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ABSTRACT

Despite associations found between physical activity and depression, and the built environment and physical activity, there appears to be inconclusive evidence regarding the role of built environment attributes with preventing depression among the elderly. This is mainly because few studies exist on this topic. In addition, the majority of existing studies have been conducted in Western countries; and there is a dearth of studies in other regions, where the built, social, and cultural environment is different than Western countries. Using data from Japanese older adults, this study examined the associations between objectively-assessed built environment attributes and depressive symptoms. We examined these associations stratified by gender, since research has well-documented gender differences in depression. Data were from 328 older adults living in Japan. Built environment attributes were objectively calculated and Walk Score® ratings were obtained from the website. Depressive symptoms were assessed using the GDS-15. Gender-stratified regression models were used to estimate the associations. We found that a walkable environment characterized by a high population density and proximate local destinations to be supportive for a better mental health among older adults, in particular for women. These findings suggest that walkable built environment attributes may influence depression among older women in an Asian urban context. This study contributed to the literature by examining how walkable urban design may influence elderly's depression in a setting with extreme level of environmental attributes. Investing in urban design to promote walkability may help in reducing the observed gender gap in depression in the Japanese population.

1. Introduction

Understanding of and interest in the role of urban design in facilitating physical activity promotion and depression mitigation among older adults has increased rapidly in the past decade. However, the majority of existing studies have been conducted in Western countries; and there is a dearth of studies in other regions. For example, research on these topics in Asian contexts is almost completely non-existent, where the built, social, and cultural environment is different than Western countries. A recent review on studies on living environment and depressive mood found only 3 out of 57 studies conducted in Asia, and none of them particularly focused on older adults (Rautio, Filatova, Lehtiniemi, & Miettunen, 2018). Environmental characteristics of Asian cities such as population density, road density, and public transport are different compared with many Western cities (Shelton, 2012; Sugiyama, Inoue, Cerin, Shimomitsu, & Owen, 2015). Therefore, the results of previous studies conducted in Western regions may be less applicable to Asia. In addition, and more importantly, research in Asia can contribute to the international body of knowledge by testing to what extent environmental attributes at the upper end of the spectrum (e.g., population density, availability of destinations) influence depression.

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Using data from Japanese older adults, this study aimed to understand the influence of neighbourhood physical environment on depressive symptoms. We examined these associations stratified by gender, since research has well-documented gender differences in depression (Parker & Brotchie, 2010; Van de Velde, Bracke, & Levecque, 2010). The study objectives were:

- To examine associations between objectively-assessed built environment attributes including population density, availability of destinations, intersection density, distance to train stations, and Walk Score® with depressive symptoms.
- To examine whether or not gender moderates associations between these built environment attributes and depressive symptoms.

2. Literature review

Older adults' depression is a growing major public health issue worldwide; because of its serious consequences (The National Alliance on Mental Illnes, 2009). Depression can negatively affect physical health, and is associated with increased death and disability among older adults (Karakus & Patton, 2011; Rodda, Walker, & Carter, 2011). There are several risk factors such as gender, having chronic illness, medication use, disability, and health habits (e.g., severe alcohol use, smoking, and physical inactivity) for depression in the elderly (Mental Health America, 2017; Sözeri-Varma, 2012; Vink, Aartsen, & Schoevers, 2008). For example, a systematic review of prospective studies has shown participation in any level of physical activity to be related with a reduced risk of developing depression (Mammen & Faulkner, 2013). While individual-based approaches (e.g., medication treatment, counselling) remains important in treating depression, the increasing prevalence of depression in older adults (World Health Organization, 2017) has resulted in a growing recognition of the need for population-based approaches for the prevention and possible treatment and management of depressive symptoms (Rautio et al., 2018).

Socio-ecological models in health emphasise the role of the built environment on people's health behaviours and outcomes (Sallis & Owen, 2015). The built environment refers to "the human-made space in which people live, work, and recreate on a day-to-day basis" such as neighbourhoods, houses, stores, roads, parks, and workplaces (Roof, 2008). Socio–ecological models have been used as a theoretical basis to understand the environmental determinants of depression among older adults. There have been a growing number of studies examining associations between built environment with older adults' depressive symptoms in the last decade. It is hypothesized that built environment attributes may influence depression through several pathways, especially via physical activity (Barnett, Zhang, Johnston, & Cerin, 2017; Julien, Richard, Gauvin, & Kestens, 2012). Several built environment attributes have been found to be associated with older adults' active behaviours (Cerin et al., 2016; Hanibuchi, Kawachi, Nakaya, Hirai, & Kondo, 2011; Thornton et al., 2017; Van Holle et al., 2014). For example, a US study found higher intersection density, more land use mix, availability of walking/cycling facilities, and availability of private recreational facilities to be positively associated with walking for errands among the elderly (Thornton et al., 2017). Another study conducted in Japan found higher population density and availability of parks to be associated with higher leisure physical activity in older adults (Hanibuchi et al., 2011). Moreover, a recent study undertaken in Finland found higher neighbourhood walkability to be associated with higher physical activity among the elderly (Portegijs, Keskinen, Tsai, Rantanen, & Rantakokko, 2017).

Despite associations found between physical activity and depression, and the built environment and physical activity, there appears to be inconclusive evidence regarding the built environment attributes associated with depression among the elderly (Barnett, Zhang, et al., 2017; Mair, Roux, & Galea, 2008). For example, one of the early studies on this topic conducted in the US found a significant association between neighbourhood walkability and depression in older men (but not older women): those who lived in more walkable areas reported less depressive symptoms (Berke, Gottlieb, Moudon, & Larson, 2007). Another US study found better perceived safety from traffic and crime to be associated with lower depressive symptoms among an older population (Ivey et al., 2015). Hernandez et al. (2015) found cross-sectional associations between better perceived safety from crime and lower depression in older adults; however, they found no associations between perceived neighbourhood walkability attributes and incident depressive symptoms after one or two years of follow-up. Moreover, a recent US study, using a nationally representative sample, found no association between objectively-measured neighbourhood greenness and depression (Pun, Manjourides, & Suh, 2018). Similarly, in an Australian study no associations between availability of public open spaces and depressive symptoms were found (Koohsari et al., 2018).

There are several reasons for the observed inconsistencies in the evidence based on associations between built environment attributes with older adults' depressive symptoms. First, this is mainly because few studies exist on this topic (Barnett, Zhang, et al., 2017; Julien et al., 2012). A recent review using meta-analysis found a noticeable lack of studies on physical (and built) environment and older adults' depression outcomes (Barnett, Zhang, et al., 2017). Second, there is a lack of spatial variability in the previous studies examining the role of built environment attributes on older adults' depression. Specifically, almost the majority of these studies conducted in the homogeneous residential built environments (i.e., low density, sprawl, and car-dependent) in the US (Barnett, Zhang, et al., 2017). It is not clear yet how extreme levels of environmental attributes may influence depressive symptoms. For instance, while several studies suggest that higher population density might lead to increased physical activity (and physical activity reduces depression) (Sallis et al., 2016; Troped, Wilson, Matthews, Cromley, & Melly, 2010), other evidence suggests that crowding in public areas may have negative consequences for mental health via stress and depression (Lederbogen et al., 2011; Sundquist, Frank, & Sundquist, 2004). Lastly, there is limited knowledge on the moderation effects of gender in associations between neighbourhood physical environment and older adults' depression. The current study aims to address these issues in investigating the associations between walkable built environment attributes and elderly's depression. It contributes to shed light on how built environment attributes may influence elderly's depression in an unexplored setting with extreme environmental attributes according to gender.

3. Methods

3.1. Study area

Matsudo city is located in the northwest of Chiba prefecture, Japan, and about 20 km to the north east of Tokyo with an area about 61.38 km^2. The city has a population around half a million residents (as of January 2017), which made it the 29th largest in Japan. Matsudo city is considered as a bedroom community for Chiba and Tokyo, and a regional commercial centre. Matsudo city is usually hot and rainy during summer, and dry and sunny during winter (www.city.matsudo.chiba.jp). Various types of public transportation including trains, buses, and taxis are available in Matsudo city, and the car ownership is low compared with other areas in Japan (Zhang, 2008). There are six train lines in Matsudo city which serve 20 train stations throughout the city (Fig. 1).

3.2. Study participants and procedures

This study forms part of a larger epidemiological study (Matsudo study), conducted at Faculty of Sport Sciences at Waseda University, exploring associations between social and physical environmental features and health among older adults living in Matsudo city. In 2013, an

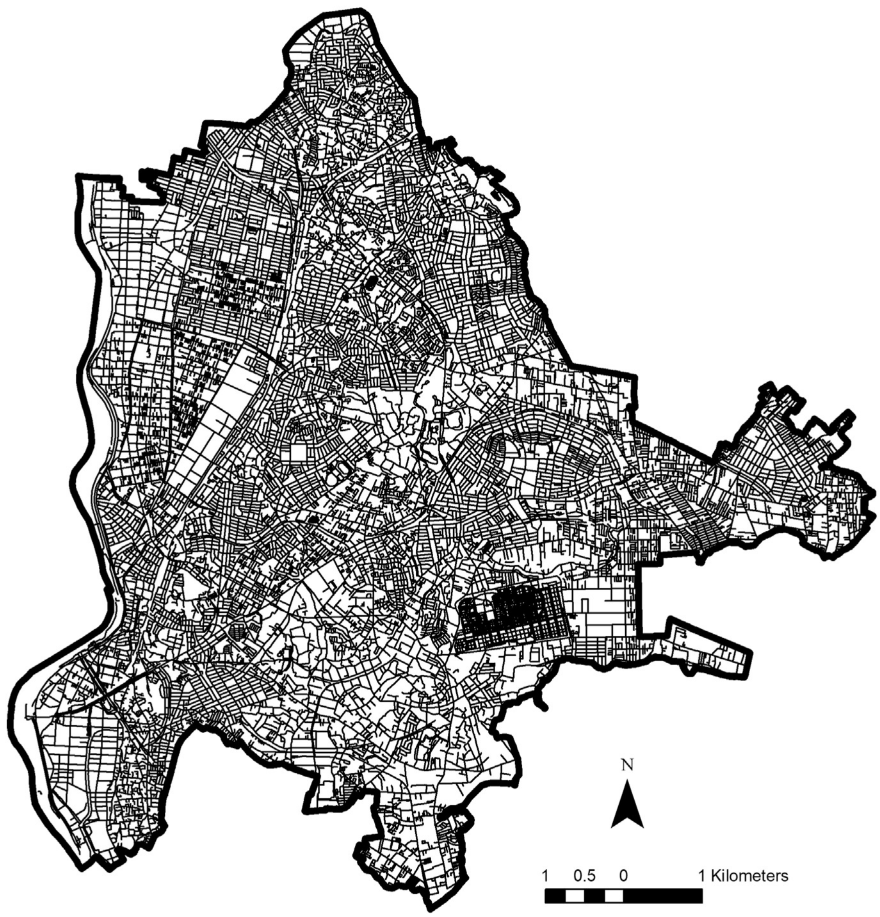

Fig. 1. Matsudo City, Chiba Prefecture, Japan.

invitation letter was mailed to 3000 randomly-selected residents aged 65–84 years old (one elderly from each household) chosen from the registry of residential addresses of total community-dwelling older adults aged 65–84 years living in Matsudo (N = 107,928, April 2013). Of these, 951 (31.7%) agreed to attend in the main study of which a further 349 (37.7%) also agreed to participate an on-site examination conducted in several community centers across Matsudo City (October to December 2013) including self-administered questionnaire, and other health assessment (e.g., physical function and body composition tests). Participants received a book voucher (¥1000) after completing the on-site examination. Written informed consent was obtained from all participants. The Institutional Ethics Committee of Waseda University (2013–265) and the Institutional Review Board of Chiba Prefectural University of Health Sciences (2012–042) granted ethics approval for the study. This study focusses only on those participants who completed the on-site examination (n = 349).

3.3. Data collection

On-site examination was conducted at several local community centers across Matsodu city on weekdays and weekends over three months (October to December 2013). As a part of the on-site examination, participants were asked to answer paper-based self-administered questionnaires capturing sociodemographic information and depressive symptoms. In addition, cognitive function was assessed by a trained research team member. The duration of each on-site examination was about two hours.

4. Measures

4.1. Depressive symptoms

Depressive symptoms were assessed using the Japanese version of the 15-item Geriatric Depression scale (GDS-15) (Niino, 1991; Yesavage et al., 1982). The GDS-15 items capture depressive symptoms felt over the past week on a yes/no response format. For 10 items, the answer 'yes' is given a score of 1, and for 5 items the answer 'no' a score of 0. In the 5 items, this scoring is reverse (1 to 'no' answer, 0 to 'yes' answer). Item responses are summed with the total score ranging from 0 to 15 (higher scores indicate more depressive symptoms). The GDS-15 score has been used both as continuous and categorical variables elsewhere (Cron et al., 2016). Consistent with other studies (Almeida & Almeida, 1999; Honjo et al., 2018; Schreiner, Hayakawa, Morimoto, & Kakuma, 2003; Wancata, Alexandrowicz, Marquart, Weiss, & Friedrich, 2006), we used a GDS-15 cut-off score of 5 or more to indicate the presence of clinically depressive symptoms (GDS-15 $<$ 5 to '0', GDS-15 $\geq$ 5 to '1'). We also examined GDS-15 continuous score as an outcome.

4.2. Covariates

The following sociodemographic characteristics were reported by the participants: age, gender, educational attainment (tertiary or higher, below tertiary), living status (alone, with others), working status (working with income, on pension), marital status (single, couple), and economic circumstances (very poor/poor, good/very good). These sociodemographic characteristics were considered as covariates in the previous studies on environment and depression symptoms (Julien et al., 2012). In addition, number of chronic disease and cognitive function were both assumed to be risk factors for depression (Chen, Lee, Su, Mullan, & Chiu, 2017; McDermott & Ebmeier, 2009). For example, a longitudinal study found a relationship between chronic diseases and mental health disorders among older adults (Chen et al., 2017). Another review using meta-analysis found cognitive function to be associated with depression (McDermott & Ebmeier, 2009). Participants reported their number of chronic diseases from a list including hypertension, cerebrovascular diseases, cardiovascular disease, diabetes, dyslipidemia, gout, peripheral vascular diseases, osteoporosis, and cancer (based on medical professional diagnosis), and the length of time in residence at their current address. The use of the number of chronic diseases measure was similar with previous studies examining associations of neighbourhood conditions with depression (Aneshensel et al., 2007; Gerst et al., 2011; Saarloos, Alfonso, Giles-Corti, Middleton, & Almeida, 2011; Yen, Rebok, Yang, & Lung, 2008). Cognitive function was assessed using the validated Japanese version of the Medical Outcomes Survey Short Form-8 questionnaire (Fukuhara & Suzukamo, 2004).

4.3. Built environment attributes

Built environment attributes were calculated using geographic information systems (GIS) software within 800 m and 1600 m network-based buffers around participants' geocoded household addresses. These chosen buffer sizes were consistent with several previous studies examining built environmental determinants of older adults' health behaviour and outcomes (Kerr et al., 2014; Troped et al., 2014). Four specific objectively-measured built environment attributes including population density, availability of destinations, intersection density, and distance to train stations, as well as a composite measure of walkability (Walk Score®) were estimated for this study. These attributes were selected based on the previous studies showing their associations with older adults' walking behaviours (Barnett, Barnett, Nathan, Van Cauwenberg, & Cerin, 2017; Van Cauwenberg et al., 2018; Cerin, Nathan, Van Cauwenberg, Barnett, & Barnett, 2017). Population density was calculated as the density of each buffer area excluding water and no-population zone. The no-population zone was specified by the Half Grid Square of population census 2010 (approximately 500 m by 500 m grid cell). Availability of destinations was defined as the total number of nine types of local destinations including banks, book stores, convenience stores, elementary schools, community centres, post offices, restaurants, supermarket/department stores, and sports/fitness clubs calculated within each buffer. The telephone directory data 2015 and the National Land Numerical Information 2010–2013 were used to obtain destinations data. Intersection density was measured as the ratio of three-way or more intersections per km^2 using data from the Digital Map (Basic Geospatial Information) 2015. Distance to train stations was defined as the road network-based distance to the nearest train station (meters). Walk Score®, a free online walkability tool, was used as a composite measure of the built environment. Walk Score® has been recently validated in Japan, as a measure of Walkability (Koohsari et al., 2018). It calculates the walkability of a location by measuring its access to a variety of destinations and street connectivity around that location within 1.6 km network-based buffer (Front Seat Management, 2017). Walk Score® ranges from 0 to 100, where higher scores mean more opportunities to walk around a location. Walk Score® were obtained manually for each participant's residential home address from their website (www.walkscore.com) by two independent project assistants in 2016. Compatibility between the Walk Score® values extracted by two members was checked by the first author. Walk Score®, as a composite measure of walkability, can be easily calculated using a free online website without the need of any special software or GIS expertise. While Walk Score® provides an overall picture of built environment attribute; it is still a composite measure. This means, similar with other walkability composite measures, it cannot provide information about specific individual-built environment attribute necessary to promote walkability. Such detailed information about individual-built environment attributes are still necessary for urban designers and policy makers. That is why in this study we included both individual-built environment measures and a composite measure of walkability, Walk Score®.

4.4. Statistical analysis

Descriptive statistics including means (and standard deviations) and frequencies were estimated for all sociodemographic, health, depression, and built environment attributes stratified by gender. We estimated the linear associations between our built environment attributes (population density, availability of destinations, and intersection density for the 400 m and 1600m buffers, distance to train stations, and Walk Score®) using Pearson's correlations. Gender-stratified multivariable linear and binary logistic regression models were used to estimate the association between each built environment variable (measured at the 800 m and 1600 m buffers) and depressive symptoms (continuous or categorical), adjusted for all sociodemographic and health variables (checked for normality). Since only one built environment variable was included per each model plus covariates; multicollinearity between these variables was not a concern. All built environment attributes were standardized (i.e., z-scores) prior to the regression analysis. For all point estimates (Beta(B): linear regression and Odd ratios(OR): logistic regression) 95% confidence intervals were estimated. Analyses were conducted using Stata 15.0 (Stata Corp, College Station, Texas).

5. Results

5.1. Sample characteristics

In total, 328 participants providing complete data were included in this study (excluding 21 participants who had missing or invalid data). In our sample, the mean (± standard deviation) age was 74.7 ± 5.3 SD years, more than half (62.9%) were men, more than one-third (36.9%) completed tertiary or higher education, and about 80% were part of a couple. These proportions differed significantly between women and men (all $p < 0.01$). In women, the mean (± standard deviation) age was 73.8 ± 5.1 years, 24.2% completed a tertiary or higher education, and 72.6% were part of a couple; these figures were higher in men: 75.2 ± 5.3, 44.6%, and 84.3%, respectively (Table 1). The mean (± standard deviation) GDS-15 score was 2.9 ± 3.1 with a median of 2.0. Based on a GDS-15 ≥ 5 (criteria for clinically depressive symptoms), 22.9% participants had depressed mood. We found no significant differences in the number of depressive symptoms between men and women (Table 1).

Correlations between built environment attributes within 800 m and 1600 m of participant's homes were in the expected direction (Tables 2 and 3). Population density was most strongly correlated with the availability of destinations and Walk Score® for the 800 m ($r = 0.54$ and $r = 0.74$) and 1600 m (r = 0.74 and $r = 0.68$) buffers, respectively. Not surprisingly, Walk Score® was also strongly positively correlated with availability of destinations at the 800 m ($r = 0.62$) and 1600 m ($r = 0.61$) buffers. Distance to train stations was negatively correlated with all other built environment attributes. Despite being statistically significant ($p < 0.05$), the weakest correlations were found between intersection density for the 800 m and 1600 m buffers and all other built environment attributes (Tables 2 and 3).

5.2. Associations between built environment attributes and depressive symptoms

Among women, adjusting for all covariates, a one standard deviation increase in population density within 800 m of home was associated with a 0.54 (95%CI −1.00, −0.07, p = 0.02) decrease in

Table 1
Characteristics of study participants (n = 328).

Variable	Mean (SD) or N (%)			p[a]
	Total	Women (n = 124)	Men (n = 204)	
Age (years)	74.7 (5.3)	73.8 (5.1)	75.2 (5.3)	< 0.01
Education				
Tertiary or higher	121 (36.9)	30 (24.2)	91 (44.6)	< 0.01
Below tertiary	202 (61.6)	93 (75.0)	109 (53.4)	
Missing	5 (1.5)	1 (0.8)	4 (2.0)	
Living status				
Alone	39 (11.9)	19 (15.3)	20 (9.8)	ns
With others	284 (86.6)	104 (83.9)	180 (88.2)	
Missing	5 (1.5)	1 (0.8)	4 (2.0)	
Working status				
Working with income	83 (25.3)	25 (20.2)	58 (28.4)	ns
On pension	244 (74.4)	99 (79.8)	145 (71.1)	
Missing	1 (0.3)	–	1 (0.5)	
Marital status				
Single	58 (17.7)	33 (26.6)	25 (12.3)	< 0.01
Couple	262 (79.9)	90 (72.6)	172 (84.3)	
Missing	8 (2.4)	1 (0.8)	7 (3.4)	
Economic circumstances				
Very poor/poor	130 (39.6)	49 (39.5)	81 (39.7)	ns
Good/very good	196 (59.8)	75 (60.5)	121 (59.3)	
Missing	2 (0.6)	–	2 (0.1)	
No of chronic diseases	1.3 (1.2)	1.6 (0.9)	1.4 (1.1)	ns
Length of residence (years)	30.9 (15.6)	30.6 (13.8)	31.1 (16.7)	ns
Cognitive function (MMSE score)	27.6 (2.7)	27.4 (3.4)	27.7 (2.2)	ns
Depression score (GDS-15 score)	2.9 (3.1)	2.9 (2.9)	2.9 (3.1)	ns
Depression (presumed from GDS-15 ≥ 5)				
Yes	75 (22.9)	23 (18.5)	52 (25.5)	ns

[a] Based on independent *t*-test or Chi-squared test.

depressive symptoms (Table 4). A one standard deviation increase in availability of destinations within 800 m (B -0.59, 95%CI −1.14, −0.04, p = 0.04) was also associated with a decrease in depressive symptoms. Further, a one standard deviation increase in availability of destination within 1600 m (B −0.42, 95%CI −0.89, 0.05, p = 0.08), Walk Score® (B −0.50, 95%CI −1.00, 0.01, p = 0.05), and decrease in distance to the nearest train station (B 0.45, 95%CI −0.04, 0.93, p = 0.07) were marginally associated with a decrease in depressive symptoms among women. Notably, among men, adjusting for all covariates, none of the built environment attributes were significantly associated with an increase or decrease in depressive symptoms (Table 4).

Among women, adjusting for all covariates, there was an association between higher availability of destinations within 1600 m of home and lower odds of having a depressed mood (OR 0.32 95%CI 0.13, 0.80, p = 0.01). In addition, increases in population density within 800 m of home, availability of destinations within 800 m of home, and Walk Score® were marginally associated with lower odds of attaining a GDS-15 score ≥ 5 among women (OR 0.46 95%CI 0.21, 1.00, p = 0.05, OR 0.31 95%CI 0.09, 1.03, p = 0.06, and OR 0.54 95%CI 0.26, 1.11, p < 0.10, respectively) (Table 5). Among men, adjusting for all covariates, none of the built environment attributes were significantly associated with attaining a GDS-15 score ≥5.

6. Discussion

This was the first study, to our knowledge, to examine the associations of objectively-measured walkable built environment attributes with older adults' depression symptoms in Japan. Much of what is known in terms of built environment-physical activity relationship and the physical activity-depression relation is based on populations in non-Asian countries. It cannot be assumed based on this previous evidence that a walkable environment will be associated with depression among Japanese older adults. This study contributed to the literature by examining how walkable built environment attributes may influence elderly's depression in a setting with extreme level of environmental attributes according to gender. Similar to some previous studies (Hernandez et al., 2015), we found that a walkable environment characterized by a high population density and proximate local destinations to be supportive for a better mental health among older adult women. Our findings extended previous research by testing how such built environment attributes influence depression in an unexplored Asian context such as Japan. Investigating the environmental correlates of depression in Japan, where built environment attributes are at the highest end of the walkable spectrum can provide new insights for environment-depression dose-response relationships. Unique attributes of many Japanese cities, such as intense densification and well-developed public transit systems provide an opportunity to inform international research on the influence of high levels of built environment attributes on depression.

We found higher population density, availability of destinations, and Walk Score® to be associated with lower depressive symptoms among women. It is likely that these attributes provide opportunities for women to walk. These environmental attributes may also increase opportunities for community participation and social interactions (Molly, Michael, Rawan, & Julie, 2015; Zhu, Yu, Lee, Lu, & Mann, 2014), which similar to walking is found to improve depression in the elderly (Forsman, Nyqvist, Schierenbeck, Gustafson, & Wahlbeck, 2012). We also found those women who have a better access to transportation stations were less likely to report depressive symptoms. Opportunities to interact and mobility (especially for those who have no cars) decrease in areas with lower access to train stations. Future studies are necessary to examine the pathways through which walkable

Table 2
Pearson's correlations between built environment attributes with 800 m of home (network buffer), distance to train stations, and Walk Score®.

Built environment attributes	Population density	Availability of destinations	Intersection density	Distance to train stations	Walk score®
Population density per km^2		0.54**	0.25**	−0.42**	0.74**
Availability of destinations			0.13*	−0.44**	0.62**
Intersection density per km^2				−0.16**	0.26**
Distance to train stations (meters)					−0.42**
Walk Score®					
Mean (SD)	9935.55 (2470.55)	55.35 (55.25)	294.86 (54.52)	1060.50 (518.61)	79.60 (10.93)

** p < 0.001.
* p < 0.05.

Table 3
Pearson's correlations between built environment attributes with 1600 m of home (network buffer), distance to train stations, and Walk Score®.

Built environment attributes	Population density	Availability of destinations	Intersection density	Distance to train stations	Walk score®
Population density per km²		0.74**	0.32**	−0.38**	0.68**
Availability of destinations			0.29**	−0.49**	0.61**
Intersection density per km²				−0.13*	0.26**
Distance to train stations (meters)					−0.42**
Walk Score®					
Mean (SD)	9125.83 (1811.37)	200.46 (98.47)	286.53 (35.76)	1060.50 (518.61)	79.60 (10.93)

** $p < 0.001$.
* $p < 0.05$.

Table 4
Multivariable linear regression estimated associations (*B* and 95CI) between built environment attributes and depressive symptom score.

Built environment attributes (z-scores)	Depressive symptoms score	
	Women (n = 124)	Men (n = 204)
	B (95CI)	B (95CI)
Population density		
Within 800 m buffer	−0.54 (−1.00, −0.07)*	−0.31 (−0.70, 0.09)
Within 1600 m buffer	−0.32 (−0.81, 0.18)	−0.12 (−0.52, 0.28)
Availability of destinations		
Within 800 m buffer	−0.59 (−1.14, −0.04)*	0.06 (−0.31, 0.43)
Within 1600 m buffer	−0.42 (−0.89, 0.05)[a]	0.10 (−0.31, 0.52)
Intersection density		
Within 800 m buffer	−0.16 (−0.59, 0.27)	0.14 (−0.28, 0.56)
Within 1600 m buffer	−0.24 (−0.69, 0.20)	0.17 (−0.25, 0.58)
Distance to train stations	0.45 (−0.04, 0.93)[a]	0.27 (−0.13, 0.67)
Walk score®	−0.50 (−1.00, 0.01)[a]	−0.06 (−0.49, 0.37)

Note: B: regression slope coefficient; CI = confidence interval; All models adjusted for age, education, living status, working status, marital status, economic circumstances, number of chronic diseases, length of residence, and cognitive function. Only one built environment variable was included per each model plus covariates.
* $p < 0.05$.
[a] $p < 0.10$.

Table 5
Multivariable logistic regression estimates associations (odds ratios and 95%CI) between built environment attributes and having a depressed mood (presumed from GDS-15 ≥ 5).

Built environment attributes (z-scores)	Depression	
	Women (n = 124)	Men (n = 204)
	OR (95CI)	OR (95CI)
Population density		
Within 800 m buffer	0.46 (0.21, 1.00)[a]	0.82 (0.56, 1.20)
Within 1600 m buffer	0.61 (0.29, 1.28)	0.95 (0.66, 1.38)
Availability of destinations		
Within 800 m buffer	0.31 (0.09, 1.03)[a]	1.06 (0.76, 1.49)
Within 1600 m buffer	0.32 (0.13, 0.80)*	1.05 (0.71, 1.55)
Intersection density		
Within 800 m buffer	0.97 (0.62, 1.51)	1.34 (0.91, 1.97)
Within 1600 m buffer	0.85 (0.50, 1.44)	1.30 (0.89, 1.90)
Distance to train stations	1.49 (0.74, 3.00)	1.19 (0.81, 1.75)
Walk score®	0.54 (0.26, 1.11)[a]	0.96 (0.65, 1.42)

Note: OR: odds ratio; CI = confidence interval; All models adjusted for age, education, living status, working status, marital status, economic circumstances, number of chronic diseases, length of residence, and cognitive function. Only one built environment variable was included per each model plus covariates.
* $p < 0.05$.
[a] $p < 0.10$.

built environment attributes influence older adults' depression. None of built environment attributes were found to be associated with depression among men. These findings indicate that older men's depression may be less impacted by environmental attributes. These results were in contrast with two previous studies contacted in the US and Australia which found neighbourhood walkable attributes to be associated with depressive symptoms among older men (Berke et al., 2007; Saarloos et al., 2011). Unlike a Western context, older men's mental health in an Asian context may be more related to social context such as belonging to a club or social activities. Population-based interventions modifying the social and physical environmental contexts may need to be tailored for older Japanese men and women, if they are to have a positive impact on depression (Haseda et al., 2017). Our findings raise possible equity challenges for broader international context, especially in cases where the same built environment characteristics differentially impact mental health of population subgroups (e.g., men vs. women).

6.1. Future research

This study had some limitations. As a cross-sectional study, we were unable to draw a causal link between the built environment and depression. Future studies using prospective designs to estimate temporal causal relations between the built environment and depression are needed to confirm our findings. Moreover, we were not able to account for residential self-selection in our analysis (i.e., older adults may choose to reside in neighbourhoods that match their behavioural preferences and possibly or in turn their physical or psychological health status). Self-reported measure of depressive symptoms may be also subject to recall and social desirability bias. Future studies need to explore associations between walkable environmental attributes with other objective indicator of depression such as medication use. Another limitation is that this study had a relatively low response rate and our participants were not a representative sample of Japanese older adults (i.e., were more active and healthy). These may limit the generalisability of our findings and introduce some bias. There was a temporal difference between data collection from participants and spatial data for calculation of built environment attributes. However, since participants came from established built out neighbourhoods, major changes in environmental characteristics such as population density, street layouts, and train stations are likely to be slow. Future studies can also use advanced geostatistical models that account for spatial autocorrelation.

6.2. Conclusions and urban design policies recommendations

Over the last decade, there has been overwhelming evidence over the role of neighbourhood environment attributes on older adults' active behaviours. A recent systematic review using meta-analysis found a neighbourhood with an easy access to shops, public transport, recreational facilities, and well-maintained and safe footpaths support older adults walking and cycling activities (Cerin et al., 2017). A well-connected street network has been also found to be supportive for older adults' walking (Kerr, Rosenberg, & Frank, 2012). More connected street network can provide shorter distance and more rout options between origins and destinations (Dill, 2004; Handy, Paterson, & Butler, 2003). Several studies have found that neighbourhood attributes may also influence depressive symptoms among elderly (Barnett, Zhang, et al., 2017; Julien et al., 2012; Rautio et al., 2018). In line with these evidences, our study also suggests that some walkable built environment attributes may influence depression among older women in an Asian context, where environmental attributes are at their extreme levels. Providing evidence that links urban design to health outcomes (not just health behaviours) is important for increasing awareness of the importance of urban and transportation planning for creating health supportive environments among policymakers, practitioners, and the public. The key message of our study for urban designers and planners is that (re)designing neighbourhood to promote active behaviours not only can promote older adults' walking, but also can promote better mental health. There are several ways through which urban designers and planners can promote neighbourhood walkability. First, walkability can be enhanced through design codes and guidelines for urban regenerations and (re)developments by encouraging a more dense and compact development, supporting mixed-use, and maintaining a well–connected network of footpaths. Second, residents' perceptions about their neighbourhoods are important in their active behaviours (Koohsari, Sugiyama, et al., 2018). Therefore, walkability can also be improved by understanding residents' perceptions about their neighbourhoods. Our study also suggests that investing in urban design and planning to promote walkability may help in reducing the observed gender gap in depression in the Japanese population.

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