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Living Alone, Environmental Hazards, and Falls Among U.S. Older Adults

Haena Lee, PhD[1,*] and Justin H. Lim, SMArch[2]

[1]Department of Sociology, Sungkyunkwan University, Seoul, South Korea.
[2]Graduate School of Environmental Studies, Seoul National University, Seoul, South Korea.

*Address correspondence to: Haena Lee, PhD. E-mail: haenalee@skku.edu

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Abstract

Background and Objectives: Physical conditions of living environments can affect the incidence of falls; however, prior work has focused typically on 1 domain at a time—either neighborhood or home, capturing limited environmental boundaries of older adults. We examined how neighborhood together with the home environment affect the incidence of falls over time and whether living arrangement modifies the influence of the environmental risks on falls.

Research Design and Methods: Using the 2012–2020 waves of the Health and Retirement Study (HRS; N = 1,893), we fitted logistic regression to estimate the incidence of falls over an 8-year study period. We used the neighborhood and housing data that are collected systematically by trained observers in the HRS to assess environmental hazards. Sidewalk quality, neighborhood disorder, and the presence of green space were measured to capture outdoor environmental hazards. Indoor environmental hazards included the presence of housing decay and poorly maintained stairways. All models were stratified by living arrangement.

Results: Neighborhood and housing environment were independently associated with the odds of falls net of demographic characteristics and preexisting health conditions, and effects were significant for people living alone only. The presence of green space and poorly maintained stairways were associated with greater odds of falling, net of covariates during 8 years of follow-up (odds ratios = 2.10 and 2.65, $p < .05$, respectively). None of the environmental risk factors were significant for those living with others.

Discussion and Implications: Falls in old age may be determined in part by a combination of outdoor and indoor risk factors. More research is needed to understand pathways that lead to greater vulnerability among older adults living alone to environmental hazards.

Translational Significance: Falls are a significant cause of disability and mortality in older adults. Efforts to identify modifiable risk factors have largely focused on the role of individual-level risk factors. This work highlights stairway quality and neighborhood amenities as significant risk factors for falls. A novel translational finding was that exposure to green space and unsafe stairways such as loose railings and missing steps increases fall incidents over time, particularly for older adults living alone. Identifying factors that confer vulnerability to falls may provide a novel opportunity to create interventions targeting older adults at increased fall risk.

Keywords: Environment, Falls, Housing, Living alone, Neighborhood

Falls are common and can result in fatal injuries and death among older adults (CDC, 2022). As of 2018, one in every three older adults falls at least once every year, and nearly 10% report an injury from a fall including broken bones, hip fractures, and head injuries (Moreland, 2020). Falls damage not only the physical functioning of older adults but also impose significant social and financial burdens. Falls are associated with social isolation, loss of autonomy and financial distress in part due to long-term hospitalization and treatment (Fabrício et al., 2004). Each year an estimated $50 billion is spent on medical care for falls in the United States (Florence et al., 2018).

An increasing number of studies have been undertaken to identify modifiable risk factors associated with falls. Studies have explored individual-level risk factors, such as chronic illness, functional limitations, medication exposure, and fatigue (Ie et al., 2021; Nicklett, Taylor, et al., 2017; Renner et al., 2021). A growing body of research has linked environmental risk factors to falls (Chippendale & Boltz, 2015; Edwards et al., 2019; Li et al., 2014; Lord et al., 2006; Nicklett, Lohman, et al., 2017; Stevens et al., 2014); however, prior work has focused typically on one domain at a time—either neighborhood or home, capturing limited environmental boundaries of older adults. Although falls can occur in both outdoor and indoor environments (Li et al., 2014), there has been limited research exploring the associations between falls and environmental hazards across both sets of conditions.

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Drawing on the recent theoretical development in sociology, gerontology, and urban planning (Lee & Waite, 2018; Schafer & Upenieks, 2015; Swope & Hernández, 2019), we extend prior work by considering both neighborhood and home as important residential contexts that compromise physical functional reserves as shown in Figure 1. Among other characteristics, we consider outdoor environmental hazards, such as poorly maintained sidewalks, neighborhood disorder, and green spaces, along with indoor environmental hazards, such as household decay and poor stairway quality, to be important factors determining the incidence of falls. For instance, poorly maintained sidewalks and neighborhood physical disorder—as characterized by the presence of broken curbs, obstruction and trash on the street, dilapidated buildings, and run-down yards—can disorient or obstruct mobility (Caldwell et al., 2017; Clarke et al., 2008), which may subsequently lead to falls (Curl et al., 2020). Parks and garden areas, in general, provide a variety of health benefits, but they can expose older adults to environmental hazards within green spaces that can increase the risk of falls (Nascimento et al., 2018). Indeed, older adults who live nearby recreational facilities such as parks, forests, and golf courses were associated with increased fall rates (Duckham et al., 2013). People living with indoor tripping hazards such as clutter in the hallway, loose railings and steps, and poor lighting inside the home may be more likely to lose balance, which can lead to fall accidents (Valipoor et al., 2020).

Incorporating insights from Bronfenbrenner's socioecological theory (1979), we argue that an individual's health is influenced by a set of layered and nested environments; thus, the health effect of place may paint an incomplete or misleading picture of the layered nature of the residential environment, which is not taken into account (Lee & Waite, 2018). Statistically, this means we would expect a positive correlation between substandard housing and neighborhood problems as individuals living in a disordered neighborhood are likely to live in a disordered household in part because of compositional factors such as a socioeconomic context that may put individuals at both sets of risk (Cornwell, 2014).

Identifying factors that confer vulnerability to falling may be critical to create effective interventions. Only a few studies, to our knowledge, have examined whether individual social conditions (e.g., gender, race, and education) compound the effect of environmental hazards on fall risks in older adults (Okoye et al., 2021; S. Lee, 2021; Schafer & Upenieks, 2015), and no prior research has examined whether the consequences of environmental hazards are amplified among older adults living alone. Prior research indicates that neighborhood problems and substandard housing are disproportionately experienced by older adults who live alone (Cornwell, 2014; Stahl et al., 2017). Specifically, older adults who live alone may be more exposed to the effects of environmental risk than others because they tend to be poorer, which means they are more likely to live in impoverished neighborhoods and dilapidated housing characterized by uneven surfaces, loose railings, broken sidewalks, and poorly kept yards in the neighborhoods. Additionally, these individuals may lack social and institutional support that could help mitigate environmental risks. A lack of financial and institutional resources may, therefore, limit one's ability to address the problems (i.e., paying for housekeeping and maintenance) when they face housing-related issues (Cornwell, 2014). Due to varying exposure and vulnerability based on living arrangements, the impact of environmental hazards on falls may be more significant for older adults living alone than those living with others.

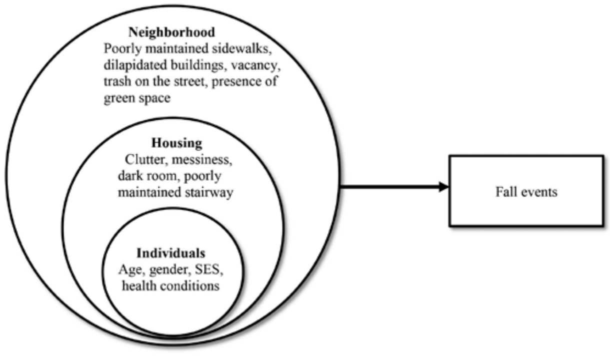

Figure 1. Conceptual framework.

Using five waves of the Health and Retirement Study (HRS; 2012–2020), we examine whether neighborhood and housing environment independently predict the incidence of falls and whether living arrangement modifies this association. We focus on the incidence of falls over 8 years of follow-up as important markers of poor later-life health. Because we expect that the influence of environmental risks may differ by living arrangement, we stratify the sample by living arrangement (living alone vs living with someone else). We hypothesize that the home and neighborhood environmental hazards can increase the likelihood of falls above and beyond individual characteristics as exposure to housing decay and neighborhood disorder may independently disorient or obstruct mobility (Hypothesis 1). However, the likelihood of falls may be more strongly affected by the housing characteristics, the more proximal environment, than by neighborhood as the more distal environment (Hypothesis 2). Last, we hypothesize that the influence of environmental risk on the incidence of falling will be more pronounced among older adults living alone as they lack resources that may be used to offset the influence of environmental risk compared with those living with others (Hypothesis 3).

Materials and Methods

Study Population

We used data from the 2012–2020 waves of the HRS. The HRS is one of the few population-based surveys of U.S. older adults that collect the incidence of falls and the evaluations of physical conditions of the homes and neighborhoods over time, which provides unique opportunities to investigate the longitudinal associations between environmental hazards and the incidence of falling. The HRS began in 1992 as a nationally representative study of U.S. older adults aged 51 and older, with subsequent waves fielded every 2 years (Sonnega et al., 2014). The neighborhood and housing data came from the HRS Interviewer Observation data (HRS-IO) that were collected by using a direct observational method known as systematic social observation. Starting in 2006, the HRS-IO was integrated into the enhanced face-to-face interview, which asked interviewers to systematically report each respondent's housing and surrounding areas after the core interview. A random half of the sample was selected to receive the enhanced face-to-face interview in 2006 with subsequent follow-ups every 4 years. The other half of the sample was administered in 2008 and followed up in 2012, 2016, and 2020.

We used the 2012 survey wave as a baseline because it was the first wave of data collection that asked about sidewalk quality in the HRS-IO data. The systematic social observation method used in the HRS to collect a direct observation of the immediate built environment features allows researchers to capture many of the structural characteristics closely related to older adult health outcomes that are not publicly available in administrative data. We limited the analytic sample to respondents who were aged 65 and older (the question about falls was administered only to those aged 65+; n = 9,806). We then excluded respondents who were not administered in the 2012 HRS-IO (n = 5,174) and who were lost to follow-up during 8 years of observation (n = 3,316). The analytic sample was further reduced due to a small amount of missing data, yielding a final analytic sample of 1,893. A chart showing the steps we took to arrive at the analytic sample is shown in Supplementary Figure 1.

Assessment of Neighborhood and Housing Environmental Hazards

Using the HRS-IO data that were systematically collected by the interviewers, we measured neighborhood and housing environmental hazards at baseline. Neighborhood environmental hazards included sidewalk quality, neighborhood disorder, and green space. Poorly maintained sidewalk was measured using the interviewers' description of the quality of sidewalks in the area near the home. The interviewers were asked to report whether "no sidewalks [are present] in the area," "sidewalks are in place on both sides of the street," "sidewalks are continuous," "sidewalks are smooth/flat/unbroken," "sidewalks are free from obstruction/debris (e.g., shrubs, trees, and leaves)," "sidewalks are wide enough for two people to pass comfortably," and "none of the above." Multiple answers were allowed. We created a binary indicator that represents the lack of quality sidewalks by coding "no sidewalks" and "none of the above" as 1 and the rest of the conditions as 0. Building on previous work (Ross & Mirowsky, 2001), neighborhood disorder was constructed by counting the presence of vandalism (graffiti, broken mailboxes, and damaged elevators), trash, litter, or junk in the street, and trash, litter, or junk around the buildings in neighborhood, abandoned or demolished houses and run-down or poorly kept yards or communal areas. We dichotomized the sum of the counts into two categories: any (coded 1) and none (coded 0). The presence of green space was measured if the interviewers reported the presence of a park, playground, or garden area within the sight of the housing unit (*yes* = 1; *no* = 0).

Following previous work (H. Lee, 2021; Schafer & Upenieks, 2015), the housing decay scale was constructed by standardizing and averaging four items from the HRS-IO. First, the interviewers were asked to describe the conditions of the room(s) in which the interview occurred, including the presence of dirtiness, brightness, messiness, and clutter in the room. These items used a 5-point scale which was reverse coded (brightness and amount of clutter only) so that higher values indicate more decay (α = 0.84 obtained in the current study). The poorly maintained stairway was assessed using the interviewers' report on the quality of the stairway. They provided responses (1 = *present* and 0 = *not present*) to the following items when interior or exterior stairways were present: "*loose railings*," "*no railings*," "*loose steps*," "*none of the above*," and "*no interior or exterior stairway present*." Multiple answers were allowed. We compared respondents who lived with loose railings, no railings, and loose steps when interior or exterior stairways were present (coded 1) with those who lived with well-maintained stairways (none of the above), and who had no interior or exterior the stairway (coded 0). More information on the items and responses is shown in Table 1.

Assessment of the Incidence of Falling

Our primary outcome variable was an incidence of falls between 2012 and 2020. Falls were measured using the question "Have you fallen down in the last two years?" Possible answers included "yes" or "no." In each follow-up survey, the participants were asked if they have fallen down since the last interview. We determined the incidence of falls if the respondent reported at least one fall during 8 years of follow-up.

Assessment of Living Alone

We determined living arrangement status by comparing the HRS respondents who lived alone (=1) to those who lived with someone else (=0) at baseline.

Individual Sociodemographic Factors and Health Conditions

Individuals at greater risk of falls (e.g., men, poor older adults, and those with functional limitations) may be more likely to live in environments with unfavorable physical conditions (Ambrose et al., 2013; Cornwell, 2014; Duckham et al., 2013). We therefore controlled for baseline sociodemographic and health covariates to minimize selection bias in the results. The application of the covariate adjustment method has been widely validated to control for selection bias in logistic regressions (Trutschel et al., 2017). Age was categorized into three groups: 65–74, 75–84, and 85+. Gender is a dummy variable that equals 1 for females and 0 for males. We created a four-category variable that contrasts non-Hispanic Black, Hispanic, and non-Hispanic others with non-Hispanic Whites (reference). Socioeconomic status was assessed through the respondent's years of education and wealth. Wealth was categorized into deciles and treated as a continuous variable in our models, with higher values indicating higher ranks of wealth distribution. The wealth variable is the net value of total wealth which sums all wealth components less all debt including value of primary residence, net value of secondary residence, net value of real estate, net value of vehicles, net value of businesses, net value of IRA, net value of checking, savings or money market accounts, net value of mortgages, etc. (Bugliari et al., 2022). We controlled for functional limitations using mobility limitation at baseline. We measured an index of mobility limitation that included five lower body functional limitation tasks: walking several blocks, walking one block, walking across the room, climbing several flights of stairs, and climbing one flight of stairs (0 = *no difficulty*; 1 = *difficulty*; Bugliari et al., 2022). The index ranged from 0 to 5, with higher values indicating limited mobility. We adjusted for physical inactivity using a question "How often do you take part in sports or activities that are moderately energetic such as gardening, cleaning the car, walking at a moderate pace, dancing, floor, or stretching exercises: (more than once a week, once a week, one to three times a month, or hardly ever or never)?" We compared individuals who reported never (=1) to those who reported some moderate activities (=0). Information on wealth, mobility, and moderate physical

Table 1. Indicators of Neighborhood and Household Hazards Rated by Health and Retirement Study Interviewers

Items	Responses	Operationalization
Sidewalk quality		
Describe the quality of sidewalks in the area near the home	0 = *no sidewalks in the area* 1 = *sidewalks are in place on both sides of the street* 2 = *sidewalks are continuous* (no missing segments) 3 = *sidewalks are smooth/flat/unbroken* 4 = *sidewalks are free from obstruction/debris* (e.g., poles, signs, cars, shrubs, tree roots, piles of leaves) 5 = *sidewalks are wide enough for two people to pass comfortably* 6 = *none of the above*	Coded 0 "*no sidewalks*" and 6 "*none of the above*" as 1
Physical disorder		
Which of the following are present within sight of the housing unit? Enter all that apply	1 = *vandalism* (graffiti, broken mailboxes, damaged elevators) 2 = *boarded houses* 3 = *abandoned cars* 4 = *abandoned or demolished houses* 5 = *trash, litter, or junk in street/road* 6 = *trash, litter, or junk around buildings in neighborhood* 7 = *factories or warehouses* 8 = *stores or other retail outlets* 9 = *run-down or poorly kept yards or communal areas* 10 = *homeless people* 11 = *prostitution* 12 = *winos or junkies* 13 = *drug use or drug dealing in the open* 14 = *a park, playground, or garden area*	Counted any presence of 1 "*vandalism*," 2 "*boarded houses*," 3, 4 "*abandoned cars and houses*," 5, 6 "*trash in street and in neighborhood*," 9 "*run-down yards*"
Green space		
Which of the following are present within sight of the housing unit?	Same as in physical disorder	Counted the presence of 14 "a park, playground or garden area"
Household decay		
Darkness	1 = "*dark*" to 5 = "*light*"	α = 0.84
Dirtiness	1 = "*clean*" to 5 = "*dirty*"	
Messiness	1 = "*neat*" to 5 = "*messy*"	
Cluttered	1 = "*very cluttered*" to 5 = "*not cluttered at all*"	
Stairway quality		
If interior or exterior stairway were present, which of the following did you observe? Enter all that apply	1 = *loose railings* 2 = *no railings* 3 = *loose steps* 4 = *none of the above* 5 = *no interior or exterior stairway present*	Coded 1 "*loose railings*," 2 "*no railings*" and 3 "*loose steps*" as 1

inactivity was drawn from the RAND HRS Longitudinal File 2018.

Statistical Analyses

Our primary purpose of this paper is to include both indoor and outdoor environmental hazards to examine how they independently influence the incidence of falling and how the associations differ by living arrangement. Therefore, we estimated three regression models using the following model specifications: (1) neighborhood only, (2) household only, and (3) both neighborhood and household measures. Specifically, in Model 1, we included neighborhood measures together with individual sociodemographic characteristics and health conditions. In Model 2, we added household measures only to examine the independent effect of the home environment such as the messiness and ambience of respondent's housing without neighborhood measures. In Model 3, we added both neighborhood and household measures to test whether neighborhood characteristics retained an independent effect on the risk of the falling net of the effects of the home environment

Table 2. Weighted Sample Characteristics by Living Arrangement Status, Health and Retirement Study, 2012–2020 (*N* = 1,893)

Variable	Total (*N* = 1,893)	Living alone (*n* = 554)	Living with others (*n* = 1,339)	*p* Value
	Mean (*SD*) or (%)	Mean (*SD*) or (%)	Mean (*SD*) or (%)	
Incidence of falls (≥1)	69.39%	73.15%	67.59%	<.05
Neighborhood				
Sidewalk quality	62.05%	60.35%	62.87%	.09
Physical disorder	8.51%	7.81%	8.85%	.57
Green space	9.14%	10.87%	8.31%	<.05
Household				
Household decay (range: 1–5)	2.07 (0.83)	2.17 (0.81)	2.02 (0.85)	<.01
Stairway quality	4.97%	6.48%	4.25%	.17
Individual				
Age				<.001
65–74	57.20%	46.84%	62.17%	
75–84	68.17%	40.91%	33.90%	
85+	6.63%	26.80%	3.94%	
Female	62.13%	75.92%	55.51%	<.001
Race/ethnicity				.15
Non-Hispanic White	82.56%	82.50%	82.59%	
Non-Hispanic Black	8.79%	10.71%	7.87%	
Hispanic	6.32%	4.50%	7.19%	
Other	2.34%	2.30%	2.36%	
Years of education (range: 0–17)	13.10 (3.16)	12.72 (2.87)	12.28 (3.27)	<.05
Wealth (range: 1–10)[a]	5.73 (2.98)	4.67 (2.81)	6.23 (2.91)	<.001
Mobility limitation (range: 0–5)	0.93 (1.31)	1.04 (1.31)	0.88 (1.30)	<.05
Physical inactivity	14.56%	17.53%	13.13%	.65

Notes: *SD* = standard deviation. We performed significant group comparisons based on Chi-square test and Wald test.
[a]10th percentile ranges from $1,510k to $3.5k (reference). 20th percentile ranges from $3.6k to $43.4k. 30th percentile ranges from $43.5k to 89k. 40th percentile ranges from 89.8k to 148k. 50th percentile ranges from $149.5k to $228k. 60th percentile ranges from $228.4k to $335k. 70th percentile ranges from 336k to 493k. 80th percentile ranges from $494.3k to $736.5k. 90th percentile ranges from 742k to $1,327k. 100th percentile includes over $1,329k.

and individual characteristics. We fitted logistic regression models for the incidence of falls over an 8-year study period. Because we expect that responses to environmental hazards may differ by living arrangement status, all analyses were stratified for people living alone and people living with others. All analytical models were adjusted for survey design (StataCorp, 2021). Detailed information on the HRS survey design has been published elsewhere (Ofstedal et al., 2011).

Results

Table 2 shows the sample at baseline by living arrangement status. Almost 70% of respondents reported at least one fall over 8 years of observation, but the experience of falling appeared to be different by living arrangement status. Respondents living alone compared with those living with others had a higher incidence of falls over time (73.15% vs 67.59%, $p < .05$). There were several other statistically significant differences between respondents who lived alone and those who did not. On average, respondents living alone were less likely to be exposed to poorly maintained sidewalks in their neighborhoods (60.35% vs 62.87%, $p < .01$) but were more likely to be exposed to green spaces (10.87% vs 8.31%, $p < .05$) and household decay (2.17 vs 2.02, $p < .01$). Demographically, people living alone tend to be older and female compared with those living with others. For example, over 65% of respondents living alone fell under the age category of 75+ ($p < .001$). Only 37% of respondents who lived with others fell into the 75+ age group. Among those living alone, 76% were female (vs 56% for people living with others, $p < .001$). Relative to those who lived with others, respondents who lived alone were more likely to report lower levels of education (12.72 vs 13.28, $p < .05$), wealth (4.67 vs 6.23, $p < .001$), and physical limitation (1.04 vs 0.88, $p < .05$).

Table 3 shows coefficients in odds ratios (OR) from logistic regression models predicting the incidence of falling over an 8-year study period. Throughout the models, coefficients from Model 1 (neighborhood only) and Model 2 (household only) remained largely the same in the direction and the size of the coefficient and p values even after controlling for both types of environmental hazards in Model 3. For instance, the odds of experiencing falling were 1.99 in Model 1 for the physical disorder ($p < .05$), and introducing household characteristics in Model 3 slightly increased the odds of falling from 1.99 to 2.10 ($p < .05$). Similarly, the coefficient of household decay was 1.50 in Model 2 ($p < .01$), which slightly increased to 1.53 when neighborhood characteristics

Table 3. Coefficients From Logistic Regressions Predicting the Risk of Falling by Living Arrangement, Health and Retirement Study, 2012–2020 (*N* = 1,893)

	Living alone			Living with others		
Variable	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Neighborhood						
Sidewalk quality	0.74		0.67	1.07		1.07
Physical disorder	1.47		1.26	0.88		0.76
Green space	1.99*		2.10*	1.06		1.04
Household						
Household decay		1.50**	1.53**		1.17	1.19
Stairway quality		2.43†	2.65*		1.29	1.34
Individual level						
Age (ref. = 65–74)						
75–84	1.09	1.36	1.30	1.39**	1.43**	1.42**
85+	1.63	1.98*	1.95*	4.00**	4.22**	4.22**
Female	2.48***	2.78***	2.86***	1.39*	1.38*	1.37*
Race/ethnicity (ref. = Non-Hispanic White)						
Non-Hispanic Black	0.56	0.57	0.52†	0.70	0.67†	0.70
Hispanic	0.74	0.97	0.84	1.02	1.00	1.05
Other	1.22	0.89	0.73	0.87	0.83	0.83
Years of education	1.04	1.05	1.05	1.03	1.03	1.04
Wealth	0.97	1.05	0.99	0.96	0.98	0.98
Mobility limitation	1.43**	1.39**	1.38**	1.33***	1.31***	1.32***
Physical inactivity	0.69	0.72	0.71	1.22	1.20	1.22

Notes: All variables were measured at baseline (2012).
*$p < .05$. **$p < .01$. ***$p < .001$. †$p < .10$.

adjusted for are shown in Table 3 ($p < .01$). Results from Wald test suggest that the effects from neighborhood and housing conditions on the incidence of falling are independent of one another.

Next, we turn to the stratified model to examine whether there are differences in living arrangement status. The results of Model 3 in Table 3 showed that environmental hazards, whether inside or outside of the home, are associated with the incidence of falling over 8 years *only* among respondents who lived alone. Environmental hazards were not significantly associated with the incidence of falling among those who lived with others. Specifically, we observed the presence of green space, such as a park, playground, and garden area nearby the housing unit, was associated with higher odds of falling for individuals who lived alone net of household characteristics and other covariates (OR = 2.10, $p < .05$). The presence of household decay and poorly maintained stairways were also associated with greater odds of falling for those living alone (OR = 1.53, $p < .01$ and OR = 2.65, $p < 0.05$, respectively). For individuals who lived with others, however, none of the environmental factors were associated with the incidence of falling over time.

To confirm the statistical significance of the ORs by living arrangement, we conducted the two-way interaction between environmental hazard measures (green spaces, household decay, and stairway quality) and living arrangement and plotted the predicted probabilities of falling in Figure 2. We displayed the predicted probabilities for green spaces and stairway quality only as their interaction terms were statistically significant. As shown in Panel A, the influence of green spaces was larger in people who lived alone than in those who did not. Whereas the probability of reporting falls did not differ for people living with others, respondents living alone in a neighborhood with the presence of green space had a significantly higher probability of reporting falls over 8 years than those living alone in a neighborhood without a park, playground, or garden area ($p < .05$). In addition, Panel B shows that living in a household with poorly maintained stairways had a statistically significant difference in the incidence of falls for people living alone ($p < .05$). The predicted probability for people living alone in a household with poorly maintained stairways was 0.85, compared with 0.68 for people living alone in a household with well-maintained stairways.

Discussion

Although a growing number of scholars have called for an integration of the layered contextual risk in health research (Lee & Waite, 2018; Schafer et al., 2018; Upenieks et al., 2016), there are few existing studies that examine the influence of both the home and neighborhood environments on the incidence of falling (Chippendale & Boltz, 2015; Edwards et al., 2019; Li et al., 2014; Lord et al., 2006; Nicklett, Lohman, et al., 2017; Stevens et al., 2014), and even fewer have done so longitudinally. This paper is one of the first to investigate whether substandard housing and neighborhood problems are associated with the incidence of falls over time and whether this association differs by living arrangement.

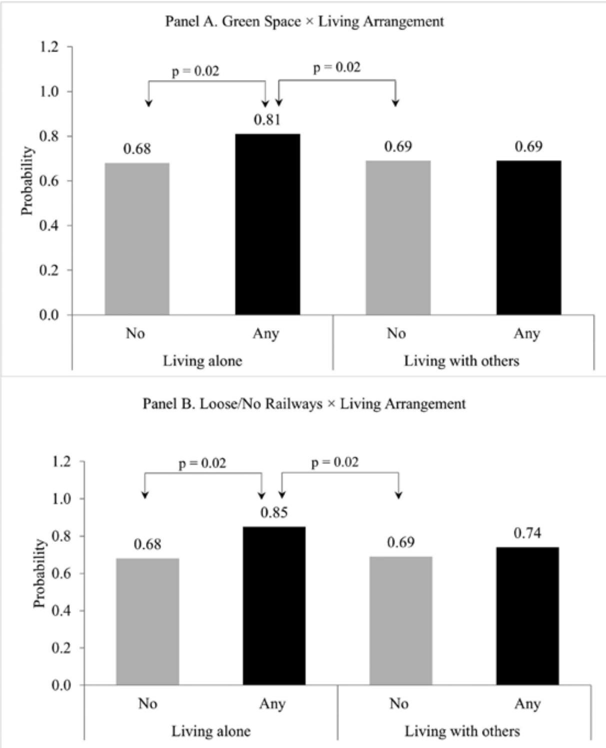

Figure 2. Predicted probabilities for the risk of falling by neighborhood measures and living arrangement, Health and Retirement Study, 2012–2020 (*N* = 1,893).

We found partial evidence supporting our hypothesis. First, falls in later life may result not from a single environmental source but from a combination of outdoor and indoor risk factors. Neighborhood and housing environment were independently associated with the odds of falling even after adjusting for individual characteristics. Second, for instance, the presence of green space and poorly maintained stairways were associated with greater odds of falling over 8 years of follow-up. Third, these associations were statistically significant for people living alone only. For people living with others, none of the environmental factors mattered for fall incidents.

Why might people who live alone be more susceptible to environmental hazards than others? First, people living alone may walk outside for errands more frequently than those living with others, which may expose them to the immediate surroundings and environmental features (Simonsick et al., 1999). Indeed, evidence suggests that older adults who live alone are more likely to walk for errands, become more aware of, and thus have greater access to environmental features (Shigematsu et al., 2009; Tsai et al., 2013), which may increase their risk of falling (Li et al., 2014). Using a representative sample of older adults in Brazil, Nascimento et al. (2018) found that people ages 80 and older are more likely to fall if they live in places with moderate green spaces. The authors posit that living in places with more green spaces is, in general, associated with more physical activity and better health, but it can also expose older adults to external environmental hazards within parks, playgrounds, or garden areas that can increase the risk of accidents and injuries such as falls. In fact, Kendrick et al. (2005) reported that accident and emergency hospital admission rates were higher in places with a greater number of parks and playgrounds. Parks, gardens, and recreational areas are often reported by older adults as places where outdoor falls occur (Li et al., 2006), but the HRS does not include information on the locations of falls. In addition, green spaces can have positive or negative health consequences depending on how they are designed and managed. However, HRS did not collect information on the quality of green spaces, and we were unable to explicitly test if green space is associated with a greater likelihood of falls because parks and gardens were poorly maintained in our study. Future research collecting detailed information on circumstances of falls and the quality of green spaces could examine differences in the characteristics of outdoor and indoor falls over time and how this association differs by living arrangement.

Findings from this study highlight the need for policymakers and community agencies working with older adults to consider their living situation when identifying high-risk populations and creating effective fall prevention strategies. Because environmental hazards may be disproportionately associated with fall incidents for those living alone, it is crucial that community agencies determine one's living situation to develop targeted support. Increasing outreach and communications with at-risk individuals (who live alone) is needed to ensure that their perspectives are incorporated into fall prevention recommendations. For example, a home safety assessment would be particularly helpful to provide education on types of environmental hazards and inform how to eliminate them to reduce fall incidents (i.e., fixing loose railings and missing steps on stairs).

Improving the design conditions of open spaces can also be beneficial to further reduce injuries and accidents associated with falls. To create safe walking environments in parks and garden areas, urban planners could avoid steep slopes in walking paths as they are more likely to create dangerous walking conditions that misclassification of may lead to fall incidents. Walking paths should also be properly maintained to avoid uneven and cracked surfaces for a safe pedestrian environment. Adequate lighting in open spaces throughout the day may provide maximum visibility for older adults. Last, local government identifying any environmental changes to accommodate design adjustments is essential to create age-friendly community amenities.

Strengths of the current study include: (a) the investigation of living alone as a potential source of compound disadvantage in the association between environmental hazards and falling; (b) the examination of environmental hazards at both the home and neighborhood levels; and (c) the assessment of the longitudinal association between environmental hazards and the incidence of falling using a nationally representative sample of U.S. older adults over 8 years of observation.

Despite these strengths, we acknowledge several limitations. First, the questions about falls in the HRS do not capture fall locations. Second, the incidence of falls was self-reported using a 2-year recall period, which could be subject to recall bias. Such bias could result in the misclassification of the outcome, which would generally bias toward the null; thus, if there is an association between exposure and outcome, the true effect could be slightly greater. Fortunately, compared with the frequency of exposure misclassification, errors in outcome classification tend to be less common and have much less impact on the estimate of association (Page

& Henderson, 2008). Despite this, the application of a 2-year recall period has been widely used in major aging studies to measure fall incidents (Bu et al., 2020; Nicklett, Lohman, et al., 2017; Quach & Burr, 2021; Wu & Ouyang, 2017). Still, the possibility of recall bias in self-reported falls suggests that caution is needed when interpreting results. Third, other features that have been previously linked to falls, such as inadequate street lighting, weather-related hazards, and slippery floors, were not measured in the HRS. Future research exploring these unobserved features might provide a broader understanding of modifiable environmental risk factors for falls.

As of 2021, 28% of U.S. older adults live alone (US Census Bureau, 2021)—thus, policy actions to protect at-risk populations and build effective prevention programs become urgent. Our study reveals that both indoor and outdoor environmental hazards may be disproportionately associated with later-life fall incidents among people living alone. This finding calls for the need to identify living arrangement status that adds a greater burden of environmental hazards. Public policy aimed at identifying groups that are particularly susceptible to substandard housing and neighborhood problems is essential to map specific needs. We conclude that older adult falls result not from a single factor but from multiple interacting environmental factors. Intervention strategies that improve design conditions of open spaces and indoor housing could promote healthy aging in later life by reducing potential accidents and injuries that lead to falls.

Supplementary Material

Supplementary data are available at *Innovation in Aging* online.

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Conflict of Interest

None.

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