Neighborhood sidewalk environment and incidence of dementia in older Japanese adults: the Japan Gerontological Evaluation Study cohort

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This study used data from Japan Gerontological Evaluation Study, which was supported by Japan Society for the Promotion of Science KAKENHI Grant (JP15H01972), Health Labour Sciences Research Grants (H28-Choju-Ippan-002), Japan Agency for Medical Research and Development (JP19dk0110034), Research Funding for Longevity Sciences from National Center for Geriatrics and Gerontology (29-42), and Japan Science and Technology Agency (JPMJOP1831(OPERA)). The authors of this paper have no financial disclosures to report.

Conflict of interest: none declared.

Running head: Sidewalk environment and dementia incidence

Data Availability: The datasets used and analyzed for the current study are from the JAGES study. All inquiries are to be addressed to the data management committee via e-mail: dataadmin.ml@jages.net. All JAGES datasets have ethical and legal restrictions for public deposition because of the inclusion of sensitive information on the human participants.

Abstract

Sidewalks are indispensable environmental resources for daily life in that they encourage physical activity. However, the percentage of sidewalks installation 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 a 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 the geographic information system. Multilevel survival models were used to estimate hazard ratios (HR) for the incidence of dementia. During the follow-up, 5310 dementia cases were found. In urban areas, compared with the lowest quartile for sidewalk coverage, the HR was 0.42 (95% confidence interval (CI): 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, stations and bus stops, education level, and unemployment rate), the HR remained statistically significant (HR=0.75, 95% CI: 0.59–0.94). Living in neighborhoods with high sidewalks installation was associated with low dementia incidence in urban areas.

Keywords: sidewalk, dementia, older adults, community dwellers

Dementia prevention is a priority in the public health sector worldwide given the rapidly aging population of some countries.(1) Recently, one-third of dementia cases have been estimated to be preventable, with nine risk factors being identified: education, hypertension, obesity, hearing loss, depression, diabetes, physical inactivity, smoking, and social isolation.(1) Physical activity can reduce 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 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 ageing bodies (4, 9) and is applicable to various activities such as shopping and sightseeing. A recent study among older people showed that lower time spent walking was associated with dementia.(10) Older people residing in poor sidewalk environments may not

walk frequently, and in turn have an increased dementia.

Even in developed countries, the percentage of sidewalks installation is low in some countries. 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, 96% in Sweden, 77% in Canada, and 74% in the United States.(11) Objective data by calculating sidewalk length per road length showed the percentage of sidewalks installation is only 14% in Japan in 2010.(12) Moreover, road widths in Japan are narrow, i.e., 6.0 m on average.(12) Thus, a car can barely pass through 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 for safe walking in urban areas, they may not encourage walking in rural areas because people can walk safely on roads. Therefore, the association between sidewalks and dementia needs to be separately examined for rural and urban areas.

One of the reasons for the lack of sidewalk research may be the difficulty in 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 proportion method using the ratio of the sidewalk length to the road length.(13, 14) In 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 the 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 the geographic information system (GIS), 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.

The aim of this study was to examine the association between neighborhood sidewalk environments and dementia in urban and rural areas based on sidewalk coverage using a population-based cohort study of Japanese older adults.

METHODS

Study Design and Participants

The Japan Gerontological Evaluation Study (JAGES) project 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 older people aged 65 years or older from 24 municipalities. Self-reported 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 eleven 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. The analytic sample for the present study comprised 76,053 participants aged 65 to 103 years. We excluded respondents with missing data for residential sidewalk environments (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 limitations (N = 1,627) or provided no answer (N = 2,868) on questions about daily activities (defined as being unable to walk, take a bath or use the toilet without assistance).

Outcome variable: Dementia Outcome

The dementia incidence was ascertained during the follow-up period, from 2010 to 2013 (mean: 3.0 years), by linking the cohort participants to the standardised in-home assessment and medical examination conducted under Japan's public long-term care insurance registry.(17) The details of 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 (Web Table 1). As described elsewhere,(8, 18) Level II or higher on the dementia scale (manifesting at least some symptoms, behaviours 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 dementia in this study.

Predictor variable: sidewalk environment and other environmental measures

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

school districts, and the average area of elementary school districts was 2.65 km^2 (SD = 3.98). For the analyses, school districts were categorized into quartiles based on the sidewalk coverage (Web Figure. 1, Table 1).

Using GIS, we calculated the degree of land slope, population density, area of school district, number of hospitals, grocery stores, parks, railway stations, and bus stops within the participants' residential school districts. Details of the methods are reported elsewhere.(8, 21, 22) We calculated the proportion of residents with higher education (total number of high school graduates / all residents × 100) and 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 the neighborhood socioeconomic status using the National Census data in 2010.

Covariates

Baseline information about age and sex were provided by the municipality. Other covariates were assessed using the self-reported questionnaire. Sociodemographic status included education level, annual household income, living situation, marital status, and employment status. Health status included medical treatments 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 three items from the *Kihon Checklist*–Cognitive Function scale, for which predictive validity for the 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. Car use 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 vce (cluster) option were estimated, yielding HRs and 95% confidence intervals (CI) for dementia incidence over the 3-year follow-up period. Data were analyzed for both sexes because the interaction term between sex and sidewalk coverage was non-significant. Model 1 was adjusted for age and sex. Model 2 was additionally adjusted for sociodemographic characteristics, health status, and duration of residence as potential confounders. Model 3 was additionally adjusted for physical activity and car use when going out as potential mediating factors. Model 4 was simultaneously adjusted for other neighborhood factors (land slope, number of hospitals, grocery stores, park, railway stations and bus stops, education 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 the city scale, we conducted a stratified analysis specifically of urban and rural areas. Of the four area levels defined by 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 the large metropolitan areas or the metropolitan areas are distinguished as urban and the others as rural. For the sensitivity analysis, a propensity score-matched cohort (the lowest quartile (Q1) and the highest quartile (Q4) of sidewalk coverage) analysis was performed to reduce the potential confounding bias for the association between sidewalk coverage and dementia. The propensity score matching was conducted with a ratio of 1:1 and a calliper distance of 0.01 using the variables. The matching generated 3,799 matched pairs and multi-level Weibull survival models with the vce (cluster) option were estimated. All analyses were conducted using Stata version 15.

Ethical consideration

The Human Subjects Committees of Nihon Fukushi University (No. 10-05) and Chiba University Faculty of Medicine (No. 1777) 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 in the study.

RESULTS

The mean sidewalk coverage within elementary school districts was 13.8%, giving an estimated sidewalk installation percentage of 37.9% (Table 1). The sidewalk coverage for Q4 was more than three times higher than that for Q1, and the difference in estimated percentage of sidewalk installation was 58% for Q4 and 18% for Q1. Sidewalk coverage was positively correlated with sidewalk area, population density, and number of hospitals, grocery stores, parks, and railway stations, proportion of higher education, and unemployment rate, and 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, 40% were under treatment for hypertension, and 13% were under treatment for diabetes. About 30% of participants walked for more than 1 hour a day, >50% went out more than four times per week, and 66% used a car when going out.

During the follow-up, 5310 dementia cases were found among the analytical sample. (cumulative dementia; 7.0% of all participants). The incidence rate of dementia per 100 000 person-years was 8.0 in Q1 of sidewalk coverage and 6.7 in Q4 (Web Table 3). Compared with Q1 of sidewalk coverage, the HR was 0.81 (95% CI: 0.69–0.94) for Q2, 0.67 (95% CI: 0.55–0.80) for Q3, and 0.55 (95% CI: 0.45–0.68) for Q4, adjusting for age, sex,

sociodemographics, health status, and duration of residence (Table 3). 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 adjusting for other neighborhood features (land slope, number of hospitals, grocery stores, park, railway stations and bus stops, education level, unemployment rate, and area of school district), higher sidewalk coverages were significantly associated with a lower dementia incidence (Model 4 in Table 3). Among neighborhood features, sidewalk coverage showed the most protective association with dementia incidence (Figure 2, Web Table 5). A propensity-score matched cohort (Q1 and Q4 of sidewalk coverage) 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 Q1, the HR for Q4 was 0.52 (95% CI: 0.37–0.74) (Web Table 7).

From 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 inhabitable 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). From the analyses stratified by driving status, higher sidewalk coverage was associated with lower dementia incidence only among non-car users (Web table 8)

DISCUSSION

This is the first study to examine the association between neighborhood sidewalk environments and dementia both in urban and rural areas. We found that higher sidewalk coverage was associated with lower dementia incidence in urban areas.

One previous study examined the link between sidewalks and cognitive functions,

and it found no significant association.(7) The difference in the installation percentage of sidewalks and the sidewalk measurement method may explain the contradictory findings. In the previous study conducted in Chicago, about 90% of participants lived in neighborhoods where sidewalks were fully installed. In contrast, in our study, the percentage of roads with sidewalks installed was around 38%. The previous study in Chicago 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 adjustments for physical activity. One reason may be mismeasurement of physical activities. As we examined only the self-reported walking times, the frequency of outings and car use, it may not reflect the actual physical activities of older people. Even if participants go out frequently, they may take the car for transport rather than go 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 driving licence or loss of family member responsible for driving, this result may be important for public health. We found that walking time does not vary with sidewalk coverage. We found that walking time did not vary with sidewalk coverage. One possibility is that we should account for landscapes such as roadside vegetation to encourage walking, because older people place importance on “changing landscapes” such as growth of plants when selecting places to walk.(25)

The association between the sidewalk coverage and dementia remained after adjusting for other neighborhood factors, suggesting that additional unobserved factors may explain this relationship. Field surveys investigating the association between road types with sidewalk environments and the conscientiousness of residents showed that community roads that have a sufficient sidewalk width 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 there. Another possibility is that in the case of wide sidewalks, there are 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 as people living in rural areas can walk about and talk safely without sidewalks without the worry of 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 sidewalks may therefore not be associated with dementia incidence. 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 underestimate the dementia incidence. A nationwide survey aimed at estimating the prevalence of dementia reported that 34% of cases of dementia were not identified in the long-term care insurance registry; however, three-quarters of these cases were mild cases of dementia.(28) Because assessment of dementia is not considered to depend on the size of sidewalk coverage, the bias from nondifferential misclassification of dementia may tend toward a null value. Second, we evaluated sidewalk conditions at one point only and used data at 4 years after the 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 increased slightly from 13.7% to 14.0% and the total road length

increased by 1.07 times.(29) Considering the past exposure, the sidewalk coverage used this study may have been slightly overestimated. Third, we could account for the length and width of the sidewalk but no other features of sidewalks such as obstacles, unevenness, and maintenance requirements, and more generally those features that affects walking gaits. Fourth, there is a possibility of selection bias. The participants included in the analysis were younger, had higher socioeconomic status, and had higher physical activities 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. 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 analysed 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 Table 11 and 12).

In conclusion, sidewalk coverage has been 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 describes 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.

REFERENCES

1. Livingston G, Sommerlad A, Orgeta V, et al. Dementia prevention, intervention, and care. *Lancet* 2017;390(10113):2673-734.

2. Hallal PC, Andersen LB, Bull FC, et al. Global physical activity levels: surveillance progress, pitfalls, and prospects. *Lancet* 2012;380(9838):247-57.

3. Bauman AE, Reis RS, Sallis JF, et al. Correlates of physical activity: why are some people physically active and others not? *Lancet* 2012;380(9838):258-71.

4. Barnett DW, Barnett A, Nathan A, et al. Built environmental correlates of older adults' total physical activity and walking: a systematic review and meta-analysis. *Int J Behav Nutr Phys Act* 2017;14(1):103.

5. Moran M, Van Cauwenberg J, Hercky-Linnewiel R, et al. Understanding the relationships between the physical environment and physical activity in older adults: a systematic review of qualitative studies. *Int J Behav Nutr Phys Act* 2014;11:79.

6. Clarke PJ, Ailshire JA, House JS, et al. Cognitive function in the community setting: the neighborhood as a source of 'cognitive reserve'? *J Epidemiol Community Health* 2012;66(8):730-6.

7. Clarke PJ, Weuve J, Barnes L, et al. Cognitive decline and the neighborhood environment. *Ann Epidemiol* 2015;25(11):849-54.

8. Tani Y, Suzuki N, Fujiwara T, et al. Neighborhood Food Environment and Dementia Incidence: the Japan Gerontological Evaluation Study Cohort Survey. *Am J Prev Med* 2019;56(3):383-92.

9. Cunningham GO, Michael YL. Concepts guiding the study of the impact of the built environment on physical activity for older adults: a review of the literature. *Am J Health Promot* 2004;18(6):435-43.

10. Tomata Y, Zhang S, Sugawara Y, et al. Impact of time spent walking on incident dementia in elderly Japanese. *Int J Geriatr Psychiatry* 2019;34(1):204-9.

11. Sallis JF, Bowles HR, Bauman A, et al. Neighborhood environments and physical activity among adults in 11 countries. *Am J Prev Med* 2009;36(6):484-90.

12. Ministry of Land, Infrastructure, Transport and Tourism. Annual Report of Road Statistics FY2010.

Tokyo, Japan: Japan Highway Users Conference. https://www.mlit.go.jp/road/ir/ir-data/tokei-nen/2010tokei-nen.html. Published 2011. Accessed November 14, 2019 [in Japanese].

13. Foster S, Hooper P, Knuiman M, et al. Are liveable neighborhoods safer neighborhoods? Testing the rhetoric on new urbanism and safety from crime in Perth, Western Australia. *Soc Sci Med* 2016;164:150-7.
14. Forsyth A, Hearst M, Oakes JM, et al. Design and Destinations: Factors Influencing Walking and Total Physical Activity. *Urban Studies* 2008;45(9):1973-96.
15. Brownson RC, Hoehner CM, Day K, et al. Measuring the built environment for physical activity: state of the science. *Am J Prev Med* 2009;36(4 Suppl):S99-123.e12.
16. Kondo K, Rosenberg, M. & World Health Organization. Advancing universal health coverage through knowledge translation for healthy ageing: lessons learnt from the Japan gerontological evaluation study. World Health Organization. 2018. https://apps.who.int/iris/handle/10665/279010. Accessed November 14, 2019
17. Tamiya N, Noguchi H, Nishi A, et al. Population ageing and wellbeing: lessons from Japan's long-term care insurance policy. *Lancet* 2011;378(9797):1183-92.
18. Tani Y, Fujiwara T, Kondo K. The association between adverse childhood experience and dementia in older Japanese adult. *JAMA Netw Open* 2020;3(2):e1920740.
19. Ministry of Health, Labor and Welfare. Textbook for expert investigators concerning a certification of needed long-term care, revised edition 2009. Tokyo, Japan: Ministry of Health, Labor and Welfare. http://www.mhlw.go.jp/file/06-Seisakujouhou-12300000-Roukenkyoku/0000077237.pdf. Published 2018. Accecced October 23, 2017. [in Japanese].
20. Hisano S. The relationship between Revised Hasegawa Dementia Scale (HDS-R), Mini-Mental State Examination (MMSE) and Bed-fast Scale, Dementia Scale. *Jpn J Geriatr Psychiatry* 2009;30:883-91. [in Japanese]
21. Fujiwara T, Takamoto I, Amemiya A, et al. Is a hilly neighborhood environment associated with

diabetes mellitus among older people? Results from the JAGES 2010 study. *Soc Sci Med* 2017;182:45-51.

22. Tani Y, Suzuki N, Fujiwara T, et al. Neighborhood food environment and mortality among older Japanese adults: results from the JAGES cohort study. *Int J Behav Nutr Phys Act* 2018;15(1):101.
23. Tomata Y, Sugiyama K, Kaiho Y, et al. Predictive ability of a simple subjective memory complaints scale for incident dementia: Evaluation of Japan's national checklist, the "Kihon Checklist". *Geriatrics & gerontology international* 2017;17(9):1300-5.
24. OECD. Functional urban areas by country. 2019. https://www.oecd.org/cfe/regional-policy/functionalurbanareasbycountry.htm. Accessed October 12, 2020
25. Yorifuji T, Kashima S, Tsuda T, et al. Long-term exposure to traffic-related air pollution and mortality in Shizuoka, Japan. *Occup Environ Med* 2010;67(2):111-7.
26. Fujita M, Yamaoka S, Matsui H. Evaluation for three types of access roads on the basis of questionnaire and field surveys. *Journal of the City Planning Institute of Japan* 2001;36:607-12. [in Japanese]
27. de Keijzer C, Gascon M, Nieuwenhuijsen MJ, et al. Long-Term Green Space Exposure and Cognition Across the Life Course: a Systematic Review. *Curr Environ Health Rep* 2016;3(4):468-77.
28. Asada T. Prevalence of dementia in urban areas and functional disability in dementia for FY2011-2012, Tokyo, Japan: Ministry of Health, Labour and Welfare. Published 2013. http://www.tsukuba-psychiatry.com/wp-content/uploads/2013/06/H24Report_Part1.pdf. [in Japanese].
29. Ministry of Land, Infrastructure, Transport and Tourism. Annual Report of Road Statistics FY2018. Tokyo, Japan: Japan Highway Users Conference. https://www.mlit.go.jp/road/ir/ir-data/tokei-nen/2018tokei-nen.html. Published 2017. Accessed November 14, 2019 [in Japanese].

Table 1: Characteristics of sidewalk coverage, Japan Gerontological Evaluation Study, 2010-2013 (n=436).

Quartile of Sidewalk Coverage	N	Sidewalk coverage[a] within residential elementary school district (%)		Estimated mean percentage of sidewalk installation[b] (%)
		Mean (SD)	Median (Min–Max)	
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
All	436	13.8 (5.8)	13.7 (0.5-34.3)	37.9

Max = maximum; Min = minimum; SD = standard deviation

[a]Sidewalk area as a percentage of area of all roads within neighborhood unit (%)

[b]Estimated mean percentage of sidewalk installation (%) was defined as the percentage of roadways with sidewalks on both sides. Estimated mean percentage of sidewalk installation was calculated under the standard road conditions, i.e., the road width should be 6.0 m or more for two lanes, the sidewalk width should be 4.0 m or more (2.0 m or more/lane), and the road shoulder should be 1.0 m or more (0.5 m or more/lane), according to the Japanese Road Construction Ordinance. For example, as the average sidewalk coverage in this study was 13.8%, it is estimated that the sidewalk is installed 37.9% (13.8 divided by 36.4×100) on the road.

Table 2: Baseline characteristics of older Japanese adults, Japan Gerontological Evaluation Study, 2010-2013 (n=76 053)

	Total		Sidewalk coverage			
Characteristic	N	%	Q1 (lowest)	Q2	Q3	Q4 (highest)
Sex						
Male	35475	46.6	46.5	47.2	46.4	46.1
Female	40578	53.4	53.5	52.8	53.6	53.9
Age (years)						
65–69	24259	31.9	32.2	34.3	30.0	27.8
70–74	21797	28.7	27.7	28.6	30.5	29.8
75–79	16493	21.7	21.4	20.5	22.7	24.2
80 ≤	13504	17.8	18.8	16.6	16.8	18.2
Sociodemographics						
Education (years)						
Low (≤9)	35736	47.0	52.4	45.5	40.6	40.5
Middle (10–12)	24125	31.7	28.5	33.6	35.2	33.7
High (≥13)	12097	15.9	13.2	16.0	19.4	20.3
Other/Missing	4095	5.4	5.8	5.0	4.9	5.5
Annual income (million yen)						
Low (<2.00)	29686	39.0	39.5	38.3	38.4	40.1
Middle (2.00–3.99)	23927	31.5	29.9	33.0	32.9	31.4
High (≥4.00)	7061	9.3	8.6	9.7	10.1	9.8
Missing	15379	20.2	22.1	19.0	18.6	18.7
Living situation						
Live with others	63849	84.0	85.2	85.1	82.1	79.5
Live alone	8866	11.7	10.1	10.8	13.8	16.0
Missing	3338	4.4	4.7	4.1	4.1	4.5
Marital status						
Married	52295	68.8	68.4	70.2	68.1	67.2
Widowed	16120	21.2	22.0	20.5	20.8	20.6
Divorced	2344	3.1	2.3	3.1	4.1	4.4
Not married	1369	1.8	1.4	1.6	2.4	3.1
Other/Missing	3925	5.2	5.9	4.7	4.5	4.8
Employment status						
Working	15667	20.6	21.1	20.6	19.6	20.1
Retired	41040	54.0	50.9	55.5	57.5	56.3
Never worked	8497	11.2	11.4	11.0	11.4	10.7
Missing	10849	14.3	16.7	12.9	11.5	12.8
Health status						

Under medical treatment						
Hypertension (Yes)	29941	39.4	39.2	39.4	39.3	39.8
Diabetes mellitus (Yes)	9640	12.7	12.1	13.1	13.2	13.0
Hearing loss (Yes)	5573	7.3	7.9	6.9	6.9	7.1
Heart disease (yes)	9052	11.9	11.6	12.1	12.7	11.6
Stroke (Yes)	1025	1.3	1.4	1.3	1.4	1.2
Depressive symptoms						
Non-depressed (GDS<5)	45029	59.2	58.4	60.1	59.8	59.3
Depressed (GDS≥5)	17245	22.7	23.0	22.9	22.4	21.5
Missing	13779	18.1	18.6	17.1	17.8	19.2
Instrumental activities of daily living						
Fully capable	28617	37.6	37.1	39.1	37.7	35.9
Less capable	37836	49.7	49.9	49.4	49.6	50.3
Missing	9600	12.6	13.0	11.6	12.7	13.8
Cognitive complaints						
No	45269	59.5	58.6	60.3	60.0	60.4
Yes	24978	32.8	33.8	32.7	31.9	31.2
Missing	5806	7.6	7.7	7.0	8.1	8.4
Duration of residence						
<5 years	9314	12.2	14.9	11.8	8.7	8.9
5-9 years	11492	15.1	17.5	15.7	10.8	11.1
10-19 years	12043	15.8	18.2	17.3	11.4	10.0
≥20 years	16845	22.1	26.4	24.7	15.4	10.3
Missing	26359	34.7	23.0	30.5	53.7	59.7
Physical activity						
Walking time						
≥90min/day	11514	15.1	16.3	15.0	13.9	13.1
60-89min/day	11135	14.6	14.2	14.6	15.3	15.4
30-59min/day	24476	32.2	30.3	33.2	33.3	34.6
<30min/day	23728	31.2	31.9	30.9	30.9	29.8
Missing	5200	6.8	7.3	6.3	6.6	7.0
Frequency of going out						
≥ 4 times/week	39479	51.9	48.7	53.5	55.2	54.6
1-3 times/week	27212	35.8	37.4	35.3	33.5	34.2
≤ 1 time/week	11116	14.6	17.2	13.3	12.1	12.2
Missing	4680	6.2	6.3	5.7	6.3	6.6
Car use when going out						
Car user	50001	65.7	79.3	69.0	44.3	39.4

GDS = geriatric Depression Scale; Q = quartile.

Table 3 Hazard ratios and 95% confidence intervals for association of dementia with neighborhood sidewalk coverage in older Japanese adults by city scale (urban/rural), Japan Gerontological Evaluation Study, 2010-2013

Variable	Model 1[a]		Model 2[b]		Model 3[c]		Model 4[d]	
	HR	95%CI	HR	95%CI	HR	95%CI	HR	95%CI
All (n=76,035)								
Sidewalk coverage								
Quartile 1 (lowest)	1.00	Referent	1.00	Referent	1.00	Referent	1.00	Referent
Quartile 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
Quartile 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
Quartile 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
City scale (urban/rural)								
Urban (n=47,364)								
Sidewalk coverage								
Quartile 1 (lowest)	1.00	Referent	1.00	Referent	1.00	Referent	1.00	Referent
Quartile 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
Quartile 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
Quartile 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 (n=28,689)								
Sidewalk coverage								
Quartile 1 (lowest)	1.00	Referent	1.00	Referent	1.00	Referent	1.00	Referent
Quartile 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
Quartile 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
Quartile 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

HR = hazard ratio; CI = confidence interval.

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

[b] Model 2: Model 1 adjusted for sociodemographics (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, cognitive complaints), and duration of residence.

[c] Model 3: Model 2 adjusted for physical activity (walking time, frequency of going out) and car use when going out.

[d] Model 4: Model 1 simultaneously adjusted for all types of neighborhood features (sidewalk, land slope, numbers of hospitals, grocery stores, parks, railway stations, bus stops, education 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, cognitive complaints], and duration of residence).

Figure 1. Methods of calculating sidewalk coverage. Sidewalk coverage (%) = (sidewalk area within neighborhood unit / area of entire road within a neighborhood unit)×100. Area of entire road = road area (grey area) + sidewalk area (yellow area). A-B) Example of neighborhood unit with high sidewalk coverage and Aerial photograph: sidewalk coverage = 19.5%. C-D) Example of neighborhood unit with low sidewalk coverage and Aerial photograph: sidewalk coverage = 9.6%. E-F) Example of neighborhood unit with low sidewalk coverage and Aerial photograph: sidewalk coverage = 5.3%. Aerial photograph by The Geospatial Information Authority of Japan in 2010.

Figure 2. Hazard ratios and 95% confidence intervals for association of dementia with neighborhood measures in older Japanese adults (n = 76,053) Model simultaneously adjusted for all types of neighborhood features (sidewalk, land slope, numbers of hospitals, grocery stores, parks, railway stations, bus stops, education level, unemployment rate, and area of school district) and individual level factors (age, sex, sociodemographics [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, cognitive complaints], and duration of residence).