

Neighborhood Environmental Attributes and Adults' Maintenance of Regular Walking

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ABSTRACT

SUGIYAMA, T., A. SHIBATA, M. J. KOOHSARI, S. K. TANAMAS, K. OKA, J. SALMON, D. W. DUNSTAN, and N. OWEN. Neighborhood Environmental Attributes and Adults' Maintenance of Regular Walking. *Med. Sci. Sports Exerc.*, Vol. 47, No. 6, pp. 1204–1210, 2015. **Purpose:** Environmental initiatives to support walking are keys to noncommunicable disease prevention, but the relevant evidence comes mainly from cross-sectional studies. We examined neighborhood environmental attributes associated cross-sectionally with walking and those associated prospectively with walking maintenance. **Methods:** Data were from the Australian Diabetes, Obesity and Lifestyle study collected in 2004–2005 (baseline) and in 2011–2012 (follow-up). Participants who did not move residence during the study period ($n = 2684$, age range: 30–77 yr at baseline) were categorized as regular walkers (walked five times per week or more) or not at baseline. Regular walkers were divided into those who stopped and those who maintained regular walking at follow-up. Regression analyses examined relationships of regular walking and walking maintenance with perceived attributes of neighborhood destinations and pedestrian environments. **Results:** Regular walking at baseline was significantly associated with availability of shops (odds ratio [OR] = 1.13, 95% confidence interval [CI] = 1.04–1.22), many alternative routes (OR = 1.12, 95% CI = 1.01–1.23), park or nature reserve (OR = 1.13, 95% CI = 1.02–1.26), bicycle or walking tracks (OR = 1.08, 95% CI = 1.00–1.17), and feeling safe to walk (OR = 1.18, 95% CI = 1.01–1.38). Maintenance of regular walking was associated with the availability of multiple alternative routes (OR = 1.19, 95% CI = 1.03–1.38). Having many alternative routes and walking tracks was associated with walking maintenance among those who were not or had stopped working. **Conclusions:** Neighborhood destinations (shops and parks) and pedestrian environments (alternative routes, walking trails, and safety from crime) were found to be associated with regular walking, but only pedestrian environment attributes were found to be related to the maintenance of regular walking. Further evidence from prospective studies is required to identify other neighborhood environmental attributes that might support walking maintenance. **Key Words:** PHYSICAL ACTIVITY, ADHERENCE, CROSS-SECTIONAL STUDIES, PROSPECTIVE STUDIES

Promoting regular walking—a realistic physical activity option across most age groups—is a key public health strategy for noncommunicable disease prevention (14,21). However, large-scale studies show that the proportion of adults who walk sufficiently to obtain health benefits is low (13,20). Environmental and policy initiatives have the potential to bring about sustainable, wide-scale

improvements in walking participation (28). In contrast to promotion strategies focusing on individuals, it is expected that environmental interventions will have long-term effects on residents' maintenance of walking behaviors (28).

Reviews have identified neighborhood destinations (e.g., stores, services, recreational facilities) and street-related attributes (e.g., connectivity, pedestrian infrastructure) to be associated with residents' walking (23,26,32,34). However, most of the existing studies on this topic are cross-sectional in design (26,34). Prospective studies identifying particular neighborhood environmental attributes that help residents to maintain regular walking are needed to provide stronger evidence to inform environmentally focused initiatives. There is a small body of evidence on environmental factors relevant to the maintenance of walking among adults. A study in Canada found the proximity to services and amenities to be conducive to older adults' continued walking during a 3-yr period (12). In the United States, it was found that older adults living in safe walking environments with easy access to activity facilities (e.g., parks) were less likely to decrease

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walking (15). In Australia, the presence of and proximity to green spaces were found to be associated with the maintenance of recreational walking among adults (31). However, studies to date do not seem to have examined explicitly whether environmental attributes associated cross-sectionally with adults walking can also support the maintenance of walking behaviors.

In examining prospective relationships between walking behaviors and environmental attributes, life changes may also influence long-term walking patterns. Work status may be particularly relevant, as whether a person is working or not working is likely to affect walking behaviors as well as levels of exposure to local environments. Those who are working may walk regularly for transport, while nonworking adults are more likely to spend longer time in their local areas and may walk more for recreation. Research has shown that neighborhood environmental attributes are more closely associated with nonemployed adults' walking (8). Work status and its change may moderate associations of environmental attributes with regular walking and with walking maintenance.

We examined neighborhood environmental attributes associated cross-sectionally with regular walking and those associated prospectively with the maintenance of regular walking for 7 yr among a sample of adults in the Australian Diabetes, Obesity and Lifestyle (AusDiab) study. We also examined whether work status modified such relationships.

METHODS

Study Sample

The AusDiab study is a prospective cohort study that was established originally to examine the prevalence and correlates of diabetes and related risk factors. Detailed methods of sample recruitment and data collection have been described elsewhere (5,33). Briefly, there were three waves of data collection: AusDiab1 (1999–2000), AusDiab2 (2004–2005), and AusDiab3 (2011–2012). The present study used AusDiab2 as baseline and AusDiab3 as follow-up owing to the unavailability of exposure measures (environmental attributes) in AusDiab1. In AusDiab1 ($n = 11,247$), the sample was drawn from private dwellings within 42 clusters of Census Collection Districts (CCD; a geographic unit defined by the Australian Bureau of Statistics with an average of 225 dwellings each). Six CCD clusters were randomly selected from each of the seven Australian states and territory. More information about the study areas and recruitment methods can be found within the AusDiab Web site (<http://www.bakeridi.edu.au/ausdiab/publications/>). Questions on neighborhood environments were introduced in AusDiab2 ($n = 6400$), which is the baseline of the current study. The follow-up survey (AusDiab3) was conducted, on average, 6.9 ± 0.3 yr after the baseline. The sample of this study consisted of those who participated in both the baseline and follow-up surveys ($n = 4802$). Of these, participants who moved residence between the surveys ($n = 1650$), were

older than 85 yr at follow-up ($n = 127$), had missing data on walking at baseline or at follow-up ($n = 201$), had missing data on environmental variables ($n = 34$), had problems in walking 100 m because of health at follow-up ($n = 392$), and lived in care facilities during the past 3 months at follow-up ($n = 27$) were excluded (numbers not mutually exclusive). The reason for excluding those with limited physical functional capacities was that their behavior changes may have been attributable largely to their functional status. Participants older than 85 yr at follow-up (older than 78 yr at baseline) were also excluded because a study has shown considerable functional decline after 78 yr of age (29). The final sample size was 2684. Written informed consent was obtained from all participants. The study was approved by the Ethics Committee of International Diabetes Institute and The Alfred Health Human Ethics Committee.

Measures and Instruments

Outcome measures. Walking was assessed using the Active Australia Survey both at baseline and follow-up (1). Participants were asked to report the frequency of walking for recreation, exercise, and transport in the last week (for at least 10 min at one time). Although walking duration was available, we used frequency of walking because overreporting of duration is common in instruments that ask about the duration of activity in the last 7 d (25). Several recent studies have also used walking frequency in light of concerns about the accuracy of walking duration (12,18). The walking frequency item of this instrument was shown to have moderate test–retest reliability (Spearman $\rho = 0.58$) and moderate criterion validity (Spearman $\rho = 0.40$) against accelerometry (3). At baseline, participants who reported walking four times per week or less were classified as “nonregular walkers,” and those who reported five times per week or more were classified as “regular walkers.” Regular walkers at baseline were further divided into those who “stopped regular walking” (reporting four times per week or less at follow-up) and those who “maintained regular walking” (reporting five times per week or more at follow-up). Five times per week was chosen as a cutoff because current guidelines for physical activity recommended $5 \text{ d}\cdot\text{wk}^{-1}$ or more (11) or five sessions per week or more (2).

To distinguish regular and nonregular walking more clearly and to reduce the possibility of misclassification, an alternative categorization in which those who reported walking three to four times per week were removed was also examined. In this categorization, cross-sectional analyses compared regular walkers (five times per week or more) and nonregular walkers (zero to two times per week) to identify environmental correlates of regular walking. Similarly, prospective analyses compared those who maintained five times per week or more at both time points and those who decreased from five times per week or more at baseline to zero to two times per week at follow-up.

Exposure measures. Neighborhood environmental attributes were measured at baseline using self-report. They included the following nine items: many stores within easy walking distance, many alternative routes to get to places, footpaths on all streets, park or nature reserve nearby, bicycle or walkway tracks nearby, attractive neighborhood, pleasant natural features in the neighborhood, local traffic not making walking difficult or unpleasant (reversed from the original survey item), and feeling safe to walk during the day. These environmental items were extracted from the Neighborhood Environment Walkability Scale, for which reasonable test–retest reliability has been reported (27). Participants were asked to assess these items in their local area, which was defined as the area within a 10- to 15-min walk from home. The response format ranged from 1 (strongly disagree) to 4 (strongly agree), and each item was treated as a continuous measure.

Covariates. The following sociodemographic characteristics were asked at baseline: sex, age, education attainment (less than high school, high school, tertiary), work status (working full-time or part-time, not working), marital status, having child in household, and annual household income (AUS\$41,599 or less, AUS\$41,600–77,999, AUS\$78,000 or more, no reporting). Because the change in the participants' life status may influence their long-term walking patterns, the change in work status, marital status, and the presence of children in household were determined using the participants' response at follow-up. For instance, participants were classified into those who kept working, stopped working, started working, and not working. In addition, participants' baseline functional status (having some problem in walking) and their baseline BMI calculated from measured weight and height were also used as covariates. Participants with severely limited mobility (having problem in walking 100 m) at follow-up were excluded from the sample, and analyses were adjusted for baseline functional status to account for reduced mobility of older adults included in the AusDiab study.

Statistical Analysis

Logistic regression analysis examined associations of each environmental attribute with regular walking (cross-sectional) and the maintenance of regular walking (prospective), adjusting for covariates that were associated with the outcome in univariate analysis ($P < 0.1$). Multilevel mixed-effects logistic regression, using each environmental attribute as an individual-level continuous predictor and CCD cluster ($n = 42$) as a random intercept, was used. Cross-sectional analyses were conducted for those who completed both the baseline and follow-up surveys. Interaction between each environmental attribute and work change status was examined. Stratified analyses were conducted when the interaction was significant ($P < 0.1$). Participants who started working were excluded from the interaction/stratified analyses because they constituted a small percentage of the sample (6%). Analysis was conducted using Stata12 (STATA Corporation, College Station, TX).

RESULTS

Figure 1 shows how participants were categorized based on their walking frequency at baseline and follow up. About two-fifths of participants were regular walkers at baseline. Of those, approximately two-thirds maintained regular walking at follow-up. Table 1 shows the characteristics of the study sample and those of each walking category. Participants' age ranged from 30 to 77 yr at baseline. Table 1 shows that baseline age, sex, education, mobility, BMI, and the change in work status and in parenthood status were associated with either regular walking or regular walking maintenance at $P < 0.1$ in univariate analyses (t -tests for continuous variables and χ^2 tests for categorical variables). Regression analyses (both cross-sectional and prospective) adjusted for these covariates. In the alternative categorization (treating only those walking zero to two times per week at baseline as being nonregular walkers), 50% of the total sample were regular walkers at baseline and 78% of the regular walkers maintained regular walking at follow-up (Fig. 1).

Table 2 shows the mean \pm SD of each environmental attribute and the odds of regular walking (cross-sectional) and of maintaining regular walking (prospective) for each environmental attribute, adjusting for the covariates discussed above. Most of these environmental attributes were not closely correlated, except for a few moderate correlations ($r < 0.5$; see Table, Supplemental Digital Content 1, Pearson's correlation coefficients between environmental attributes, <http://links.lww.com/MSS/A446>). Cross-sectional analyses found that having many stores, having many alternative routes, having a park or nature reserve, having bicycle or walkway tracks, and feeling safe to walk during the day in their neighborhood were associated with a higher likelihood of being a regular walker at baseline. Prospective analyses found that participants who had many alternative routes in their local area were more likely to maintain regular walking at follow-up. In analyses using the alternative walking categorization, regular walking was associated with the same environmental attributes and with having pleasant natural features in the neighborhood. Having multiple

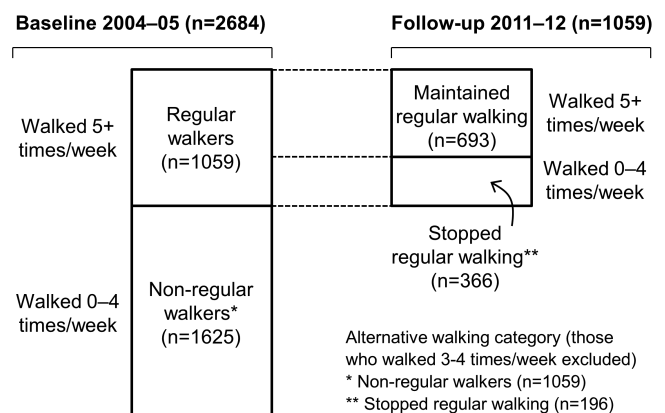


FIGURE 1—Categorization of participants according to walking frequency.

TABLE 1. Characteristics of the study sample by walking categories.

Baseline Characteristics (Except for Change Variables)	Total	Cross-sectional		Prospective	
		Nonregular Walkers	Regular Walkers	Stopped Regular Walking	Maintained Regular Walking
<i>n</i> (%)	2684	1625 (61)	1059 (39)	366 (35)	693 (65)
Sex, ^a % men	44	42	48	48	47
Age, ^a mean ± SD	54.4 ± 10.1	54.1 ± 10.3	54.8 ± 9.7	55.2 ± 9.8	54.7 ± 9.6
Education attainment, ^a %					
Less than high school	33	36	28	31	27
High school	23	22	23	24	22
Tertiary	44	42	49	45	51
Change in working status, ^{a,b} %					
Kept working	40	41	40	35	42
Stopped working	17	18	16	20	15
Started working	6	5	7	5	8
Not working	20	19	21	22	21
Unknown (missing)	17	17	16	18	14
Change in child status, ^{a,b} %					
Kept living with child	23	25	20	17	21
Stopped living with child	16	16	16	19	15
Started living with child	3	3	3	3	3
Not living with child	43	41	47	43	48
Unknown (missing)	15	15	14	18	13
Change in marital status, %					
Kept living with partner	68	68	68	66	69
Stopped living with partner	4	4	4	4	4
Started living with partner	2	2	2	2	1
Not living with partner	11	11	12	10	12
Unknown (missing)	15	15	14	18	13
Annual household income, %					
AUS\$41,599 or less	37	37	37	39	35
AUS\$41,600–\$77,999	30	30	29	28	30
AUS\$78,000 or more	31	31	32	31	33
No reporting	2	2	2	2	2
Mobility, ^a % problem in walking	12	13	10	12	10
BMI (kg·m ⁻²), mean ± SD ^a	27.4 ± 4.9	27.6 ± 5.1	27.1 ± 4.6	27.4 ± 4.7	26.9 ± 4.6

^aDifference between nonregular and regular walkers at *P* < 0.1.

^bDifference between those who stopped and maintained regular walking at *P* < 0.1.

alternative routes was also associated with regular walking maintenance for the alternative categorization.

A significant interaction with work change status was found for having many alternative routes (*P* = 0.07) in cross-sectional analyses. In prospective analyses, interactions with work change status were significant for having many alternative routes (*P* = 0.08), footpaths (*P* = 0.03), a park and nature reserve (*P* = 0.04), and bicycle or walkway tracks (*P* = 0.02). The results of stratified analyses for these variables are shown in Table 3. Having many alternative routes was associated with regular walking as well as the maintenance of regular walking only among “nonworking” participants (those who were not working or had stopped working). Having bicycle or walkway tracks nearby was associated with

the maintenance of regular walking only among nonworking participants. For the other environmental attributes, stratified analyses showed that the two groups differed in the direction of associations (negative associations for those who kept working, positive associations for nonworking participants), but the relationships were not statistically significant. For the alternative walking categorization, no significant interaction was found in cross-sectional analyses, but the same pattern of moderations was found for regular walking maintenance.

DISCUSSION

In this cohort of Australian adults, neighborhood environmental attributes associated prospectively with the maintenance

TABLE 2. Odds ratios (95% CI) of regular walking and maintenance of regular walking by environmental attributes.

Environmental Attributes	Mean ± SD	Cross-sectional ^a (<i>n</i> = 2684)	Prospective ^b (<i>n</i> = 1059)
Many stores within easy walking distance	2.9 ± 1.1	1.13 (1.04–1.22)**	1.06 (0.94–1.20)
Many alternative routes to get to places	3.3 ± 0.9	1.12 (1.01–1.23)*	1.19 (1.03–1.38)*
Footpaths on all streets	3.1 ± 1.1	1.07 (0.99–1.15)	0.94 (0.82–1.08)
Park or nature reserve nearby	3.6 ± 0.8	1.13 (1.02–1.26)*	0.96 (0.80–1.15)
Bicycle or walkway tracks nearby	3.1 ± 1.1	1.08 (1.00–1.17)*	1.10 (0.97–1.24)
Neighborhood attractive	3.6 ± 0.6	0.98 (0.86–1.13)	1.05 (0.84–1.32)
Pleasant natural features in neighborhood	3.4 ± 0.9	1.10 (0.997–1.22)	1.01 (0.86–1.19)
Local traffic not making walking difficult or unpleasant	3.2 ± 0.9	0.95 (0.86–1.04)	0.97 (0.83–1.12)
Feeling safe to walk during the day	3.8 ± 0.5	1.18 (1.01–1.38)*	0.83 (0.62–1.09)

Models were adjusted for age, sex, education, work status change, child status change, mobility, and BMI and were corrected for clustering. All environmental attributes ranged from 1 to 4 (continuous) and were examined separately.

^aOdds (95% CI) of regular walking (five times per week or more at baseline).

^bOdds (95% CI) of maintaining regular walking (five times per week or more at baseline and follow-up) among regular walkers at baseline.

**P* < 0.05.

***P* < 0.01.

TABLE 3. Odds ratios (95% CI) of regular walking and maintenance of regular walking by environmental attributes: analyses stratified by the change in work status.

Environmental Attributes	Change in Work Status	Cross-sectional ^a (n = 2086)	Prospective ^b (n = 823)
Many alternative routes	Kept working ^c	1.04 (0.91–1.20)	1.08 (0.86–1.35)
	Stopped/not working ^d	1.23 (1.06–1.42)**	1.49 (1.15–1.93)**
Footpaths on all streets	Kept working ^c		0.87 (0.70–1.07)
	Stopped/not working ^d		1.13 (0.92–1.40)
Park or nature reserve nearby	Kept working ^c		0.78 (0.57–1.07)
	Stopped/not working ^d		1.17 (0.86–1.59)
Bicycle or walkway tracks nearby	Kept working ^c		0.93 (0.76–1.14)
	Stopped/not working ^d		1.31 (1.07–1.61)**

Models were adjusted for age, sex, education, child status change, mobility, and BMI and were corrected for clustering. All environmental attributes ranged from 1 to 4 (continuous), and were examined separately.

^aOdds (95% CI) of regular walking (five times per week or more at baseline).

^bOdds (95% CI) of maintaining regular walking (five times per week or more at baseline and follow-up) among regular walkers at baseline.

^cn = 1087 for cross-sectional analysis, 422 for prospective analysis.

^dn = 999 for cross-sectional analysis, 401 for prospective analysis.

**P < 0.01.

of walking were found to be different from correlates of walking identified in cross-sectional analyses. Having many alternative routes (i.e., high street connectivity) was the only environmental attribute that was commonly associated cross-sectionally and prospectively. Access to bicycle and walking tracks was associated with regular walking at baseline for the whole sample and with the maintenance of walking only among those who did not work or had stopped working. These findings were also observed for the alternative categorization of regular and nonregular walking. Three environmental attributes, namely, the presence of footpaths, attractiveness, and local traffic, were associated neither with regular walking nor with walking maintenance. Differences between cross-sectional and prospective analyses were observed for the following attributes: having many stores nearby, having open spaces such as parks, and feeling safe to walk during the day. These were significantly associated cross-sectionally with regular walking but not with the maintenance of regular walking. The findings of having stores nearby are consistent with existing cross-sectional studies reporting the relevance of nonresidential destinations to walking (16,19,22,32). Studies on safety from crime and physical activity have reported mixed findings (9), yet there are some recent studies that have shown positive associations between perceived safety from crime and walking (6,30). These findings suggest that some environmental correlates of walking identified in the existing cross-sectional studies may not necessarily help adult residents to maintain their walking over a period of time.

It may be argued from the present findings that pedestrian or route environments (alternative routes, walking trails) may be important to encourage long-term maintenance of regular walking, whereas both destinations (stores, parks) and pedestrian environments (alternative routes, walking trails, and safety from crime) are relevant to regular walking at one point in time. An obvious question is why environmental attributes that are associated cross-sectionally with walking are not related to walking maintenance. For instance, why was the presence of stores, which has been consistently shown as a correlate of walking, not associated with maintenance? Our findings do not provide an empirical answer to this question. However, it may be that those who maintained walking over a period of time have established a habit of walking, and

habitual and nonhabitual walking may be influenced by different environmental factors. For habitual walkers, what matters may be the availability of walkable pedestrian environments. On the other hand, for nonhabitual or occasional walkers, decisions to walk may be dependent more on the presence of places to walk to. It has been shown that motivational/attitudinal factors are relevant to the maintenance of physical activity (4). Further research exploring individual, social, and environmental factors that would contribute to adults' walking habit is warranted.

It was found that having many alternative routes and access to walking tracks were the only environmental attributes relevant both to regular walking and to maintenance of regular walking. Intersection density was found to be associated with walking in previous cross-sectional studies (17,36). Stratified analyses found that significant associations of having many alternative routes with walking were observed for participants who stopped or were not working. The pronounced association for nonworkers or those who had stopped working was obtained perhaps because they tended to be more exposed to local environments. However, it is not totally clear whether well-connected street network is conducive to regular walking and to walking maintenance simply because of the availability of more direct route options or because of other environmental or social factors that coexist with higher street connectivity. A study examining the mechanisms through which street connectivity influences walking could provide useful insights into how to facilitate walking maintenance. Walking trails seem to be an important resource to support regular walking. Recent natural experiments have found an increase in walking after an urban trail was built or retrofitted (7,35). However, research on this type of walking facility is relatively limited compared to studies on neighborhood walkability or on public open spaces. Further studies on attributes of walking trails that can contribute to habitual walking will provide relevant information that helps promote walking through the increased use of this resource.

Limitations and Strengths

Several limitations need to be considered in interpreting the present findings and identifying fruitful directions for future research. Walking categories were created using a self-report

question with a short timeframe (the last 7 d) at baseline and at follow-up. Fluctuation in walking behaviors that could have occurred during the study period may have led to misclassification of participants. In addition, regular walking and walking maintenance were determined using the cut point of five times per week, which corresponds to current physical activity guidelines (11). Although the alternative categorization produced similar results, these categories may have also misclassified participants. Measures that can accurately characterize long-term patterns of walking need to be developed.

The walking measure used for the study incorporated both walking for transportation and for recreation. Review articles show consistently that these walking domains are associated with different environmental attributes because they tend to take place in different settings (26,32). Thus, it is possible that combining them has masked the relationship between a specific type of walking and an attribute that may actually have existed. A further limitation is that there may have been some environmental changes between baseline and follow-up. A recent longitudinal study has shown increases in recreational facilities around home to be associated with a less pronounced decline in recreational physical activity (24). However, it is unlikely that such changes happened in a systematic way across study areas (e.g., areas with more destinations where people walked regularly at baseline lost destinations at follow-up).

Participants who have a habit of walking may have chosen to live in a local area with particular attributes. A cross-sectional study found that both neighborhood walkability and attitudes toward active travel accounted for residents' walking behaviors (10). However, the effect of self-selection and attitudinal factors on a long-term walking pattern needs to be examined in future prospective studies. Further, a relatively small number of environmental attributes were used in the study, and they may have missed some relevant environmental characteristics. The response options for these items were four integers (1, 2, 3, and 4), which may be a metric that is too crude for examining complex relationships (e.g., nonlinear associations) between environmental attributes and walking outcomes. In addition, there may be other interpersonal, intra-personal, and area-level characteristics (e.g., attitude toward activity, social ties, social norms) that may have confounded the relationships between walking and environmental attributes.

The strengths of this study include its large sample size, longitudinal design, and consideration of the change in life circumstances (work status, household composition). Because participants were recruited from diverse locations (urban,

suburban, and regional) throughout Australia, our findings may be applicable to broader settings in a similar context. However, the generalizability of the findings to localities with different environmental characteristics (e.g., Europe or Asia with higher residential density) remains to be determined. We have also used multiple criteria to exclude participants who were likely to have difficulty walking around to minimize the inclusion of participants who stopped walking because of a decline in functional capacity.

CONCLUSIONS

In summary, this study found that neighborhood environmental attributes associated cross-sectionally with adults' regular walking were not necessarily related to the maintenance of regular walking. Our findings suggest that better pedestrian environments (well-connected street network, access to walking trails) may contribute to the maintenance of walking behavior. Given the importance of long-term habitual walking for health benefits, more prospective studies are needed to further explicate these relationships.

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