/MSS.0b013e31817c67a4>. [PubMed: 18562973]
18. Heath GW, Brownson RC, Kruger J, et al. The effectiveness of urban design and land use and transport policies and practices to increase physical activity: a systematic review. *J Phys Act Health*. 2006; 3(Suppl 1):S55–76.

19. Smith KR, Brown BB, Yamada I, Kowaleski-Jones L, Zick CD, Fan JX. Walkability and body mass index: density, design, and new diversity measures. *Am J Prev Med.* 2008; 35(3):237–244. <http://dx.doi.org/10.1016/j.amepre.2008.05.028>. [PubMed: 18692736]
20. Berke EM, Koepsell TD, Moudon AV, Hoskins RE, Larson EB. Association of the built environment with physical activity and obesity in older persons. *Am J Public Health.* 2007; 97(3): 486–492. <http://dx.doi.org/10.2105/AJPH.2006.085837>. [PubMed: 17267713]
21. Grafova B, Freedman VA, Kumar R, Rogowski J. Neighborhoods and obesity in later life. *Am J Public Health.* 2008; 98(11):2065–2071. <http://dx.doi.org/10.2105/AJPH.2007.127712>. [PubMed: 18799770]
22. Michael YL, Gold R, Perrin N, Hillier T. Built environment and change in body mass index in older women. *Health Place.* 2013; 22:7–10. <http://dx.doi.org/10.1016/j.healthplace.2013.02.001>. [PubMed: 23531924]
23. Li F, Harmer P, Cardinal BJ, et al. Built Environment and 1-Year Change in Weight and Waist Circumference in Middle-Aged and Older Adults Portland Neighborhood Environment and Health Study. *Am J Epi.* 2009; 169(4):401–408. <http://dx.doi.org/10.1093/aje/kwn398>.
24. McDonald KN, Oakes JM, Forsyth A. Effect of street connectivity and density on adult BMI: results from the Twin Cities Walking Study. *J Epi Comm Health.* 2012; 66(7):636–640. <http://dx.doi.org/10.1136/jech.2010.122556>.
25. Hirsch JA, Diez Roux AV, Moore KA, Evenson KR, Rodriguez DA. Change in walking and body mass index following residential relocation: The multi-ethnic study of atherosclerosis. *Am J Public Health.* 2014; 3:e49–e56. <http://dx.doi.org/10.2105/AJPH.2013.301773>.
26. Hirsch JA, Moore KA, Evenson KR, Rodriguez DA, Diez Roux AV. Walk score and transit score and walking in the multi-ethnic study of atherosclerosis. *Am J Prev Med.* 2013; 45(2):158–166. <http://dx.doi.org/10.1016/j.amepre.2013.03.018>. [PubMed: 23867022]
27. Matthews SA, Moudon AV, Daniel M. Work group II: Using Geographic Information Systems for enhancing research relevant to policy on diet, physical activity, and weight. *Am J Prev Med.* 2009; 36(4):S171–176. <http://dx.doi.org/10.1016/j.amepre.2009.01.011>. [PubMed: 19285210]
28. [Accessed December 16, 2014] Front Seat Managment. Walk Score Methodology. 2012. www.walkscore.com/professional/methodology.php
29. Duncan DT, Aldstadt J, Whalen J, Melly SJ, Gortmaker SL. Validation of walk score for estimating neighborhood walkability: an analysis of four U.S. metropolitan areas. *Int J Environ Res Public Health.* 2011; 8(11):4160–4179. <http://dx.doi.org/10.3390/ijerph8114160>. [PubMed: 22163200]
30. Riley DL, Mark AE, Kristjansson E, Sawada MC, Reid RD. Neighborhood walkability and physical activity among family members of people with heart disease who participated in a randomized controlled trial of a behavioral risk reduction intervention. *Health Place.* 2013; 21:148–155. <http://dx.doi.org/10.1016/j.healthplace.2013.01.010>. [PubMed: 23474354]
31. Brown SC, Pantin H, Lombard J, et al. Walk score associations with purposive walking in recent Cuban immigrants. *Am J Prev Med.* 2013; 45(2):202–206. <http://dx.doi.org/10.1016/j.amepre.2013.03.021>. [PubMed: 23867028]
32. Women's Health Initiative Study Group. [Accessed April 6, 2016] WHI Extension Study Protocol. 2012. <https://www.whi.org/researchers/studydoc/Consents/Protocol%202010-2015.pdf>
33. Meyer AM, Evenson KR, Morimoto L, Siscovick D, White E. Test–retest reliability of the Women's Health Initiative physical activity questionnaire. *Med Sci Sports Exerc.* 2009; 41(1): 530–538. <http://dx.doi.org/10.1249/MSS.0b013e31818ace55>. [PubMed: 19204598]
34. Pettee KG, McClain JJ, Lee CD, et al. Evaluation of physical activity measures used in middle-aged women. *Med Sci Sports Exerc.* 2009; 41(7):1403–1412. <http://dx.doi.org/10.1249/MSS.0b013e31819b2482>. [PubMed: 19516161]
35. LaCroix AZ, Guralnik JM, Berman LF, Wallace RB, Satterfield S. Maintaining mobility in late life: smoking, alcohol consumption, physical activity, and body mass index. *Am J Epidemiol.* 1993; 137:858–869. [PubMed: 8484377]
36. Kaplan MS, Huguet N, Newsom JT, McFarland BH, Lindsay J. Prevalence and correlates of overweight and obesity among older adults: Findings from the Canadian National Population Health Survey. *J Gerontol A Biol Sci Med Sci.* 2003; 58:M1018–M1030. <http://dx.doi.org/10.1093/gerona/58.11.M1018>.

37. Yan LL, Daviglus ML, Liu K, et al. BMI and Health-Related Quality of Life in Adults 65 Years and Older. *Obesity Research*. 2004; 12:69–76. <http://dx.doi.org/10.1038/oby.2004.10>. [PubMed: 14742844]
38. McHorney CA, Ware JE, Lu RJ, Sherbourne C. The Mos 36-item short-form health survey (SF-36): Tests of data quality, scaling assumptions, and reliability across diverse patient groups. *Med Care*. 1994; 32:40–66. <http://dx.doi.org/10.1097/00005650-199401000-00004>. [PubMed: 8277801]
39. Baron RM, Kenny DA. The moderator–mediator distinction in social psychological research: conceptual, strategic, and statistical considerations. *J Pers Soc Psychol*. 1986; 51:1173–1182. <http://dx.doi.org/10.1037/0022-3514.51.6.1173>. [PubMed: 3806354]
40. Sayhoun NR, Maynard LM, Zhang XL, Serdula MK. Factors associated with errors in self-reported height and weight in older adults. *J Nutr Health Aging*. 2008; 12:108–115. [PubMed: 18264637]
41. Menke A, Muntner P, Wildman RP, Reynolds K, He J. Measures of adiposity and cardiovascular disease risk factors. *Obesity*. 2007; 15:785–795. <http://dx.doi.org/10.1038/oby.2007.593>. [PubMed: 17372330]
42. Villareal DT, Apovian CM, Kushner RF, Klein S. Obesity in older adults: technical review and position statement of the American Society for Nutrition and NAASO, the obesity society. *Am J Clin Nutr*. 2005; 82:923–934. <http://dx.doi.org/10.1038/oby.2005.228>. [PubMed: 16280421]
43. Van Dyck D, Cerin E, Cardon G, et al. Physical activity as a mediator of the associations between neighborhood walkability and adiposity in Belgian adults. *Health Place*. 2010; 16(5):952–960. <http://dx.doi.org/10.1016/j.healthplace.2010.05.011>. [PubMed: 20542461]
44. Vargo J, Stone B, Glanz K. Google walkability: a new tool for local planning and public health research? *J Phys Act Health*. 2012; 9(5):689. [PubMed: 21946250]
45. Van Dyck D, Cardon G, Deforche B, Owen N, De Bourdeaudhuij I. Relationships between neighborhood walkability and adults' physical activity: How important is residential self-selection? *Health Place*. 2011; 17(4):1011–1014. <http://dx.doi.org/10.1016/j.healthplace.2011.05.005>. [PubMed: 21596613]

Table 1

Descriptive Characteristics of Women's Health Initiative Long Life Study Participants by Street Smart Walk Score Category^a

Characteristic	Overall (N=6,526)	Very car- dependent (N=2,550)	Car-dependent (n=1,799)	Somewhat walkable (n=1,274)	Very walkable (n=708)	Walker's paradise (n=195)	p-value
Age							
Younger than 70	801 (12.3)	316 (12.4)	219 (12.2)	165 (13.0)	74 (10.4)	27 (13.8)	<0.001
70 to 74	1,083 (16.6)	439 (17.2)	254 (14.1)	221 (17.4)	129 (18.2)	40 (20.5)	
75 to 79	1,222 (18.8)	453 (17.8)	337 (18.7)	236 (18.5)	151 (21.3)	45 (23.1)	
80 to 84	1,802 (27.6)	745 (29.2)	521 (29.0)	318 (25.0)	170 (24.0)	48 (24.6)	
85 to 89	1,264 (19.4)	477 (18.7)	366 (20.3)	263 (20.6)	140 (19.8)	18 (9.2)	
90 or older	354 (5.4)	120 (4.7)	102 (5.7)	71 (5.6)	44 (6.2)	17 (8.7)	
Race/ethnicity							
Non-Hispanic white	3,334 (51.1)	1,534 (60.2)	926 (51.5)	573 (45.0)	242 (34.2)	59 (30.3)	<0.001
Non-Hispanic black	2,094 (32.1)	673 (26.4)	530 (29.5)	459 (36.0)	346 (48.9)	86 (44.1)	
Hispanic	1,098 (16.8)	343 (13.4)	343 (19.1)	242 (19.0)	120 (17.0)	50 (25.6)	
Income							
<\$20,000	998 (15.3)	327 (12.8)	279 (15.5)	227 (17.8)	127 (17.9)	38 (19.5)	<0.001
\$20,000-\$34,999	1,683 (25.8)	626 (24.6)	490 (27.2)	350 (27.5)	174 (24.6)	43 (22.0)	
\$35,000-\$49,999	1,421 (21.8)	555 (21.8)	406 (22.6)	269 (21.1)	159 (22.5)	32 (16.4)	
\$50,000-\$74,999	1,304 (20.0)	525 (20.6)	361 (20.1)	224 (17.6)	145 (20.5)	49 (25.1)	
>\$75,000	1,120 (17.2)	517 (20.3)	263 (14.6)	204 (16.0)	103 (14.6)	33 (16.9)	
Education							
Less than high school	302 (4.6)	83 (3.2)	99 (5.5)	65 (5.1)	46 (6.5)	9 (4.6)	<0.001
High school diploma	1,072 (16.4)	437 (17.1)	300 (16.7)	217 (17.0)	96 (13.6)	22 (11.3)	
Some college or associate's degree	2,493 (38.2)	967 (37.9)	689 (38.3)	520 (40.8)	260 (36.7)	57 (29.2)	
College degree or higher	2,659 (40.7)	1,063 (41.7)	711 (39.5)	472 (37.0)	306 (43.2)	107 (54.9)	
Married/common-law							
Yes	3,840 (58.8)	1,722 (67.5)	1,064 (59.1)	663 (52.0)	321 (45.3)	70 (35.9)	<0.001
No	2,686 (41.2)	828 (32.5)	735 (40.9)	611 (48.0)	387 (54.7)	125 (64.1)	
Self-rated health status							
Excellent	597 (9.2)	228 (8.9)	184 (10.2)	104 (8.2)	59 (8.3)	22 (11.3)	<0.01
Very good	2,610 (40.0)	1,082 (42.4)	697 (38.7)	474 (37.2)	287 (40.5)	70 (35.9)	
Good	2,624 (40.2)	1,006 (39.4)	726 (40.4)	531 (41.7)	282 (39.8)	79 (40.5)	

Characteristic	Overall (N=6,526)	Very car- dependent (N=2,550)	Car-dependent (n=1,799)	Somewhat walkable (n=1,274)	Very walkable (n=708)	Walker's paradise (n=195)	p-value
Fair/poor	695 (10.6)	234 (9.2)	192 (10.7)	165 (13.0)	80 (11.3)	24 (12.3)	
Smoking status							
Non-smoker	6,333 (97.0)	2,485 (97.5)	1,743 (96.9)	1,228 (96.4)	688 (97.2)	189 (96.9)	0.47
Current smoker	193 (3.0)	65 (2.6)	56 (3.1)	46 (3.6)	20 (2.8)	6 (3.1)	
Treated diabetes							0.0031
No	6,207 (95.1)	2,442 (95.8)	1,696 (94.3)	1,210 (95.0)	683 (96.5)	176 (90.3)	
Yes	319 (4.9)	108 (4.2)	103 (5.7)	64 (5.0)	25 (3.5)	19 (9.7)	
Treated hypertension							0.10
No	6,118 (93.8)	2,371 (93.0)	1,692 (94.0)	1,202 (94.4)	664 (93.8)	189 (96.9)	
Yes	408 (6.2)	179 (7.0)	107 (6.0)	72 (5.6)	44 (6.2)	6 (3.1)	
Physical function	66.6 (26.3)	67.5 (25.6)	66.6 (26.7)	64.5 (27.1)	67.6 (27.0)	67.2 (26.0)	0.018
Total physical activity (min/week)	152.5 (168.1)	154.9 (173.7)	152.4 (166.6)	139.4 (155.4)	153.0 (161.2)	203.8 (202.4)	<0.001
Walking expenditure (MET-hours/week)	3.7 (5.5)	3.6 (5.4)	3.6 (5.5)	3.5 (5.4)	3.9 (5.7)	5.8 (6.7)	<0.001

Note: Boldface indicates significance ($p < 0.05$).

^aCategorical data are expressed as n(%), continuous data are expressed as means (SD)

^bp-value from χ^2 test for categorical variables and one-way ANOVA for continuous variables

Table 2

Mean Differences in BMI and ORs of Overweight and of Obesity Among WHI Long Life Study Participants (N=6,526)

	Mean difference in BMI (95% CI)			OR of overweight (95% CI)			OR of obesity (95% CI)		
	Model 2 ^a	Model 3 ^b	Model 4 ^c	Model 2 ^a	Model 3 ^b	Model 4 ^c	Model 2 ^a	Model 3 ^b	Model 4 ^c
SS Walk Score (10 point increase)	−0.030 (−0.079, 0.019)	−0.024 (−0.073, 0.024)	−0.029 (−0.078, 0.020)	0.98 (0.95, 1.00)	0.98 (0.96, 1.01)	0.98 (0.95, 1.00)	0.99 (0.96, 1.01)	0.99 (0.97, 1.02)	0.99 (0.96, 1.01)
SS Walk Score category									
Car-dependent	0.029 (−0.29, 0.35)	0.027 (−0.29, 0.34)	0.028 (−0.29, 0.35)	0.98 (0.85, 1.14)	0.098 (0.84, 1.14)	0.98 (0.84, 1.14)	1.03 (0.87, 1.22)	1.02 (0.86, 1.21)	1.02 (0.86, 1.21)
Somewhat walkable	−0.24 (−0.63, 0.11)	−0.24 (−0.59, 0.12)	−0.26 (−0.61, 0.097)	0.87 (0.74, 1.04)	0.88 (0.74, 1.04)	0.87 (0.73, 1.03)	0.89 (0.74, 1.07)	0.89 (0.74, 1.08)	0.88 (0.73, 1.06)
Very walkable	−0.018 (−0.46, 0.43)	0.005 (−0.43, 0.45)	−0.022 (−0.47, 0.42)	0.89 (0.72, 1.11)	0.90 (0.73, 1.12)	0.89 (0.72, 1.10)	0.99 (0.78, 1.25)	1.003 (0.79, 1.27)	0.98 (0.78, 1.25)
Walker's paradise	−0.28 (−1.05, 0.49)	−0.11 (−0.88, 0.66)	−0.19 (−0.96, 0.58)	0.76 (0.52, 1.12)	0.81 (0.56, 1.19)	0.79 (0.54, 1.16)	0.84 (0.56, 1.26)	0.92 (0.61, 1.39)	0.88 (0.58, 1.32)

Note: Boldface indicates significance ($p < 0.05$). Reference category for BMI is 'normal weight' (18.5–24.9 kg/m²); reference category for SS Walk Score is "very car-dependent."

^aModel 2 adjusted for the following covariates: age at LLS visit, race/ethnicity, educational attainment, income, marital status, self-rated health, smoking status, treated diabetes, treated hypertension, and physical function

^bModel 3 adjusted for walking expenditure in addition to all other covariates

^cModel 4 adjusted for total minutes of physical activity per week in addition to all other covariates WHI, Women's Health Initiative; SS, Street Smart

Table 3

Mean Differences in Waist Circumference and ORs of Abdominal Obesity Among WHI Long Life Study Participants (N=6,526)

	Mean difference in WC (95% CI)			OR of abdominal obesity (95% CI)		
	Model 2 ^a	Model 3 ^b	Model 4 ^c	Model 2	Model 3	Model 4
SS Walk Score (10 point increase)	-0.11 (-0.23, 0.0037)	-0.10 (-0.22, 0.017)	-0.11 (0.23, 0.0063)	0.99 (0.97, 1.01)	0.99 (0.97, 1.01)	0.99 (0.97, 1.01)
SS Walk Score category						
Car-dependent	-0.056 (-0.82, 0.70)	-0.024 (-0.79, 0.74)	-0.022 (-0.78, 0.74)	1.041 (0.91, 1.18)	1.039 (0.91, 1.18)	1.040 (0.91, 1.18)
Somewhat walkable	-0.25 (-1.10, 0.61)	-0.17 (-1.0, 0.67)	-0.23 (-1.08, 0.63)	1.029 (0.89, 1.19)	1.031 (0.89, 1.19)	1.022 (0.88, 1.18)
Very walkable	-0.68 (-1.74, 0.38)	-0.54 (-1.60, 0.52)	-0.60 (-1.67, 0.46)	0.95 (0.79, 1.14)	0.96 (0.80, 1.15)	0.95 (0.79, 1.13)
Walker's paradise	-1.75 (-3.58, 0.087)	-1.46 (-3.31, 0.38)	-1.62 (-3.46, 0.23)	0.72 (0.53, 0.99)	0.77 (0.56, 1.05)	0.75 (0.54, 1.02)

Note: Boldface indicates significance ($p < 0.05$). Reference category for SS Walk Score is "very car-dependent."

^aModel 2 adjusted for the following covariates: age at LLS visit, race/ethnicity, educational attainment, income, marital status, self-rated health, smoking status, treated diabetes, treated hypertension, and physical function

^bModel 3 adjusted for walking expenditure in addition to all other covariates

^cModel 4 adjusted for total minutes of physical activity per week in addition to all other covariates WHI, Women's Health Initiative; SS, Street Smart