



Longitudinal associations between neighbourhood physical environments and depressive symptoms of older adults in Hong Kong: The moderating effects of terrain slope and declining functional abilities

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ABSTRACT

Little is known about the accumulative impacts of neighbourhood physical environments on older adults' depressive symptoms over time. Based on a cohort study of 2081 older adults in Hong Kong, this study examined longitudinal relationships between neighbourhood physical environments and depressive symptoms among older adults, with a particular focus on the moderating effects of terrain slope and individual functional ability using latent growth curve modelling. Results indicated that the availability of community centres and passive leisure facilities reduced depressive symptoms over time. The protective effects of residential surrounding greenness on depressive symptoms among older adults differed by the terrain slope types. Longitudinal associations between neighbourhood physical environments and depressive symptoms varied between older adults with and without functional limitations. This study has implications for the Ecological Theory of Ageing by identifying the dynamic interplay of environment demands and individual functional ability. Planning policies for building age-friendly neighbourhoods are discussed.

1. Introduction

Late-life depression is a significant public health problem worldwide. The prevalence of depressive disorders among older adults ranges from 4.5% to 37.4% across different countries (Luppa et al., 2012). It was ranked the fifth leading global disease burden among older adults in 2010 (Prince et al., 2015). It is predicted to be more widespread in future due to the projected rapid growth in the older adult population worldwide (United Nations, 2019). Adverse outcomes of late-life depression include cognitive impairment, functional decline, and mortality (Diniz et al., 2013; Mirza et al., 2016). Asian societies are under tremendous pressure to alleviate the economic burden placed on health systems by late-life depression since they will experience the most significant increase in the older adult population (i.e., 312 million) by 2050 (United Nations, 2019). As one of these, Hong Kong's population is ageing at an unprecedented pace to the extent that its population of older adults is

projected to double from 16% of the total population in 2016 to 31% in 2036 (Census and Statistics Department, 2017).

The Ecological Theory of Ageing theorizes the relationship between neighbourhood physical environments and late-life depression (Lawton and Nahemow, 1973; Lawton, 1986; Nahemow, 2000). Lawton and Nahemow argue that neighbourhood physical environments influence older adults' mental health through interacting with their physical functioning and that neighbourhood environmental stimuli impose a greater demand on older adults as their functional ability decreases. Building on Lawton and Nahemow's work, Glass and Balfour (2003) further indicate that environments can also be facilitating. Environmental facilitators are elements of the environment allowing or supporting older adults' daily activities, such as proximity to facilities and quantity of green and blue space (Glass and Balfour, 2003; Kochtitzky, 2011). Older adults' behaviour and mental health are contingent on the dynamic interaction between environmental demands and older adults'

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ability to deal with those demands. When both components are in balance, older adults can have adaptive behaviours and good mental health. In contrast, when either component is out of balance, maladaptive behaviours and poor mental health occur.

Existing studies have focused on individual and neighbourhood social environment risk factors of late-life depression (Gerst et al., 2011); however, only a few of these have investigated the impact of neighbourhood physical environments (Barnett et al., 2018). Existing studies reveal that neighbourhood physical environments can reduce the risk of depressive symptoms in later life through the restorative effect of nature (Kaplan, 1995; Ulrich et al., 1991) and also through facilitating an active lifestyle (De Keijzer et al., 2019; Moore et al., 2018; Pun et al., 2018). As a restorative environment, neighbourhood green space can promote feelings of contemplation, spiritual peace, and rejuvenation among older adults (Kaplan, 1995; Ulrich et al., 1991). It offers older adults opportunities to view various species (e.g., plants, insects, and animals), enjoy fresh air, and escape from the 'muddle' of everyday life. Empirical studies have demonstrated its relationship with better mental health among older adults (De Keijzer et al., 2019; Domènech-Abella et al., 2020; Guo et al., 2021; Huang et al., 2020a,b; Kabisch et al., 2017; Liu et al., 2019a,b; Moore et al., 2018; Pun et al., 2018; Xiao et al., 2019; Xie et al., 2021). Apart from its direct impact, neighbourhood green space is beneficial to older adults' mental health by facilitating social and physical activities with attractive settings and convenient locations (Astell-Burt et al., 2013; Finlay et al., 2015; Lu et al., 2021). Nevertheless, Astell-Burt et al. (2013) suggest that the relation between neighbourhood green space and older adults' mental health becomes increasingly dependent on older adults' functional abilities as they age. Older adults are likely to gain decreasing health benefits from neighbourhood green space when they have increasing functional limitations and difficulties accessing it.

Neighbourhood facilities have both a direct and indirect impact on older adults' mental health. For the direct effects, neighbourhood facilities function as resources but may also introduce stressors that may negatively impact the mental health of older adults (Huang et al., 2020a,b; Lehning et al., 2014; Liu et al., 2017; Pun et al., 2019). Neighbourhood facilities (e.g., retail shops and health care facilities) satisfy older adults' everyday needs, which have direct positive effects on their mental health (Yeo and Heshmati, 2014; Lu et al., 2021). However, potential stressors include air pollution, noise, overcrowding, poor street lighting, and heavy traffic (Day, 2008). As for the indirect effects, neighbourhood facilities affect older adults' mental health by influencing the duration and frequency of health-related behaviours (i.e., physical and social activities) (Frank and Engelke, 2001; Guo et al., 2020; Liu et al., 2017). Older adults in neighbourhoods which support physical and social activities tend to participate in more physical activities and social interactions (Sugiyama and Thompson, 2007; Yen et al., 2009). The frequency and duration of these health-related behaviours further influence older adults' mental health.

However, most of these studies only reveal cross-sectional associations between neighbourhood physical environments and depressive symptoms among older adults (Barnett et al., 2018). The long-term trajectories of depressive symptoms and their associations with neighbourhood physical environments have received less attention. Cross-sectional studies overlook the contextual effects of neighbourhood physical environments on mental health among older adults over time. In fact, it is a place-based process, and the influences of neighbourhood physical environments on mental health may accumulate over time (Pearce et al., 2018). Therefore, longitudinal research providing adequate follow-up periods is superior to cross-sectional studies since it can examine the long-term effects of neighbourhood physical environments on mental health.

Moreover, existing studies have treated older adults' functional ability as static in nature and thereby ignored the dynamic relationship between their functional ability and neighbourhood physical environments. In fact, functional ability declines as older adults age. Compared

with older adults with unimpaired functional ability, older adults with functional limitations may have restricted access to neighbourhood facilities, gradually become isolated, and thereby are at higher risk of depression. Furthermore, environmental barriers in a neighbourhood may form facilitating or pressing environments, interact with functional ability, and generate adaptive or maladaptive responses among older adults over time (Glass and Balfour, 2003; Lawton, 1986). For instance, residing in a neighbourhood with a hilly terrain may deter physical activity and induce social isolation among older adults, especially for those with functional limitations, leading to depression.

Hong Kong is a representative Asian city (e.g., high population density, collectivism) experiencing a rapid ageing process (Census and Statistics Department, 2017). Its high percentage of older adults (17.9 percent of the total population), characterized by long life expectancy (average 84.68 years old) and low-level education (60.4 percent receiving primary school or lower education), has placed an increasing burden on public services, infrastructure, and housing (Census and Statistics Department, 2018). Meanwhile, older adults in Hong Kong are accustomed to residing in high-rise buildings offering easy access to public facilities and getting support from intensive local social ties. Research in Hong Kong thereby provides insights for studies on the challenges of the ageing population in other Asian cities. Furthermore, with few exceptions (Wang et al., 2018; Zhang et al., 2018; Helbich et al., 2019), most existing research on neighbourhood environments and depressive symptoms among older adults has been conducted in Western cities. Older adults in Asian and Western cities differ in living arrangements, lifestyle, and social norms. Therefore, it is crucial to reveal associations between neighbourhood physical environments and depressive symptoms among older adults in Hong Kong.

This study examined the longitudinal relationship between neighbourhood physical environments and depressive symptoms among older adults and the moderating effects of environmental barriers and individual functional ability. It used data from a four-year cohort study of older adults conducted in Hong Kong. Based on previous research, we proposed three research questions: (1) How are longitudinal trajectories of depressive symptoms structured over time among older adults? (2) Are specific neighbourhood physical environment attributes associated with the initial status of depressive symptoms and changes in them over time? (3) Are these longitudinal associations modified by the terrain slope and individual functional ability? This study contributes to the body of knowledge on neighbourhood physical environments and depressive symptoms among older adults in three ways. First, it extends existing research by considering the accumulative effects of neighbourhood physical environments on depressive symptoms among older adults and examining the influences of neighbourhood physical environments over time. Second, it considers the moderating effect of terrain slope as an environmental barrier, assuming that longitudinal associations between neighbourhood physical environments and depressive symptoms differ between older adults residing in neighbourhoods with low and high terrain slopes. Third, it considers the potential influence of declining functional ability and its interactive association with neighbourhood physical environments on depressive symptoms.

2. Methods

2.1. Study design

This analysis applied data from a four-year cohort study of older adults in Hong Kong. Participants were aged 65–101 years at baseline. The database contained socio-demographic characteristics, cognition, physical health, functional ability, mental health, and social activity. It adopted an age-stratification random sampling method to select participants, a method that has been reported in previous research (Liu et al., 2018). Given a higher attrition rate among the old-old and oldest-old age groups in longitudinal studies, participants were randomly selected within each age group in the ratio 50:60:70 (65–74,

75–84, and 85 years and above) in twelve public rental housing neighbourhoods (approx. 180 participants in each neighbourhood). A total of 2081 participants were recruited at baseline in 2014. Subsequently, three waves of follow-up data collection were undertaken between 2015 and 2017. Follow-up interviews were conducted during home visits by trained researchers. The flow of data collection is illustrated in Fig. 1. The study was reviewed and approved by the Human Research Ethics Committee of The University of Hong Kong (Reference number: EA050814 & EA1610004).

2.2. Measures

2.2.1. Measurement of depressive symptoms

Depressive symptoms were assessed by the Geriatric Depression Scale 15-item version (Sheikh and Yesavage, 1986), which has been validated among Chinese participants (Wong et al., 2002). Cronbach’s alpha was 0.850. Participants were asked to report whether they had experienced any of fifteen specified symptoms. Responses to the scale were aggregated into a total score, ranging from 0 to 15. A higher score indicates more depressive symptoms than a lower one. We assessed older adults’ depressive symptoms repeatedly over the four years of the study.

2.2.2. Measurement of functional ability

Functional ability was measured by The Chinese Lawton Instrumental Activities of Daily Living scale (IADL), which has been validated in Hong Kong (Tong and Man, 2002). IADL consists of nine self-care items required for independent community living (Supplementary Table S1). The IADLs score ranges from 0 to 18; a higher score indicates higher levels of independence. Cronbach’s alpha was 0.894. Participants whose total score was two or more points below 18, indicating that they were ‘in need of some help’ to perform at least two mentioned tasks or were ‘not capable of doing’ at least one task, were considered to have functional limitations (Schoevers et al., 2006). We evaluated older adults’ functional ability repeatedly over the four years of the study.

2.2.3. Measurement of neighbourhood physical environments

Neighbourhood physical environments were assessed within 200-m and 500-m three-dimension network buffer areas of participants’ residence using ArcGIS 10.5 with Spatial Analyst and Network Analyst

extension. Data relating to terrain, land use mix, and facilities were provided by The Lands Department of Hong Kong Government. These buffer area sizes were selected for two reasons. First, both buffer areas capture neighbourhood physical environments within acceptable walking distance from home for older adults (Gehl, 2013; Millward et al., 2013; Tsunoda et al., 2020). The 200-m buffer area captures neighbourhood physical environments within 5 min’ walk from older adults’ residences. The 500-m buffer area is regarded as the maximum comfortable walking distance from home to basic services for older adults with various functional abilities (Burton and Mitchell, 2006). Older adults undertake most of their daily activities within 500 m of their home (Gehl, 2013; Millward et al., 2013; Tsunoda et al., 2020). Second, the small size buffer areas reveal the high-density nature of physical environments in local neighbourhoods in Hong Kong and have been applied in previous studies (Cochrane et al., 2019). Four attributes were assessed with reference to previous studies on the mental health of older adults (Barnett et al., 2018).

2.2.3.1. Residential surrounding greenness. Exposure to residential surrounding greenness was captured by the Mean Normalized Difference Vegetation Index (NDVI) within the two buffer areas. NDVI reveals the quality and intensity of greenery by calculating the difference between absorbance and reflectance of wavelengths by chlorophyll in leaf cells in plants (Crippen, 1990). The chlorophyll absorbs visible red and blue light but reflects near-infrared light. More luxuriant plants in an area generate more near-infrared lights but less visible red lights are reflected. The following formula can capture the difference:

$$NDVI = (NIR - RED) / (NIR + RED)$$

RED and NIR stand for the reflectance measurements captured in the red and near-infrared spectrum, respectively. The score ranges from –1 to 1, with a high positive value representing a dense coverage of green vegetation. For this study, NDVI greenness was derived from a series of 6-m resolution images collected by Satellite Pour l’Observation de la Terre (SPOT) (De Bie et al., 2011). To reduce noise from satellite images, we applied cloud-free images in 2016 to calculate the values of NDVI.

2.2.3.2. Terrain. The terrain slope was calculated within the two buffer areas based on a digital elevation model with a 5-m resolution. The mean and standard deviation of the slope were calculated. The mean

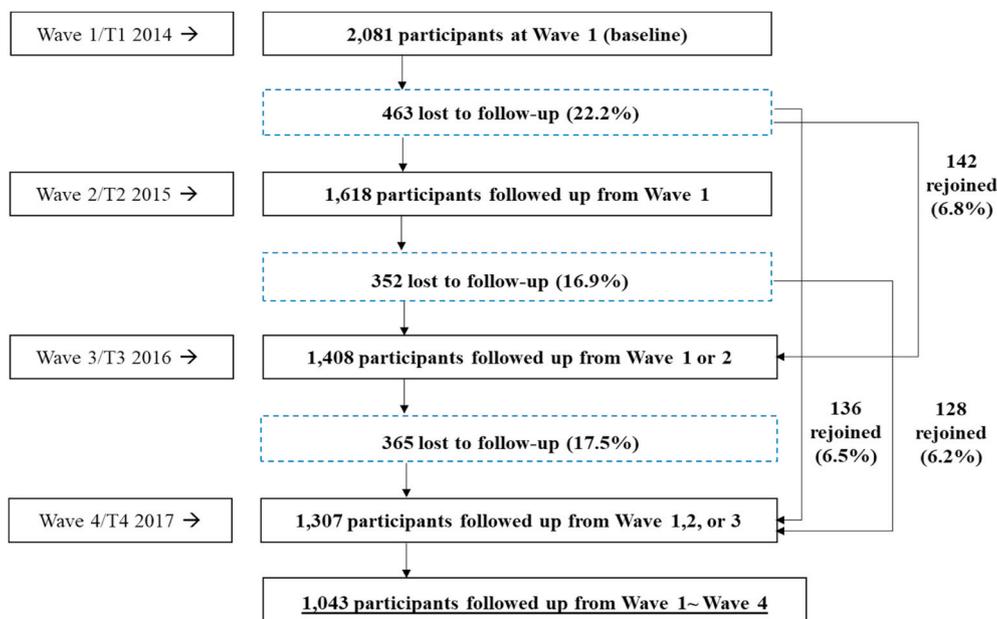


Fig. 1. Flowchart of the study sample.

slope of 4.76° was selected as the cut-off point of low and high terrain slope according to standards on creating walkable sidewalks applied in Hong Kong (Architectural Services Department, 2004) and the United States (Architectural and Transportation Barriers Compliance Board, 1998). It indicates the physical strains older adults overcome when they access neighbourhood facilities.

2.2.3.3. *Land use mix.* Land use mix captures the diversity of five land-use types: residential, commercial/industrial, institutional, open space, and others (Frank et al., 2006). It was computed by the following formula:

$$\text{Land use mix} = - \left[\sum_{j=1}^k P^j \ln(P^j) \right] / \ln(k)$$

P^j is the percentage of each land-use type j in the area, and k is the number of land-use types. The score ranges from 0 (homogeneous use) to 1 (equal mix of five categories).

2.2.3.4. *Availability of facilities.* The availability of each type of facility was computed by its number within the two buffer areas. Commercial facilities refer to convenience stores, supermarkets, bazaars, and malls. Community centres contain community centres, family service centres, and welfare centres. Cultural facilities are libraries, civic centres, and town halls. Active leisure facilities include indoor sports venues, sports grounds, football fields, and swimming pools. Passive leisure facilities are parks, pavilions, playgrounds, and small open spaces. Public transport terminals contain bus terminals, green minibus terminals, and metro stations.

2.2.4. *Neighbourhood- and individual-level covariates*

The study controlled for neighbourhood median monthly family income to identify the socioeconomic status of the sampled public rental housing neighbourhoods. Data were derived from the 2016 Hong Kong Population Census. For individual-level covariates, the study adjusted for age, sex, marital status, educational attainment, chronic diseases, and cognitive function. Chronic diseases were assessed by the total number of chronic diseases reported by participants. Participants were asked to indicate whether they had one or more of 27 types of chronic diseases, including diabetes, hypertension, heart diseases, congestive heart failure, angina, stroke, arthritis, rheumatism, femoral fracture, osteoporosis, gout, lumbar disc herniation, arthrosis, chronic obstructive pulmonary disease, asthma, tuberculosis, pneumonia, urethritis, nephropathy, stomach diseases, pain, cancer, glaucoma, cataract, parkinsonism, anxiety, and bipolar disorder. Cognitive ability was assessed by the Cantonese Chinese Montreal Cognitive Assessment (hereafter Cantonese Chinese MoCA) (Chu et al., 2015), with a total score ranging from 0 to 30. A higher score indicated better cognitive function. Table 1 shows the baseline characteristics of participants.

2.3. *Statistical analysis*

Missing data of the outcome variable and covariates are shown in Appendix Table 2. Little’s χ^2 test indicated that the attrition of depressive symptoms and IADL scores, and missing covariates (e.g., cognitive function) at baseline, were not missing completely at random (χ^2 distance = 400.615, $df = 203, p < 0.001$; χ^2 distance = 40.789, $df = 11, p < 0.001$), but both could be viewed as covariate-dependent missing (χ^2 distance = 696.284, $df = 812, p = 0.998$; χ^2 distance = 41.518, $df = 44, p < 0.579$), a special case of missing at random (hereafter MAR) (Little, 1995). MAR means that the probability of data being missing is related to the observed data, not to unobserved data (Rubin, 1976). Considering the MAR nature of the data, the study applied full information maximum likelihood (hereafter FIML) to maximise statistical power while minimising bias in the Mplus 8.3 software. FIML maximizes the sample log-likelihood function to compute estimations. It estimates a likelihood

Table 1
Baseline characteristics of participants.

	Participants (N = 2081)	
	Mean/ Frequency	(S. D.)
Age	79.64	7.97
Sex (Male): Ref	44.20	
Female	55.80	
Marital status (Single, divorced, widowed): Ref	40.80	
Married	59.20	
Educational attainment (Primary school and below): Ref	78.50	
Secondary school (junior and senior)	19.50	
Associate and above	2.00	
Number of chronic diseases at baseline (Two or more types of chronic diseases) Ref	64.90	
One type of chronic diseases	21.50	
No chronic diseases	13.60	
Cognitive function (MoCA education adjusted score) at baseline	19.62	5.76
Functional ability		
IADL score	14.88	4.16
Neighbourhood socioeconomic status		
Median monthly family income (range = 1.30–2.13; unit: HK\$10,000)	1.73	0.26
Neighbourhood built environments within 200 m buffer area of participant’s residence		
Slope of terrain (range = 0.26–25.68)	11.29	7.62
NDVI (mean NDVI per IQR) (range = 1.59–4.12)	2.61	0.68
Land use mix (range = 0.24–0.98)	0.72	0.17
Number of commercial facilities (range = 0–6)	1.72	1.52
Number of community centres (range = 0–3)	0.53	0.64
Number of cultural facilities (range = 0–1)	0.11	0.31
Number of active leisure facilities (range = 0–3)	0.36	0.59
Number of passive leisure facilities (range = 0–7)	1.61	1.82
Number of public transport terminals (range = 0–4)	0.39	0.67
Neighbourhood built environments within 500 m buffer area of participant’s residence		
Slope of terrain (range = 0.53–27.57)	12.73	8.19
NDVI (mean NDVI per IQR) (range = 0.83–2.89)	1.69	0.57
Land use mix (range = 0.55–0.84)	0.84	0.69
Number of commercial facilities (range = 1–25)	10.01	6.20
Number of community centres (range = 1–5)	2.68	1.28
Number of cultural facilities (range = 0–2)	0.84	0.62
Number of active leisure facilities (range = 0–7)	2.12	1.59
Number of passive leisure facilities (range = 2–16)	7.19	3.47
Number of public transport terminals (range = 0–9)	2.69	2.19

function for each case based on the variables with available data (Graham, 2003; Little and Rubin, 2019). This method can model missing covariates when they are explicitly brought into the model and given a distributional assumption (Ji et al., 2018; Johansson and Karlsson, 2013; Muthén et al., 2017). FIML is more suitable than traditional missing data imputation approaches (e.g., ad-hoc imputation, multiple imputation) for its more accurate estimations and a lower rate of convergence failures and Type 1 error (Enders and Bandalos, 2001).

Compared to pooled ordinary least squares regressions and multi-level models, the latent growth curve model (hereafter LGCM) is more appropriate in analyzing the longitudinal data derived from this study because of the characteristics of data and the advantages of this method (Curran et al., 2010; Hsu et al., 2018; Preacher et al., 2008). For the characteristics of the data, statistical evidence indicates that only 1.2% variance of the outcome variable (GDS-15 scores) over the four years’ period were attributed to the rental housing neighbourhood level (Intra Class Correlation = 0.012 < 0.05). This indicates that there is no strong evidence for the clustering effects (Hayes 2006). In terms of its advantages, LGCM can model changes of outcome variables over time as random effects, in which case means, variances, and covariances of individual differences in intercept and slope can be estimated. It can examine the initial level of the outcome variable and represent a curve for each individual. Besides, it allows researchers to model longitudinal associations between several outcome variables repeatedly measured

Table 2
Repeated measures ANOVA on changes of depressive symptoms of older adults over time (2014–2017).

	2014 (T1)		2015 (T2)		Change	P-Value	2016 (T3)		Change	P-Value	2017 (T4)		Change	P-Value
	Score	S.D.	Score	S.D.			Score	S.D.			Score	S.D.		
Overall	2.63	3.13	2.45	3.12	-0.17	0.110	2.30	3.23	-0.33	0.003	1.86	2.89	-0.77	<0.001
Stratified by IADL														
Older adults with no IADL limitations	2.03	0.12	1.74	0.12	-0.29	0.024	1.71	0.12	-0.32	0.021	1.38	0.11	-0.65	<0.001
Older adults with one or more IADL limitations	3.28	0.16	3.24	0.17	-0.04	0.818	2.95	0.17	-0.33	0.053	2.39	0.15	-0.89	<0.001
Stratified by Slope														
Older adults residing in neighbourhoods with average slope below 4.76°	2.56	3.20	1.97	2.70	-0.59	0.001	2.25	3.04	-0.31	0.112	1.83	2.85	-0.73	<0.001
Older adults residing in neighbourhoods with average slope above 4.76°	2.65	3.10	2.67	3.30	0.02	0.899	2.32	3.32	-0.33	0.014	1.87	2.90	-0.78	<0.001

Notes: Change refers to the GDS-15 score of each wave compared to that of 2014. The P-values in this table were derived from multiple comparison tests.

over time.

Considering these strengths, we applied LGCs in our statistical analysis. To answer research questions 1 and 2, we firstly conducted

LGCs with the full sample to examine the longitudinal associations within the two buffer areas (Models 1 and 2). To answer research question 3, we stratified the fully adjusted models by the slope (Models 3

Table 3
Longitudinal associations between neighbourhood physical environments and depressive symptoms of older adults: Latent growth curve models.

Variables	Model 1					
	Intercept			Slope		
	β	95%CI	P-Value	β	95%CI	P-Value
Functional ability						
Intercept of IADL	-0.27	(-0.31,-0.23)	<0.001			
Slope of IADL				-0.66	(-0.83,-0.49)	<0.001
Within 200-m buffer area of participants' dwellings						
NDVI (mean NDVI per IQR)	-0.47	(-0.76,-0.19)	<0.001	0.07	(-0.06,0.19)	0.30
Land use mix	-0.55	(-1.56,0.46)	0.29	0.07	(-0.38,0.51)	0.77
Number of commercial facilities	-0.15	(-0.29,-0.01)	0.04	0.03	(-0.03,0.10)	0.28
Number of community centres	-0.05	(-0.27,0.16)	0.64	0.04	(-0.06,0.13)	0.47
Number of cultural facilities	-0.15	(-0.60,0.30)	0.52	-0.05	(-0.25,0.15)	0.62
Number of active leisure facilities	0.19	(-0.10,0.48)	0.20	0.06	(-0.07,0.19)	0.37
Number of passive leisure facilities	-0.06	(-0.17,0.04)	0.21	0.01	(-0.04,0.05)	0.70
Number of public transportation terminals	0.28	(0.03,0.53)	0.03	-0.03	(-0.14,0.08)	0.56
Mean of intercept	11.61	(8.99,14.24)	<0.001			
Mean of slope	-0.48	(-1.65,0.69)	0.42			
Residual of intercept	3.78	(3.13,4.44)	<0.001			
Residual of slope	0.07	(-0.09,0.22)	0.40			
N	2081					
CFI	0.957					
RMSEA	0.026					
SRMR	0.025					
Variables	Model 2					
	Intercept			Slope		
	β	95%CI	P-Value	β	95%CI	P-Value
Functional ability						
Intercept of IADL	-0.27	(-0.31,-0.23)	<0.001			
Slope of IADL				-0.67	(-0.84,-0.50)	<0.001
Within 500-m buffer area of participants' dwellings						
NDVI (mean NDVI per IQR)	-0.29	(-0.66,0.09)	0.13	0.04	(-0.12,0.21)	0.61
Land use mix	-1.12	(-4.13,1.90)	0.47	-0.28	(-1.59,1.03)	0.68
Number of commercial facilities	-0.01	(-0.05,0.04)	0.72	-0.01	(-0.03,0.02)	0.61
Number of community centres	0.00	(-0.11,0.11)	0.95	-0.05	(-0.09,0)	0.07
Number of cultural facilities	-0.17	(-0.45,0.11)	0.24	0.02	(-0.10,0.15)	0.70
Number of active leisure facilities	-0.10	(-0.22,0.01)	0.08	0.04	(-0.01,0.09)	0.13
Number of passive leisure facilities	-0.05	(-0.17,0.07)	0.40	0.01	(-0.05,0.06)	0.84
Number of public transportation terminals	0.05	(-0.03,0.12)	0.23	0.02	(-0.02,0.05)	0.36
Mean of intercept	11.26	(6.88,15.63)	<0.001			
Mean of slope	0.19	(-1.72,2.11)	0.84			
Residual of intercept	3.82	(3.16,4.48)	<0.001			
Residual of slope	0.05	(-0.10,0.21)	0.49			
N	2081					
CFI	0.953					
RMSEA	0.028					
SRMR	0.024					

Notes: 1) Individual-level adjusted variables: age, sex, marital status, education attainment, number of chronic diseases, cognitive function, participation in mental wellbeing activities. 2) Neighbourhood-level adjusted variables: median monthly family income. 3) VIF check <10.

and 4) and IADL limitations (Models 5 and 6), respectively. We included the IADL score as a repeatedly-measured variable and other variables as time-invariant covariates (measured at the baseline) in the models. The following variables were included in the models as continuous variables: cognitive function, IADL score, NDVI, land use mix, and the number of facilities. The remaining variables were entered as categorical variables. We conducted descriptive analysis with Stata 14 software, and modelling analysis with Mplus 8.3 software.

3. Results

This study recruited 2081 participants at baseline. The average age of participants was 79.64 (SD = 7.97) years, and 1162 (55.80%) were women. Over 64.90% of participants reported two or more chronic diseases. The average IADL score was 14.88 (S.D. = 4.16), indicating that study participants had few functional limitations. The average score for depressive symptoms was 2.63, and significantly decreased at T3 (-0.33 , $P = 0.003$) and T4 (-0.77 , $P < 0.001$) (Table 2). Compared to older adults with IADL limitations, older adults with no IADL limitations had fewer depressive symptoms on average at T1 (2.03 vs. 3.28; $t = 9.19$, $P < 0.001$). This differential existed over time. Older adults residing in neighbourhoods with low terrain slope had slightly fewer depressive symptoms (2.56 vs. 2.65; $t = 4.05$, $P < 0.001$) at baseline than their counterparts living in neighbourhoods with high terrain slope.

LGCM was applied to capture the individual variations in the depressive symptom trajectories and factors associated with the longitudinal changes in depressive symptoms. An unconditional model of LGCM with good model fit ($\chi^2 = 26.53$, $df = 5$, $P < 0.001$; CFI = 0.981, RMSEA = 0.046, SRMR = 0.031) showed that older adults had differing initial status ($\beta = 2.97$, $P < 0.001$) and change rates in depressive symptoms (-0.29 , $p < 0.001$). Moreover, the intercept of depressive symptoms was negatively associated with its slope (-0.61 , $p < 0.001$), revealing that older adults having more depressive symptoms were more likely to change over time.

Two conditional models of LGCM examined the longitudinal association between neighbourhood physical environments, functional ability, and depressive symptoms with the full sample (Table 3). A lower IADL score (-0.27 , $P < 0.001$; -0.27 , $P < 0.001$) was associated with more depressive symptoms at baseline, and decreases in IADL scores (-0.66 , $P < 0.001$; -0.67 , $P < 0.001$) were related to increased depressive symptoms over time. Neighbourhood physical environments within a 200-m buffer area had associations with depressive symptoms at baseline, while those within a 500-m buffer area showed marginal associations with depressive symptoms over time. Within the 200-m buffer area, an interquartile increment in NDVI greenness was associated with fewer depressive symptoms at baseline (-0.47 , $P < 0.001$). As for facilities, the number of commercial facilities was negatively associated with depressive symptoms (-0.15 , $P = 0.04$). The number of public transportation terminals was related to more depressive symptoms (0.28, $P = 0.03$). Interestingly, neighbourhood physical environments within the 200-m buffer area showed no significant associations with depressive symptoms over time. For the 500-m buffer area, the number of active leisure facilities was associated with fewer depressive symptoms at baseline (-0.10 , $P = 0.08$). The number of community centres within a 500-m buffer was associated with a greater decreasing rate of depressive symptoms (-0.05 , $P = 0.07$) over time, although no impact was present at baseline.

A stratified analysis between older adults residing in neighbourhoods with low and high terrain slopes was conducted (Table 4). In the 200-m buffer area, the number of public transportation terminals was related to more depressive symptoms (0.41, $P = 0.01$) at baseline among older adults in neighbourhoods with high terrain slope. Different patterns between the two groups of older adults were mainly evident within the 500-m buffer area. NDVI greenness was associated with a steeper decrease in depressive symptoms (-3.25 , $P = 0.003$) among older adults in neighbourhoods with low terrain slope but related to a slight increase

in the growth curve of depressive symptoms (0.29, $P = 0.02$) among those in neighbourhoods with high terrain slope. The number of commercial facilities was associated with a steeper decrease in depressive symptoms (-0.28 , $P = 0.004$) among older adults in neighbourhoods with low terrain slope, but a more stable trajectory of depressive symptoms (0.04, $P = 0.02$) among those in neighbourhoods with high terrain slope. Land use mix (4.47, $P = 0.01$), the number of cultural facilities (4.08, $P = 0.03$), and the number of active leisure facilities (0.54, $P = 0.001$) were associated with an increasing rate of depressive symptoms among older adults in neighbourhoods with low terrain slope. Meanwhile, none significantly impacted changes in depressive symptoms among those in neighbourhoods with high terrain slope over the study period. The number of community centres was associated with a decrease of depressive symptoms (-0.08 , $P = 0.02$) over time for older adults in neighbourhoods with high terrain slope. Interestingly, the number of passive leisure facilities was related to a significant decrease of depressive symptoms for older adults in both types of neighbourhood (-0.53 , $P = 0.02$; -0.06 , $P = 0.01$).

We then repeated the stratified analysis between older adults having no IADL limitations and those having one or more IADL limitations at baseline with neighbourhood physical environments (Table 5). Within the 200-m buffer area, active leisure facilities (0.22, $P = 0.01$) were associated with more depressive symptoms for older adults with no IADL limitations over time, while NDVI greenness (0.19, $P = 0.05$) was related to depressive symptoms for older adults with one or more IADL limitations over time. In the 500-m buffer area, for older adults with no IADL limitations, NDVI greenness (0.27, $P = 0.02$) and the number of commercial facilities (0.04, $P = 0.04$) were related to an increase in the growth curve of depressive symptoms, while the number of community centres was associated with a slightly decreased growth curve (-0.06 , $P = 0.04$). The number of commercial facilities was associated with fewer depressive symptoms at baseline (-0.12 , $P = 0.003$) but with an increase in depressive symptoms over time (0.04, $P = 0.04$). By contrast, for older adults with one or more IADL limitations, only the number of passive leisure facilities was associated with fewer depressive symptoms (-0.04 , $P = 0.04$) over time. The number of active leisure facilities was related to a lower level of depressive symptoms (-0.21 , $P = 0.003$) at baseline but with an increase in the growth curve of depressive symptoms (0.08, $P = 0.01$) over time.

4. Discussion

To our knowledge, this is the first study ever undertaken to investigate the association between neighbourhood physical environments and trajectories of depressive symptoms among older adults over time, with a particular focus on the dynamic interplay of environment demands and individual functional ability. We observed that depressive symptoms among older adults slightly decreased over time. Exposure to residential surrounding greenness and the availability of commercial facilities were associated with fewer depressive symptoms at baseline within the 200-m buffer area. The availability of community centres within a 500-m buffer area led to a steeper decreasing rate of depressive symptoms over time.

The moderating effects of terrain slope and older adults' functional ability were significant only within the 500-m buffer area. There are three reasons for this finding. First, the variation of terrain slope in the 500-m buffer area is larger than that in the 200-m buffer area. Second, older adults without functional limitations have a larger activity space than their counterparts with functional limitations. They can use neighbourhood facilities located at a farther distance for daily activities compared to other older adults who have functional limitations. Third, the number of neighbourhood facilities within the 500-m buffer area is significantly larger than that within the 200-m buffer area. For the moderating effect by terrain slope, residential surrounding greenness was associated with a steeper decrease of depressive symptoms among older adults in neighbourhoods with low terrain slope, but associated

Table 4

Longitudinal associations between neighbourhood physical environments and depressive symptoms of older adults: Multi-group latent growth curve models between older adults residing in neighbourhoods with low and high terrain slope.

Variables	Model 3											
	Neighbourhoods with average slope below 4.76° (within 200-m buffer area)						Neighbourhoods with average slope above 4.76° (within 200-m buffer area)					
	Intercept			Slope			Intercept			Slope		
	β	95%CI	P-Value	β	95%CI	P-Value	β	95%CI	P-Value	β	95%CI	P-Value
Functional ability												
Intercept of IADL	-0.31	(-0.40,-0.22)	<0.001				-0.26	(-0.31,-0.22)	<0.001			
Slope of IADL				-0.67	(-1.21,-0.12)	0.02				-0.67	(-0.85,-0.49)	<0.001
Within 200-m buffer area of participants' dwellings												
NDVI (mean NDVI per IQR)	0.27	(-2.78,3.32)	0.86	-0.17	(-1.49,1.15)	0.80	-0.06	(-0.47,0.35)	0.78	-0.15	(-0.33,0.04)	0.12
Land use mix	-2.28	(-7.54,2.99)	0.40	0.28	(-2.02,2.59)	0.81	-0.58	(-1.75,0.59)	0.33	0.46	(-0.06,0.97)	0.08
Number of commercial facilities	-0.23	(-0.62,0.16)	0.25	0.10	(-0.07,0.26)	0.27	0.03	(-0.17,0.23)	0.78	-0.04	(-0.13,0.05)	0.34
Number of community centres	-0.23	(-1.04,0.59)	0.58	0.34	(-0.02,0.70)	0.06	-0.13	(-0.39,0.13)	0.31	0.07	(-0.04,0.19)	0.22
Number of active leisure facilities	0.36	(-0.32,1.04)	0.30	0.06	(-0.24,0.37)	0.68	-0.11	(-0.58,0.36)	0.64	0.07	(-0.13,0.27)	0.49
Number of passive leisure facilities	-0.07	(-1.07,0.93)	0.89	0.02	(-0.41,0.45)	0.94	0.05	(-0.09,0.18)	0.50	0.00	(-0.06,0.06)	0.90
Number of public transportation terminals	-1.06	(-5.23,3.12)	0.62	0.60	(-1.2,2.4)	0.51	0.41	(0.09,0.73)	0.01	-0.09	(-0.23,0.05)	0.21
Mean of intercept	15.78	(2.24,29.31)	0.02				9.59	(6.33,12.85)	<0.001			
Mean of slope	-1.00	(-6.84,4.84)	0.74				0.33	(-1.13,1.78)	0.66			
Residual of intercept	3.49	(2.47,4.52)	<0.001				3.67	(2.86,4.49)	<0.001			
Residual of slope	0.07	(-0.18,0.31)	0.59				0.03	(-0.16,0.22)	0.78			
N	570						1511					
CFI	0.944											
RMSEA	0.032											
SRMR	0.033											
Model 4												
Variables	Neighbourhoods with average slope below 4.76° (within 500-m buffer area)						Neighbourhoods with average slope above 4.76° (within 500-m buffer area)					
	Intercept			Slope			Intercept			Slope		
	β	95%CI	P-Value	β	95%CI	P-Value	β	95%CI	P-Value	β	95%CI	P-Value
Functional ability												
Intercept of IADL	-0.30	(-0.39,-0.22)	<0.001				-0.27	(-0.31,-0.22)	<0.001			
Slope of IADL				-0.68	(-1.23,-0.14)	0.01				-0.68	(-0.86,-0.50)	<0.001
Within 500-m buffer area of participants' dwellings												
NDVI (mean NDVI per IQR)	3.53	(-1.33,8.39)	0.16	-3.25	(-5.37,-1.13)	0.003	-1.28	(-1.84,-0.71)	<0.001	0.29	(0.04,0.54)	0.02
Land use mix	-4.97	(-3.00,12.95)	0.22	4.47	(1.00,7.94)	0.01	-3.74	(-7.12,-0.36)	0.03	0.38	(-1.09,1.86)	0.61
Number of commercial facilities	0.34	(-0.10,0.78)	0.13	-0.28	(-0.47,-0.09)	0.004	-0.10	(-0.18,-0.03)	0.01	0.04	(0.01,0.08)	0.02
Number of community centres	0.12	(-1.29,1.52)	0.87	-0.19	(-0.79,0.41)	0.54	-0.03	(-0.17,0.11)	0.65	-0.08	(-0.14,-0.01)	0.02
Number of cultural facilities	-6.21	(-14.5,2.07)	0.14	4.08	(0.5,7.65)	0.03	0.01	(-0.32,0.34)	0.96	0.01	(-0.14,0.15)	0.94
Number of active leisure facilities	-0.63	(-1.38,0.12)	0.10	0.54	(0.22,0.87)	0.001	0.08	(-0.11,0.28)	0.41	0.05	(-0.04,0.13)	0.30
Number of passive leisure facilities	0.51	(-0.53,1.55)	0.34	-0.53	(-0.98,-0.08)	0.02	0.09	(-0.01,0.19)	0.08	-0.06	(-0.11,-0.02)	0.01
Number of public transportation terminals	0.26	(-0.51,1.03)	0.50	-0.06	(-0.39,0.27)	0.73	0.13	(-0.05,0.31)	0.15	-0.05	(-0.13,0.03)	0.18
Mean of intercept	22.37	(-7.59,52.34)	0.14				15.31	(9.83,20.79)	<0.001			
Mean of slope	-8.33	(-21.33,4.67)	0.21				-0.58	(-3.00,1.83)	0.64			
Residual of intercept	3.31	(2.31,4.31)	<0.001				3.64	(2.83,4.46)	<0.001			
Residual of slope	-0.05	(-0.29,0.19)	0.67				0.06	(-0.14,0.25)	0.57			
N	601						1480					
CFI	0.937											
RMSEA	0.033											
SRMR	0.035											

Notes: 1) Individual-level adjusted variables: age, sex, marital status, education attainment, number of chronic diseases, cognitive function, participation in mental wellbeing activities. 2) Neighbourhood-level adjusted variables: Median monthly family income. 3) Number of cultural facilities was not included in Model 3 because it has a zero variance in the model of those living in neighbourhoods with slope below 4.76°. 4) VIF check <10.

with an increase in depressive symptoms among those in neighbourhoods with high terrain slope over time. The availability of passive leisure facilities was associated with fewer depressive symptoms for older adults from both types of neighbourhood. For older adults with good functional ability, residential surrounding greenness and the availability of commercial facilities were associated with an increase in depressive symptoms over time, while the availability of community centres was related to a decrease in depressive symptoms over the study period. As for older adults with functional limitations, the availability of active leisure facilities was related to an increase in depressive symptoms. The availability of passive leisure facilities was associated with fewer depressive symptoms over time for older adults with good functional ability and those with functional limitations.

The contrary impacts of residential surrounding greenness between neighbourhoods with high and low terrain slope indicate that hard-to-access residential greenness leads to more depressive symptoms among older adults over time. This finding refines the protective effect of greenness on mental health among older adults found in other countries (De Keijzer et al., 2019; Kabisch et al., 2017; Moore et al., 2018; Pun et al., 2018). Moreover, it provides empirical evidence to support the hypothesis from the Ecological Theory of Ageing that older adults may suffer from mental health problems when environment demands exceed their own abilities to cope. In this study, older adults gained fewer benefits from neighbourhood greenness and even experienced depressive symptoms when the demand from the environment (i. e., the steepness of the terrain) exceeded their functional ability to cope. The steepness of terrain becomes an environmental barrier to older adults' use of green space and their ability to undertake physical and social activities in their neighbourhoods (Hanibuchi et al., 2011; Keskinen et al., 2020). Older adults may become trapped in their own home and thereby experience social isolation and loneliness. Residential greenness on hilly terrain may further strengthen the sense of social isolation and loneliness over time. The cut-off point of 4.76° in this study is the maximum suggested slope for building walkable sidewalks in Hong Kong (Architectural Services Department, 2018) and the United States (Architectural and Transportation Barriers Compliance Board, 1998). In fact, the study participants experienced greater physical strains when accessing neighbourhood greenness and facilities since the average slope of sampled neighbourhoods was 12.72°.

Unlike existing studies, this research considered the impact of declining functional ability and its moderating effect with neighbourhood physical environments on depressive symptoms over time. First, the findings indicated significant moderating effects of older adults' functional ability within the 500-m buffer area. Second, both older adults with and without functional limitations living in areas with more greenness had a higher risk of being depressed. It is noteworthy that most greenness measured in this study is greenery on hilly terrain because two-thirds of the neighbourhoods in the study are located in this type of terrain. The steepness of terrain remains an environmental barrier for older adults even with greenery (Sarkar et al., 2018). It induces depressive symptoms among older adults in the long run. Third, the findings also revealed that older adults with functional limitations were at particular risk of experiencing increased depressive symptoms when active leisure facilities were located in their neighbourhood. In contrast, they had a lower risk of suffering from more depressive symptoms over time with the presence of passive leisure facilities in their neighbourhood. For one thing, functional limitations restrict older adults' access to and use of facilities in their neighbourhood. Older adults with functional limitations may usually conduct light-intensity physical activities using passive leisure facilities, such as parks and pavilions. Active leisure facilities designed primarily for physically active users may not take older adults' needs for physical activities into

account. For another, the presence of active leisure facilities may exacerbate feelings of worthlessness among older adults with functional limitations. Older adults with functional limitations are confronted with challenges to accomplishing daily tasks and are thereby likely to feel hopelessness, a chronic strain that contributes to the risk of depressive symptoms (Kennedy et al., 1990; Yang, 2006).

This study also presents the first evidence of the long-term effects of neighbourhood facilities on the mental health of older adults, using individual-location neighbourhood delineation data. As indicated by the Ecological Theory of Ageing, the long-term effects of neighbourhood facilities are contingent on changes in older adults' functional ability and their health-related behaviour patterns. Neighbourhood facilities may have less influences on older adults' mental health when they experience functional decline and difficulties accessing and using these facilities. Our findings reveal that the availability of community centres and passive leisure facilities displayed significant effects on reducing depressive symptoms over time. By contrast, the availability of active leisure facilities was associated with increased depressive symptoms over time. Community centres are arenas facilitating health-related behaviours for older adults, especially through hosting social activities and providing professional consultation and support in daily life. Older adults can benefit from using community centres even if they experience functional decline. The contrary influences of passive and active leisure facilities are due to changes in individual functional ability and health-related behaviours. Passive leisure facilities offer even older adults experiencing functional decline the space to conduct light-intensity physical activities and interact with others. However, active leisure facilities (e.g., sports venues), designed for high- and middle-intensity physical activities, are less likely to be used by older adults as they age, especially when they experience a significant decline in functional ability, as well as providing an evident reminder of their decline (Van Stralen et al., 2009).

Therefore, findings from our study provide new insights into the Ecological Theory of Ageing by revealing the moderating effect of terrain slope and individual functional ability. It also provides significant theoretical implications for the WHO Healthy Ageing Framework (World Health Organization, 2015), especially for creating age-friendly physical environments. As indicated by the Ecological Theory of Ageing, demands from neighbourhood physical environments and older adults' functional ability are two significant aspects in promoting healthy ageing and designing age-friendly environments. Our findings provide practical insights for more targeted interventions for older adults exposed to environmental barriers. Specifically, our findings first highlight that depression prevention strategies related to urban design should distinguish neighbourhoods with and without hilly terrain. For neighbourhoods with hilly terrain, we should ensure the availability of community centres and passive leisure facilities to help older adults to maintain their mental health. For neighbourhoods without hilly terrain, we should provide a supportive environment by increasing the green space and the number of commercial and passive leisure facilities to reduce the progression of depressive symptoms among older adults. Second, our findings also highlight that depression prevention strategies related to urban design should be different between older adults with and without functional limitations. For older adults with functional limitations, we should increase the number of passive leisure facilities within a short distance from home (e.g., within a 500-m buffer area). For older adults without functional limitations, we can develop an enabling environment that offers more community centres and passive leisure facilities within their local neighbourhood.

Our study has four strengths. First, it is the first research to examine the long-term effects of neighbourhood physical environments on depressive symptoms among older adults, using individual-location

Table 5

Longitudinal associations between neighbourhood physical environments and depressive symptoms of older adults: Multi-group latent growth curve model between older adults with and without IADL limitations at baseline.

Variables	Model 5											
	No IADL limitations						Having one or more IADL limitations					
	Intercept			Slope			Intercept			Slope		
	β	95%CI	P-Value	β	95%CI	P-Value	β	95%CI	P-Value	β	95%CI	P-Value
Functional ability												
Intercept of IADL	-1.32	(-1.94,-0.69)	<0.001				-0.27	(-0.32,-0.22)	<0.001			
Slope of IADL				3.07	(-1.86,8.01)	0.22				-0.52	(-0.68,-0.36)	<0.001
Within 200-m buffer area of participants' dwellings												
NDVI (mean NDVI per IQR)	-0.25	(-0.62,0.12)	0.19	-0.13	(-0.29,0.03)	0.11	-0.58	(-0.98,-0.18)	0.004	0.19	(0.004,0.38)	0.05
Land use mix	-1.09	(-2.37,0.20)	0.10	-0.18	(-0.72,0.37)	0.53	-0.20	(-1.64,1.23)	0.78	0.36	(-0.31,1.03)	0.29
Number of commercial facilities	-0.12	(-0.30,0.07)	0.21	-0.03	(-0.11,0.05)	0.47	-0.15	(-0.35,0.04)	0.13	0.07	(-0.03,0.16)	0.17
Number of community centres	0.06	(-0.22,0.34)	0.67	0.04	(-0.08,0.16)	0.49	-0.14	(-0.45,0.16)	0.36	0.03	(-0.11,0.17)	0.67
Number of cultural facilities	-0.43	(-1.00,0.13)	0.13	-0.09	(-0.33,0.15)	0.48	0.07	(-0.58,0.71)	0.84	0.03	(-0.27,0.33)	0.84
Number of active leisure facilities	0.20	(-0.19,0.59)	0.32	0.22	(0.06,0.39)	0.01	0.19	(-0.21,0.59)	0.35	-0.08	(-0.27,0.11)	0.40
Number of passive leisure facilities	-0.04	(-0.17,0.09)	0.55	0.00	(-0.05,0.06)	0.96	-0.10	(-0.24,0.04)	0.17	0.03	(-0.04,0.09)	0.45
Number of public transportation terminals	0.29	(-0.05,0.63)	0.09	-0.06	(-0.20,0.09)	0.45	0.24	(-0.10,0.59)	0.17	0.00	(-0.16,0.16)	0.99
Mean of intercept	30.50	(18.02,42.98)	<0.001				12.00	(8.28,15.73)	<0.001			
Mean of slope	-1.68	(-5.45,2.09)	0.38				-1.09	(-2.87,0.68)	0.23			
Residual of intercept	1.74	(1.03,2.45)	<0.001				4.89	(3.84,5.95)	<0.001			
Residual of slope	0.42	(-0.30,1.14)	0.25				0.17	(-0.09,0.43)	0.19			
N	797						1284					
CFI	0.921											
RMSEA	0.029											
SRMR	0.034											
Model 6												
	No IADL limitations						Having one or more IADL limitations					
	Intercept			Slope			Intercept			Slope		
	β	95%CI	P-Value	β	95%CI	P-Value	β	95%CI	P-Value	β	95%CI	P-Value
Functional ability												
Intercept of IADL	-1.25	(-1.85,-0.66)	<0.001				-0.27	(-0.32,-0.22)	<0.001			
Slope of IADL				2.73	(-1.01,6.46)	0.15				-0.52	(-0.68,-0.37)	<0.001
Within 500-m buffer area of participants' dwellings												
NDVI (mean NDVI per IQR)	-0.69	(-1.22,-0.17)	0.01	0.27	(0.05,0.49)	0.02	-0.21	(-0.75,0.32)	0.44	-0.04	(-0.29,0.21)	0.77
Land use mix	-4.88	(-8.99,-0.78)	0.02	0.38	(-1.34,2.1)	0.67	-0.81	(-5.12,3.50)	0.71	0.08	(-1.91,2.07)	0.94
Number of commercial facilities	-0.12	(-0.20,-0.04)	0.003	0.04	(0,0.07)	0.04	-0.03	(-0.11,0.04)	0.41	0.00	(-0.03,0.04)	0.90
Number of community centres	0.08	(-0.06,0.22)	0.27	-0.06	(-0.12,-0.003)	0.04	0.01	(-0.14,0.16)	0.90	-0.05	(-0.12,0.02)	0.14
Number of cultural facilities	-0.10	(-0.50,0.31)	0.64	-0.02	(-0.19,0.15)	0.80	-0.10	(-0.48,0.27)	0.59	0.03	(-0.15,0.20)	0.75
Number of active leisure facilities	-0.11	(-0.24,0.02)	0.10	0.02	(-0.03,0.08)	0.39	-0.21	(-0.35,-0.07)	0.003	0.08	(0.02,0.15)	0.01
Number of passive leisure facilities	0.13	(0.05,0.21)	0.001	-0.03	(-0.07,0)	0.06	0.07	(-0.02,0.15)	0.11	-0.04	(-0.08,-0.001)	0.04
Number of public transportation terminals	0.16	(0.03,0.29)	0.02	-0.03	(-0.09,0.03)	0.30	0.13	(0,0.26)	0.05	-0.01	(-0.08,0.05)	0.65
Mean of intercept	33.78	(21.14,46.41)	<0.001				11.52	(5.31,17.72)	<0.001			
Mean of slope	-2.90	(-6.67,0.87)	0.13				0.02	(-2.86,2.90)	0.99			
Residual of intercept	1.75	(1.06,2.44)	<0.001				4.97	(3.92,6.03)	<0.001			
Residual of slope	0.38	(-0.21,0.97)	0.21				0.16	(-0.10,0.41)	0.24			
N	797						1284					
CFI	0.9											
RMSEA	0.032											
SRMR	0.034											

Notes: 1) Individual-level adjusted variables: age, sex, marital status, education attainment, number of chronic diseases, cognitive function, participation in mental wellbeing activities. 2) Neighbourhood-level adjusted variables: Median monthly family income. 3) VIF check <10.

neighbourhood delineation data. Second, it reveals the moderating effect of environmental barriers on the longitudinal association between neighbourhood physical environments and depressive symptoms among older adults. It indicates that hilly terrain can moderate the protective effect of residential greenness. Third, it considers the potential influence of declining functional ability and its interactive association with neighbourhood physical environments on depressive symptoms. It reveals that the long-term effects of neighbourhood facilities are contingent on the changes in older adults' functional ability and health-related behaviour patterns. Fourth, using latent growth curve modelling incorporating longitudinal data, we avoid methodological issues associated with cross-sectional data. This strengthens the evidence base of the effect of neighbourhood environments on depressive symptoms among older adults.

However, our study has four limitations. First, the measurement of depressive symptoms in our study (GDS-15) was based on self-reported scores and thereby may be prone to bias. Older adults tend to underestimate or conceal their depressive symptoms since the stigma of mental illness is severe in Asian societies (Laubert and Rössler, 2007). Second, we did not include factors related to housing conditions in the analysis due to the limitations of the questionnaire. Third, statistical models did not examine how changes in neighbourhood physical environment (e.g., changes in greenness, opening or closing of facilities) may influence changes in older adults' mental health over time. Fourth, the analysis was limited to low-income and less-educated older adult residents in public rental housing neighbourhoods.

5. Conclusion

In conclusion, we found that the availability of community centres and passive leisure facilities reduced depressive symptoms among older adults over time. The protective effects of residential surrounding greenness on depressive symptoms among older adults differed by the terrain slope. This finding refined the protective effect of greenness on mental health among older adults found in other countries. Longitudinal associations between neighbourhood physical environments and depressive symptoms varied between older adults with and without functional limitations. Specifically, older adults without functional limitations have less difficulty accessing neighbourhood greenness and facilities and are thereby more easily influenced by them than their counterparts with functional limitations. We suggest that neighbourhood environment barriers for older adults should first be identified and then targeted residential environment interventions applied. Residential environment improvements, such as increasing green space, community centres, and passive leisure facilities, are effective ways to reduce the risk of depressive symptoms among older adults. Design and locations of neighbourhood facilities should consider older adults' declining functional ability and their health-related behaviour patterns.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.healthplace.2021.102585>.

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