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Cole, Rachel, Koohsari, Javad, Carver, Alison, Owen, Neville and Sugiyama, Takemi

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Authors: Rachel Cole,[a] Mohammad Javad Koohsari,[b,c] Alison Carver,[d] Neville Owen,[c,e] and Takemi Sugiyama[d,e]

Affiliations: [a] University of the Sunshine Coast, Australia. [b]Faculty of Sport Sciences, Waseda University, Japan. [c] Baker Heart & Diabetes Institute, Australia. [d] Mary MacKillop Institute for Health Research, Australian Catholic University, Australia. [e] Swinburne University of Technology, Australia.

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Authors: Rachel Cole,[a] Mohammad Javad Koohsari,[b,c] Alison Carver,[d] Neville Owen,[c,e] Takemi Sugiyama[d,e]

[a] University of the Sunshine Coast, Australia

[b] Faculty of Sport Sciences, Waseda University, Japan

[c] Baker Heart & Diabetes Institute, Australia

[d] Mary MacKillop Institute for Health Research, Australian Catholic University, Australia

[e] Swinburne University of Technology, Australia

Corresponding Author

Takemi Sugiyama, PhD

Mary MacKillop Institute for Health Research

Australian Catholic University

Melbourne, VIC 3000, Australia

takemi.sugiyama@acu.edu.au

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Abstract

Older adults are often considered more vulnerable to environmental factors than are younger adults. We examined whether the associations of objectively-measured environmental attributes (Walk Score; street connectivity) with walking for transport differed between younger- (25-44 years), middle- (45-64 years), and older-aged (65-84 years) adults, using a large of Australian sample of 14,656. Walk Score and street connectivity were similarly associated with walking (any; 30+ min/day) in all age groups. Contrary to commonly held views, the study did not find any evidence suggesting that older adults may be more sensitive to their environment to get out and walk than are younger adults, at least for the environmental attributes examined in this study. Further research is needed to investigate if there are particular environmental factors that hinder older adults from being active.

Key words: Physical activity, Household travel survey, Destinations, Street connectivity, Age differences

Introduction

There is a growing body of evidence on associations between the neighborhood environmental attributes and physical activity among older adults (King et al., 2011; VanCauwenberg et al., 2011; Yen, Michael, & Perdue, 2009). A recent review found higher residential density, better walkability, well-connected street network, better access to destinations, mixed land use, and availability of pedestrian-friendly features to be consistently positively associated with older adults' walking (Cerin, Nathan, van Cauwenberg, Barnett, & Barnett, 2017). Neighborhood environments are considered particularly important for older adults' getting out and about due to their declining physical functioning, and resulting lack of confidence in overcoming environmental barriers (Buffel et al., 2012; King et al., 2011; Rantakokko et al., 2009; Haselwandter et al., 2015; VanCauwenberg et al., 2011; Winters et al., 2015; Yen et al., 2009). Consistent with theoretical predictions about the relationships of environmental press and competence (Lichtenberg, MacNeill, & Mast, 2000), it may be argued that older adults are more sensitive to barriers in local areas, thus neighborhood environmental factors are more closely associated with older adults' physical activity than they are to younger adults' activity. However, few studies have directly examined whether and how age groups may differ in the positive associations of environmental factors with physical activity.

Shigematsu et al (2009) examined age-related differences in the associations between perceived neighborhood environmental attributes and physical activity. Perceived residential density, land use mix, street connectivity, walking/cycling facilities, neighborhood aesthetics, pedestrian/traffic safety, and recreational facilities and parks near home were significantly related to walking for transport in the youngest age group (20-39 year olds). Only the presence of non-residential destinations (land use mix) and recreational facilities within walking distance were associated with walking for transport among the oldest age group (66+ years); however those associations were stronger for older adults. Other studies examining differential associations of the built environment with physical activity have focused on subgroups by gender, ethnicity, education level, presence of children in the household, employment status, and car ownership, rather than age (Forsyth, Oakes, Lee, & Schmitz, 2009; Humpel et al., 2004; Owen et al., 2007).

No previous study has examined directly the moderating effects of age on the associations of objectively-measured built environment attributes with walking. It is thus unclear whether older adults are more sensitive to walking-related facilitators and barriers in their neighborhood, compared with younger adults. To address this gap, we examined how associations between objectively-measured neighborhood environmental attributes and walking may be moderated by age in a large sample of Australian adults.

Material and Methods

Data source

Data were drawn from the *2009 South-East Queensland Travel Survey* (SEQTS), a cross-sectional survey administered by the Queensland Government in the Sunshine Coast, Brisbane, and Gold Coast Statistical Divisions. This region covers a geographic area of 10,946 km^2, with a mix of urban, suburban, and regional areas and the population was approximately 2.9 million in 2009.

The SEQTS used multistage random sampling in which Census Collection Districts (CCDs), the smallest geographic units for Census data collection (Australian Bureau of Statistics, 2006), were selected first, followed by households within each. Data were collected from 10,335 households (4.4% of households from the selected CCDs; 60% response rate). All residents and visitors in the selected households on the night before the specified "survey day" were asked to complete self-administered questionnaires. Visitors were not excluded as their travel behaviors on the day (e.g., mode choice, duration) should still be influenced by local environmental attributes. They reported details of their travels conducted on the travel day, including origin, destination, start time, end time, mode, and purpose, using a 24-hour travel diary. The survey was administered in accordance with ethical guidelines under government statutes and regulations. Informed consent was obtained from participants.

Measures

Outcome measures. Home-based walking, derived from participants’ reports in their 24-hour travel diaries, was the outcome of the study. Walking trips lasting at least five minutes that commenced or ended at home were identified to ensure walking took place in the neighborhood where environmental exposure variables were measured. A five-minute criterion was applied because this can be part of a 10-minute return walking trip, which is the minimum duration for walking in physical activity guidelines (World Health Organization, 2010). Participants were classified as: those who did home-based walking or not; and, those who did home-based walking for over 30 min/day or not. The cut-off of 30 minutes was derived from physical activity guidelines (Australian Department of Health, 2014).

Exposure measures. Access to local destinations and street connectivity in the neighborhood were calculated at the Statistical Area 1 (SA1) level. SA1 is the smallest geographic unit for Australian Census data since 2011 (median geographic size: 0.23 km^2, interquartile range: 0.26 km^2). SA1s rather than CCDs were used as an area unit in the study because the former is more consistent in population size and homogeneous than the latter (Australian Bureau of Statistics, 2011). For each SA1, Walk Score of its centroid was obtained from walkscore.com, and used as a measure of access to local destinations. Walk Score is a publicly-available web-based tool that (in 2010) scored the availability of various destination types based on proximity as the crow flies. Walk Score ranges from 0 to 100, where higher scores denote better access. For street connectivity, a space syntax measure of street integration was used. Street integration shows how topologically close a street is to all other streets within a specified street network (Hillier & Iida, 2005; Koohsari, Kaczynski, McCormack, & Sugiyama, 2014). A more integrated street segment requires fewer turns to reach a destination from other streets within the network, compared with less-integrated street segments (Hillier & Iida, 2005; Kostakos, 2010; Peponis, Ross, & Rashid, 1997). Street integration was calculated for each street segment using Axwoman (Jiang, 2012) and University College London DepthMap (Turner, 2004) software within a 1 km buffer from its centre. For each SA1, the mean integration value of all street segments was computed and used as the area-level measure of street connectivity. Higher integration denotes greater connectivity.

Covariates. The SEQTS asked participant's age, gender, marital status (single, couple, other), employment status, and driving license status. For households, car ownership (0, 1 and 2+), household income, and household composition (sole person, couple with no children, couple with children, single parent with children, other) were collected. For household composition, we considered marital status and children in the household separately to be consistent with other epidemiological studies where these are treated distinctly. The Index of Relative Socio-Economic Disadvantage (IRSD) was extracted for each SA1 as an area-level indicator of socio-economic status. This index is based on area-level factors indicative of low-level income, education, employment, occupation, and housing, and reflects lack of economic and social resources for residents in an area (Australian Bureau of Statistics, 2008). It is standardized to a mean of 1000 with a standard deviation of 100. A lower IRSD score denotes a greater level of disadvantage (Australian Bureau of Statistics, 2008).

Data analysis

Participants were categorized into three adult age groups: younger (25–44 years), middle (45–64 years), and older (65–84 years), based on typical cut points used in Australian health surveys (Australian Bureau of Statistics, 2013). Multilevel logistic regression models were used to estimate the adjusted odds ratio of any walking and walking ≥30 min/day, according to Walk Score and street integration, for each age group. Since participants in the older age group are likely to be diverse, we further tested effect modification within this group by dividing them into 65–70 and 71–84 years old (median split). Walk Score and street integration scores were recoded into deciles at the SA1 level for analyses. Interaction terms between each environmental attribute and age groups were calculated for each outcome. All models were adjusted for gender, marital status, car ownership, and area-level SES, and accounted for clustering by household and SA1. Socio-demographic characteristics that naturally differ between age groups (e.g., work status, household income, driving license) were not adjusted for because holding them constant may disregard the reality of aging. Model parameters were estimated using SPSS Version 21. Statistical significance was set at $p < .05$, except for interaction effects ($p < .1$), since interaction terms may be underpowered (Whisman & McClelland, 2005). This level of significance was used for interactions to identify potential effect modification by age group.

Results

Characteristics of study participants

After removing participants in SA1s with missing IRSD (n = 91), and those who did not report any travel on the survey day (n = 3,616), the final sample size was 14,656. Participants were from 8,920 households in 1,275 SA1s. Of those, 10.8% (n = 1,589) reported any walking and 4.5% (n = 659) reported walking for over 30 minutes on the survey day. The mean (sd) Walk Score and street integration scores for participants' residential SA1s were 46.5 (21.9) and 73.2 (45.6), respectively. The correlation coefficient between them was 0.59. Table 1 presents the characteristics of study participants for each age group. The prevalence of walking differed between age groups: the proportion of younger, middle, and older adults who reported any walking was 11.0%, 9.6%, and 13.7%; and that of walking over 30 min/day was 4.1%, 4.4%, and 5.8%, respectively. For the subgroups in the older group, the prevalence of any walking for 65–70 years (n = 1,144) and 71–84 years (n = 1,228) was 12.2% and 15.1%, and that of walking for over 30 min/day was 6.2% and 5.5%, respectively.

Association of environmental attributes with walking, by age group

There were significant associations of Walk Score and street integration with any walking and walking ≥ 30 min/day for all age groups (Table 2). Each one-decile increment in Walk Score was associated with 20%, 19%, and 16% higher odds of reporting any walking; and, 7%, 7%, and 9% higher odds of reporting walking ≥ 30 min/day, for younger, middle, and older age groups, respectively. A significant interaction with Walk Score was found for any walking in older adults (p = .098) in comparison to younger adults. For street integration, each one-decile increment was associated with 17%, 13%, and 13% higher odds of reporting any walking; and, 5%, 5%, and 7% higher odds of reporting walking ≥ 30 min/day, for younger, middle, and older age groups, respectively. No statistically-significant interactions by age groups were found for street integration. The regression coefficients for the older subgroups (65–70 and 71–84 years) are shown in Table 3. No significant interaction effects were found between the older subgroups for either environmental attribute.

Discussion

This study did not find that the associations of objectively-measured neighborhood environmental attributes with home-based walking were stronger for older than for younger adults. Of the four associations examined (Walk Score with any walking; Walk Score with walking ≥ 30 min/day; integration with any walking; integration with walking ≥ 30 min/day), we found effect modification by age groups for only one of them (Walk Score with any walking). However, that effect modification was not in the expected direction: the association was greater among younger adults. This is inconsistent with the findings of Shigematsu et al (2009), where access to non-residential destinations was more strongly associated with walking for transport among older compared with younger adults. These inconsistencies may reflect differences in the methods used to calculate environmental attributes. Shigematsu et al (2009) used participants' perceptions rather than objective measures of environmental attributes, which have been demonstrated to have different associations with walking for transport (Yen et al., 2009). It is possible that "knowing" many destinations in local areas may be closely associated with older adults' walking. In contrast, Walk Score is a measure reflecting the presence of destinations within 1.6 km, which may include places that are too far to walk to for older adults.

A potential explanation for the findings is that we did not examine environmental barriers to walking, for which we did not have data available. The presence of local destinations and better street connectivity may work equally for all age groups. But, it is possible that the presence of barriers, such as high-speed traffic, poor-quality footpaths, and vandalism, may have greater impact on older adults. For example, a study conducted in the U.S. found that better sidewalk quality as well as safety from traffic and crime were associated with older adults' walking (Gallagher et al., 2010). The relevance of perceived sidewalk availability and safety from crime to older adults' walking has been also shown (Shigematsu et al., 2009). A recent literature review also reported that older adults' walking for transport was positively related to better pedestrian infrastructure and negatively with issues such as vandalism and urban decay (Cerin et al., 2017). Such street-level factors, which may not deter younger adults from walking, may influence older adults' decision to walk. Future research needs to examine how street-level barriers are associated with walking for different age groups.

This study is limited by travel behavior data collected only for one day. Although working adults tend to be constant in their daily travel behaviors, this may not be the case for older adults who are not working. Their travel behaviors may be different between days within a week, and one day may not be long enough to capture different patterns. Another limitation is that environmental attributes were calculated for each SA1 rather than for each participant. The area within SA1 may not match participant's local area. The strengths of this study include data collected from a large sample residing in diverse areas (urban, suburban, and regional). The use of a travel diary and detailed travel data are also a strength of the study. Although its reliability and validity have not been reported, the 24-hour travel diary, in which participants reported the origin, destination, and mode of each travel on one specific day, may be less susceptible to measurement bias and recall errors (Manaugh & El-Geneidy, 2011; Merom, Van Der Ploeg, Corpuz, & Bauman, 2010). Another strength is that we focused on walking trips that started or ended at home, which improves the correspondence between where behaviors occur and where environmental attributes are measured.

Conclusions

We found that access to destinations and street connectivity were significantly associated with Australian adults' walking, and similarly so for those in younger and older age groups. The findings do not support the case that neighborhood environmental attributes may be more important for walking among older adults than they are for younger adults. Our findings suggest that environmental initiatives developed building on empirical evidence may enhance physical activity levels across all age groups. Living in walkable areas (with many accessible destinations and well-connected street network) has been shown to help older residents maintain their walking (Sugiyama et al., 2018), which contributes to their functional independence and wellbeing. However, it has to be noted that our study examined only two environmental attributes. There may be other environmental factors such as pedestrian infrastructure (the availability and maintenance of sidewalks) as well as safety from crime and traffic that may be specifically relevant to older adults. Maintaining regular activities such as walking is important for older adults so that they remain functionally independent as they age. Further studies investigating whether the impact of street-level barriers on walking differs between age groups is needed to identify the attributes of local environments that can facilitate active ageing.

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Table 1: Characteristics of study participants.

	Total	Younger (25–44 years)	Middle (45–64 years)	Older (65–84 years)	p[#]
N	14,656	5,982	6,302	2,372	-
Gender, %women	52.5	54.1	52.5	48.4	<0.001
Working, %yes	70.6	84.9	77.9	15.2	<0.001
Marital status, %					<0.001
Single	12.7	9.9	13.1	18.7	
Couple	75.3	77.2	74.8	71.6	
Other	12.0	12.9	12.1	9.7	
Children in household					<0.001
Yes	44.7	64.0	41.1	5.6	
No	43.3	23.2	46.8	84.7	
Other	12.0	12.9	12.1	9.7	
Household income, %					<0.001
<$799/week	19.1	10.1	16.8	47.8	
$800-$1399/week	20.3	18.3	20.1	25.8	
$1400-$2499/week	34.9	41.3	35.0	18.5	
$2500+/week	25.7	30.3	28.0	7.9	
Driving license, %yes	96.1	96.5	97.5	91.4	<0.001
Car ownership, %					<0.001
No car	2.2	1.8	1.4	5.6	
1 car	27.7	22.9	23.7	50.4	
2 cars or more	70.1	75.3	74.9	44.0	
IRSD[a], mean (SD)	1018.7 (74.0)	1019.2 (73.0)	1021.2 (74.3)	1011.3 (75.4)	<0.001
Walk Score, mean (SD)	46.5 (21.9)	47.4 (22.0)	45.1 (22.0)	47.9 (20.9)	<0.001
Integration, mean (SD)	73.2 (45.6)	76.6 (48.0)	70.4 (44.1)	71.9 (42.8)	<0.001
Any walking, %	10.8	11.0	9.6	13.7	<0.001
Walking ≥30 min/day, %	4.5	4.1	4.4	5.8	0.003

[a] Index of Relative Socio-economic Disadvantage

[#] based on Chi-squared or independent t-test

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Table 2: Adjusted odds ratios (95%CI) of any walking and walking ≥30 in/day, according to environmental attributes, stratified by age group.

	Environmental attributes	OR (95% CI)		
		Younger	Middle	Older
Any walking	Walk Score	1.20 (1.16, 1.24)***	1.19 (1.14, 1.23)***	1.16 (1.10, 1.23)*** †
	Integration	1.17 (1.13, 1.22)***	1.13 (1.09, 1.18)***	1.13 (1.08, 1.19)***
Walking ≥30 min/day	Walk Score	1.07 (1.03, 1.11)***	1.07 (1.03, 1.12)**	1.09 (1.03, 1.16)**
	Integration	1.05 (1.01, 1.10)**	1.05 (1.01, 1.09)*	1.07 (1.00, 1.14)*

All models adjusted for gender, marital status, car ownership and area-level SES, and corrected for clustering at the household and SA1 level. Regression coefficients correspond to each increment in decile of Walk Score or integration.

*p<0.05; **p<0.01; ***p<0.001; † Age interaction at p < 0.1 (reference group: 25–44 years)

Table 3: Adjusted odds ratios (95%CI) of any walking and walking ≥30 min/day, according to environmental attributes, stratified by age within the older group.

	Environmental attributes	OR (95% CI)	
		65–70 years	71–84 years
Any walking	Walk Score	1.15 (1.06, 1.24)**	1.18 (1.09, 1.27)***
	Integration	1.13 (1.05, 1.22)**	1.14 (1.06, 1.23)***
Walking ≥30 min/day	Walk Score	1.08 (0.99, 1.17)	1.11 (1.01, 1.21)*
	Integration	1.07 (0.99, 1.16)	1.07 (0.97, 1.17)

All models adjusted for gender, marital status, car ownership and area-level SES, and corrected for clustering at the household and SA1 level. Regression coefficients correspond to each increment in decile of Walk Score or integration.

*p < .05; **p < .01; ***p < .001