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Objective food store access was associated with calcium intake among older Japanese adults: a cross-sectional analysis from the Japan Gerontological Evaluation Study at Taisetsu Community Hokkaido

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ABSTRACT

Preventing osteoporosis in older populations is important for extending healthy life expectancy. Calcium is a crucial nutrient for maintaining bone health in this group. However, more than half of people aged ≥ 65 years have insufficient calcium intake. We investigated the influence of food store access on calcium intake in community-dwelling older adults. Our study employed a population-based cross-sectional design, using data from older adults aged 70–74 years living in three towns in northern Japan. Perceived food store access was assessed using a single question, while objective food store access was measured using a geographic information system. Dietary information was obtained using a brief-type self-administered diet history questionnaire. Insufficient calcium intake was defined as calcium consumption below the estimated average requirement for the participant's age and sex. A log-binomial regression analysis was performed to determine the association between food store access and insufficient calcium intake. A total of 716 participants (mean age, 71.8 ± 1.4 years; 55.3% women) were included in this study. After adjusting for potential confounders, low objective food store access was associated with insufficient calcium intake (adjusted prevalence ratio for low vs high accessibility, 1.24; 95% confidence interval, 1.05–1.46). However, the perceived food store access was not associated with insufficient calcium intake. Our findings showed that low objective food store access is associated with insufficient calcium intake among independent older Japanese adults. Improving access to food stores may help prevent insufficient calcium intake in this population.

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Keywords: calcium intake, food store access, older adults, population-based study

Abbreviations:
JAGES: Japan Gerontological Evaluation Study
BDHQ: brief-type self-administered diet history questionnaire

INTRODUCTION

Preventing the need for long-term care is a top priority in Japan, which is a super-aging society. In 2022, fractures and falls accounted for over 10% of all cases requiring long-term care.[1] Osteoporosis increases the risk of fractures and falls in older adults. The prevalence of osteoporosis among Japanese individuals aged ≥ 40 years is approximately 12.8 million, and the prevalence increases with age.[2] Furthermore, osteoporosis significantly increases the risk of developing sarcopenia and frailty in the future. Therefore, osteoporosis prevention is an urgent issue closely related to the prevention of long-term care and ultimately contributes to extending healthy life expectancy.

Calcium is a major component of bone minerals and an essential nutrient for preventing and treating osteoporosis. Asian populations, including Japanese, generally have lower calcium intake than Western populations.[3] Asian populations have an average dietary calcium intake of < 600 mg/day, whereas western and many European populations have an average dietary calcium intake that exceeds 700 and 900 mg/day, respectively.[3] As indicated in the Dietary Reference Intakes for Japanese 2020, the Recommended Dietary Allowance for calcium required to maintain bone mass in individuals aged ≥ 65 years is 750 and 650 mg/day for men and women, respectively.[4] However, the Japanese National Health and Nutrition Survey conducted in 2019 reported that the median calcium intake for Japanese aged 65–74 years was 512 and 531 mg/day in men and women, respectively.[5] Thus, more than half of the older adults in this age group did not achieve the Recommended Dietary Allowance for calcium.

A review of 59 randomized controlled trials, most of which were conducted in the USA, Europe, and Oceania, indicated that increasing calcium intake from dietary sources slightly increases bone mineral density.[6] Another review of longitudinal studies on the relationship between calcium intake and risk of fractures revealed that dietary calcium intake is not associated with fracture risk.[7] However, epidemiological studies conducted in Japan[8,9] and China[10] have demonstrated that calcium intake is positively and significantly associated with bone mineral density and negatively and significantly associated with fractures. Thus, in populations with a low calcium intake, such as those in Asian countries, preventing insufficient calcium intake is necessary to maintain bone health in older adults, potentially allowing them to maintain their independence.

In Japan, difficulty in purchasing fresh food has become a concern for some individuals owing to the limited number of food stores in their neighborhoods. Older adults with limited access to transportation or limited familial and societal support commonly experience greater difficulty in shopping,[11] which negatively affects their health[12,13] and diet.[14] Previous studies have suggested that supermarket accessibility is associated with the frequency of fruit and vegetable intake,[15,16] dietary patterns,[17] diet quality,[18] and dietary diversity.[19] However, few studies have examined the association between food store access and mineral intake. A previous study reported that a healthy food environment, as measure by the modified retail food environment index, is positively associated with potassium intake and negatively associated with the sodium–potassium ratio.[20] Another study reported that the increasing neighborhood availability of supermarkets/grocery stores

is positively associated with 24-hour urinary potassium excretion among young Japanese women.[21] However, no study has evaluated the association between food store access and calcium intake. Furthermore, previous systematic reviews of studies on the correlation between food store access and dietary intake, conducted using both perceived and objective measures, have reported different results between the two indicators.[14,22] It is recommended to assess multiple aspects to capture the characteristics of the food access environment. Caspi et al proposed a framework based on five dimensions: availability, accessibility, affordability, accommodation, and acceptability.[14] Therefore, this study aimed to investigate the relationship between both perceived and objective food store access and insufficient calcium intake among older adults with low calcium intake living in Japan.

METHODS

Study participants

This cross-sectional study was conducted using data from the Japan Gerontological Evaluation Study at Taisetsu Community Hokkaido. The Japan Gerontological Evaluation Study at Taisetsu Community Hokkaido was conducted as an additional survey for the Japan Gerontological Evaluation Study (JAGES) 2013 and has been described elsewhere.[23] The JAGES 2013 survey included independent individuals aged ≥ 65 years from 30 municipalities in 14 prefectures across Japan who were not receiving long-term care.[12] Among them, individuals aged 70–74 years who were living in three towns in Hokkaido (Higashikagura, Higashikawa, and Biei), northern Japan, were enrolled in the present study. Two self-administered questionnaires on health and dietary habits were mailed to 1,127 participants between June and July 2014, and 824 (73.1%) responded. Completion of the health questionnaire was voluntary, and refusal to fill out the questionnaires did not cause any disadvantages. The voluntary return of the questionnaire indicated that participants provided informed consent. The study protocol was approved by Ethics Review Committee of Graduate School of Medicine, Hokkaido University (no. 14-024).

Food store access

Perceived food store access, as "availability" according to the framework proposed by Caspi et al[14] was assessed using the following question from JAGES 2013: "How many stores or facilities selling fresh fruits and vegetables are located within walking distance of approximately 1 km of your home?" Participants were required to select the most appropriate response among the following five options: "many," "some," "few," "none," or "unknown."[12] Perceived food store access was categorized into two groups based on the responses "many" and "some," which were categorized as "high" access, whereas "few" and "none" were categorized as "low" access.

Objective food store access, as the dimension of "accessibility,"[14] was assessed using a geographical information system. The distance from each participant's home to the nearest fresh food store was calculated by using a road network system (ArcGIS 10.1 software, ESRI Japan). Information on grocery store addresses was obtained from the yellow pages of the telephone directory of commercial facility addresses published by the Nippon Telegraph and Telephone East Corporation in 2014. We categorized objective food store access based on whether the participant's home was within or over 1,000 m from the nearest food store. We additionally categorized objective food store access based on a distance of 500 m using the same concept as that for a distance of 1,000 m. This is supported by the National Urban Traffic Characteristics Survey conducted in Japan, which found that approximately 40% of adults aged ≥ 75 years reported that the distance they could walk comfortably without resting is ≤ 500 m.[24] Moreover, a previous study examining the association between food store access and the incidence of

functional disability among independent individuals aged ≥ 65 years, using JAGES survey data, defined ≤ 500 m as a reasonable "walkable" distance to a food store.[25]

Insufficient calcium intake

Information on calcium intake was obtained using a brief-type self-administered diet history questionnaire (BDHQ).[26] The BDHQ is a food frequency questionnaire that is used to determine the habitual dietary intake of respondents based on 58 food and beverage items consumed during the preceding month. The validity and reproducibility of the BDHQ for Japanese adults have been verified in a previous study using a 16-day dietary record.[26] In that study, Pearson's correlation coefficients for calcium intake based on a 16-day dietary record and the BDHQ were 0.51 for 92 women aged 31–69 years and 0.66 for 92 men aged 32–76 years.[26] Insufficient calcium intake[4] was defined using the estimated average requirement of calcium established in the Dietary Reference Intakes for Japanese 2020. The estimated average requirement is the amount that meets the nutrient requirements of 50% of the population of the same age and sex. Based on a previous study that determined nutritional inadequacy using the BDHQ data and the estimated average requirement,[27] we calculated the adjusted calcium intake for comparison with the Dietary Reference Intakes for Japanese 2020 using the following formula:

$$adjusted\ calcium\ intake\ \left(\frac{mg}{day}\right) = \frac{reported\ calcium\ intake\ \left(\frac{mg}{day}\right)}{reported\ energy\ intake\ \left(\frac{kcal}{day}\right)} \times the\ estimated\ energy\ requirement\ \left(\frac{kcal}{day}\right) \quad (1).$$

Participants with adjusted calcium intake below the corresponding the estimated average requirement (600 and 550 mg/day for men and women, respectively) were considered to have insufficient calcium intake.

Other variables

Demographic data, including age, sex, and residential area, were obtained from the municipal government. Body mass index was calculated using the following formula: weight (kg) divided by height squared (m^2). Height and weight data were obtained using self-reported values on the BDHQ. Smoking habits, car use, and living arrangements were reported in the lifestyle questionnaire used in the Japan Gerontological Evaluation Study at Taisetsu Community Hokkaido. Smoking habits were divided into three categories: current smokers, former smokers, and never-smokers. Older people, particularly women, were assumed to generally travel by car and be driven by family members. Therefore, car use should include cases where the participant was driven by a family member or acquaintance. Car use was divided into two categories: yes or no. Living arrangements were categorized as either living alone or with others. Information on educational attainment and annual income was obtained from the JAGES 2013 questionnaire. Educational attainment was classified into three categories: ≤9 years, 10–12 years, and ≥13 years. Equivalized annual household income was determined by dividing the annual household income by the square of the number of household members and was classified into three categories: "low" (< 2.00 million yen), "middle" (2.00–3.99 million yen), and "high" (≥ 4.00 million yen).[13]

Statistical analysis

Participants who did not return the BDHQ (n = 35), those with overreporting or underreporting of energy intake (n = 33), those who answered "unknown" (n = 2) to the question on food store access, and those who refused to answer the question on food store access (n = 38) were excluded from our analysis (Figure). Overreporting of energy intake was defined as > 1.5 times the estimated energy requirement for individuals with level III physical activity (high), whereas underreporting of energy intake was defined as < 0.5 times the estimated energy requirement for individuals with level I physical activity (low). Thus, 716 participants with available information on calcium intake and food store access were included in the final analysis (Figure). Continuous variables are presented as mean ± standard deviation, whereas categorical variables are presented as numbers (percentages). Sex, residential area (town), car use, living arrangements, educational attainment, and equivalized annual household income were considered potential confounding factors. Age was excluded from the model because the study participants were limited to those aged 70–74 years. Propensity scores were calculated based on the potential confounders. A log-binomial regression analysis was performed to examine the association between food store access and insufficient calcium intake by calculating the adjusted prevalence ratio and 95% confidence interval for insufficient calcium intake. Model 1 was adjusted for sex and residential area, whereas model 2 was further adjusted for propensity scores (ie, car use, living arrangements, educational attainment, and equivalized annual household income). Statistical significance was set at $P < 0.05$. All statistical analyses were performed using the JMP software (version 11.0; SAS Institute Inc, USA).

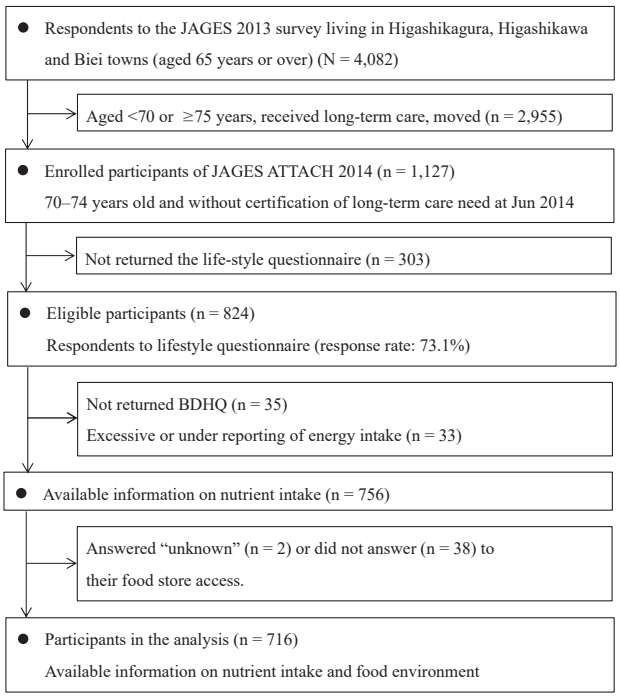

Fig. Flowchart of eligible participants for the study in final analysis
JAGES ATTACH: Japan Gerontological Evaluation Study at Taisetsu Community Hokkaido
BDHQ: brief-type self-administered diet history questionnaire

RESULTS

The mean age ± standard deviation of the participants was 71.8 ± 1.4 years, with women accounting for 55.3% of the cohort. Regarding food store access, 27.1% of participants reported low

Table 1 Characteristics of participants according to perceived and objective food store access

	Overall	Perceived food store access		Objective food store access*	
				Distance to the nearest food store from the participant's home	
		Low	High	Over 1,000 m	Within 1,000 m
	(N = 716)	(n = 194)	(n = 522)	(n = 208)	(n = 504)
Age (years)	71.8 ± 1.4	71.8 ± 1.4	71.8 ± 1.4	71.7 ± 1.4	71.8 ± 1.4
Women	396 (55.3)	107 (55.2)	289 (55.4)	106 (51.0)	288 (57.1)
Residential area					
Higashikagura	216 (30.2)	56 (28.9)	160 (30.7)	58 (27.9)	157 (31.2)
Higashikawa	210 (29.3)	61 (31.4)	149 (28.5)	75 (36.1)	135 (26.8)
Biei	290 (40.5)	77 (39.7)	213 (40.8)	75 (36.1)	212 (42.1)
Body mass index (kg/m^2)					
< 18.5	41 (5.7)	9 (4.6)	32 (6.1)	11 (5.3)	30 (6.0)
18.5–25.0	496 (69.3)	132 (68.1)	364 (69.7)	139 (66.8)	353 (70.0)
≥ 25.0	179 (25.0)	53 (27.3)	126 (24.2)	58 (27.9)	121 (24.0)
Smoking habits					
Current smoker	59 (8.8)	18 (10.0)	41 (8.3)	15 (7.9)	44 (9.2)
Former smoker	227 (33.7)	62 (34.4)	165 (33.5)	67 (35.5)	160 (33.3)
Never smoker	387 (57.5)	100 (55.6)	287 (58.2)	107 (56.6)	276 (57.5)
Car user	609 (85.1)	173 (89.2)	436 (83.5)	195 (93.8)	411 (81.5)
Living alone	84 (11.7)	24 (12.4)	60 (11.5)	20 (9.9)	64 (12.9)
Educational attainment (years)					
≤ 9	340 (47.8)	113 (58.3)	227 (43.5)	141 (69.5)	195 (39.2)
10–12	248 (34.6)	52 (26.8)	196 (37.6)	40 (19.7)	208 (41.9)
≥ 13	116 (16.2)	26 (13.4)	90 (17.2)	22 (10.8)	94 (18.9)
Equivalized annual household income (million yen)					
Low (< 2.00)	390 (64.3)	101 (63.9)	289 (64.4)	102 (57.6)	292 (66.8)
Middle (2.00–3.99)	180 (29.6)	41 (26.0)	139 (31.0)	53 (29.9)	129 (29.5)
High (≥ 4.00)	37 (6.1)	16 (10.1)	21 (4.7)	22 (12.4)	16 (3.7)
Energy intake (kcal/day)	1,823 ± 535	1,808 ± 548	1,829 ± 531	1,842 ± 542	1,816 ± 534
Calcium intake (mg/day)†	709.5 (576.5–870.7)	696.0 (548.6–863.2)	718.9 (586.3–875.2)	663.6 (537.6–876.6)	723.9 (590.1–869.9)

Data were presented as the means ± standard deviation, median (interquartile rage) or the number (%) of the participants in that category.
* We excluded the participants whose home address was unknown (n = 4).
† Adjusted calcium intake (mg/day) = reported calcium intake (mg/day)/reported energy intake (kcal/day) × Estimated Energy Requirement (kcal/day).

perceived food store access, whereas 29.2% lived more than 1,000 m from the nearest food store (Table 1). Participants residing over 1,000 m from the nearest food store were more likely to use cars and less likely to live alone than those living within 1,000 m of the nearest store (Table 1).

Out of the entire cohort, 23.5% of participants exhibited insufficient calcium intake. Measurement of objective food access using 1,000 m as the threshold showed that 28.8% and 21.2% of participants with a distance exceeding and within the threshold of food store access, respectively, exhibited insufficient calcium intake (Table 2). After adjusting for sex and residential area (model 1), we observed a significant association between food store access over 1,000 m and insufficient calcium intake. The adjusted prevalence ratio for insufficient calcium intake was 1.16 (95% confidence interval, 1.01–1.33; Table 2). We additionally found a significant association between food store access over 1,000 m and insufficient calcium intake after adjusting for all potential confounders in model 2 (the adjusted prevalence ratio, 1.24; 95% confidence interval, 1.05–1.46). Similarly, when a 500-m threshold was used, food store access was significantly associated with insufficient calcium intake. However, no association was found between perceived food store access and calcium intake.

Table 2 Adjusted prevalence ratio of insufficient calcium intake in participants with low and high food access

Perceived food store access (N = 716)		
	Low	High
N	194	522
Insufficient calcium intake, n	52	115
Prevalence (%)	26.8	22.0
APR (95% CI), model 1	1.11 (0.96–1.27)	1.00
APR (95% CI), model 2	1.08 (0.91–1.27)	1.00
Objective food store access (N = 712)		
Divided by the distance to the nearest food store from the participant's home		
	Over 1,000 m	Within 1,000 m
N	208	504
Insufficient calcium intake, n	60	107
Prevalence (%)	28.8	21.2
APR (95% CI), model 1	1.16 (1.01–1.33)	1.00
APR (95% CI), model 2	1.24 (1.05–1.46)	1.00
	Over 500 m	Within 500 m
N	399	313
Insufficient calcium intake, n	109	58
Prevalence (%)	27.3	18.5
APR (95% CI), model 1	1.21 (1.06-1.40)	1.00
APR (95% CI), model 2	1.31 (1.11-1.56)	1.00

APR: adjusted prevalence ratio
CI: confidence interval
Log binominal regression analysis was used to calculate APR (95% CI) with the high perceived food store access group or within 1,000 m (500 m) group as reference group.
Model 1: Adjusted for sex and residential area (town).
Model 2: Model 1 + adjusted for car use, living arrangement, educational attainment and equivalized annual household income. The confounding factors added in model 2 was input in the model as a propensity score.

DISCUSSION

In this study, participants residing more than 1,000 m from the nearest food store exhibited a significantly higher risk of insufficient calcium intake than those residing within 1,000 m, after adjusting for potential confounders such as sex, residential area, car use, living arrangement, educational attainment, and household income. To our knowledge, this is the first study to determine the association between food store access and insufficient calcium intake in older adults. Several previous studies have indicated that perceived measurements are more strongly associated with dietary outcomes than objective measurements[16,19,28]; however, the results of the present study are inconsistent with this finding.

Milk and dairy products, vegetables, and pulses are rich in calcium. The National Nutrition Survey conducted in 2019 showed that milk and dairy products, vegetables, and pulses accounted for 28.2%, 17.3%, and 12.5% of the total calcium intake, respectively.[5] These foods are heavy, bulky, and/or perishable. Thus, some people may consider transporting them over a relatively long distance a hassle, and people living further away from the nearest food store inevitably use their cars for shopping. In fact, most of our participants (approximately 85%) used their cars when going out; however, participants who had a distance of over 1,000 m to the nearest food store from their home were more likely to use a car for shopping than those with high food store access. However, older people may find driving a certain distance and purchasing the abovementioned foods burdensome. This leads to reduced shopping frequency, which may promote insufficient calcium intake. Gustat et al reported that the number of shopping trips per month is positively associated with car ownership and food store access but inversely and significantly associated with distance to the patronized store.[29] Unfortunately, we could not obtain data on shopping frequency; thus, we could not determine the impact of shopping frequency on the risk of insufficient calcium intake.

The participants' perception of whether the food store was within walking distance of their home was not associated with the risk of insufficient calcium intake. This finding is inconsistent with those reported in previous studies.[14,16,19,28] No standard method exists for evaluating perceived food store access, and evaluation methods vary.[30] This variation might lead to different results regarding the association of perceived food store access between our study and previous studies. Additionally, as the question assessing perceived store access inquired regarding access to fresh food, the participants may not have considered access to calcium-rich foods, such as milk and dairy products, when responding.

This study has several strengths. We defined insufficient calcium intake distribution according to the Japanese dietary guidelines (Dietary Reference Intakes for Japanese 2020) and not based on the calcium intake of the study population. Additionally, information on calcium intake was obtained using a validated food frequency questionnaire. However, this study has some limitations. First, the cross-sectional design precluded us from determining a causal relationship between long-distance food store access and insufficient calcium intake. However, the reverse relationship was unlikely in individuals with low calcium intake living far from the nearest food store. Second, the study participants resided in a limited area of northern Japan; thus, they may not be representative of the broader older Japanese population. Third, considering that the BDHQ used to assess calcium intake included questions on the frequency of food intake over the previous month, our calcium intake data may have subjected to some information bias. However, the estimates of insufficient and excessive energy intake were excluded from the analysis. Fourth, we obtained information on food store addresses from a telephone directory rather than from field surveys. Actual food store data and information from the telephone directory may have differed. Nevertheless, this study demonstrated an association between low objective food store

access and insufficient calcium intake among older adults living in the rural areas of northern Japan. According to our study and previous studies, it might be necessary to implement measures to improve food access, such as mobile vendors and shopping support services. Moreover, it is important to create a local environment where neighbors can easily provide and receive social support from one another. Further studies using cohort designs and conducted in other regions are needed to examine the association between food store access and diet in greater detail.

CONCLUSION

In our study investigating the influence of food store access on calcium intake in 716 community-dwelling older adults, objective food store access was associated with insufficient calcium intake whereas perceived calcium intake was not. Improving access to food stores may help prevent insufficient calcium intake and contribute to the maintenance of health among older adults.

CONFLICTS OF INTEREST DISCLOSURE

The authors declare no conflicts of interest.

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