American Journal of Epidemiology

Vol. 190, No. 7
https://doi.org/10.1093/aje/kwab043
Advance Access publication:
February 19, 2021

Original Contribution

Neighborhood Sidewalk Environment and Incidence of Dementia in Older Japanese Adults

The Japan Gerontological Evaluation Study Cohort

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Initially submitted June 4, 2020; accepted for publication February 15, 2021.

Sidewalks are indispensable environmental resources for daily life in that they encourage physical activity. However, the proportion of sidewalk coverage is low even in developed countries. We examined the association between neighborhood sidewalk environment and dementia in Japan. We conducted a 3-year follow-up (2010–2013) among participants in the Japan Gerontological Evaluation Study, a population-based cohort study of community-dwelling older adults. We ascertained the incidence of dementia for 76,053 participants from the public long-term care insurance system. We calculated sidewalk coverage (sidewalk area as a percentage of road area) within 436 residential neighborhood units using geographic information systems. Multilevel survival models were used to estimate hazard ratios for the incidence of dementia. During follow-up, 5,310 dementia cases were found. In urban areas, compared with the lowest quartile of sidewalk coverage, the hazard ratio was 0.42 (95% confidence interval: 0.33, 0.54) for the highest quartile, adjusting for individual covariates. After successive adjustments for other neighborhood factors (land slope; numbers of hospitals, grocery stores, parks, railway stations, and bus stops; educational level; and unemployment rate), the hazard ratio remained statistically significant (hazard ratio = 0.71, 95% confidence interval: 0.54, 0.92). Living in a neighborhood with a high level of sidewalk installation was associated with low dementia incidence in urban areas.

aged; community-dwellers; dementia; neighborhood characteristics; older adults; sidewalks

Abbreviations: CI, confidence interval; JAGES, Japan Gerontological Evaluation Study.

Dementia prevention is a high priority in the public health sector worldwide, given the rapidly aging population of some countries (1). It was recently estimated that one-third of dementia cases are preventable, with 9 risk factors being identified: education, hypertension, obesity, hearing loss, depression, diabetes, physical inactivity, smoking, and social isolation (1). Physical activity can reduce levels of these preventable risk factors, including hypertension, obesity, depression, and diabetes (2).

Because the neighborhood environment is an important factor that influences how physically active older people are in daily life (3–5), an approach targeting environmental features may be effective in preventing dementia. Recent studies showed that the low availability of better environmental destinations was associated with cognitive impairment and dementia (6–8). However, little is known about the environmental factors that support ease of access to such destinations.

Sidewalks may prompt people to walk, and the walkability of paths positively motivates older people to engage in physical activity (4, 5). Walking is the most common and preferred type of physical activity for older people because it is associated with low costs, has low risk for aging bodies (4, 9), and is applicable to various activities, such as shopping and sightseeing. A recent study among older people showed that a lower amount of time spent walking was associated with dementia (10). Older people residing in environments with poor sidewalk coverage may not walk frequently, and in turn may have an increased risk of dementia.

Even in developed countries, the proportion of sidewalk coverage is low in some countries. In one survey, the percentage of city residents who agreed that their neighborhoods had sidewalks on most streets was only 59% in Japan, whereas these figures were 97% in Hong Kong, China, 96% in Sweden, 77% in Canada, and 74% in the United States (11). Objective data calculated by dividing sidewalk length by road length showed that the proportion of sidewalk coverage was only 14% in Japan in 2010 (12). Moreover, road widths in Japan are narrow—6 m, on average (12). Thus, 2 cars can barely pass each other, and there is little space left for pedestrians to pass. The role of sidewalks in physical activity can differ between urban and rural areas. While sidewalks may play an important role in walking safety in urban areas, they may not encourage walking in rural areas, because people can walk safely on the roads in many rural areas. Therefore, the association between sidewalks and dementia needs to be examined separately for rural and urban areas.

One of the reasons for the lack of research on sidewalks may be the difficulty of quantifying sidewalk environments. Two methods are mainly used, one involving an objective measurement in which a trained observer visits the site to evaluate the sidewalk environment (6, 7) and the other being a proportional method using the ratio of sidewalk length to road length (13, 14). With the first method, although it is possible to carefully evaluate the quality of the sidewalk environment (e.g., sidewalk width, continuity, and obstacles), it is time-consuming to cover a whole country. In contrast, the second method is suitable for large-scale surveys if an existing regional database on sidewalk lengths and road lengths is available (15). Nevertheless, this method only considers the percentage of sidewalk length and does not evaluate other quantifiers of sidewalk environments, such as width. Therefore, we measured sidewalk coverage (the ratio of sidewalk area to road area) using geographic information systems, adopting the measure to quantify sidewalk environments in our large-scale survey. This new method takes into account not only road length but also width.

Our aim in this study was to examine the association between neighborhood sidewalk environment and dementia in urban and rural areas on the basis of sidewalk coverage, using data from a population-based cohort study of Japanese older adults.

METHODS

Study design and participants

The Japan Gerontological Evaluation Study (JAGES) was established in 2010 to evaluate the social determinants of healthy aging among older people in Japan (16). We conducted a baseline survey between August 2010 and January 2012 among people aged 65 years or more from 24 municipalities in Japan. Self-report questionnaires were distributed by mail to 106,468 older people who were not eligible for benefits from the long-term care insurance system (17)—that is, they were physically and cognitively independent and lived independently in the community. Random samplings were conducted in 13 large municipalities, and a complete survey was conducted in the remaining 11 smaller municipalities. A total of 86,055 participants returned the questionnaire (response rate = 66%). Among the respondents, 81,980 participants were successfully linked to dementia records during the 3-year follow-up period. The analytical sample for the present study comprised 76,053 participants aged 65–103 years. We excluded respondents with missing data for residential sidewalk environment ($n = 1{,}432$). In addition, to ensure that the analytical sample included only participants who were actually physically and cognitively independent, we also excluded those who reported having limitations ($n = 1{,}627$) or provided no answer ($n = 2{,}868$) for questions about daily activities (ability to walk, take a bath, or use the toilet without assistance).

Outcome variable: dementia outcome

Dementia incidence was ascertained during the follow-up period, from 2010 to 2013 (mean = 3.0 years), by linking the cohort participants to the standardized in-home assessment and medical examination conducted for Japan's public long-term care insurance registry (17). Details on the assessment of dementia have been reported elsewhere (8, 18). Briefly, trained investigators evaluated applicants' eligibility for benefits by evaluating the following statuses: 1) physical function; 2) activities of daily living; 3) cognitive function; 4) mental and behavioral disorders; 5) adaptation to social life; and 6) past medical treatment (8, 19). Investigators classified the applicants on a dementia scale according to the severity of their cognitive impairment (see Web Table 1, available online at https://doi.org/10.1093/aje/kwab043). As described elsewhere (8, 18), being at level II or higher on the dementia scale (manifesting at least some symptoms, behaviors, or communication difficulties that hinder daily activities; level II corresponds to a 16-point rating on the Mini-Mental State Examination (20)) was defined as having dementia in this study.

Predictor variable: sidewalk environment and other environmental measures

We calculated sidewalk coverage by dividing sidewalk area by the total area of roads that included sidewalks within each neighborhood unit (Figure 1). Sidewalk coverage was calculated using the 2014 ArcGIS data collection detail map (ESRI Japan, Tokyo, Japan). These data contain polygons in the area of roads and in the area of sidewalks; ArcGIS, version 10.1 (ESRI Japan), was used for all spatial calculations. We visually confirmed that the newly adopted sidewalk data reflected actual sidewalk conditions using the baseline 2010 photos (Figure 1). As in previous studies (21), we defined a neighborhood unit as an elementary school district, which is a primary residential spatial area of community-dwelling people in which older persons are able to move around on foot or by bicycle easily. Our study sample ($n = 76{,}053$) was nested within 436 elementary school districts, and the average area of the elementary school districts was 2.65

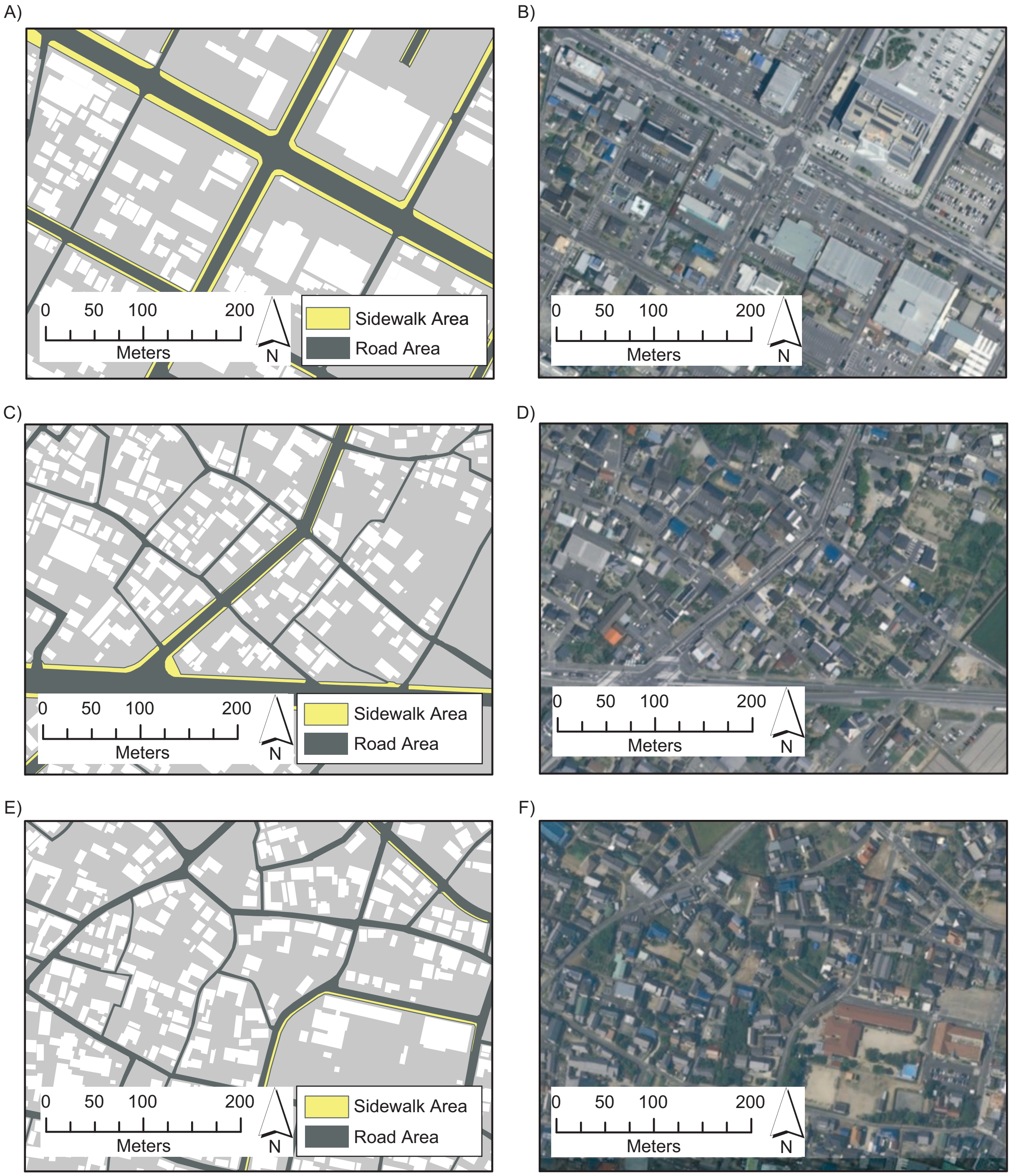

Figure 1. Methods of calculating sidewalk coverage at 3 different city scales in Japan, with accompanying aerial photographs. Sidewalk coverage (%) = (sidewalk area within neighborhood unit/area of entire road within a neighborhood unit) × 100. Area of entire road = road area (gray) + sidewalk area (yellow). Panels A and B: a neighborhood unit with high sidewalk coverage (sidewalk coverage = 19.5%); panels C and D: a neighborhood unit with low sidewalk coverage (sidewalk coverage = 9.6%); panels E and F: a neighborhood unit with very low sidewalk coverage (sidewalk coverage = 5.3%). Aerial photographs were provided by the Geospatial Information Authority of Japan in 2010.

(standard deviation, 3.98) km^2. For the analyses, school districts were categorized into quartiles based on sidewalk coverage (Web Figure 1, Table 1).

Using geographic information systems, we calculated the degree of land slope; population density; the area of the school district; and numbers of hospitals, grocery stores,

Table 1. Characteristics of Sidewalk Coverage in the Study Areas (n = 436 Areas), Japan Gerontological Evaluation Study, 2010–2013

Quartile of Sidewalk Coverage	No. of Areas	Sidewalk Coverage[a] in District, %		Mean Sidewalk Coverage, %[b]
		Mean (SD)	Median (Range)	
1 (lowest)	109	6.6 (2.5)	6.9 (0.5–9.9)	18.1
2	109	11.9 (1.0)	12.0 (10.0–13.7)	32.7
3	109	15.4 (1.0)	15.4 (13.7–17.1)	42.3
4 (highest)	109	21.2 (3.5)	20.1 (17.1–34.3)	58.2
Total	436	13.8 (5.8)	13.7 (0.5–34.3)	37.9

Abbreviation: SD, standard deviation.

[a] Sidewalk area as a percentage of the area of all roads within the neighborhood unit (i.e., residential elementary school district).

[b] Estimated mean percentage of roadways with sidewalks on both sides, calculated under standard road conditions—that is, the road width should be 6 m or more for 2 lanes, the sidewalk width should be 4 m or more (≥2 m/lane), and the road shoulder width should be 1 m or more (≥0.5 m/lane), according to the Japanese Road Construction Ordinance. For example, since the average sidewalk coverage in this study was 13.8%, it is estimated that sidewalks were installed on 37.9% (13.8/36.4 × 100) of the roads.

parks, railway stations, and bus stops within the participants' residential school districts. Details on the methods are reported elsewhere (8, 21, 22). Using national census data from 2010, we calculated the proportion of residents with higher education (number of high school graduates/total number of residents × 100) and the unemployment rate (1 − total number of employees aged ≥15 years/labor force of people aged ≥15 years × 100) within the participants' residential school districts as neighborhood socioeconomic status.

Covariates

Baseline information on age and sex was provided by the municipality. Other covariates were assessed using the self-report questionnaire. Sociodemographic status included educational level, annual household income, living situation, marital status, and employment status. Health status included medical treatment of diseases/symptoms (hypertension, diabetes, hearing loss, heart disease, or stroke), depressive symptoms, instrumental activities of daily living, and cognitive function. Baseline cognitive function was assessed using 3 items from the Kihon Checklist–Cognitive Function scale, for which predictive validity for dementia incidence was confirmed (23). Duration of residence was assessed by how long participants had lived in the same municipality. Physical activity included walking time and frequency of outings. Use of a car when going out was assessed by whether participants drove a car by themselves or rode in a family member's car when going out (8). All covariates were controlled as categorical variables (Table 2).

Statistical analysis

Multilevel Weibull survival models with the "vce" (cluster) option in STATA (StataCorp LLC, College Station, Texas) were fitted, yielding hazard ratios and 95% confidence intervals for dementia incidence over the 3-year follow-up period. Data were analyzed for both sexes because the term for interaction between sex and sidewalk coverage was nonsignificant. Model 1 adjusted for age and sex. Model 2 additionally adjusted for sociodemographic characteristics, health status, and duration of residence as potential confounders. Model 3 additionally adjusted for physical activity and use of a car when going out as potential mediating factors. Model 4 simultaneously adjusted for other neighborhood factors (land slope; numbers of hospitals, grocery stores, parks, railway stations, and bus stops; educational level; unemployment rate; and area of school district) as well as individual-level factors to examine whether the association between sidewalk coverage and dementia was independent of these factors. To investigate the difference according to city scale (i.e., urban or rural area), we conducted an analysis stratified specifically by city scale. Of the 4 area levels defined according to the Organisation for Economic Co-operation and Development's Functional Urban Areas (large metropolitan areas, metropolitan areas, medium-sized urban areas, and small urban areas) (24), the school districts included in large metropolitan areas or metropolitan areas were distinguished as urban and the other areas were distinguished as rural. For the sensitivity analysis, a propensity-score–matched (lowest quartile (quartile 1) and highest quartile (quartile 4) of sidewalk coverage) cohort analysis was performed to reduce potential confounding bias in the association between sidewalk coverage and dementia. The propensity score matching was conducted with a ratio of 1:1 and a caliper distance of 0.01 using the variables. The matching generated 3,799 matched pairs, and multilevel Weibull survival models with the "vce" (cluster) option were fitted. All analyses were conducted using STATA, version 15.

Table 2. Baseline Characteristics of Older Japanese Adults (n = 76,053), Japan Gerontological Evaluation Study, 2010–2013

Characteristic	Total		Sidewalk Coverage in District, %			
	No.	%	Q1 (Lowest)	Q2	Q3	Q4 (Highest)
Sex						
Male	35,475	46.6	46.5	47.2	46.4	46.1
Female	40,578	53.4	53.5	52.8	53.6	53.9
Age, years						
65–69	24,259	31.9	32.2	34.3	30.0	27.8
70–74	21,797	28.7	27.7	28.6	30.5	29.8
75–79	16,493	21.7	21.4	20.5	22.7	24.2
≥80	13,504	17.8	18.8	16.6	16.8	18.2
Sociodemographic characteristics						
Educational level						
Low (≤9 years)	35,736	47.0	52.4	45.5	40.6	40.5
Middle (10–12 years)	24,125	31.7	28.5	33.6	35.2	33.7
High (≥13 years)	12,097	15.9	13.2	16.0	19.4	20.3
Other/missing data	4,095	5.4	5.8	5.0	4.9	5.5
Annual income level						
Low (<2.00 million yen)	29,686	39.0	39.5	38.3	38.4	40.1
Middle (2.00–3.99 million yen)	23,927	31.5	29.9	33.0	32.9	31.4
High (≥4.00 million yen)	7,061	9.3	8.6	9.7	10.1	9.8
Missing data	15,379	20.2	22.1	19.0	18.6	18.7
Living situation						
Lived with others	63,849	84.0	85.2	85.1	82.1	79.5
Lived alone	8,866	11.7	10.1	10.8	13.8	16.0
Missing data	3,338	4.4	4.7	4.1	4.1	4.5
Marital status						
Married	52,295	68.8	68.4	70.2	68.1	67.2
Widowed	16,120	21.2	22.0	20.5	20.8	20.6
Divorced	2,344	3.1	2.3	3.1	4.1	4.4
Not married	1,369	1.8	1.4	1.6	2.4	3.1
Other/missing data	3,925	5.2	5.9	4.7	4.5	4.8
Employment status						
Working	15,667	20.6	21.1	20.6	19.6	20.1
Retired	41,040	54.0	50.9	55.5	57.5	56.3
Never worked	8,497	11.2	11.4	11.0	11.4	10.7
Missing data	10,849	14.3	16.7	12.9	11.5	12.8
Health status						
Under medical treatment						
Hypertension	29,941	39.4	39.2	39.4	39.3	39.8
Diabetes mellitus	9,640	12.7	12.1	13.1	13.2	13.0
Hearing loss	5,573	7.3	7.9	6.9	6.9	7.1
Heart disease	9,052	11.9	11.6	12.1	12.7	11.6
Stroke	1,025	1.3	1.4	1.3	1.4	1.2

Table continues

Table 2. Continued

Characteristic	Total		Sidewalk Coverage in District, %			
	No.	%	Q1 (Lowest)	Q2	Q3	Q4 (Highest)
Depressive symptoms						
Nondepressed (GDS score <5)	45,029	59.2	58.4	60.1	59.8	59.3
Depressed (GDS score ≥5)	17,245	22.7	23.0	22.9	22.4	21.5
Missing data	13,779	18.1	18.6	17.1	17.8	19.2
Instrumental activities of daily living						
Fully capable	28,617	37.6	37.1	39.1	37.7	35.9
Less capable	37,836	49.7	49.9	49.4	49.6	50.3
Missing data	9,600	12.6	13.0	11.6	12.7	13.8
Cognitive complaints						
No	45,269	59.5	58.6	60.3	60.0	60.4
Yes	24,978	32.8	33.8	32.7	31.9	31.2
Missing data	5,806	7.6	7.7	7.0	8.1	8.4
Duration of residence in the area, years						
<5	9,314	12.2	14.9	11.8	8.7	8.9
5–9	11,492	15.1	17.5	15.7	10.8	11.1
10–19	12,043	15.8	18.2	17.3	11.4	10.0
≥20	16,845	22.1	26.4	24.7	15.4	10.3
Missing data	26,359	34.7	23.0	30.5	53.7	59.7
Physical activity						
Walking time, minutes/day						
≥90	11,514	15.1	16.3	15.0	13.9	13.1
60–89	11,135	14.6	14.2	14.6	15.3	15.4
30–59	24,476	32.2	30.3	33.2	33.3	34.6
<30	23,728	31.2	31.9	30.9	30.9	29.8
Missing data	5,200	6.8	7.3	6.3	6.6	7.0
Frequency of going out, no. of times/week						
≥4	39,479	51.9	48.7	53.5	55.2	54.6
1–3	27,212	35.8	37.4	35.3	33.5	34.2
≤1	11,116	14.6	17.2	13.3	12.1	12.2
Missing data	4,680	6.2	6.3	5.7	6.3	6.6
Used a car when going out	50,001	65.7	79.3	69.0	44.3	39.4

Abbreviations: GDS, Geriatric Depression Scale; Q, quartile.

Ethical consideration

The human subjects committees of Nihon Fukushi University (Mihama, Japan) and the Chiba University Faculty of Medicine (Chiba, Japan) approved the JAGES protocol. Participants were informed that participation in the study was voluntary and that completing and returning the questionnaire via mail indicated their consent to participate.

RESULTS

The mean sidewalk coverage within elementary school districts was 13.8%, producing an estimated sidewalk installation percentage of 37.9% (Table 1). Sidewalk coverage for quartile 4 (58%) was more than 3 times higher than that for quartile 1 (18%), a 40–percentage-point difference. Sidewalk coverage was positively correlated with sidewalk area, population density, numbers of hospitals, grocery stores, parks, and railway stations, proportion of higher education, and unemployment rate and was inversely correlated with road area, area of school district, and land slope (Web Table 2).

The characteristics of the participants are summarized in Table 2. Among all participants, 47% were male, 12% lived alone, 69% were married, 21% were working, 39% were under treatment for hypertension, and 13% were under

Table 3. Hazard Ratios for the Association Between Dementia and Neighborhood Sidewalk Coverage in Older Japanese Adults, Overall and by City Scale, Japan Gerontological Evaluation Study, 2010–2013

City Scale and Quartile of Sidewalk Coverage	Model 1[a]		Model 2[b]		Model 3[c]		Model 4[d]	
	HR	95% CI	HR	95% CI	HR	95% CI	HR	95% CI
Total (*n* = 76,035)								
1 (lowest)	1.00	Referent	1.00	Referent	1.00	Referent	1.00	Referent
2	0.78	0.66, 0.91	0.81	0.69, 0.94	0.82	0.71, 0.96	0.81	0.68, 0.96
3	0.63	0.52, 0.76	0.67	0.55, 0.80	0.69	0.57, 0.84	0.78	0.62, 0.98
4 (highest)	0.51	0.42, 0.63	0.55	0.45, 0.68	0.58	0.47, 0.71	0.73	0.58, 0.92
Urban areas (*n* = 47,364)								
1 (lowest)	1.00	Referent	1.00	Referent	1.00	Referent	1.00	Referent
2	0.74	0.61, 0.91	0.79	0.65, 0.96	0.80	0.66, 0.97	0.79	0.66, 0.95
3	0.58	0.46, 0.72	0.65	0.52, 0.82	0.69	0.55, 0.86	0.85	0.67, 1.08
4 (highest)	0.42	0.33, 0.54	0.49	0.38, 0.63	0.52	0.41, 0.68	0.71	0.54, 0.92
Rural areas (*n* = 28,689)								
1 (lowest)	1.00	Referent	1.00	Referent	1.00	Referent	1.00	Referent
2	0.81	0.64, 1.03	0.85	0.67, 1.08	0.87	0.68, 1.11	1.09	0.81, 1.45
3	1.13	0.71, 1.81	1.12	0.70, 1.80	1.13	0.70, 1.80	0.80	0.49, 1.30
4 (highest)	1.27	0.90, 1.81	1.28	0.91, 1.81	1.27	0.89, 1.80	0.73	0.52, 1.02

Abbreviations: CI, confidence interval; HR, hazard ratio.

[a] Model 1 included individual neighborhood features and adjusted for age and sex.

[b] Model 2 additionally adjusted for sociodemographic factors (education, annual income, living situation, marital status, and employment status), health status (hypertension, diabetes mellitus, hearing loss, heart disease, stroke, depressive symptoms, instrumental activities of daily living, and cognitive complaints), and duration of residence.

[c] Model 3 additionally adjusted for physical activity (walking time and frequency of going out) and use of a car when going out.

[d] Model 4 simultaneously adjusted for all types of neighborhood features (sidewalk coverage; land slope; numbers of hospitals, grocery stores, parks, railway stations, and bus stops; educational level; unemployment rate; and area of school district) and individual factors (education, annual income, living situation, marital status, employment status, health status (hypertension, diabetes mellitus, hearing loss, heart disease, stroke, depressive symptoms, instrumental activities of daily living, and cognitive complaints), and duration of residence).

treatment for diabetes. Approximately 30% of participants walked for more than 1 hour per day; 52% went out more than 4 times per week, and 66% used a car when going out.

During the follow-up period, 5,310 dementia cases were found in the analytical sample (cumulative dementia; 7.0% of all participants). The incidence rate of dementia per 100,000 person-years was 8.0 in quartile 1 of sidewalk coverage and 6.7 in quartile 4 (Web Table 3). Compared with quartile 1 of sidewalk coverage, the hazard ratio was 0.81 (95% confidence interval (CI): 0.69, 0.94) for quartile 2, 0.67 (95% CI: 0.55, 0.80) for quartile 3, and 0.55 (95% CI: 0.45, 0.68) for quartile 4, after adjustment for age, sex, sociodemographic factors, health status, and duration of residence (Table 3, model 2). Similar results were obtained using continuous values for sidewalk coverage (Web Table 4). Adjusting for potential mediating factors, including physical activity and car use, reduced the correlation only slightly. After adjustment for other neighborhood features (land slope; numbers of hospitals, grocery stores, parks, railway stations, and bus stops; educational level; unemployment rate; and area of school district), higher sidewalk coverage was significantly associated with lower dementia incidence (Table 3, model 4). Among neighborhood features, sidewalk coverage showed the most protective association with dementia incidence (Figure 2, Web Table 5). A propensity-score–matched (quartiles 1 and 4 of sidewalk coverage) cohort analysis was further employed for the sensitivity analysis. The characteristics of the participants before and after propensity-score matching are shown in Web Table 6. We confirmed that compared with quartile 1, the hazard ratio for quartile 4 was 0.52 (95% CI: 0.37, 0.74) (Web Table 7).

In the analyses stratified by city scale, higher sidewalk coverage was associated with lower dementia incidence in urban areas but not in rural areas (Table 3). Similar results were obtained in the stratified analyses using the population density of habitable areas. Higher sidewalk coverage was significantly associated with lower dementia incidence in school districts with high population density but not in school districts with low population density (data not shown). In the analyses stratified by driving status, higher sidewalk coverage was associated with lower dementia incidence only among non–car-users (Web Table 8).

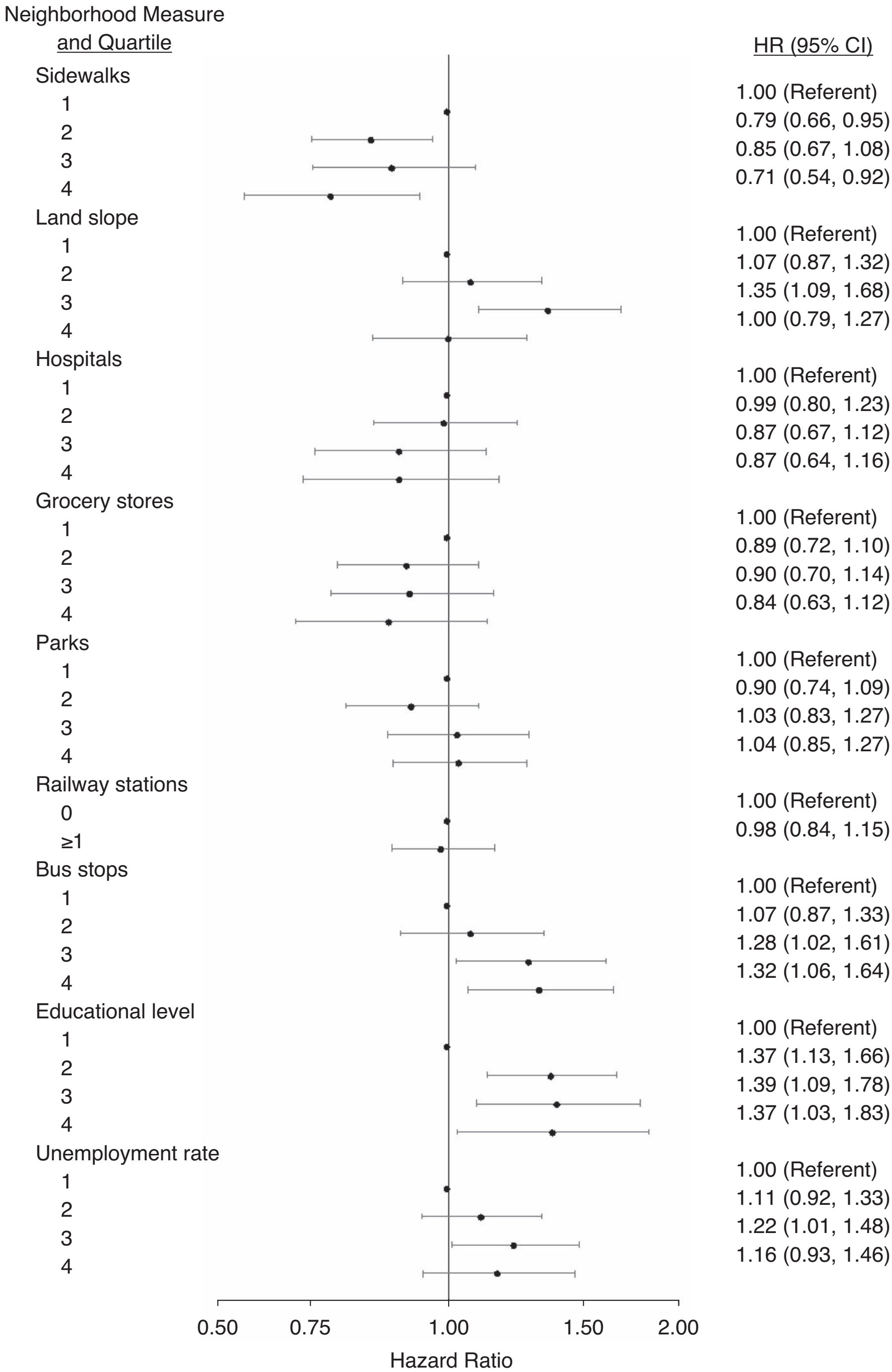

Figure 2. Hazard ratios (HRs) for the association between dementia and neighborhood measures in older Japanese adults (n = 76,053), Japan Gerontological Evaluation Study, 2010–2013. The model simultaneously adjusted for all types of neighborhood features (sidewalk coverage; land slope; numbers of hospitals, grocery stores, parks, railway stations, and bus stops; educational level; unemployment rate; and area of school district) and individual-level factors (age, sex, sociodemographic factors (education, annual income, living situation, marital status, and employment status), health status (hypertension, diabetes mellitus, hearing loss, heart disease, stroke, depressive symptoms, instrumental activities of daily living, and cognitive complaints), and duration of residence). Bars, 95% confidence intervals (CIs).

DISCUSSION

To our knowledge, this is the first study that has examined the association between neighborhood sidewalk environment and dementia in both urban and rural areas. We found that higher sidewalk coverage was associated with lower dementia incidence in urban areas.

In a previous study, Clarke et al. (7) examined the link between sidewalks and cognitive function and found no significant association. Differences in the installation percentage of sidewalks and the sidewalk measurement method used may explain the contradictory findings. In the previous study, conducted in Chicago, Illinois, about 90% of participants lived in neighborhoods where sidewalks were fully installed (7). In contrast, in our study, the percentage of roads with sidewalks installed was around 38%. The previous study did not account for the width of sidewalks, whereas we assessed sidewalks taking into account both length and width.

Little attenuation of the association between sidewalk coverage and dementia was found after adjustment for physical activity. One reason may be mismeasurement of physical activity. Because we examined only self-reported walking times, frequency of outings, and car use, the physical activity measure may not have reflected the actual physical activities of older people. Even if participants go out frequently, they may use a car for transportation rather than travel by foot. We found that higher sidewalk coverage was related to lower dementia incidence among only non–car users (Web Table 8). Because older people may be unable to use a car for several reasons, such as loss of a driver's license or loss of a family member who was responsible for driving, this result may be important for public health. We found that walking time did not vary by sidewalk coverage. One possibility is that we should account for landscaping features such as roadside vegetation planted to encourage walking, because older people may place importance on "changing landscapes," such as growth of plants, when selecting places to walk (25).

The association between sidewalk coverage and dementia remained after adjustment for other neighborhood factors, suggesting that additional unobserved factors may explain this relationship. A field survey investigating the associations of road types with sidewalk environments and the consciousness of residents showed that community roads which have sufficient sidewalk widths are places where not only passing is possible but also daily social interactions happen (26). Therefore, higher sidewalk coverage may facilitate the social activities of people living in the area. Another possibility is that in the case of wide sidewalks, there may be tree-planting zones that can increase pedestrians' exposure to greenness, which is linked to beneficial cognitive function (27). Because the mechanisms underlying this association can be complex and multiple, future studies should investigate factors that mediate the association between sidewalk coverage and dementia incidence.

We found that higher sidewalk coverage was associated with lower dementia incidence only in urban areas and not in rural areas. This finding is plausible, since people living in rural areas can walk about and talk safely without sidewalks, without the worry about traffic that plagues urban areas. We found differences in frequency of going out and use of a car by city scale (Web Table 9). In rural areas, the percentage of people using cars is higher and the frequency of going out is lower than in urban areas. These factors suggest that rural people may be less exposed to sidewalks and that sidewalks may therefore not be associated with dementia incidence in rural areas. Given the potential role of sidewalks in encouraging safe walking and physical and social activities, it is convincing that there was a protective association only in urban areas and only among non–car-users.

This study had several limitations. First, the definition of dementia in this study might have underestimated dementia incidence. In a nationwide survey aimed at estimating the prevalence of dementia, Asada et al. (28) reported that 34% of dementia cases were not identified in the long-term care insurance registry; however, three-quarters of these cases were mild cases of dementia. Because assessment of dementia is not considered to depend on the level of sidewalk coverage, the bias from nondifferential misclassification of dementia may tend toward a null value. Second, we evaluated sidewalk conditions at 1 point only and used data collected 4 years after baseline. Therefore, it was not possible to evaluate the secular change in sidewalk environments. During the 10-year period from 2008 to 2018, the percentage of sidewalk installation in Japan increased slightly from 13.7% to 14.0% and total road length increased by 1.07 times (29). Considering past exposure, the sidewalk coverage used this study may have been slightly overestimated. Third, we were able to account for the length and width of sidewalks but no other features of sidewalks, such as obstacles, unevenness, and maintenance requirements, and more generally those features that affect walking gait. Fourth, there was a possibility of selection bias. The participants included in the analysis were younger, had higher socioeconomic status, and had a higher level of physical activity than those in the excluded sample. This suggests that our sample lacked subjects who were vulnerable to dementia, which may have led to underestimation of the effect of sidewalk coverage on dementia risk. Fifth, because we did not have a clinical test for dementia in participants at baseline, people with mild dementia who were able to live independently may have been included in the analysis. However, the results were similar when we analyzed only participants with no cognitive complaints at baseline (Web Table 10). Sixth, generalizability may not be high, because differences in factors such as city scale, traffic volume, and cultural background may affect the association between sidewalks and dementia. Seventh, we were only able to provide follow-up for 3 years. Considering the pathology of dementia, long-term follow-up is needed. Finally, we cannot rule out the possibility of a reverse association. However, the results were substantially similar when we excluded participants with early dementia incidence (within 1 year) from the analysis or participants who had lived in the same municipality for fewer than 5 years (Web Tables 11 and 12).

In conclusion, sidewalk coverage was associated with a decreased incidence of dementia only in urban areas. This study provides new evidence that place of residence can affect dementia risk, and we have described the potential impact of these findings on dementia research by proposing a new modifiable environmental risk factor. Indeed, urban planning could be a new way to promote healthy aging, if the present results are confirmed. Further studies are needed to elucidate the mechanisms underlying this association.

ACKNOWLEDGMENTS

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This study used data from the Japan Gerontological Evaluation Study, which was supported by the Japan Society for the Promotion of Science (KAKENHI grant JP15H01972), a Health and Labour Sciences Research Grant (grant H28-Choju-Ippan-002), the Japan Agency for Medical Research and Development (grant JP19dk0110034), a Research Funding for Longevity Sciences grant (grant 29-42) from the National Center for Geriatrics and Gerontology, and the Japan Science and Technology Agency (grant JPMJOP1831(OPERA)).

Conflict of interest: none declared.

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