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Does the neighborhood built and social environment reduce long-term care costs for Japanese older people? The JAGES2010-2019 cohort study

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ABSTRACT

Japan's population has been aging steadily, evidenced by it spending JPY 11 trillion (USD 110 billion) on annual long-term care (LTC) costs in 2021. In this context, understanding the factors influencing LTC costs has become increasingly vital. Although studies have reported positive relationships between neighborhood environment and health outcomes, the connection between LTC costs and neighborhood environment remains unclear. To address this gap in the literature, this cohort study, conducted from 2010 to 2019 across seven Japanese municipalities and involving 34,982 older people, examined the relationship between eight neighborhood environment elements and the mean monthly cumulate costs (MMCC) of LTC. The results showed that older people who reported the presence of fresh food stores nearby and dangerous places for walking alone at night in the neighborhood had lower MMCC, by JPY 1,367.6 and 1,383.3 per month, respectively, than respondents who did not report the presence of these neighborhood elements. Meanwhile, older people whose neighborhoods had easily accessible facilities had higher MMCC of JPY 739.4. This study's key findings reveal significant relationships between neighborhood environment elements and LTC costs and can be used to support developments in urban design to support healthy aging and reduced LTC costs.

1. Introduction

Driven by lower mortality and increased survival rate, the world's population is getting older; however, the increase in the number of older people has caused ongoing concerns about their increasing long-term care (LTC) needs and costs. According to the World Health Organization (WHO), by 2050, the population of individuals aged ≥60 years in the world is expected to double to 2.1 billion, while the population of those aged ≥80 years is estimated to triple, reaching 426 million (United Nations [UN], 2022; WHO, 2022). Japan has now become a super-aged society, a society where more than 21% of the population is 65 years or older. In 2021, Japan had the highest life expectancy at birth at approximately 85 years; at the time, 28.9% of the population was aged 65 years or older (Ministry of Health, Labour and Welfare [MHLW], 2021; UN, 2022; Tahara, 2016). With Japan's rapidly aging population, the number of individuals certified as needing LTC exceeded 6.82 million nationwide as of 2021 (MHLW, 2020). The increasing number of individuals certified as needing LTC have led the Japanese government to investigate ways to prevent LTC and focus on limiting overall LTC costs. LTC costs are expected to rise from JPY 11 trillion (USD 110 billion) in 2021 to JPY 25.8 trillion (USD 258 billion) by 2040 in Japan alone and continue to increase worldwide (Cabinet Secretariat, 2022; MHLW, 2021).

Neighborhood environments are an essential contributor to older people's health. With increasing age, the environments older people inhabit and their interactions with these environments become crucial because neighborhoods can develop and maintain older people's functional abilities and contribute to healthy aging (WHO, 2015). Accordingly, the WHO proposed a primordial prevention strategy, referring to building neighborhood environments in which people become healthy

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by living in them (Bonita et al., 2006; Hanazato, 2019). Additionally, one of the actions of the UN's Decade of Health Aging 2020–2030 was fostering age-friendly cities and communities that allow individuals to maximize their abilities across their lives (WHO, 2020).

According to systematic reviews, positive neighborhood environments have protective effects against low physical activity, type II diabetes, and depression among older people (Barnett et al., 2018; Cerin et al., 2017; Chu et al., 2019; den Braver et al., 2018). Older people living in neighborhoods with high walkability tend to go outside and walk more often (Sharmin and Kamruzzaman, 2018). Researchers have identified that improved neighborhood environments reflected improvements in cardiovascular diseases and body mass index (Hanibuchi et al., 2011; Inoue et al., 2016; Nakamura et al., 2017; Shiba et al., 2020). Moreover, older people living in neighborhoods with many hills and steps present less risk of type II diabetes (Fujiwara et al., 2017). Furthermore, investigators have found that older people living near elementary schools or in residential areas with more greenness and blocks experience less depression (Chen et al., 2022; Nishida et al., 2021; Nishigaki et al., 2020; Tani et al., 2021). Additionally, Mori et al. (2022) identified that neighborhood environments with more parks, fresh food stores, and fascinating views were significantly associated with lower risk of frailty. In terms of neighborhood improvement on reducing the risk of needing LTC a cohort study found that older people with more fresh food stores in their neighborhood were less likely to need LTC and that communities with more sidewalk areas were associated with fewer cases of dementia (Tani et al., 2021).

Regarding saving medical costs, a study demonstrated that improving built environments to encourage physical activity can yield notable health and economic advantages. Zapata-Diomedi et al. (2016) modeled scenarios of the relationship between adults' physical activity and the elements of built environments such as population density, availability of destinations, and walkability and then translated the results to the influence of these elements on health-adjusted life years; the aim was calculating the potential savings in medical expenses through these elements. The study identified potential savings in medical expenses from physical activity-related diseases ranging between AUD 4,698 and 36,777 per year per 100,000 adults exposed to such improved environments (Zapata-Diomedi et al., 2016). Although the relationship between built environments and LTC costs remains unclear, studies have shown that older people who maintain healthy behaviors can reduce their cumulative LTC costs. For example, older people who went out and walked frequently, actively participated in hobby, sports, or volunteer groups, or were employed had lower future cumulative LTC costs (including home care and facility expenses) than those who did not engage in or had the opportunity to engage in these activities (Hirai et al., 2021; Saito et al., 2021).

In summary, studies have demonstrated the relationships between neighborhood environments and older people's health outcomes; however, there are no indicators revealing how such data can be used to lower LTC costs. Some studies have described the social implications of modifying environmental risk factors; however, such modifications require a financial aspect and huge expenses; thus, we believe that cost–outcome analyses will be essential to examine the possibility of it. Therefore, clarifying whether there is a relationship exists between neighborhood environments and LTC costs is necessary. This study's aim was to examine the relationships between multifaceted neighborhood environment elements and LTC costs for older people.

2. Methods

2.1. Study participants

We merged the 2010 dataset from the Japan Gerontological Evaluation Study (JAGES) with two additional datasets—the "Certification of Long-term Care from 2010 to 2019" and "Cumulative Long-term Care Costs from 2010 to 2019"—to create a comprehensive nine-year follow-up cohort dataset. The JAGES is a population-based epidemiological research initiative conducted with older people every three years since 2010; it focuses on the social determinants of health and the social/built environment (Kondo et al., 2018). Self-administered questionnaires were mailed to independent individuals aged ≥65 years across 31 municipalities in Japan between August 2010 and January 2012. A total of 169,215 questionnaires were distributed and 102,869 were completed and returned (response rate: 60.7%).

Next, we combined the 2010 JAGES baseline data with two datasets from the Japanese government database: "2010–2019 certification of LTC" and "2010–2019 cumulative LTC costs" (Hirai et al., 2021; Saito et al., 2021; Tsutsui and Muramatsu, 2005). Over the nine years from baseline, we collected relevant data on 38,164 older people who had an identifiable sex and age and lived in seven Japanese municipalities spanning 331 elementary school districts. In Japan, elementary school districts play a significant role in shaping community units. They serve as venues for fire brigades, local festivals, election polling stations, and disaster evacuation shelters (Hanibuchi et al., 2008; Nishigaki et al., 2020). To generate regional variables at the elementary school district level, we excluded questionnaires data that were missing residential information.

Additionally, in selecting the data for this study, we excluded respondents who required assistance with daily living activities; those with missing data on height, weight, or residential years; and those who had moved out of the residence. After excluding the aforementioned groups, 34,982 older Japanese individuals were considered eligible for our analysis (Fig. 1). We conducted this study through a collaborative research agreement with the associated municipalities and received approval no. 2493 for this study from the Ethics Board of Chiba University. All methods were performed according to relevant guidelines and regulations or as per the Declaration of Helsinki.

2.2. Outcome variable

The outcome variable was mean monthly cumulate costs (MMCC) for LTC (Japanese yen per capita at the currency exchange rate of JPY 100 to USD 1). In Japan, the LTC system is based on social insurance principles; only services (e.g., daycare, nurse visitations, and rehabilitation at home or community facilities) are provided, not cash allowances. Recipients can choose their services and providers. Individuals who have been certified as requiring LTC (there are seven levels of LTC: support levels 1 and 2 and care need levels 1–5) are allowed to use LTC services; generally, 90% of the costs are paid by insurance agencies and 10% are paid via co-payments. Please see Tsutsui et al. and Saito et al. for more information about the LTC system (Saito et al., 2021; Tsutsui and Muramatsu, 2005).

Japan's National Health Insurance Organization collects monthly cumulative LTC costs divided into two types of service expenses: (1) home care, comprising home-visit care, daycare services, group home care, and specified facility resident care and (2) facilities, including services provided by LTC welfare, health, and medical facilities for older people. We combined these two types into a single measure, cumulative LTC costs, spanning August 2010 to January 2020 (114 months; Akiyama et al., 2018; Saito et al., 2021). Finally, we divided the cumulative LTC costs during the nine-year follow-up period by the number of days tracked and multiplied this figure by 30 days to identify the MMCC.

2.3. Explanatory variable

In this study, we included eight neighborhood environment elements from the baseline data as the explanatory variables. The variables pertinent to the case of Japan were selected and refined based on Mujahid et al. (2007) and the International Physical Activity Questionnaire environmental scale (Inoue et al., 2009). Specifically, we administered self-report questionnaires asking respondents whether the

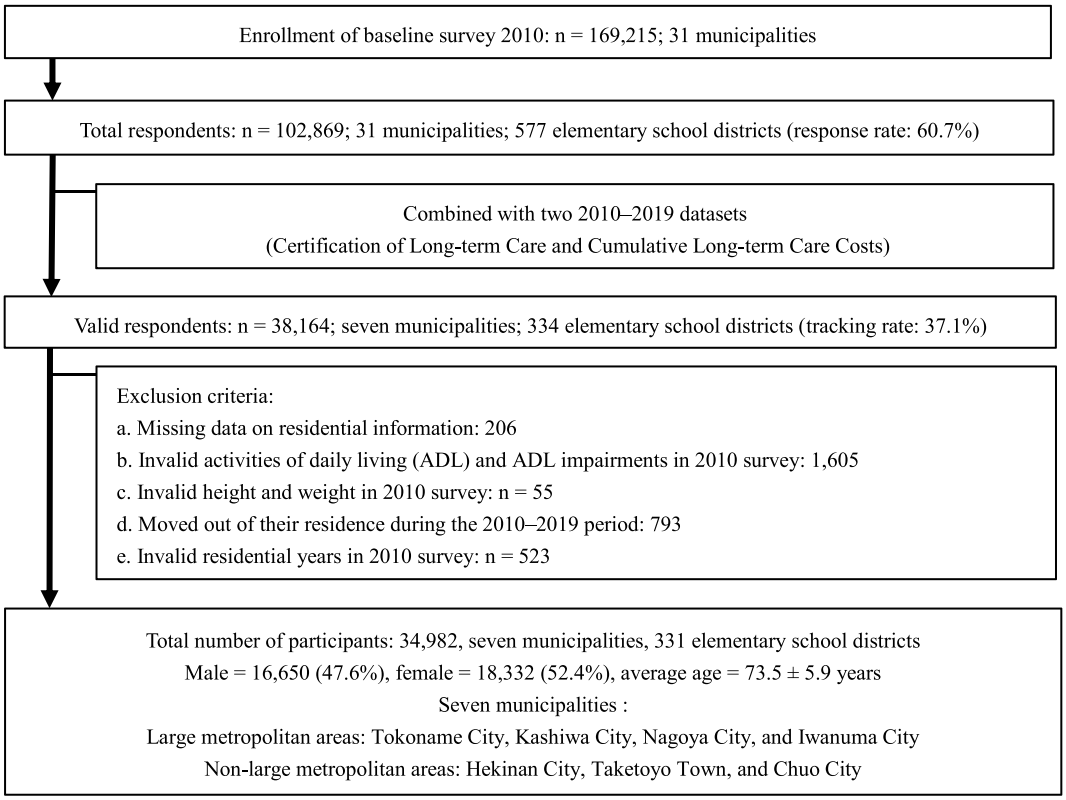

Fig. 1. Participant selection in this study. (Large metropolitan areas and non-large metropolitan areas are defined by OECD's Functional Urban Areas.)

following were present within 1 km of their home: "locations with noticeable graffiti or undisposed garbage (locations with graffiti or garbage)"; "parks or sidewalks suitable for exercise or walking (parks or sidewalks)"; "locations difficult for walking, such as hills or steps (locations with hills or steps)"; "roads or crossroads with a high risk of traffic accidents (roads with traffic accidents)"; "fascinating views or buildings"; "shops or facilities selling fresh fruits and vegetables (fresh food stores)"; "dangerous places when walking alone at night"; and "houses or facilities where you feel free to drop in (facilities where you feel free to drop in)." Previous studies have investigated health issues such as frailty, knee pain, and back pain using these eight categories (Mori et al., 2022; Okabe et al., 2019). The participants responded on 5-point Likert scales for each neighborhood element; the responses were many, some, few, none, and "I do not know." We dichotomized these responses into present ("many" and "some") or absent ("few" and "none") and replaced responses of "I do not know" with other responses using multiple imputations, which were then categorized into the present or the absent groups.

2.4. Covariates

We controlled for demographic, socioeconomic, psychological, physical, and regional factors that may have been correlated with the study outcomes or exposures. The demographic and socioeconomic covariates included sex (male or female), age (65–69, 70–74, 75–79, 80–84, or ≥85 years), equivalent household income (< JPY 2, 2–3.99, or ≥ 4 million per year), educational attainment (≤9 or ≥ 10 years of education), marital status (married, widowed, divorced, or never married), living status (living alone or with others), and years of residence in the neighborhood (<10, 10–19, 20–29, 30–39, 40–49, or ≥50 years). The following psychological and physical covariates were considered: depression (yes or no), subjective health status (healthy or unhealthy), decrease in higher-level functional capacity (yes or no), receiving medical treatment (yes or no), driving status (car user, including receiving rides from others, or non-car user), frequency of going out (annually/none, weekly, or daily), and duration of daily walking (<30, 30–59, or ≥ 60 min/day). Personal ability has been found to play a role in shaping perceptions of neighborhood characteristics. For instance, one's driving status can potentially influence a person's perception of the neighborhood environment. Moreover, previous studies focusing on the relationship between perceived neighborhood environment and health outcomes have considered behaviors and health status as covariates (Fritz et al., 2020; Momosaki et al., 2019; Okabe et al., 2019; Peters et al., 2020; Tani et al., 2019). Therefore, we controlled for driving/going out/walking as we utilized subjective neighborhood environment variables in our study. We measured the following regional variables: population density (low <3,568.8, lower-moderate 3, 629.3–6,753.6, moderate 6,773.8–9,150.4, higher-moderate 9, 185.9–11,459.8, or high 11,464.2–27,781.3 individuals/km^2 in the school district), daylight (low <5.2, moderate 5.6–5.7, or high >5.7 h/day), and snowfall (low <1, moderate 1.3–3, or high >3.1 cm/year). We added population density considering the population size and added the other variables to account for climate considerations because our study area encompassed different municipalities. Regional variables were quintiled or tertiled at the elementary school district level. We assessed all covariates using a questionnaire in the baseline survey (Nishigaki et al., 2020; Wang and Yang, 2019).

2.5. Statistical analysis

The methods we used to analyze the study data included descriptive analysis and mixed-effects linear regression. First, for the descriptive analysis, we calculated the MMCC for each variable. To determine significant differences within the variables, we employed the Kruskal–Wallis and Mann–Whitney U tests. Second, we used multilevel mixed-effects linear regression via forced entry and controlled for covariates in the model to examine the relationships between neighborhood environments and LTC costs in older Japanese people. Our

model was based on the assumption of layered or multilevel strata within the data; we chose this multilevel modeling approach for its relevance to our study, which involved data with nested or clustered structures (Leyland and Groenewegen, 2020). In this study, we applied multilevel mixed-effects linear regression by considering elementary school districts as the fundamental units of the neighborhood environment. Using random intercept models with individuals and elementary school districts as level 1 and 2 variables, we conducted two analyses. For Model 1, we input the eight neighborhood environment elements into the same model to estimate their relationships with MMCC; meanwhile, in Model 2, we added all the covariates in Model 1.

To deal with missing data in our model, we performed 20 imputations using chained equations under the missing values at random assumption, accounting for possible systematic differences between missing and observed values. Specifically, we imputed missing responses to questions about educational attainment, marital status, and individual-level neighborhood environments, including for those with the response "I do not know." The imputed datasets incorporated all measurement variables using multivariate normal imputation. We then combined the estimated parameters from the 20 imputed datasets using Rubin's combination.

Furthermore, we performed two sensitivity analyses, one using cumulative LTC costs from a six-year follow-up (baseline 2010) dataset to compare the results with Saito et al.'s (2021) investigation, and the other involved conducting five models to observe changes in the associations between the neighborhood environment and MMCC, with covariates being sequentially added. To discuss the results of the relationships between the neighborhood environment and MMCC, we used a field survey and a geographic information system to analyze the results. We performed all statistical analyses using Stata/MP 16.1 (Stata Corp, College Station, TX, USA).

3. Results

Among the 34,982 older participants (mean age: 73.5 years, 52.4% female), 21.6% (n = 7,569) used LTC services during the nine-year follow-up period. Table 1 shows the characteristics of the respondents and the MMCC, indicating that for most of the eight neighborhood environments, the MMCC were lower when the neighborhood elements were present than when they were absent. Table 2 shows the results of Models 1 and 2. In Model 1, five neighborhood environment elements were clearly associated with MMCC: locations with graffiti or garbage; access to parks or sidewalks; locations with hills or steps; nearby fresh food stores; and dangerous places when walking alone at night. After we controlled for all covariates, three of the neighborhood elements remained significantly associated with MMCC. Older people who reported that there were fresh food stores nearby and dangerous places for walking alone at night in their neighborhoods had an MMCC of JPY 1,367.6 (95% confidence interval [CI]: −1,990.6 to −744.6) and JPY 1,383.3 (95% CI: −1,945.2 to −821.5) lower, respectively, than the MMCC for respondents who report the absent of these elements. In contrast, older people who perceived that there were facilities where they felt free to drop in had an MMCC of JPY 739.4 (95% CI: 172–1,306.8) higher than those for whom this element was not present. Additionally, the result of the first sensitivity analysis supported the earlier finding that MMCC was lower for older adults who reported that there were fresh food stores nearby (−34,809.2 JPY; 95% CI: −69,348.8 to −269.6 JPY) than for respondents who did not (Supplementary Materials Table S1). For additional results from the two sensitivity analyses, please refer to the Supplementary Materials.

4. Discussion

This study demonstrated the relationship between multifaceted neighborhood environment elements and the MMCC of older people in Japan. The main findings of the study are as follows: the MMCC among

Table 1
Characteristics of the study participants and the MMCC (n = 34,982).

Table 1-1. Characteristics of the neighborhood environment elements and the MMCC (n = 34,982)

	Total		MMCC[a]		
	N	%	Mean	SD	*p*-value
Locations with graffiti or garbage					
Present	10,243	29.3	6,051	22,902	<0.001
Absent	21,302	60.9	7,129	24,767	
Missing	3,437	9.8	13,384	34,093	
Access to parks and sidewalks					
Present	25,170	72	6,715	23,950	<0.001
Absent	8,121	23.2	7,678	25,689	
Missing	1,691	4.8	16,837	39,353	
Locations difficult for walking (hills or steps)					
Present	12,171	34.8	7,716	25,151	<0.001
Absent	21,188	60.6	6,686	24,231	
Missing	1,623	4.6	14,948	37,927	
Roads/crossroads with risk of traffic accidents					
Present	23,812	68.1	7,000	24,408	<0.001
Absent	9,510	27.2	7,339	25,260	
Missing	1,660	4.7	14,067	36,784	
Fascinating views or buildings					
Present	12,001	34.3	6,776	23,725	<0.001
Absent	20,223	57.8	6,868	24,393	
Missing	2,758	7.9	14,369	36,357	
Access to fresh food stores					
Present	26,242	75	6,591	23,693	<0.001
Absent	7,573	21.6	8,919	27,660	
Missing	1,167	3.3	16,561	40,573	
Dangerous places for walking alone at night					
Present	21,830	62.4	6,364	22,912	<0.001
Absent	9,847	28.1	7,456	25,615	
Missing	3,305	9.4	14,368	36,789	
Houses or facilities where you feel free to drop in					
Present	12,324	35.2	7,231	25,238	<0.001
Absent	18,741	53.6	6,733	23,821	
Missing	3,917	11.2	11,372	32,048	

Table 1-2. Characteristics of the study participants and MMCC (n = 34,982)

	Total		MMCC[a]		
	n	%	Mean	SD	*p*-value
Sex					
Male	16,650	47.6	5,934	21,771	<0.001
Female	18,332	52.4	8,785	28,235	
Age group, years					
65–69	10,760	30.8	1,616	11,623	<0.001
70–74	10,690	30.6	3,752	17,877	
75–79	7,592	21.7	8,861	26,009	
80–84	4,120	11.8	18,584	38,103	
≥85	1,820	5.2	32,144	49,422	
Equivalent household income, million yen					
Low (<2.00)	13,309	38	7,407	25,390	<0.001
Middle (2.00–3.99)	12,236	35	5,970	22,608	
High (≥4.00)	3,613	10.3	5,786	22,375	
Missing	5,824	16.6	11,554	31,560	
Subjective health status					
Healthy	28,533	81.6	6,284	23,449	<0.001
Unhealthy	6,095	17.4	12,453	32,026	
Missing	354	1	13,046	35,079	
Education level, years					
≤9	14,450	41.3	9,277	28,816	<0.001
≥10	19,863	56.8	5,822	21,933	
Others	238	0.7	11,096	28,308	
Missing	431	1.2	17,381	39,967	
Marital status					<0.001
Married	25,188	72	5,399	20,944	
Widowed	7,193	20.6	14,014	35,470	
Divorced	1,215	3.5	6,142	21,419	
Never married	782	2.2	10,961	33,728	
Missing	604	1.7	11,582	31,412	
Living situation					<0.001
Lives alone	4,095	11.7	10,770	31,153	
Lives with others	30,178	86.3	6,818	24,093	
Missing	709	2	14,054	37,539	

(*continued on next page*)

Table 1 (*continued*)

Table 1-2. Characteristics of the study participants and MMCC (n = 34,982)

	Total		MMCC[a]		
	n	%	Mean	SD	*p*-value
Receiving medical treatment					<0.001
No	23,856	68.2	7,870	25,797	
Yes	8,121	23.2	5,408	22,987	
Missing	3,005	8.6	9,375	28,030	
Depression					<0.001
No	21,372	61.1	6,025	22,624	
Yes	7,907	22.6	9,833	29,737	
Missing	5,703	16.3	9,347	28,206	
Decrease in **higher-level functional capacity**					<0.001
No	13,728	39.2	4,680	19,753	
Yes	17,358	49.6	8,816	27,718	
Missing	3,896	11.1	10,926	30,819	
Driving status					<0.001
Not a car user	3,087	8.8	12,979	33,630	
Car user	18,761	53.6	8,188	26,787	
Missing	13,134	37.5	5,037	20,359	
Duration of daily walking, min/day					<0.001
Low (<30)	10,572	30.2	10,485	30,173	
Moderate (30–59)	11,837	33.8	6,546	23,588	
High (≥60)	10,581	30.2	4,824	20,181	
Missing	1,992	5.7	10,272	30,573	
Frequency of going out					<0.001
Annually or none	1,689	4.8	17,055	38,939	
Weekly	11,814	33.8	9,748	29,013	
Daily	19,643	56.2	5,069	20,512	
Missing	1,836	5.2	8,876	28,354	
Years of residence					<0.001
<10	1,089	3.1	8,536	26,597	
10–19	1,425	4.1	7,818	28,300	
20–29	2,072	5.9	5,686	22,005	
30–39	4,024	11.5	5,035	21,191	
40–49	6,891	19.7	4,975	20,786	
≥50	19,481	55.7	8,884	27,531	
Snowfall, cm/year					<0.001
Low	15,220	43.5	8,358	27,050	
Moderate	7,224	20.7	4,471	18,369	
High	12,538	35.8	8,002	26,677	
Population density, people/km^2					<0.001
Low	5,628	16.1	10,184	30,695	
Lower-moderate	15,557	44.5	8,777	27,579	
Moderate	4,736	13.5	4,334	17,878	
Upper-Moderate	5,106	14.6	4,978	20,298	
High	3,955	11.3	5,063	20,458	
Daylight, hour/day					<0.001
Low	6,674	19.1	8,683	27,592	
Moderate	11,686	33.4	5,889	21,781	
High	16,622	47.5	8,006	26,766	

[a] Japanese yen per capita at the currency exchange rate of JPY 100 to USD 1.

the respondents who perceived fresh food stores to be nearby and those who perceived dangerous places for walking alone at night in their neighborhoods were lower than that for those who did not, and older people who perceived the presence of facilities where they felt free to drop in were associated with a higher MMCC.

The MMCC was lower for respondents who reported that there were fresh food stores nearby than for those who did not report these stores nearby. This finding is consistent with the results of previous studies indicating that good nutritional intake and maintenance of cognitive function positively impact health. Older people who reported poor grocery store accessibility had a significantly lower frequency of consuming vegetables/fruits and meat/fish than those who reported that grocery stores were accessible (Yamaguchi et al., 2019). Furthermore, low subjective grocery store accessibility is associated with the risk of developing frailty (Mori et al., 2022), increased the risk of needing LTC (Momosaki et al., 2019), and dementia (Tani et al., 2019) among older Japanese people. Therefore, we believe that policies and programs related to improving neighborhood environments are needed for better quality of life. For example, under the United States' FRESH project, tax breaks were given to fresh food stores in areas with limited access to affordable and nutritious food (New York City Economic Development Corporation, 2009). Furthermore, mobile food vendors and implementing shuttle bus services to grocery stores may have protective effects on residents' health (Tamura et al., 2023) and potentially lead to lower LTC costs.

The MMCC of respondents who perceived dangerous places for walking alone at night in their neighborhoods was lower than that for those who did not report this perception. Although this result is contrary to those of previous studies, we found in our data that individuals who walked for >30 min a day were more likely to perceive that there were dangerous places for walking alone at night (69%) than were those who did not (66%). Moreover, our analysis using a geographic information system revealed that nearly 70% of the locations that respondents perceived as unsafe for walking alone at night were located within a 1-km radius of train stations. Our field survey also found that some of these areas were indeed close to train stations, despite the high volume of traffic on main streets. Thus, the lower LTC costs for respondents in these neighborhoods may be due to the benefits available in the area around the station, such as convenient transportation and liveliness; furthermore, streets with sidewalks encourage the walking behavior.

Another potential reason for the lower LTC costs for people reporting dangerous places for walking alone at night in their neighborhood is that individuals who are aware of their surroundings may generally take better care of their health. Previous studies have highlighted the characteristics of conscientiousness, such as constraint and a tendency to avoid risk-taking (Roberts et al., 2014); risk-averse individuals display other health-related behaviors such as being less likely to smoke and more likely to use seat belts (Anderson and Mellor, 2008). Therefore, we hypothesize that individuals who perceive their neighborhoods as having unsafe areas for walking alone at night may be more conscientious, which could be linked with health-promoting behaviors that, in time, would ultimately reduce LTC costs. Nevertheless, the mechanism of this relationship should be investigated in detail in the future.

Higher MMCC was associated with older people who perceived the presence of houses or facilities in their neighborhood where they felt free to drop in. We were unable to specify the types of facilities considered here; we believe this may be one of the reasons for the negative impact of the availability of such neighborhood facilities on older peoples' LTC costs. Social participation and informal communication happen in environments where we feel relaxed and free to drop in, and neighborhoods with places where people feel free to drop in were associated with less risk of developing frailty among older people (Kerr et al., 2014; Mori et al., 2022). Furthermore, Saito et al. (2021) found that older people participating in group activities have lower cumulative LTC costs than those who did not.

In contrast, Shiba et al. (2020) found that changes in the proximity to food and recreation destinations, such as health care facilities, sports facilities, and pachinko (Japanese gaming facility), and move from areas with lower walkability to higher areas were associated with unhealthy cardiometabolic profiles, such as higher body mass index (Shiba et al., 2020). They explained that even if these neighborhoods contain healthy built elements, the less healthy elements such as pachinko can potentially cause sedentary behavior that we consider ultimately can lead to higher LTC costs.

This study has several strengths. First, to the best of our knowledge, this is the first longitudinal investigation of the relationship between neighborhood environment elements and LTC costs for older Japanese adults. Second, our data covered seven municipalities across Japan, allowing us to capture the neighborhood environments in large metropolitan areas and non-large metropolitan areas. Third, researchers have found a relationship between neighborhood environments and initial and intermediate outcomes, such as physical activity and mental health, and long-term outcomes, such as frailty and death. In this study, we

Table 2
Multilevel mixed-effects linear regression results for the associations between the neighborhood environment elements and MMCC (n = 34,982).

		Model 1				Model 2			
	n	Coefficient	95% CI		*p*-value	Coefficient	95% CI		*p*-value
Access to parks and sidewalks									
Present	25,170	−1090.4	−1733.3	−447.4	0.001*	−84.3	−692.5	523.9	0.786
Fascinating views or buildings									
Present	12,001	−16.8	−622.7	589.1	0.957	404.2	−168.8	977.1	0.167
Access to fresh food stores									
Present	26,242	−2635.8	−3297.6	−1974.0	<0.001*	−1367.6	−1990.6	−744.6	<0.001*
Houses or facilities where you feel free to drop in									
Present	12,324	265.7	−322.0	853.4	0.376	739.4	172	1306.8	0.011*
Locations with graffiti or garbage									
Present	10,243	−1622.8	−2226.3	−1019.3	<0.001*	−433.3	−1007.0	140.3	0.139
Locations difficult for walking (hills or steps)									
Present	12,171	1644.7	1047.1	2242.4	<0.001*	246.3	−312.4	805.1	0.388
Roads/crossroads with risk of traffic accidents									
Present	23,812	−391.8	−1008.2	224.6	0.213	139.7	−445.2	724.5	0.64
Dangerous places for walking alone at night									
Present	21,830	−2355.7	−2946.4	−1765.0	<0.001*	−1383.3	−1945.2	−821.5	<0.001*

The reference group for each neighborhood environment variable is "absent." 95% CI: 95% confidence interval; *significant at < 0.05. Model 1 includes eight neighborhood environment elements and MMCC. Model 2 builds on Model 1 and controls for sex, age, equivalent household income, educational attainment, marital status, living status, years of residence, depression, subjective health status, decrease in higher-level functional capacity, receiving medical treatment, driving status, frequency of going out, duration of daily walking, population density, daylight, and snowfall. Costs are based on Japanese yen per capita with a currency exchange rate of JPY 100 to USD 1.

provide new insights using the impact indicator of LTC to evaluate the relationship of LTC costs with neighborhood environments.

Nevertheless, this study has some limitations. First, although we analyzed multiple study areas, our data do not reflect a nationally representative sample. Second, we may have underestimated actual LTC costs because our per-month calculation might not have considered that individual LTC costs increase with age. Third, our dataset only includes expenses from public long-term care insurance; notably, older people with the highest level of LTC needs (care need 5) are more likely to be hospitalized. As these medical costs were not included in our LTC cost dataset, in the future, it will be necessary to add the costs of medical and private long-term care insurance to examine the relationships between insurance outlays and neighborhood environment elements. Fourth, there are unmeasured confounders, and the explanatory variables and confounders are from the same point in time, rendering the causal relationship unclear. Fifth, we measured the neighborhood environment variables with a self-reported survey; therefore, there is a possibility of measurement bias. Objective indicators measured using a geographic information system may minimize the bias; however, studies have reported that subjective indicators that can capture the accessibility and usage of neighborhood environments were associated with more health outcomes such as cognitive ability and mortality among older individuals (Tani et al., 2018). Sixth, our study focused on eight aspects of the neighborhood environment but omitted certain areas such as public transportation, natural environments, and healthcare facilities, which are crucial for older adults' health (Barnett et al., 2017). Future studies should conduct a comprehensive analysis of both subjective and objective measurements.

In this study, we established and clarified the relationships between multifaceted neighborhood environment elements and LTC costs among older people over a follow-up period of nine years. We found that older people who reported that fresh food stores were nearby had an MMCC of 1367.6 JPY per month lower than those who did not. We estimated that if the people who did not report being near a fresh food store (n = 8,740) could live near such stores, their MMCC could be reduced by approximately 5.6% or 11,952,824 JPY per month. Saito et al. (2021) reported that cumulative LTC costs were approximately 60,000 JPY lower per person among employed older people than among retirees for six years. We analyzed a six-year dataset and found that the cumulative LTC cost was 34,809 JPY per person lower among those who reported that there were fresh food stores nearby than those who did not (see Supplementary Material Table S1). This demonstrates that environmental and behavioral effects can positively contribute to health outcomes.

5. Conclusions

With the high population of older adults in Japan, understanding the role of environment elements in the neighborhood of older people could be influential in controlling LTC costs, which is essential for promoting the policy of primordial prevention. Moreover, quantitative assessments of the health impacts of neighborhood elements could be useful for policy-makers because policies and programs related to neighborhood environments are needed for better living. Studies are being conducted to evaluate the effectiveness of LTC prevention programs and support the development of urban design.

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Data sharing statement

The dataset supporting the conclusions of this article is available upon request from the researchers admitted by the JAGES committee (dataadmin.ml@jages.net). All JAGES datasets have ethical or legal restrictions for public deposition due to inclusion of sensitive information from the human participants.

CRediT authorship contribution statement

Yu-Ru Chen: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Conceptualization. **Masamichi Hanazato:** Writing – review & editing, Supervision, Investigation, Funding acquisition, Conceptualization. **Masashige Saito:** Writing – review & editing, Funding acquisition, Data curation. **Chie Koga:** Writing – review & editing, Funding acquisition. **Yoko Matsuoka:** Writing – review & editing, Methodology, Funding acquisition. **Hiroaki Yoshida:** Writing – review & editing. **Katsunori Kondo:** Writing – review & editing, Visualization, Funding acquisition, Data curation.

Declaration of competing interest

All authors declare that they have no competing interests.

Data availability

Data will be made available on request.

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This study used data from the JAGES, conducted by the Nihon Fukushi University Center for Well-Being and Society. Additionally, JAGES data were combined with two datasets from the Japanese government database: "2010–2019 certification of LTC dataset" and "2010–2019 cumulative LTC costs." This study was conducted through a collaborative research agreement with the associated municipalities. Ethical approval (No. 2493) was provided by the Ethics Board of Chiba University. All methods were performed according to relevant guidelines and regulations or as per the Declaration of Helsinki.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.healthplace.2024.103223.

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