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The association between street layout (connectivity and integration) and social interaction in older Japanese adults

A Japan Gerontological Evaluation Study (JAGES) three-year longitudinal study

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ABSTRACT

Street layout, namely, connectivity and integration, indicates neighborhood walkability and is reported to be associated with health. However, the relationship between street layout and social interaction—which is a determinant of health—needs further investigation. This study examines the relationship between street layout and older people's social interaction with their neighbors. We analyzed data from the Japan Gerontological Evaluation Study (JAGES) that encompasses 17 municipalities with 40,677 independent participants aged ≥65 years in Japan. We measured the change in participants' social interaction with neighbors between 2013 and 2016. Two street layout indexes—connectivity and integration—were calculated using space syntax analysis. Poisson regression analysis was performed to calculate the incidence rate ratio (IRR) and 95% confidence interval (CI) for a decrease in social interaction with neighbors after three years. All analyses were stratified by two age groups: young–old (<75) and old–old (≥75). In the old–old group, we observed that, compared with those living in low-connectivity and low integration areas, the decrease in social interaction after three years was 25% and 24% lower among participants living in areas with high street connectivity and high street integration, respectively. We found that well-designed street layout was associated with less decline in social interaction among old–old people in Japan. This research provides evidence supporting healthy community design.

KEYWORDS

Street layout, sense of community, neighborhood environment, Japan

1 INTRODUCTION AND LITTERATURE REVIEW

Social interaction with neighbors has a positive impact on health among older people. For example, participants who spent more time interacting with others reported being more satisfied with their lives than those who spent less time doing so (Nezlek et al., 2002). Moreover, Nezlek et al. (2002) found that older people with a higher level of enjoyment and intimacy interaction show greater psychological well-being. Different sources of interaction—such as spouses, children, friends, and neighbors that older people are close to—are essential and discussed in the previous study (Okabayashi et al., 2004; Venkatraman, 1995; Nezlek et al., 2002). A previous study reported that older Japanese people who receive social support—including opportunities to share and talk about their worries or problems—from their spouses instead of their children or others enjoy a greater degree of well-being (Okabayashi et al., 2004). The same results were also found in America and India (Venkatraman, 1995; Nezlek et al., 2002). However, in an aging society, the number of bereaved people is increasing rapidly; additionally, the co-residence rate with children is declining among older Japanese (Cabinet Office, 2017; Statistics Bureau, 2015), which may influence the frequency of social interaction with spouses and children. Concerning the sources that older people interact with, previous studies reported that neighbors are considered one of the preferred sources of assistance, following spouse and children (Antonucci, 2001; Okabayashi et al., 2004). Thus, social interaction with neighbors is essential in the well-being of the older people in Japan.

Maintaining social interaction among older people, particularly those older than 75 years, is essential. The decline in physical ability and the frequency of going out seen with increasing age has been reported by previous studies (Fujita et al., 2004; Sun, Norman and While, 2013). Additionally, according to a Berlin aging study, the reduction of participation in activities such as hobbies, traveling, and sports has been reported among older people (Bukov, Maas, and Lampert, 2002). Bukov et al. (2002) described it as social "dying," as they found that after the age of 90, more than 30% of the participants' social participation decreased. Thus, it is important to research maintaining social interaction among older people, particularly in those older than 75 years.

A literature review reported that neighborhood walkability design had been the environmental factor that positively affected social interaction with neighbors (Talen and Koschinsky, 2014). For example, an Australian study revealed that more walkable neighborhoods encourage adults to wave or chat over the fence with others (Toit du et al., 2007). According to an American study, sense of community measured by neighboring behaviors—including talking and exchanging favors with neighbors—is positively associated with a higher commercial building floor area ratio (the total land area devoted to commercial uses within a 1 km network buffer) (Wood, Frank, and Giles-Corti, 2010). Wood et al. (2010) discussed that different destinations, such as a local corner store, may enhance social connections more than others. Moreover, Enssle and Kabisch (2020) reported that older Germans who visit urban green spaces daily were significantly more likely to meet neighbors regularly and to make friends in the neighborhood. Among walkability indexes, street layout is directly planned and can be controlled by urban planners. Street layout has been reported to be associated with pedestrian movement (Sharmin and Kamruzzaman, 2018) and health outcomes such as physical activity, cognitive function, and depression (Wineman et al., 2014; Koohsari et al., 2019; Lam, Loo, and Mahendran, 2020). Regarding social interaction with neighbors, a Japanese study reported that street connectivity and space syntax walkability, measured by street integration and population density, are significantly and negatively associated with social interaction with neighbors (Koohsari et al., 2021). Contrarily, Wood et al. (2010) reported that street connectivity did not predict a sense of community.

These previous studies had some limitations. First, such studies commonly highlight the disadvantage of cross-sectional study designs, as they do not establish causal relationships, and the change in social interaction with increasing age remained unknown. Second, there was a small sample size of around 1,000 participants and a limited representation of the target population and study area (Wood, Frank, and Giles-Corti, 2010; Koohsari et al., 2021). As reported by previous studies, the association between street layout and social interaction with neighbors among older adults remains debatable and needs further research.

Consequently, our study aimed to illustrate whether a better street layout—connectivity and integration—can suppress the decrease in social interaction with neighbors observed with advancing age. Based on large-scale longitudinal data, we used space syntax to measure street layout and to examine its association with social interaction with neighbors among older Japanese people (young–old and old–old).

Clarifying this issue is essential because, through street layout, understanding where an area yields or limits the communications between people may inform urban design.

2 DATASETS AND METHODS

We analyzed data from the Japan Gerontological Evaluation Study (JAGES), which was initiated in 1999 to obtain scientific findings through population-based epidemiological research. JAGES has been conducting surveys of older people every three years since 2010 and focuses on the social determinants of health and the social/built environment (Kondo and Rosenberg, 2018).

Our study areas and participants encompass 17 municipalities, with 40,677 adults aged ≥65 years in Japan. In selecting participating respondents, we excluded the respondents who needed assistance with daily living activities; where data on age were missing; whose age difference between baseline and three years later did not fall within the range of 2–4 years; who had missing data on years of residence; who lived in the same place for less than three years; and who had missing scores from the outcome variable “social interaction with neighbors” in 2013 and 2016 (Fig. 1).

Based on the questionnaire that participants responded to in 2013 and 2016, we measured the change in social interaction with neighbors (decrease or no decrease) as the outcome variable. The question presented was “What kind of interactions do you have with people in your neighborhood?” and the four response choices were as follows:

1. Mutual consultation, lending and borrowing daily commodities, and cooperation in daily life
2. Daily chatting
3. No more than exchanging greetings
4. None, not even greetings

We subtracted the value reflecting the level of social interaction with neighbors in 2013 from the value in 2016. Then, we categorized the subtraction into two groups: decrease and no decrease.

We applied explanatory variables as two street layout indexes—connectivity and integration—both divided into tertiles (low, moderate, high). Street connectivity and integration have been used in public health to investigate the relationships between street layout and health problems (Watts et al., 2015; Koohsari et al., 2019; Nichani, Koohsari, and Mccormack, 2021). Connectivity measures the number of spaces (paths, streets, homes, etc.) immediately connecting the space of origin (Watts et al., 2015; Hillier & Hanson, 1984). Integration refers to how a street is connected to other streets within the network by calculating how many turns there are from the original space (paths, streets, homes, etc.) to all other spaces (Watts et al., 2015; Hillier & Hanson, 1984).

We used space syntax to calculate each index value within 800 meters around the participants’ residence (chocho-aza point data: the smallest administrative unit used for the 1995 population census of Japan, roughly comparable to a European parish or a US block group) (Nakaya et al., 2014). Since we could not use the participants’ actual residential addresses, we used the latitude and longitude of a representative point in the participant’s residence, which had been identified through geocoding to the smallest administrative unit. To calculate connectivity and integration, first, we used the street network data in 2013 from Zenrin Co. Ltd and simplified the data in ArcGIS version 10.3.1 (Environmental Systems Research Institute, Redlands, CA, USA). Second, we imported the adjusted data into depthmapX software (settings: spatial model = segment, tulip bin = 1024, radius type = R800 metric) (University College London, n.d.), where the values for each street segment were calculated on space syntax theory (Turner, 2001; Marcus, 2003). Third, we assigned values to each street segment using QGIS version 3.8 (QGIS, 2019) to calculate each mean value of street connectivity and street integration within 800 meters of the center of each participant’s residence (Figs. 2, 3A, 3B). We set 800 meters as the buffer to be consistent with previous research findings of a correlation between older people’s behavior and environmental outcomes (Hess and Russell, 2012).

Covariates included sex (male or female), equivalent annual household income (<2, 2–3.99, or ≥4 million yen or data missing), educational attainment (≤9 or ≥10 years or data missing), marital status (married, widowed, divorced, never married, or data missing), living status (living alone, living with others, or data missing), driving status (car user, including receiving rides from others, or not a car user), frequency of going out (none/rarely, weekly, daily, or data missing), daily walking time (<30, 30–59, or ≥60 minutes or data missing), depressed or nondepressed measured by 15-item Geriatric Depression Scale (short form; GDS-15) (Yesavage & Sheikh, 1986), sidewalk coverage (≤8.0%, 8.1%–14.2%, or >14.2% sidewalk area within neighborhood unit/area of entire road within a neighborhood unit or data missing), and population density by tertile (<3,308.5, 3,308.5–9,088.6, or >9,088.6 people/km^2 school district). Time living in the neighborhood is considered to affect social interaction, so we included years of residence in 2016 (<10, 10–19, 20–29, 30–39, 40–49, or ≥50 years) in our model (Zuniga-Teran et al., 2017). Besides years of residence, all the covariates were assessed by questionnaire in the baseline survey (Saarloos et al., 2011; Nishida, Hanazato, and Koga, 2021). We categorized the covariates with missing data as “missing,” and our analysis included participants with missing data in each covariate.

Poisson regression analysis was performed to calculate the incidence rate ratio (IRR) and 95% confidence interval (CI) of a decrease in social interaction with neighbors after three years. Two stratified age groups were used for all analyses—young–old (<75 years) and old–old (≥ 75 years)—because it was assumed that functional ability and intrinsic capacity declined more in the old–old. We also conducted the sensitivity analysis stratified by urban and rural areas to check for differences between various population densities.

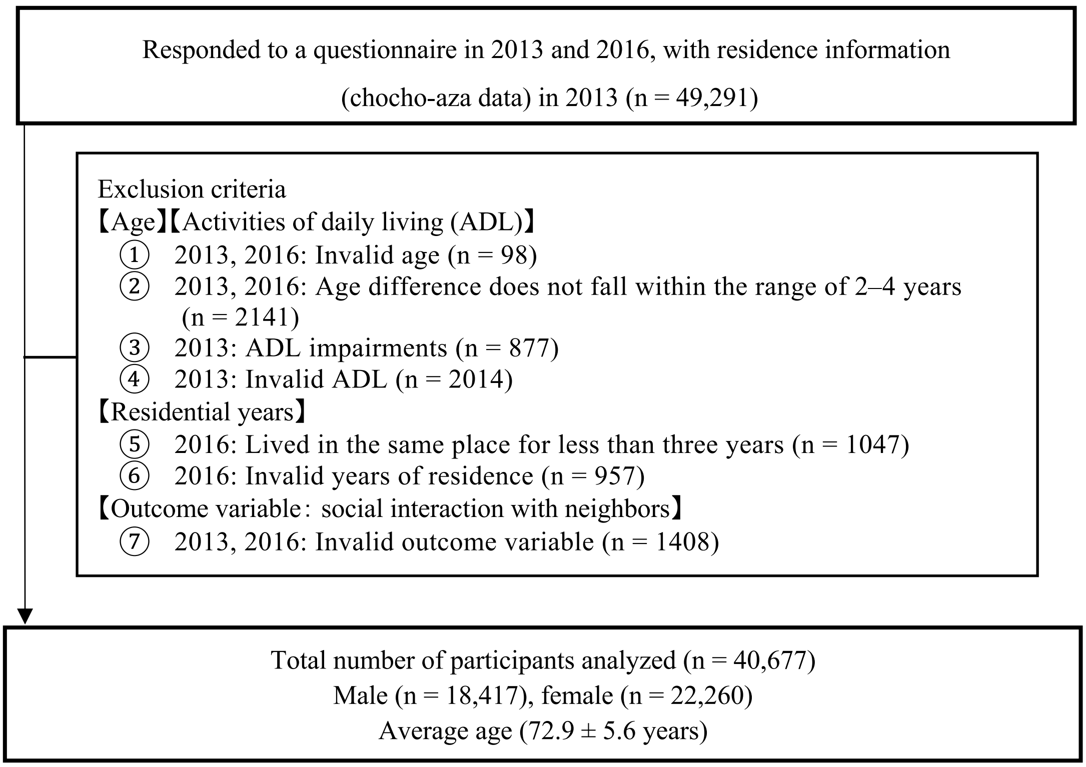

Fig. 1. Flowchart of participants in the study.

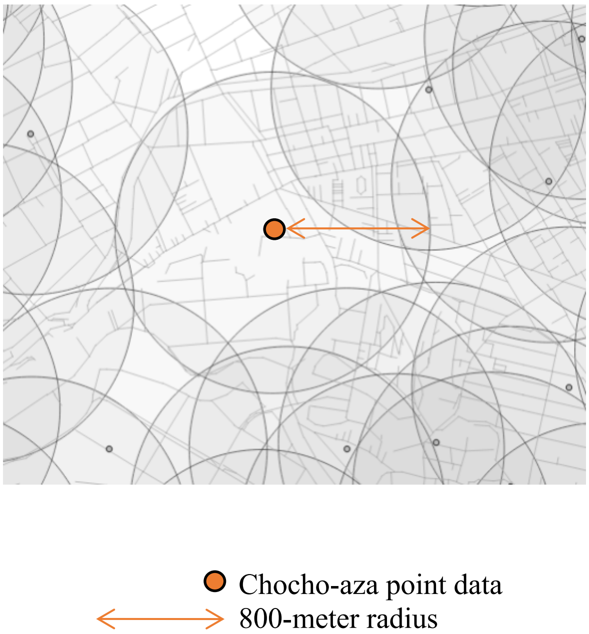

Figure 2: Representative point of residence information (chocho-aza point data) and 800-meter buffer.

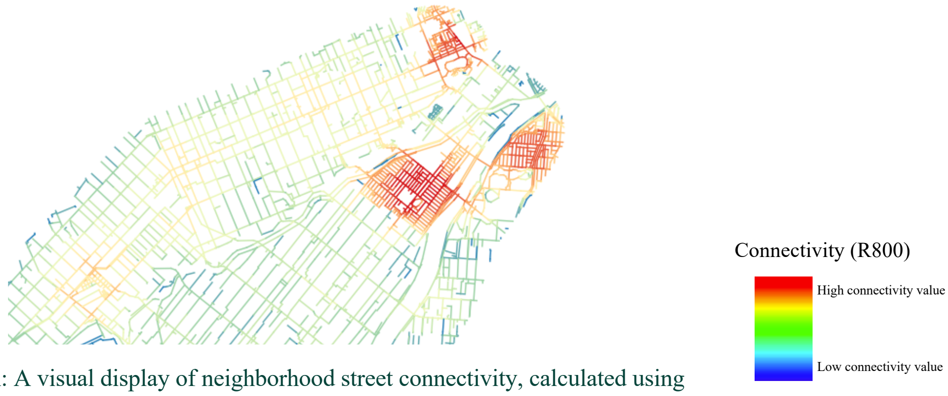

Figure 3A: A visual display of neighborhood street connectivity, calculated using space syntax analysis and color-coded (distribution setting: natural breaks (Jenks)) in QGIS.

Figure 3B: A visual display of neighborhood street integration, calculated using space syntax analysis and color-coded (distribution setting: natural breaks (Jenks)) in QGIS.

3 RESULTS

Among the 40,677 older adult participants, 15.1% (n = 6139) had decreased social interaction with neighbors at the three-year follow-up period, of whom 50.9% (n = 3122) were women. Moreover, among old–old, the participants in the decrease group outnumbered those in the group with no decrease (Table 1).

Table 2 presents the results of Poisson regression analysis for the study participants' characteristics and demonstrates the association between a decrease in social interaction and space layout after three years. We observed that decreased social interaction is negatively associated with street connectivity and street integration among old–old. As shown in model 1, compared with those living in low-connectivity areas, the decrease in social interaction after three years is 15% and 25% lower among participants living in areas with moderate (IRR = 0.85, 95% CI = 0.76–0.95) and high (IRR = 0.75, 95% CI = 0.65–0.87) street connectivity, respectively.

In model 2, social interaction decreased by 15% among participants living in areas with low integration, compared with moderate (IRR = 0.85, 95% CI = 0.76–0.95) street integration; and social interaction decreased by 24% among participants living in areas with low integration, compared with high (IRR = 0.76, 95% CI = 0.66–0.87) street integration.

The results for sensitivity analysis stratified by urban and rural area showed that point estimates of decrease in social interaction remained suppressed in the same direction among both young–old and old–old living in the rural areas with high-connectivity and high-integration (Table 3).

Table 1: Study participant characteristics divided by change in social interaction with neighbors (n = 40,677).

Characteristics (total numbers)	Change in social interaction with neighbors				χ^2
	No decrease		Decrease		*p*-Value
	No.	%	No.	%	
Sex					
Male (n = 18,417)	15,400	83.6	3,017	16.4	<0.001
Female (n = 22,260)	19,138	86.0	3,122	14.0	
Age group, years					
65–69 (n = 12,657)	10,878	85.9	1,779	14.1	<0.001
70–74 (n = 13,585)	11,590	85.3	1,995	14.7	
75–79 (n = 8,745)	7,367	84.2	1,378	15.8	
80–84 (n = 4,226)	3,519	83.3	707	16.7	
≥85 (n = 1,464)	1,184	80.9	280	19.1	
Education level, years					
≤9 (n = 16,313)	13,704	84.0	2,609	16.0	<0.001
≥10 (n = 23,844)	20,407	85.6	3,437	14.4	
Missing (n = 520)	427	82.1	93	17.9	
Equivalent household income, million yen					
Low (≤199) (n = 16,542)	13,897	84.0	2,645	16.0	<0.001
Mid (200–399) (n = 13,567)	11,650	85.9	1,917	14.1	
High (≥400) (n = 3,994)	3,464	86.7	530	13.3	
Missing (n = 6,574)	5,527	84.1	1,047	15.9	
Marital status					
Married (n = 29,854)	25,419	85.1	4,435	14.9	0.049
Widowed (n = 7,776)	6,565	84.4	1,211	15.6	
Divorced (n = 1,241)	1,041	83.9	200	16.1	
Never married (n = 889)	760	85.5	129	14.5	
Others/missing (n = 917)	753	82.1	164	17.9	
Living situation					
Living with others (n = 33,877)	28,857	85.2	5,020	14.8	<0.001
Living alone (n = 4,586)	3,857	84.1	729	15.9	
Missing (n = 2,214)	1,824	82.4	390	17.6	
Driving status					
Not a car user (n = 8,639)	7,330	84.6	1,309	15.4	0.86
Car user (n = 32,038)	27,208	84.4	4,830	15.6	
Outgoing frequency		84.9		15.1	
None/rarely (n = 901)	725	85.8	176	14.2	<0.001
Weekly (n = 7,936)	6,672	84.8	1,264	15.2	
Daily (n = 31,395)	26,775	84.8	4,620	15.2	
Missing (n = 445)	366		79		
Daily Walking time, minutes		83.6		16.4	
<60 (n = 23,157)	19,633	86.0	3,524	14.0	0.128
≥60 (n = 16,905)	14,398		2,507		
Missing (n = 615)	507	85.9	108	14.1	
Years of residence		85.3		14.7	
<10 (n = 1,711)	1,447	84.2	264	15.8	0.436
10–19 (n = 3,770)	3,180	83.3	590	16.7	
20–29 (n = 3,994)	3,390	80.9	604	19.1	
30–39 (n = 5,890)	5,053		837		
40–49 (n = 9,152)	7,758	84.0	1,394	16.0	
≥50 (n = 16,160)	13,710	85.6	2,450	14.4	

Table 1 continued

Characteristics (total numbers)	Change in social interaction				χ^2 *p*-Value
	No decrease		Decrease		
	No.	%	No.	%	
Depressive symptoms					
Nondepressed (GDS < 5) (n = 27,075)	23,110	85.4	3,965	14.6	<0.001
Depressed (GDS ≥ 5) (n = 7,679)	6,420	83.6	1,259	16.4	
Missing (n = 5,923)	5,008	84.6	915	15.4	
Tertiles of population density, people/km^2					
<3308.5 (n = 15,479)	12,984	83.9	2,495	16.1	<0.001
3308.5–9088.6 (n = 11,115)	9,426	84.8	1,689	15.2	
>9088.6 (n = 14,083)	12,128	86.1	1,955	13.9	
Sidewalk coverage (%)					
≤8.0% (n = 11,643)	9,784	84.0	1,859	16.0	0.013
8.1–14.2% (n = 11,793)	10,038	85.1	1,755	14.9	
>14.4% (n = 11,233)	9,568	85.2	1,665	14.8	
Missing (n = 6,008)	5,148	85.7	860	14.3	
Street connectivity					
Low (n = 13,565)	11,279	83.1	2,286	16.9	<0.001
Moderate (n = 13,554)	11,595	85.5	1,959	14.5	
High (n = 13,558)	11,664	86.0	1,894	14.0	
Street integration					
Low (n = 13,562)	11,297	83.3	2,265	16.7	<0.001
Moderate (n = 13,557)	11,601	85.6	1,956	14.4	
High (n = 13,558)	11,640	85.9	1,918	14.1	

χ^2 = chi-square test; GDS = 15-item Geriatric Depression Scale (short form; GDS-15)

Table 2: Poisson regression results for associations between social interaction and explanatory variables.

Model	**Stratified by age**					
	Young–old (n = 26,242)			Old–old (n = 14,435)		
Model 1: street connectivity	IRR	95% CI	*p*-Value	IRR	95% CI	*p*-Value
Low (28.0–1587.9)		Ref.			Ref.	
Moderate (1588.0–2114.1)	0.89	0.81–0.97	**0.006**	0.85	0.76–0.95	**0.004**
High (2114.6–4562.7)	0.93	0.83–1.03	0.167	0.75	0.65–0.87	**<0.001**
Model 2: street integration	IRR	95% CI	*p*-Value	IRR	95% CI	*p*-Value
Low (5.2–119.23)		Ref.			Ref.	
Moderate (119.24–162.08)	0.91	0.83–0.99	**0.023**	0.85	0.76–0.95	**0.003**
High (162.09–354.12)	0.95	0.86–1.06	0.351	0.76	0.66–0.87	**<0.001**

Ref. = reference group; IRR = incidence rate ratio; 95% CI = 95% confidence interval; *p*-Value = significant p values (<0.05) are in bold

Table 3: Poisson regression results for sensitivity analysis stratified by urban and rural.

	Urban (n = 19,571)						Rural (n = 21,106)					
	Young–old (n = 12,754)			Old–old (n = 6,817)			Young–old (n = 13,488)			Old–old (n = 7,618)		
Connectivity	IRR	95% CI	*p*-Value	IRR	95% CI	*p*-Value	IRR	95% CI	*p*-Value	IRR	95% CI	*p*-Value
Low		Ref.			Ref.			Ref.			Ref.	
Moderate	0.92	0.80–1.07	0.281	0.93	0.77–1.12	0.440	0.88	0.78–0.99	**0.038**	0.88	0.76–1.03	0.103
High	1.07	0.90–1.28	0.435	0.89	0.71–1.12	0.328	0.84	0.73–0.96	**0.011**	0.81	0.68–0.96	**0.018**
Integration	IRR	95% CI	*p*-Value	IRR	95% CI	*p*-Value	IRR	95% CI	*p*-Value	IRR	95% CI	*p*-Value
Low		Ref.			Ref.			Ref.			Ref.	
Moderate	0.94	0.82–1.13	0.332	0.96	0.82–1.12	0.564	1.00	0.90–1.13	0.884	0.92	0.80–1.05	0.227
High	0.97	0.81–1.12	0.591	0.92	0.79–1.08	0.317	0.85	0.75–0.97	**0.016**	0.79	0.67–0.94	**0.006**

Ref. = reference group; IRR = incidence rate ratio; 95% CI = 95% confidence interval
p-Value = significant p values (<0.05) are in bold

4 DISCUSSION AND CONCLUSIONS

For the relationship between street layout (connectivity and integration) and social interaction, old–old showed a significant positive association in both street layout indexes compared with young–old. Generally, old–old are less healthy than young–old, with a lower frequency of going out and lower daily walking duration. While old–old may have limited capacity, those living in high-connectivity and high-integration areas may still be able to access destinations (such as transportation hubs, shops, medical facilities, and community centers) and may ultimately have opportunities to interact with others. With increasing age, the environments that older people inhabit and how they interact with them are important since the neighborhood can develop and maintain the functional ability of older people and can eventually contribute to healthy aging (WHO, 2015). Among young–old, although the point estimations of street connectivity and street integration were in the same direction, there were no significant results in the high-connectivity and high-integration areas. High-connectivity and high-integration areas are considered to generate higher pedestrian volumes; however, as discussed in a previous study, people may encounter many strangers daily in high-density areas, especially in Asia. It is challenging to discern familiar faces in large populations; thus, interaction with others may be restricted (French et al., 2014; Koohsari et al., 2021).

In this study, similar results were found between street connectivity and street integration (Table 2). Both of these values evaluate neighborhood walkability (Frank et al., 2005; Koohsari et al., 2016). High-connectivity areas represent neighborhoods with many grids and streets with many turns, providing more pedestrian routes. The characteristics of high-integration regions with more straightforward navigation include higher pedestrian volume, information regarding transportation, and shops. Thus, the higher the street layout indexes are, the more chances of interaction an area provides.

Street connectivity and social interaction

Among old–old, we found that, with higher street connectivity, there was a lower incidence of decreased interaction after three years. Our result is consistent with the previous study, which reports that the perception of connectivity is positively associated with broadening the social network with friends and neighbors(Leslie and Cerin, 2008). Watts et al. (2015) discussed that, with higher street connectivity, there are more grids in the street network, providing short and direct routes and creating many alternative paths for access to a place. An America study used Global Positioning System to track pedestrians' walking routes and found that pedestrians tended to choose different routes for their daily round-trip (Bongiorno et al., 2021). That is, the higher the street connectivity is, the more alternative routes there are for people to walk in the street networks. Watts et al. (2015) also mentioned that areas with high intersection densities yield more potential routes and destinations for meeting and encountering people. Thus, such areas deliver more opportunities for social interaction. Contrarily, a previous study of Japanese adults (40–69 years old) reported that street connectivity (measured by the number of three-way or more intersections per km^2) was negatively associated with activities with neighbors (Koohsari et al., 2021). Additionally, their study found no association between perceived street connectivity and activities with neighbors. They suggested that traffic safety between pedestrians and vehicles is of concern in higher-connectivity areas, and thus, such areas might limit interactions. However, Koohsari et al. (2021) did not consider sidewalk coverage. Considering that high-connectivity areas carry heavy traffic, the presence of streets with sidewalks may ease safety concerns and may encourage pedestrians, thus not limiting interactions. Zuniga-Teran et al. (2017) discussed that neighborhood design type influences social interaction. Neighborhoods with low street connectivity—for example, a neighborhood with many cul-de-sacs or a gated community that is fenced on the outer boundary—may decrease the possibility for people to interact with others because such enclosed communities with low accessibility lead to fewer people passing through and a lack of diversity.

Street integration and social interaction

Koohsari et al. (2016) used street integration and population density to develop an alternative walkability index called space syntax walkability. They reported the first study using space syntax walkability to examine how it relates to Japanese adults' social interaction. However, the study results found a negative association between space syntax walkability and activities with neighbors (Koohsari et al., 2021). Because of the cross-sectional design, we do not know the causal relationship between space syntax walkability and activities with neighbors. Furthermore, the study focused more on middle-aged people, which means that the characteristics of working age and time of staying in the neighborhood may differ from older people. Compared with the results of our longitudinal study, we found that higher- and moderate-street-integration areas exert a protective effect from decreasing social interaction among both young–old and old–old. The central part of areas—usually with higher street integration—may increase walking behavior because there is no required complicated cognitive function for navigation. Moreover, one of the types of walking (walking for recreation, such as dog walking and exercise) showed significant association with social interactions because it may be more likely to yield simple communication or greeting of neighbors (Zuniga-Teran et al., 2017).

Strengths and limitations

The present study used longitudinal data to capture the change in social interaction over three years among young–old and old–old. Moreover, we excluded the participants that moved out during the study period; thus, we focused on the same built environment exposure among participants. To the best of our knowledge, only one cross-sectional study has been conducted on the relationship between social interaction with neighbors and street layout measured by space syntax. Therefore, the current study results provide the evidence to compare these findings with previous studies.

However, this study has several limitations. First, our study area was not randomly selected, so it may not necessarily reflect Japan as a whole. However, our study covered a wide range of regions across Japan, from north to south. Second, the participants' residential data that we used in the analysis may differ from the actual address. Due to privacy reasons, the chocho-aza data used in our study were only a relatively accurate representation of the participants' residential addresses. Third, we did not control the frequency of social interaction and social participation. For example, people who participate in cultural activities may know more neighbors than those who do not, and this may have influenced the study results. Fourth, the street layout values were measured with an 800-meter circular buffer, which may cause bias. As Koohsari et al. (2021) discussed, a circular buffer may not genuinely represent the built environment attributes to which participants were exposed. Thus, our findings need to be replicated in different types of spatial buffers in further studies.

In conclusion, we discovered that better street layout is associated with lower incidence of decreased social interaction among old–old people in Japan. This research provides supporting evidence to inform urban design to aid in healthy community development.

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AVAILABILITY OF DATA AND MATERIALS

Data are from the JAGES study. Please contact JAGES data management committee and Email dataadmin@jages.net requests for access.

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