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Neighborhood Food Environment and Dementia Incidence: the Japan Gerontological Evaluation Study Cohort Survey

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Introduction: Interventions targeting built environmental factors may encourage older people to engage in favorable behaviors and decrease dementia risk, but epidemiologic evidence is limited. This study investigated the association between neighborhood food environment and dementia incidence.

Methods: A 3-year follow-up (2010−2013) was conducted among participants in the Japan Gerontological Evaluation Study, a population-based cohort study of older adults aged ≥65 years. Dementia incidence for 49,511 participants was assessed through the public long-term care insurance system. Availability of food stores (defined as the number of food stores selling fruits and vegetables within 500 meters or 1 kilometer of residence) was assessed for each participant using objective (GIS-based) and subjective (participant-reported) measurements. Data were analyzed from 2017 to 2018.

Results: A total of 3,162 cases of dementia occurred during the follow-up. Compared with the highest quartile for objective availability of food stores, the hazard ratio adjusting for age and sex was 1.60 (95% CI=1.43, 1.78) for the second-lowest quartile. Compared with the highest subjective availability of food stores, the hazard ratio was 1.74 (95% CI=1.49, 2.04) for the lowest category. After successive adjustment for sociodemographic characteristics, health status, and other geographic neighborhood factors (availability of restaurants, convenience stores, and community centers), the hazard ratio remained statistically significant.

Conclusions: Lower food store availability was associated with increased dementia incidence. Given that food shopping is a routine activity and a main motive for going out among older adults, increasing the availability of food stores may contribute to dementia prevention.

INTRODUCTION

Dementia is a major public health concern worldwide because of population aging.[1,2] Globally, around 47 million people had dementia in 2015, and this number is projected to triple by 2050.[2] The number of people with dementia is increasing in Japan,[3] where more than 30% of the population is aged 60 years or older—the highest percentage worldwide.[4] Dementia causes not only disability among older people with this condition, but also psychological morbidity among their

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family caretakers.[5] Dementia prevention has become a priority for public health.

Around one third of dementia cases are estimated to be preventable, and the following nine risk factors should be addressed: education, hypertension, obesity, hearing loss, depression, diabetes, physical inactivity, smoking, and social isolation.[2] Most of these preventable factors are related to behaviors, but behavioral change is difficult to achieve and does not last in unsupportive environments.[6] Recently, there has been increasing interest in understanding the association between environmental features, especially community-level socioeconomic disadvantage, and cognitive impairment and dementia.[7–10] However, as most existing studies have used compositional measurements, which are generated by aggregating individual or household characteristics,[7] it is important to investigate specific built environmental features to create a dementia-friendly environment. Living in disadvantaged neighborhoods may be related to having lower availability of environmental resources (e.g., walking paths, healthy food stores, community centers), which may prevent favorable behaviors and cognitive stimulation.[8]

A healthy food environment is one aspect of the built environment that is indispensable in daily life and may have a protective effect on dementia, as a population-level approach. Most of the modifiable risk factors for dementia, such as hypertension, obesity, and diabetes, are linked to neighborhood food environment.[11–15] However, no studies seem to have investigated the association between neighborhood food environment and dementia incidence.

The data set used is the Japan Gerontological Evaluation Study (JAGES), a large-scale, population-based cohort study of older Japanese people.[16,17] More than 80% of the participants in the present study had lived in the same municipality for 30 or more years, which afforded an opportunity to examine the long-term relationship of neighborhood environment. Using the JAGES data, the association between neighborhood availability of food stores and the incidence of dementia is examined.

METHODS

Study Population

The details of the study design and participants have been reported elsewhere.[18] Briefly, this research drew on data from the JAGES, a population-based cohort study of Japanese people aged ≥65 years who were physically and cognitively independent, were not eligible for benefits from the long-term care insurance (LTCI) system,[19] and lived independently in the community. The present analyses used data on 49,511 participants, after excluding participants with missing information on dementia incidence, home address, sex, or subjective availability of food stores, as well as those who reported limitations in activities of daily living, defined as being unable to walk, take a bath, or use the toilet without assistance (Appendix Figure 1, available online). 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. The protocol of this study was approved by the Ethics Committees on Research on Human Subjects at Nihon Fukushi University (No. 10-05) and Chiba University Faculty of Medicine (No. 1777).

Measures

Dementia incidence was ascertained during the follow-up period, from 2010 to 2013 (mean=2.9 years, range, 2.1 years–3.5 years), by linking the cohort participants to the standardized in-home assessment and medical examination conducted under Japan's public LTCI registry.[19] In this system, a certification committee in each municipality dispatches trained investigators to applicants' homes to evaluate their eligibility for benefits (e.g., a home-helper or day care). Investigators assessed 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.[20,21] Following these assessments, investigators classified the applicants on a dementia scale according to the severity of their cognitive impairment (Appendix Table 1, available online).[21–23] A validation study showed a high correlation with the Mini-Mental State Examination (Spearman rank correlation $\rho = -0.74$).[24] Another study reported that the dementia scale used in the LTCI system is a good reflection of dementia as classified by the Clinical Dementia Rating.[25] 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[24]) was defined as dementia in this study, as has been described elsewhere.[23,26]

The objective availability of food stores was assessed using 500-meter mesh data from the Ministry of Economy, Trade and Industry Commerce Establishment Survey of 2007.[27] Healthy food stores were defined as stores providing fresh fruits and vegetables, which included department stores, general merchandise stores, specialized supermarkets, and daily commodities stores. GIS was used to calculate the number of food stores along a straight line within a 500-meter and a 1-kilometer radius of the center of participants' residential community blocks (*chocho-aza*, the smallest administrative unit in Japan, roughly comparable to a U.S. Census-block group). Assuming the equal distribution of all types of food stores within the 500-meter mesh, the number of food stores along a straight line within a 500-meter and a 1-kilometer radius of participants' residences was calculated using the proportional distribution area.[18] ArcGIS, version 10.1, was used for all spatial calculations. For analyses, participants were categorized into quartiles according to the number of food stores.

The subjective availability of healthy food stores was assessed using self-report questionnaires asking, *How many stores or facilities selling fresh fruits and vegetables are there within 1 km of your home?* With responses on a 4-point Likert scale: *many*,

some, *few*, or *none*.[18,28] These responses were categorized as highest, middle-high, middle-low, and lowest subjective food availability, respectively.

Using the same method used for calculating the objective availability of food stores, the number of restaurants, convenience stores, and community centers along a straight line within a 500-meter radius of participants' residences was calculated using GIS. Restaurants were defined as places to eat or drink, which included all types of restaurants, fast-food establishments, bars, and coffee shops. The number of restaurants was calculated using 500-meter mesh data from the Economic Census for Business Frame in 2009[29] divided by the 100-meter mesh land area data about residential, commercial, and office use. Assuming the equal distribution of restaurants within the 100-meter mesh, the number of restaurants along a straight line within a 500-meter radius of participants' residences was calculated using the proportional distribution area. The number of convenience stores was calculated using the same method used to calculate the objective availability of food stores. The number of community centers was calculated using data from the National Land Numerical Information download service 2010 data.[30]

Information about age at baseline and sex were provided by the municipality. Other covariates were assessed by self-report questionnaire. Sociodemographic characteristics included education level, annual household income, living situation, marital status, and employment status.[31] Environmental status included use of car and public transportation, and prefecture of residence. Participants were asked whether they drive a car by themselves or ride in a family member's car, and if they use a train or bus when they go out. Nutritional status included BMI and frequency of vegetable/fruit intake over the past month.[16,28] Physical activity included walking time and frequency of going out. Health status included medical treatment of diseases/symptoms (hypertension, diabetes mellitus, or hearing loss), depressive symptoms,[16,31] instrumental activities of daily living,[17,32] and cognitive function.[33] Cognitive function was assessed with three items from the Kihon Checklist —Cognitive Function scale, for which predictive validity for dementia incidence has been confirmed previously.[33] Participants were grouped based on whether they had cognitive complaints on at least one item. The population density of inhabitable area in the participants' residential school districts[34] was included, divided into quartiles. Covariates with missing data were categorized as missing, and participants with missing data on the covariates were included in the analysis.

Statistical Analysis

Cox proportional hazards models were estimated, yielding hazard ratios (HR) and 95% CIs for dementia incidence over the 3-year follow-up period. Model 1 adjusted for age and sex. Model 2 additionally adjusted for sociodemographic characteristics as potential confounders and elements of environmental status as covariates to examine whether the relationship between food store availability and dementia was independent of other aspects of environmental status. Model 3 also adjusted for nutritional status as potential mediating factors linking food store availability to dementia. Model 4 adjusted for physical activity instead of nutritional status as potential mediating factors. Model 5 adjusted for nutritional status, physical activity, and health status. Model 6 additionally adjusted for the population density of inhabitable area to examine whether the relationship between food store availability and dementia was independent of neighborhood wealth. Models adjusting for other geographic neighborhood factors (the objective availability of restaurants, convenience stores, and community centers) were also constructed to examine whether the relationship between food store availability and dementia was independent of these factors. All analyses were conducted from 2017 to 2018 using Stata, version 14.

RESULTS

Among all participants, 16.0% rated food store availability as highest, 60.6% as middle-high, 18.0% as middle-low, and 5.4% as lowest. The mean number of food stores within a 500-meter radius of the participant's residence, attained by objective measure, was 27 for Quartile 4, 11 for Quartile 3, 4 for Quartile 2, and 0.8 for Quartile 1 (Appendix Table 2, available online). The number of food stores within 500 meters of residence (objective availability of food stores) was correlated with the number of restaurants, convenience stores, and community centers (Appendix Table 3, available online). During the follow-up, 3,162 dementia cases were found among the analytic sample (cumulative dementia n=3,162/49,511, 6.4%). The incidence rate of dementia per 100,000 person-years for was 5.2 in the highest quartile (Quartile 4) of objective availability within a 500-meter radius of residence and 7.4 in the lowest quartile (Quartile 1; Table 2). Regarding subjective availability of food stores, the incidence rate of dementia per 100,000 person-years for was 5.4 for participants with the highest subjective availability and 10.4 for participants with the lowest subjective availability.

Lower ratings for both objective and subjective availability of healthy food stores were associated with increased dementia incidence (Table 3). Compared with the highest quartile (Quartile 4) of objective availability within 500 meters of residence, the HR adjusting for age and sex was 1.46 (95% CI=1.31, 1.64) for Quartile 3, 1.60 (95% CI=1.43, 1.78) for Quartile 2, and 1.45 (95% CI=1.30, 1.61) for Quartile 1 (Model 1). For the analyses using the subjective availability of food stores, compared with the highest subjective availability, the HRs adjusting for age and sex were 1.22 (95% CI=1.09, 1.36) for the middle-high category, 1.47 (95% CI=1.30, 1.67) for the middle-low category, and 1.74 (95% CI=1.49, 2.04) for the lowest category (p_{trend} <0.001; Model 1). After successive adjustment for sociodemographic characteristics and environmental status, this HR was attenuated but remained statistically significant (Model 2). In models adjusting for potential mediating factors, including physical activity reduced the association more than did including nutritional status (Models 3 and 4). After

Table 1. Baseline Characteristics Among Older Japanese Adults by Quartile of Objective Availability of Food Stores (*n*=49,511)

Characteristics	All, *n* (%) (*n*=49,511)	Objective availability of food stores within 500 meters of residence			
		Q1 (%), (*n*=12,441)	Q2 (%), (*n*=12,685)	Q3 (%), (*n*=12,010)	Q4 (%), (*n*=12,375)
Age					
65–69 years	15,785 (31.9)	33.1	34.9	31.2	28.3
70–74 years	14,512 (29.3)	27.5	29.6	30.0	30.1
75–79 years	10,813 (21.8)	21.5	20.3	22.1	23.5
≥80 years	8,401 (17.0)	17.9	15.2	16.7	18.1
Sex					
Male	23,092 (46.6)	47.2	47.7	46.5	45.2
Female	26,419 (53.4)	52.8	52.3	53.5	54.8
Subjective availability of food stores					
Highest	7,898 (16.0)	13.6	13.4	17.5	19.4
Middle-high	30,013 (60.6)	54.4	60.5	64.3	63.5
Middle-low	8,935 (18.0)	21.4	20.2	15.6	14.8
Lowest	2,665 (5.4)	10.6	5.9	2.6	2.4
Sociodemographic characteristics					
Education, years					
Low (≤9)	22,736 (45.9)	52.9	47.6	44.6	38.4
Middle (10–12)	16,250 (32.8)	29.4	32.5	33.5	35.9
High (≥13)	8,147 (16.5)	12.8	15.3	17.3	20.6
Other/missing	2,378 (4.8)	4.9	4.6	4.6	5.1
Annual income (million yen)					
Low (<2.00)	20,101 (40.6)	43.4	40.4	41.0	37.6
Middle (2.00–3.99)	15,636 (31.6)	29.0	32.0	32.2	33.2
High (≥4.00)	4,496 (9.1)	7.4	8.9	9.1	10.9
Missing	9,278 (18.7)	20.2	18.7	17.7	18.3
Living situation					
Live with others	41,237 (83.3)	85.9	85.3	82.7	79.1
Live alone	6, 810(13.8)	11.0	11.7	14.7	17.7
Missing	1,464 (3.0)	3.1	3.0	2.6	3.2
Marital status					
Married	34,309 (69.3)	70.1	71.7	69.5	65.8
Widowed	10,294 (20.8)	21.2	19.6	20.8	21.6
Divorced	1,694 (3.4)	2.5	2.9	3.9	4.4
Not married	963 (1.9)	1.1	1.2	1.8	3.6
Other/missing	2,251 (4.5)	5.0	4.7	4.0	4.5
Employment status					
Working	10,208 (20.6)	22.0	19.5	19.1	21.9
Retired	27,388 (55.3)	49.7	57.3	58.2	56.1
Never worked	5,469 (11.0)	12.0	10.3	11.0	10.9
Missing	6,446 (13.0)	16.3	12.9	11.7	11.1
Environmental status					
Driving status					
Car user	29,676 (59.9)	81.1	74.4	53.9	29.7
Use public transportation					
Train (Yes)	9,470 (19.1)	19.7	25.6	19.7	11.4
Bus (Yes)	6,605 (13.3)	16.7	17.4	12.4	6.8
Prefecture of residence					
Hokkaido	4,253 (8.6)	16.9	9.9	5.2	2.2

(*continued on next page*)

Table 1. Baseline Characteristics Among Older Japanese Adults by Quartile of Objective Availability of Food Stores (*n*=49,511) (*continued*)

Characteristics	All, *n* (%) (*n*=49,511)	Objective availability of food stores within 500 meters of residence			
		Q1 (%), (*n*=12,441)	Q2 (%), (*n*=12,685)	Q3 (%), (*n*=12,010)	Q4 (%), (*n*=12,375)
Aomori	3,057 (6.2)	10.3	4.5	4.9	5.0
Yamanashi	3,033 (6.1)	11.0	7.0	6.1	0.3
Aichi	36,041 (72.8)	50.2	74.1	76.4	90.6
Nagasaki	3,127 (6.3)	11.6	4.4	7.5	1.8
Nutritional status					
BMI					
Underweight (<18.5)	3,354 (6.8)	6.2	6.6	6.8	7.6
Normal weight (18.5–24.9)	32,836 (66.3)	65.2	67.1	67.1	65.9
Overweight (25.0–29.9)	9,222 (18.6)	19.6	18.4	18.3	18.3
Obese (≥30.0)	1,134 (2.3)	2.4	2.2	2.3	2.3
Missing	2,965 (6.0)	6.7	5.7	5.6	6.0
Frequency of vegetable/fruit intake					
≥1/day	37,209 (75.2)	75.1	74.9	75.5	75.1
<1/day	9,451 (19.1)	19.8	19.4	18.7	18.4
Missing	2,851 (5.8)	5.1	5.7	5.8	6.5
Physical activity					
Walking time					
≥30 minutes/day	31,072 (62.8)	61.8	62.6	62.8	63.8
<30 minutes/day	15,345 (31.0)	31.6	31.1	31.6	29.7
Missing	3,094 (6.2)	6.6	6.3	5.6	6.4
Frequency of going out					
≥2 times/week	39,544 (79.9)	75.1	80.6	81.4	82.4
≤1 time/week	7,039 (14.2)	19.4	13.7	12.6	11.1
Missing	2,928 (5.9)	5.5	5.7	6.0	6.5
Health status					
Under medical treatment					
Hypertension	19,540 (39.5)	40.1	38.3	40.3	39.2
Diabetes mellitus	6,247 (12.6)	12.2	12.2	13.1	13.0
Hearing loss	3,567 (7.2)	7.9	6.8	7.3	6.8
Depressive symptoms					
Non-depressed (GDS <5)	29,877 (60.3)	60.1	61.2	60.4	59.6
Depressed (GDS ≥5)	11,365 (23.0)	23.8	22.9	22.6	22.5
Missing	8,269 (16.7)	16.1	15.9	17.0	17.9
Instrumental activities of daily living					
Fully capable	37,157 (75.0)	73.6	75.3	74.6	76.7
Less capable	8,940 (18.1)	19.9	18.0	18.5	16.0
Missing	3,414 (6.9)	6.6	6.8	6.9	7.4
Cognitive complaints					
No	29,749 (60.1)	59.3	60.3	59.8	60.9
Yes	16,159 (32.6)	34.3	32.6	32.7	30.9
Missing	3,603 (7.3)	6.4	7.1	7.5	8.1

GDS, Geriatric Depression Scale; Q, quartile.

further adjusting for health status, the association remained statistically significant (Model 5). After adjusting for population density, the association with objective availability attenuated, whereas the association with subjective availability was unchanged (Model 6). When the same analyses were conducted using a 1-kilometer radius instead of a 500-meter radius for the objective measure, similar results were obtained.

Lower values of objective and subjective availability of food stores were associated with increased dementia

Table 2. Incidence of Dementia During the 3-Year Follow-up Period Among Older Japanese Adults (*n*=49,511)

Food store availability	Dementia cases, *n* (%)	Incidence rate per 100,000 person-years (95% CI)
Objective availability of food stores within 500 meters of residence		
Quartile 4 (highest)	508 (4.1)	5.2 (4.7, 5.6)
Quartile 3	781 (6.5)	7.3 (6.8, 7.9)
Quartile 2	943 (7.4)	7.5 (7.1, 8.0)
Quartile 1 (lowest)	930 (7.5)	7.4 (7.0, 7.9)
Objective availability of food stores within 1 kilometer of residence		
Quartile 4 (highest)	418 (3.4)	4.4 (4.0, 4.9)
Quartile 3	776 (6.3)	7.0 (6.5, 7.5)
Quartile 2	974 (7.9)	7.8 (7.3, 8.3)
Quartile 1 (lowest)	994 (8.0)	8.0 (7.5, 8.5)
Subjective availability of food stores		
Highest	381 (4.8)	5.4 (4.8, 5.9)
Middle-high	1,816 (6.1)	6.6 (6.3, 6.9)
Middle-low	701 (7.8)	8.4 (7.8, 9.0)
Lowest	264 (9.9)	10.4 (9.2, 11.7)

incidence after adjusting for other geographic neighborhood factors (the objective availability of restaurants, convenience stores, and community centers; Table 4 and Appendix Table 4, available online).

DISCUSSION

This is the first study to examine the association between neighborhood food environment and dementia incidence using a population-based cohort sample. It was found that lower availability of healthy food stores, assessed by either objective or subjective measures, was associated with increased dementia incidence.

Walking time or frequency of going out partially mediated the association between the availability of food stores and dementia. A nationally representative survey in Japan reported that 81% of older adults selected "shopping at a neighborhood store" as their main reason for going out,[35] and 60% of older adults in charge of the food shopping go shopping three or more times per week.[36] Older adults who live in neighborhoods with a high availability of food stores may go shopping frequently on foot. It was found that older adults who lived in neighborhoods with low food store availability were less likely to go out than were those who lived in neighborhoods with high food store availability (Table 1). Thus, neighborhood availability of food stores may contribute to preventing dementia by promoting outing activities.

Little attenuation of the association between the availability of healthy food stores and dementia was found after adjustment for nutritional status. This may be partly explained by transportation options and the high density of the food store environment. All participants were physically and cognitively independent, so they had a variety of transportation options to get healthy foods, despite living in neighborhoods with low availability of food stores (Table 1). In the present study, the median number of food stores within a 1-kilometer radius of residence was 24, and more than 90% of the participants had more than two stores within a 1-kilometer radius. Only 5% of participants rated their subjective availability of food stores as lowest (Table 1). Therefore, nutritional risk caused by the unavailability of food stores may be relatively low in Japan's high-density food store environment. Alternatively, an aspect of nutritional status other than BMI and vegetable/fruit intake, such as dietary diversity,[37] may mediate the association between the availability of food stores and dementia. Future studies should conduct a detailed analysis of nutritional status, such as diet quality and total energy intake, to elucidate the mechanism.

The association between the availability of food stores and dementia remained after adjusting for potential mediating factors, population density, and the objective availability of other neighborhood places, suggesting that additional unobserved factors explain this relation. In addition to the indirect pathway through lifestyle factors, such as physical activity, the built environment can directly impact cognition through cognitive and sensory stimulation.[38,39] Therefore, the food environment may directly stimulate cognitive function by increasing attentional resources. In the context of the present study, older

Table 3. HRs for the Association of Dementia With the Availability of Food Stores (n=49,511)

Food store availability	Model 1,[a] HR (95% CI)	Model 2,[b] HR (95% CI)	Model 3,[c] HR (95% CI)	Model 4,[d] HR (95% CI)	Model 5,[e] HR (95% CI)	Model 6,[f] HR (95% CI)
Objective availability of food stores within 500 meters of residence						
Quartile 4 (highest)	ref	ref	ref	ref	ref	ref
Quartile 3	**1.46 (1.31, 1.64)**	**1.39 (1.24, 1.56)**	**1.38 (1.23, 1.55)**	**1.35 (1.21, 1.52)**	**1.31 (1.17, 1.47)**	**1.19 (1.06, 1.34)**
Quartile 2	**1.60 (1.43, 1.78)**	**1.51 (1.34, 1.69)**	**1.48 (1.32, 1.66)**	**1.45 (1.29, 1.62)**	**1.40 (1.25, 1.57)**	**1.20 (1.07, 1.35)**
Quartile 1 (lowest)	**1.45 (1.30, 1.61)**	**1.29 (1.15, 1.45)**	**1.27 (1.13, 1.43)**	**1.21 (1.07, 1.36)**	**1.17 (1.04, 1.31)**	0.98 (0.87, 1.11)
Objective availability of food stores within 1 kilometer of residence						
Quartile 4 (highest)	ref	ref	ref	ref	ref	ref
Quartile 3	**1.68 (1.49, 1.90)**	**1.66 (1.47, 1.88)**	**1.63 (1.44, 1.85)**	**1.61 (1.42, 1.82)**	**1.55 (1.37, 1.76)**	**1.34 (1.18, 1.53)**
Quartile 2	**1.90 (1.69, 2.13)**	**1.89 (1.67, 2.15)**	**1.84 (1.62, 2.08)**	**1.79 (1.58, 2.03)**	**1.72 (1.52, 1.95)**	**1.41 (1.23, 1.61)**
Quartile 1 (lowest)	**1.78 (1.58, 1.99)**	**1.63 (1.44, 1.85)**	**1.60 (1.41, 1.82)**	**1.51 (1.33, 1.71)**	**1.45 (1.28, 1.65)**	1.16 (1.00, 1.34)
Subjective availability of food stores						
Highest	ref	ref	ref	ref	ref	ref
Middle-high	**1.22 (1.09, 1.36)**	**1.21 (1.08, 1.35)**	**1.19 (1.07, 1.33)**	**1.16 (1.04, 1.30)**	1.11 (0.99, 1.24)	1.10 (0.98, 1.23)
Middle-low	**1.47 (1.30, 1.67)**	**1.43 (1.26, 1.62)**	**1.40 (1.24, 1.59)**	**1.33 (1.17, 1.50)**	**1.20 (1.06, 1.37)**	**1.19 (1.04, 1.35)**
Lowest	**1.74 (1.49, 2.04)**	**1.65 (1.40, 1.93)**	**1.61 (1.37, 1.88)**	**1.46 (1.24, 1.71)**	**1.32 (1.13, 1.55)**	**1.30 (1.10, 1.52)**

Note: Boldface indicates statistical significance (p<0.05).
[a]Model 1 adjusted for age and sex.
[b]Model 2: Model 1 + adjusted for sociodemographic characteristics (education, annual income, living situation, marital status, and employment status) and environmental status (driving status, public transportation [train and bus], and prefecture of residence).
[c]Model 3: Model 2 + adjusted for nutritional status (BMI and frequency of vegetable/fruit intake).
[d]Model 4: Model 2 + adjusted for physical activity (walking time and frequency of going out).
[e]Model 5: Model 2 + adjusted for nutritional status (BMI and frequency of vegetable/fruit intake), physical activity (walking time and frequency of going out), and health status (hypertension, diabetes mellitus, hearing loss, depressive symptoms, instrumental activities of daily living, and cognitive complaints).
[f]Model 6: Model 5 + adjusted for population density of inhabitable area of residence.
HR, hazard ratio.

Table 4. HRs for the Association of Dementia With the Objective Availability of Neighborhood Places (*n*=49,511)

Objective availability of places within 500 meters of residence[a]	Model 1,[b]HR (95% CI)	Model 2,[c]HR (95% CI)	Model 3,[d]HR (95% CI)	Model 4,[e]HR (95% CI)
Food stores				
Quartile 4 (highest)	ref	ref	ref	ref
Quartile 3	**1.46 (1.31, 1.64)**	**1.31 (1.15, 1.49)**	**1.31 (1.15, 1.49)**	**1.26 (1.11, 1.44)**
Quartile 2	**1.60 (1.43, 1.78)**	**1.34 (1.16, 1.55)**	**1.32 (1.14, 1.53)**	**1.29 (1.11, 1.49)**
Quartile 1 (lowest)	**1.45 (1.30, 1.61)**	1.19 (1.00, 1.42)	1.15 (0.96, 1.37)	1.08 (0.90, 1.30)
Restaurants				
Quartile 4 (highest)	ref	ref	ref	ref
Quartile 3	**1.37 (1.21, 1.54)**	1.14 (0.99, 1.32)	**0.86 (0.73, 1.00)**	**0.84 (0.72, 0.97)**
Quartile 2	**1.63 (1.45, 1.82)**	**1.29 (1.09, 1.52)**	0.89 (0.75, 1.06)	0.90 (0.76, 1.07)
Quartile 1 (lowest)	**1.50 (1.34, 1.68)**	**1.24 (1.01, 1.52)**	0.83 (0.67, 1.03)	0.86 (0.70, 1.07)
Convenience stores				
Tertile 3 (highest)	ref	ref	ref	ref
Tertile 2	**1.25 (1.13, 1.37)**	1.07 (0.96, 1.19)	0.99 (0.89, 1.11)	0.97 (0.87, 1.09)
Tertile 1 (lowest)	**1.31 (1.20, 1.44)**	1.11 (0.98, 1.25)	0.99 (0.88, 1.13)	0.96 (0.85, 1.09)
Community centers				
Present (≥1)	ref	ref	ref	ref
Absent (0)	1.04 (0.97, 1.11)	0.96 (0.89, 1.03)	0.96 (0.89, 1.04)	0.96 (0.85, 1.09)

Note: Boldface indicates statistical significance ($p<0.05$).
[a]The number of neighborhood places along a straight line within a 500-meter radius of each participant's residence was calculated using GIS.
[b]Model 1 used availability of places individually and adjusted for age and sex.
[c]Model 2 included all types of availability of places (food stores, restaurants, convenience stores, and community centers) simultaneously and adjusted for age and sex.
[d]Model 3: Model 2 + adjusted for population density of inhabitable area of residence.
[e]Model 4: Model 3 + adjusted for sociodemographic characteristics (education, annual income, living situation, marital status, and employment status), environmental status (driving status, public transportation [train and bus], and prefecture of residence), nutritional status (BMI and frequency of vegetable/fruit intake), physical activity (walking time and frequency of going out), and health status (hypertension, diabetes mellitus, hearing loss, depressive symptoms, instrumental activities of daily living, and cognitive complaints).
HR, hazard ratio.

adults were found to have a wide choice of stores; they may have much to consider in terms of store selection, such as food variety, price, and service quality. Alternatively, frequent exposure to a variety of food items may give older adults opportunities to see, touch, and choose foods directly. More work is needed to elucidate the mechanisms through which food availability prevents dementia.

Objective and subjective availability of food stores appear to have different meanings. In line with the findings of a systematic review,[40] the subjective—not the objective—measure of availability was related to vegetable/fruit intake (Table 1 and Appendix Table 6, available online). Therefore, the subjective availability of food stores may reflect the actual ease of use of food stores. By contrast, the objective availability of food stores was more reflective of population density (Appendix Table 5, available online) and showed positive correlations with the objective availability of other neighborhood places (Appendix Table 3, available online), suggesting that the objective measure includes not only the potential availability of food stores but also other local factors. These differences between the measurements may explain the different pattern of results.

Limitations

This study had several limitations. First, using a cut off point for the dementia scale (level II) corresponding to a 16-point rating on the Mini-Mental State Examination[24] might have underestimated the dementia incidence. A nationwide survey aimed at estimating the prevalence of dementia among older people in Japan reported that 34% of cases of dementia did not appear in Japan's public LTCI registry; however, three quarters of these cases were mild cases of dementia.[41] Second, the present analysis was limited to all-cause dementia. Third, data on some potentially confounding neighborhood factors, such as area deprivation,[8,9] natural environment,[39] and traffic conditions,[42] were lacking, although population density and some geographic neighborhood characteristics were taken into account. Fourth, information on the presence of other family members responsible for the household's food supply, which may explain the association between the availability of food stores and dementia, was missing. For example, even when a participant lived in an area with lower availability of food stores, the person responsible for the household's food supply might be able to obtain food easily. Fifth, the use of home-delivery meal or

food services were not taken into account. However, it has been reported that fewer than 5% of older adults in Japan receive home-delivered meals.[43] Finally, the actual use of food stores was not measured; thus, food availability may be a surrogate variable that prevents dementia. Further study using GPS data[44] may reveal the direct impact of access to food stores on dementia.

CONCLUSIONS

Lower objective and subjective availability of food stores were associated with increased dementia incidence. Given that food shopping is a routine activity and a main motive for going out among older adults, increasing the availability of food stores may reduce the risk or delay the onset of dementia among independent-living older adults. Future studies should address the mechanisms underlying this distal relationship.

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SUPPLEMENTAL MATERIAL

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