


# Age-friendliness of city, loneliness and depression moderated by internet use during the COVID-19 pandemic

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## Summary

The purpose of this study was to examine the association between age-friendliness of a city, loneliness and depression moderated by internet use among older people during the coronavirus disease 2019 (COVID-19) pandemic. The survey was from 'The 2020 Survey of Needs Assessment for a Safe Community and Age-Friendly City' in Xinyi District, Taipei, which was conducted by face-to-face interviews with community-based older adults who were aged 65 and above from one district of Taipei City from May to June 2020 ( $n = 335$ ). Partial least square structural equation modeling and the SPSS PROCESS macro were used for data analysis. Two domains of an age-friendly city (*housing and community support and health services*) were found to be associated with reduced loneliness, while one (*respect and social inclusion*) was associated with decreased depression. The age-friendliness of cities mitigates depression through moderator (internet use) and mediation (loneliness) mechanisms. Although some age-friendly domains of the city reduced loneliness and depression directly, the age-friendliness–loneliness–depression mechanism held true only for older adults who used the internet and not for nonusers. Maintaining the age-friendliness of an environment is beneficial to mental health, and internet use is a necessary condition to gain optimum benefits from age-friendly initiatives. Policy suggestions are discussed.

**Key words:** elderly, health promotion environment, ICT, mental health, structural equation model

## INTRODUCTION

Inevitable physical, mental, and social changes occur in the aging process. According to the ecological theory of person–environment fit (Lawton and Nahemow, 1973;

Lawton, 1985), the mismatch between older adults' competency and environmental demands causes stress and results in negative outcomes such as loneliness and depression. The World Health Organization [World

Health Organization (WHO), 2017) promotes the age-friendly city in eight domains: built environment, transport, housing, social participation, respect and inclusion, civic participation and employment, communication and information and community support and health services. Most studies concentrate on the direct impacts of age-friendly cities on mental health (Yang *et al.*, 2019; Gibney *et al.*, 2020; Hsu, 2020; Liu *et al.*, 2020; Lei and Feng, 2021). Although some studies have investigated the mediating role of loneliness on an age-friendly environment and outcomes such as depression (Park *et al.*, 2021) and mental health (Domènech-Abella *et al.*, 2021), there is little research examining all eight domains of the age-friendly city in explaining their relative impacts on loneliness, depression and the friendliness–loneliness–depression mechanism. Moreover, given the COVID-19 pandemic, loneliness may become a ‘new normal’ situation for older adults (Dahlbeg, 2021), and internet use plays a more prominent role in maintaining older people’s connectivity to alleviate loneliness (Lifshitz *et al.*, 2018; Torres *et al.*, 2021). Thus, internet use could be an important conditional factor in the friendliness–loneliness–depression mechanism taking effect in the pandemic. This study examines the mechanisms behind the eight domains of the age-friendly city with respect to loneliness and depressive symptoms under the moderation of internet use in the Xinyi district of Taipei City. Two research questions are examined:

1. What are the impacts of the eight domains of the age-friendly city on loneliness and depression in older people?
2. Does internet use moderate the age-friendliness–loneliness–depression mechanism among older people?

### Theoretical explanation: ecological theory of person–environment fit

Aging in place is defined as ‘elderly people, including those in need of care and support, should, wherever possible, be enabled to continue living in their own homes, and that, where this is not possible, they should be enabled to live in a sheltered and supportive environment that is as close to their community as possible, in both the social and geographical senses’ [Organization for Economic Co-operation Development (OECD), 1994]. Aging in place is driven by the ecological theory of person–environment fit, that the interaction between personal competencies and environmental conditions determines the extent to which an older person is able to age in place successfully (Lawton and Nahemow, 1973). The better the fit between an older person’s competency and environmental demands, the better the positive

affect and behavior, and the less anxiety, stress or maladaptive behavior. To support aging in place, age-friendly city resources such as friendly and safe neighborhoods, functional transportation and easy access to health care and essential services greatly enhance the person–environment fit, allowing older people to function at an optimum level.

### Age-friendly city, loneliness and depression

Loneliness is commonly defined as an unpleasant subjective state due to a discrepancy between desired companionship and the actual social support received from the environment (Blazer, 2002), not the objective state of being alone (Adams *et al.*, 2004). Depression is commonly experienced by older people and is especially prevalent among urban community dwellers (Zhifeng and Yin, 2021) due to the more restrictive urban environment. The association between loneliness and depressive symptoms has been widely explored (Adams *et al.*, 2004; Quach and Burr, 2020).

Measurement of the age-friendliness of cities can be realized through physical and social environmental factors [World Health Organization (WHO), 2015]. Empirical findings across countries support the relationship between age-friendliness of the physical or social environment and mental health. Built, social and physical environment characteristics are related to loneliness or disconnectedness for older adults (Cao *et al.*, 2020; Domènech-Abella *et al.*, 2021). Older people with more positive ratings of neighborhood (Lei and Feng, 2021) and built environment factors in terms of transport, green parks, surrounding street coverage, public hygiene and surrounding noise (Pan *et al.*, 2021), along with living environment factors such as natural landscape, low building height and low density (Zhifeng and Yin, 2021), showed a negative relationship with depression, and this relationship was weaker among older people with higher income (Pan *et al.*, 2021). A supportive transportation environment also reduced depression risk in older people when it made the acquisition of basic needs easier while promoting socialization and physical activity (Yang *et al.*, 2019). In addition, support from family, friends and government is negatively associated with urban older adults’ depressive symptoms (Liu *et al.*, 2020). A greater age-friendly environment would lower loneliness and result in fewer depressive symptoms (Schwartz *et al.*, 2019; Gibney *et al.*, 2020; Kim *et al.*, 2022).

Several studies have investigated the mediating role of loneliness. Loneliness fully mediates an age-friendly environment and depression (Domènech-Abella *et al.*,

2021; Park *et al.*, 2021). An age-friendly environment supports active behaviors through social and community participation opportunities, giving older people a sense of inclusion and leading to reduced loneliness and lower depressive risk. However, these studies used a limited number of age-friendly domains and were thus unable to evaluate the overall impact of the WHO's eight age-friendly domains in the friendliness–loneliness–depression mechanism.

### Internet use and mental health

Internet use has been reported to enhance mental health in older people. Internet use enhances the psychological well-being of older people, as it facilitates connectivity with family members; the relationship is stronger for older people who are frail (Fang *et al.*, 2018; Yuan, 2020). Internet use significantly reduces emotional loneliness, especially among educated older adults, where e-mail is commonly used to facilitate social contact (Fokkema and Knipscheer, 2007). Older people use the internet more for interpersonal communication, information seeking, task performance, and leisure and reaction. All four functions of internet use are positively related to life satisfaction, but using the internet only for task performance and leisure activity are related to lower depression (Lifshitz *et al.*, 2018). With the COVID-19 pandemic, internet use has played an even more prominent role in alleviating loneliness. Older people who used the internet less and therefore had less virtual talking connectivity suffered from higher loneliness risk during the COVID-19 pandemic (Torres *et al.*, 2021). Thus, internet use could be the conditional factor in the friendliness–loneliness–depression mechanism.

### This study

Although the impacts of age-friendly communities and environments on depression (Yang *et al.*, 2019; Gibney *et al.*, 2020; Liu *et al.*, 2020; Lei and Feng, 2021) and the mediating role of loneliness have been explored (Domènech-Abella *et al.*, 2021; Park *et al.*, 2021), several questions remain unanswered. First, the relative importance of the eight WHO age-friendly domains in mitigating loneliness and depression has not been evaluated. Second, whether internet use is the confounding factor acting on the environment–loneliness–depression mechanism is unknown.

Taiwan was aware of the severity of COVID-19 very early and maintained a low percentage of cases compared with other countries from December 2019 to December 2020 (Ma *et al.*, 2021). The total cumulative number of infections on 31 December 2020 was only

799 persons (the infection rate was 3.3 per 100 000 persons). The first confirmed case of COVID-19 in Taiwan was announced on 21 January 2020. The Taiwan Central Epidemic Command Center (CECC) became the primary facility to lead disease control policy in February 2020. During 2020, the CECC started enacting infection control at the border and case identification, set up a rule to purchase masks in turn and required the entire population to wear masks in public as the public health approach to respond to COVID-19 before vaccines were available. The population in Taiwan has experienced SARS; therefore, people are aware of the importance of wearing a mask and are willing to cooperate with the health policy set by the CECC (Wang *et al.*, 2020). The number of confirmed cases either from abroad or from community transmission stayed low in 2020, with only 447 cumulative confirmed cases on 30 June 2020 (Ministry of Health and Welfare, 2022). The older population experienced a mild COVID-19 outbreak when the study was conducted.

Thus, this study addresses these gaps, and we propose that during the COVID-19 pandemic, Taipei's age-friendly environment may reduce older people's loneliness, resulting in decreased depression, especially among those who used the internet.

## METHODS

### Data and sample

The data were from 'The 2020 Survey of Needs Assessment for a Safe Community and Age-Friendly City', conducted by the health center of the Xinyi District, Taipei City Government. Our data were collected from community-based older people aged 65 and above living in the Xinyi District of Taipei City. The Taipei City government building, World Trade Center, Taipei 101 and many department stores are located in this district. Some neighborhoods of Xinyi District are surrounded by four mountains for hiking, and some older communities are villages for veterans or military families. Thus, Xinyi District is a mix of old and new communities.

According to Taiwan's population statistics, in 2019, 43 093 people aged above 65 years lived in Xinyi District. A stratified, multistage cluster sample design of 41 neighborhoods was used to obtain representative samples collected by the Xinyi District Health Center from May to June 2020. The COVID-19 pandemic occurred, but the epidemic situation in Taiwan was still mild and well-controlled during the period of data collection. There was no lockdown policy during the

interviews. The interviewers comprised nurses and volunteers in the health center, and they were given professional training prior to data collection. All the participants were recruited from the community centers or by community leaders. The survey was conducted by face-to-face interviews. Informed consent was obtained before the interviews were conducted by the health center. A total of 335 respondents were included for analysis (Xinyi District Health Center and Taipei City Government, 2020).

## Measures

The age-friendliness of the city was measured using the eight World Health Organization [World Health Organization (WHO), 2007] domains. The items for all eight domains were validated (Xinyi District Health Center and Taipei City Government, 2019). Cronbach's alpha for the items of the eight domains ranged from 0.81 to 0.95, indicating good internal consistency. The items of the age-friendly city variables are shown in Table 2 (see details in the Supplementary Table S1). The eight domains of the age-friendly city and some example questions were as follows: *outdoor spaces and buildings* (e.g. satisfaction with the barrier-free facilities of government departments, public safety of the community; safety of department stores etc.); *transportation* (e.g. public transportation is safe and convenient, the passenger-only pathways are enough; satisfaction in the use of the Senior Easy Card for public transportation etc.); *housing* (e.g. having devices for safety at home; realizing the residential subsidy application policy; no worries of being attacked in the neighborhoods etc.); *social participation* (e.g. the community activity centers are sufficient; the hiking roads are safe; the parks in the community are safe etc.); *respect and social inclusion* (e.g. satisfaction in one-on-one consultations for older adults; the officials in the government departments help with your problems; the older people in this community are respected etc.); *civic participation and employment* (e.g. vocational training courses suitable for older people; volunteering opportunities for older people, etc.); *communication and information* (e.g. receiving messages related to older people's activities and services, satisfaction with phone calls to government departments; the font size of the signage boards in the community is large enough etc.), and *community support and health services* (e.g. satisfaction with age-friendly services in the health centers; health promotion activities or health screening in the community; conveniently located clinics or hospitals etc.). Some questions related to COVID-19 were added in the domain of *community support and health services*, such as satisfaction with pharmacists' services when purchasing masks, and clinics/hospitals are happy to

help if medical consultation about COVID-19 is needed. Overall, the age-friendliness of the Xinyi community was measured using eight domains, with a total of 56 items, using a 5-point Likert scale, from 1 = strongly disagree to 5 = strongly agree. The average scores for the items of each domain were used in the analysis below.

Loneliness was measured using a single item, i.e. 'Do you feel lonely?', ranging from 1 = not lonely at all to 5 = very lonely. As suggested in several studies, the single-item measurement scale of loneliness is more appropriate than the composite scale when older people are the subject of research (Victor *et al.*, 2009; Shiovitz-Ezra and Ayalon, 2012; Nicolaisen and Thorsen, 2014). Depression was measured using the 15-item Geriatric Depression Scale refined by Brown and Schinka (2005). Each item was scored dichotomously (yes or no). Higher summation scores indicate higher depressive symptoms. Internet use was measured using a single item ('Do you use a smartphone, tablet or desktop to access the internet?') on a dichotomous scale (yes or no). In addition, respondents who responded 'yes' were invited to further indicate their internet use behavior on a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree) to understand whether they used the internet to seek out public transport, medical or public agency information.

The other variables included age (65–74 and 75 years old and above), sex (male/female), education (no formal education, illiterate/no formal education, literacy/primary high school/senior high school/college or university/graduate school or above), living arrangement (living alone or with others), and self-rated health (score 1–5, from poor to excellent).

## Analysis

In addition to descriptive analysis, two main analysis methods were used in this study. Partial least square structural equation modeling was used to examine the effects of age-friendly city domains on loneliness and depression. We performed two separate structural models: eight domains of the age-friendly city as exogenous and loneliness and depression as endogenous. Regarding the moderating role of internet use in the age-friendliness–loneliness–depression mediation model, we used the PROCESS macro (Model 7) of SPSS created by Hayes (Hayes, 2013) for analysis.

## RESULTS

Descriptive analysis of the variables is shown in Table 1. The sample comprised mainly older women (73.10%)

**Table 1:** Demographics of the participants

Demographic attribute	Frequency	Percent
Gender		
Males	90	26.90
Females	245	73.10
Age		
65–74 years old	222	66.30
75 years old and above	113	33.70
Education		
No formal education, illiterate	16	4.80
No formal education, literate	3	0.90
Elementary school	88	26.30
Primary high school	46	13.70
Senior high school	92	27.50
College or university	85	25.40
Graduates or above	5	1.50
Living arrangement		
Alone	27	8.10
With others	308	91.90
Self-rated health	3.483	0.856
Age-friendly city	3.914	0.442
Public area convenience and safety	3.865	0.535
Public transportation safety and friendliness	4.177	0.598
Housing community/infrastructure support	3.631	0.601
Social participation	3.781	0.607
Respect and social inclusion	4.143	0.488
Civic participation and employment	3.729	0.617
Communication and interaction	3.831	0.621
Community support and health services	4.064	0.510
Loneliness	1.532	0.740
Depression	1.212	1.902
Internet use		
Know spots in Xinyi with free internet	2.945	1.533
Use internet to seek medical information	3.902	1.228
Use internet for public agency information	3.798	1.258
Use internet for public transport information	4.239	0.954
Able to use on-line healthcare passbook	2.994	1.523
Use internet for medical health-related information	3.828	1.250
Use apps to communicate with community leader	3.141	1.523
Satisfied with health service center websites	2.926	1.597
Use LINE apps to check COVID-19 information and measures	3.712	1.284

*n* = 335.

aged 65–74 years old (66.30%) who completed high school (27.5%) and lived with others (91.90%). The overall mean score for the eight domains was 3.914 (higher than midpoint), indicating that older people in the Xinyi District were generally pleased with the age-friendly facilities and services. This indicates Taipei City's success in maintaining an age-friendly environment. The most highly rated domain was public

transport safety and friendliness (mean = 4.177), while the least highly rated was housing community/infrastructure support (mean = 3.631). In terms of loneliness and depression, older people in Xinyi distinctly seemed to demonstrate low levels of loneliness, with a mean of 1.532 (lower than the midpoint of 3), and low depression, with a mean of 1.212 (lower than the midpoint of 8). Of the 335 participants surveyed,

**Table 2:** Measurement model of age friendly city

Domains of age-friendly city	Item	Weight	SE	t-value	P value	VIF
Outdoor spaces and buildings	A1. Barrier-free government departments	0.197	0.058	3.400	0.001	1.471
	A2. Barrier-free entrance of public buildings	0.124	0.055	2.263	0.024	1.673
	A3. Public safety of the community	0.161	0.065	2.471	0.014	2.055
	A4. Community safety	0.241	0.064	3.774	0.000	1.827
	A5. Safe department stores	0.159	0.056	2.834	0.005	1.406
	A6. Available seats	0.221	0.059	3.737	0.000	1.902
	A7. Public toilets	0.160	0.065	2.463	0.014	1.921
	A8. Aware of AED	0.218	0.049	4.418	0.000	1.238
Transportation	B1. Safe and convenient public transportation	0.186	0.047	3.931	0.000	1.382
	B2. Passenger-only pathways	0.104	0.062	1.674	0.095	2.185
	B3. Crossing street seconds	0.266	0.073	3.629	0.000	2.197
	B4. Public transportation information	0.260	0.064	4.068	0.000	1.797
	B5. Waiting environment for public transportation	0.198	0.062	3.172	0.002	2.297
	B6. Senior Easy Card subsidy	0.188	0.056	3.368	0.001	1.342
	B7. No worry in traffic accidents	0.168	0.055	3.064	0.002	1.505
Housing	C1. Safety devices at home	0.182	0.063	2.909	0.004	1.242
	C2. Subsidy of household modification	0.429	0.059	7.229	0.000	1.339
	C3. No worry o	0.162	0.071	2.289	0.023	1.457
	C4. Personal safety from violence	0.168	0.068	2.482	0.013	1.315
	C5. Personal safety from accidents	0.582	0.060	9.771	0.000	1.232
Social participation	D1. Community activity centers	0.167	0.054	3.076	0.002	2.566
	D2. Co-meal spots	0.075	0.051	1.484	0.138	2.826
	D3. Safe hiking roads	0.102	0.061	1.679	0.094	2.599
	D4. Greenery or parks	0.259	0.048	5.341	0.000	1.945
	D5. Accessible activity information	0.184	0.044	4.161	0.000	2.111
	D6. Suitable activity kinds	0.003	0.053	0.052	0.959	3.335
	D7. Suitable activity time	0.077	0.081	0.951	0.342	5.232
	D8. Accessible activity place	0.031	0.081	0.385	0.701	5.742
	D9. Autonomy to participate	0.036	0.048	0.746	0.456	3.427
	D10. Diverse and interesting activities	0.184	0.066	2.810	0.005	4.931
	D11. Activity for intergenerational interaction	0.118	0.120	1.884	0.060	3.895
	D12. Activity satisfaction	0.038	0.062	0.616	0.538	3.181
	D13. Reasonable cost	0.016	0.056	0.289	0.772	2.175
Respect and Social Inclusion	E1. One-on-one consultation	0.242	0.061	3.933	0.000	2.322
	E2. Officials actively help	0.213	0.065	3.304	0.001	2.403
	E3. Staff training	0.240	0.050	4.797	0.000	1.728
	E4. Disadvantage group welfare	0.238	0.052	4.612	0.000	1.923
	E5. Residents are kind	0.186	0.064	2.917	0.004	2.858
	E6. Older people are respected	0.194	0.058	3.317	0.001	2.357
Civic participation and employment	F1. Vocational training	0.731	0.136	5.356	0.000	3.142
	F2. Volunteering opportunity	0.346	0.128	2.702	0.007	2.788
	F3. Volunteering training	-0.012	0.160	0.075	0.941	3.924
Communication and information	G1. Service messages	0.176	0.052	3.412	0.001	1.232
	G2. Personal help on the telephone	0.250	0.071	3.552	0.000	1.811
	G3. Easy-to-read documents	0.170	0.092	1.847	0.065	2.413
	G4. Easy to identify signs	0.439	0.083	5.293	0.000	2.018
	G5. Long-term care information	0.282	0.045	6.261	0.000	1.313

(continued)

**Table 2:** (Continued)

Domains of age-friendly city	Item	Weight	SE	t-value	P value	VIF
Community support and health services	H1. Health promotion activity	0.342	0.047	7.313	0.000	1.392
	H2. Health check-up	0.211	0.042	5.008	0.000	1.131
	H3. Age-friendly health center	0.335	0.046	7.346	0.000	1.440
	H4. Convenient medical care accessibility	0.262	0.080	3.272	0.001	2.870
	H5. Convenient prescribed medicine	-0.061	0.079	0.766	0.444	2.750
	H6. Preventing suicidal	0.049	0.040	1.212	0.226	1.522
	H7. Family violence protection	0.214	0.045	4.706	0.000	1.372
	H8. Pharmacy satisfaction for purchasing masks during COVID-19	0.044	0.047	0.936	0.350	1.285
	H9. COVID-19 consultation	0.168	0.045	3.711	0.000	1.506

VIF, variance inflation factor; AED, automated external defibrillator.

almost half (48.5% or 162 participants) used the internet.

### Measurement model

The psychometric properties of the measurement items for the age-friendly city were assessed in terms of significance and weight as well as collinearity. Through the bootstrapping technique, most indicators (40/56) were found to significantly explain their domains. Sixteen indicators were not significantly related to their domains. However, all items were kept to fully capture the contents of the domains (Hair *et al.*, 2020). We employed the variance inflation factor (VIF) to determine indicator multicollinearity. As shown in Table 2, the VIF values for all indicators are below 10, indicating that multicollinearity is not an issue (O'Brien, 2007).

### Predictors of loneliness and depression

As shown in Table 3, *housing* ( $\beta = -0.110$ ) and *community support and health services* ( $\beta = -0.143$ ) were negatively associated with loneliness. Meanwhile, *respect and social inclusion* ( $\beta = -0.102$ ) were negatively associated with depression. Of the four control variables, self-rated health was the most significant predictor of both loneliness ( $\beta = -0.211$ ) and depression ( $\beta = -0.190$ ). Although living with others was significantly associated with both, it mitigated loneliness ( $\beta = -0.072$ ) and enhanced depression ( $\beta = 0.063$ ). Age was positively related to loneliness ( $\beta = 0.086$ ), indicating that the older the participants were, the lonelier they felt. With regard to explanatory power, the eight domains of the age-friendly city explain 19.9% of the variance in loneliness and ~24.4% of the variance in depression.

### Moderated mediation model testing

Figure 1 reports the results for the moderated mediation relationship. The age-friendly city does not directly reduce depression ( $\beta = -0.508$ ), the interaction of the age-friendly city and internet use significantly reduces loneliness ( $\beta = -0.433$ ), and loneliness positively influences depression ( $\beta = 0.792$ ). The slope of internet users is steeper and negative, indicating a negative relationship between age-friendly cities and loneliness among internet users. However, the slope for non-users is flat, indicating no relationship. That is, the age-friendliness–loneliness–depression mechanism is significant only for older people who used the internet (the indirect effect  $\beta = -0.243$ , 95% CI =  $-0.487$  to  $0.057$ ) and not significant for those who did not use the internet (the indirect effect  $\beta = 0.101$ , 95% CI =  $-0.082$  to  $0.325$ ; please see Supplementary Table S2).

## DISCUSSION

This study examines the impact of the age-friendly city as a protective factor in mitigating loneliness and depression risk among older people residing in the Xinyi District, Taipei City. Two domains of the age-friendly city, *housing* and *community support and health services*, were found to be associated with reduced loneliness, and one domain, *respect and social inclusion*, was associated with decreased depression. The age-friendliness–loneliness–depression mechanism was supported in the internet users.

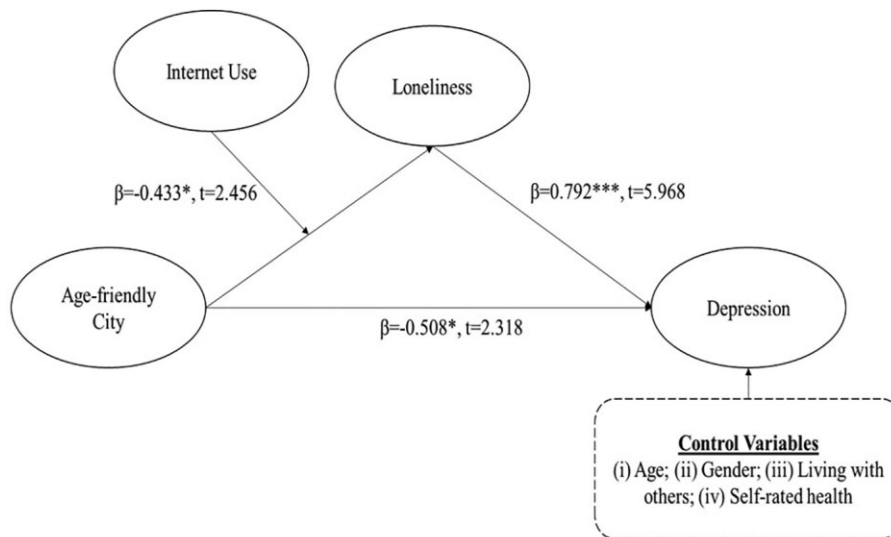
To answer the first research question on the impact of the age-friendly city domains on loneliness and depression, *housing* and *community support and health services* were found to be negatively associated with loneliness, whereas *respect and social inclusion* were negatively associated with depression. These results



**Table 3:** Impacts of age-friendly city domains on loneliness and depression by structural equation model

Age-friendly city dimension	Loneliness ( $R^2 = 0.199$ )					Depression ( $R^2 = 0.244$ )				
	Std beta	SE	t Value	P value	VIF	Std beta	SE	t value	P value	VIF
Public area convenience and safety	-0.139	0.119	1.163	0.123	1.080	-0.055	0.086	0.642	0.261	1.227
Public transportation safety and friendliness	-0.046	0.082	0.567	0.286	1.132	-0.085	0.070	1.211	0.113	1.323
Housing community/infrastructure support	-0.110	0.060	1.816	0.035	1.169	-0.125	0.080	1.558	0.060	1.132
Social participation	-0.097	0.137	0.711	0.239	1.050	-0.127	0.086	1.481	0.070	1.113
Respect and social inclusion	-0.001	0.067	0.013	0.495	1.301	-0.102	0.061	1.672	0.048	1.304
Civic participation and employment	-0.061	0.059	1.041	0.149	1.139	-0.029	0.082	0.349	0.364	1.099
Communication and interaction	-0.051	0.090	0.569	0.285	1.130	-0.154	0.095	1.624	0.052	1.323
Community support and health services	-0.143	0.081	1.770	0.039	1.161	-0.006	0.072	0.086	0.466	1.388
Control variables										
Age	0.086	0.049	1.738	0.041		0.025	0.047	0.526	0.299	
Gender	0.013	0.047	0.282	0.389		0.056	0.043	1.295	0.098	
Living with others	-0.072	0.042	1.685	0.046		0.063	0.036	1.778	0.038	
Self-rated health	-0.211	0.057	3.707	0.000		-0.190	0.057	3.346	0.000	

VIF, variance inflation factor.

**Fig. 1:** Results of moderated mediation.

concur with those of Adams et al. (Adams et al., 2004), who found that entirely different environmental factors predicted loneliness and depression. Functional housing and a supportive community may contribute to network socialization and result in reduced loneliness, while

social inclusion makes older people feel that they fit in and comfortable when socializing with community help in reducing depression.

To answer the second research question on the moderating role of internet use in the age-friendliness–



loneliness–depression mediation model, the results support a moderated mediation relationship, indicating that the age-friendliness–loneliness–depression mechanism is indeed true for older people who use the internet. This finding is in line with those of Park *et al.* (Park *et al.*, 2021) and Domènech-Abella *et al.* (Domènech-Abella *et al.*, 2021). An age-friendly environment increases person–environment fit, resulting in less anxiety and freeing older people by giving them peace of mind for physical and mental activities that make them happy (Lawton and Nahemow, 1973), leading to reduced loneliness and depression risk. Despite our study using different numbers and different indicators to measure age-friendly city domains compared with previous studies, the age-friendliness–loneliness–depression mechanism is still supported.

In addition, the conditional role of internet use in the age-friendliness–loneliness–depression mechanism is supported, underscoring the crucial role of internet use. Our results support previous findings that internet use enhances mental health in older people (Yuan, 2020) along with their psychological well-being (Fang *et al.*, 2018) while reducing loneliness (Fokkema and Knipscheer, 2007) and depression (Lifshitz *et al.*, 2018). Our results indicate that internet use is a significant moderator in reducing loneliness, especially during the COVID-19 pandemic. Since efforts to prevent loneliness may indirectly help prevent depression, ideas to reduce older people's boredom should be adopted, for instance, informal helping networks such as neighborhood walking groups, reading or game groups (Scharlach, 2017) and 'befriending schemes' in which volunteers visit socially isolated older people in the community every week (Andrews *et al.*, 2003). In fact, the same survey of Xinyi District, Taipei, was conducted again from September to October 2021. Taiwan experienced a lockdown from May to August 2021, and most community-based services and activities were canceled during the lockdown. The older people in Xinyi District scored lower in satisfaction in all domains of the age-friendly city, except internet use, and satisfaction with the smart city policy increased compared with 2020. Most older people are also willing to attend online activities if health centers help them learn (Xinyi District Health Center and Taipei City Government, 2021). This means that the internet became even more important than other physical community-based services of age-friendliness during the pandemic lockdown. Therefore, empowering older people to use the internet developing online services or activities by health centers or community centers are necessary to respond to pandemics such as COVID-19.

This study contributes to the literature in three ways. First, it extends the ecological theory of person–environment fit by testing its applicability to mitigating loneliness and depression risk in older people in Taipei City. We find that two domains of an age-friendly city (*housing* and *community support and health services*) significantly reduce loneliness, while one domain (*respect and social inclusion*) reduces depression. This indicates that initiatives to increase the fit between older people's competency and environmental demands via age-friendly guidelines indeed reduce mental health problems, providing support to the ecological theory of person–environment fit that matching personal competency and environmental demands promotes positive outcomes among older people (Lawton and Nahemow, 1973). Second, this study uncovers the underlying mechanism and moderator of how the age-friendliness of a city reduces mental health problems. We find that age-friendly initiatives managed to mitigate loneliness and depression only in older people who use the internet. Deeper investigation into internet use behavior finds that older people use the internet to check transport schedules, health center services, health knowledge and the COVID-19 situation and to communicate with community leaders via the LINE chat group, the most popular social media used in Taiwan (Xinyi District Health Center and Taipei City Government, 2020). Internet connectivity not only allows older people to enjoy age-friendly services virtually but also enhances their chance to socialize with community members, which greatly reduces boredom and loneliness while spending more time at home during the COVID-19 pandemic. Third, this study contributes to information communication technology (ICT) research in older people. ICT intervention for the well-being of older people is much needed and may work, especially during a pandemic, when face-to-face interaction is minimal. This is because older people's motivation to learn ICT may increase during such periods.

There are several limitations of this study. First, it used a cross-sectional approach, and therefore, it did not find a causal relationship. Second, the sample was conducted by purposive sampling, and these data were only from the Xinyi District of Taipei City. Thus, the results may not be generalizable to Taipei City as a whole. Third, although multiple items measured age-friendly city domains and depression, only a single measurement item applied to loneliness, which compromised its ability to capture various manifestations of loneliness. Future studies might consider using multiple items to measure loneliness.

## CONCLUSION

This study investigates the impact of eight age-friendly domains in mitigating loneliness and depression. Some domains (*housing, community support and health services, respect and social inclusion*) of an age-friendly city are negatively related to loneliness and depression but overall manage to alleviate loneliness, leading to reduced depression risk in older people who use the internet. Taipei's age-friendly initiatives as a whole are found to be effective in mitigating loneliness and depression in older people who use the internet. The following are suggestions for age-friendly city policies. First, the mean score for housing was lowest among the eight age-friendly city domains. The government should work closely with developers in initiating affordable and age-friendly housing projects with appropriate infrastructure to support older people in urban areas. Second, community support and health services could be improved by making geriatric clinics or health centers more accessible for older adults so they can obtain physical and mental health advice whenever needed. Mental health should not be undervalued. Regular check-ups should incorporate more mental health testing in addition to physical health evaluation procedures. Third, businesses could make older people feel more included by providing paid employment to needy groups and allocating a sufficient number of benches within and outside business premises. Community leaders and non-governmental organizations could create social activities within small neighborhood communities to promote intergenerational interaction in which older people could be engaged to mentor young people in relevant areas. Fourth, awareness campaign posters or TV messages could be aired from time to time as reminders. Fifth, the internet infrastructure is well developed in Taipei. Health centers or community centers should help older people learn how to use the internet and attend online meetings or use mental health apps. Then, the authorities may hold online programs or activities to provide age-friendly services even during the pandemic. A remote health consultation is also suggested.

## SUPPLEMENTARY MATERIAL

[Supplementary material](#) is available at *Health Promotion International* online.

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## INSTITUTIONAL REVIEW BOARD STATEMENT

The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Taipei Medical University Joint Institutional Review Board (No. N202010050).

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