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Association between a hilly neighborhood environment and falls among rural older adults: a cross-sectional study

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Abstract

Objective: Falls in older adults are a major public health issue, and it is unclear whether the neighborhood environment is associated with falls among this group. This cross-sectional study investigated whether hilly neighborhood environmental factors were associated with fall status (falls or fear of falling) in rural Japanese older adults.

Materials and Methods: Data obtained from 965 participants aged 65 years and older living in Unnan City, Shimane Prefecture, Japan, in 2017 were analyzed. Fall status was assessed based on the 1-year fall incidence (yes/no) for the past year and fear of falling (yes/no) using a self-report questionnaire. For hilly neighborhood environmental factors, the mean elevation and land slope were assessed using a geographic information system. The logistic regression model examined the odds ratios (OR) and 95% confidence intervals (CIs) of fall status in quartiles for elevation and land slope, respectively, and was adjusted for confounders.

Results: Falls and fear of falling were observed in 16.8% and 43.2% of participants, respectively. Falls were associated with elevation (OR 1.99, 95% CI 1.17–3.37 for Q2 vs. Q1; OR 2.02, 95% CI 1.19–3.44 for Q3 vs. Q1) and land slope (OR 1.74, 95% CI 1.04–2.93 for Q3 vs. Q1; OR 1.74, 95% CI 1.04–2.93 for Q4 vs. Q1). Fear of falling was associated with elevation (OR 1.78, 95% CI 1.19–2.65 for Q3 vs. Q1) and land slope (OR 1.51, 95% CI 1.01–2.25 for Q4 vs. Q1).

Conclusion: Our study found that elevation and land slope as hilly neighborhood environment factors were positively associated with falls or fear of falling among older adults living in rural Japan. Prospective observational studies that investigate the effects of region-specific environmental factors on falls among older adults should be conducted.

Keywords: elevation, hilliness, community-dwelling older adults, falls, fear of falling

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Introduction

Falls in older adults are among the most important problems in public health today, causing serious injury, reduction of functional capacity and quality of life, and, in the most serious cases, even death[1, 2]. Around the world, sizable percentages of community-dwelling older adults are estimated to experience at least one fall per year, at roughly 30% in Europe and the United States and 10–20% in Japan, with an increased incidence being observed with advanced age[1, 3–5]. The rapid pace of aging worldwide in the modern era has raised concerns about the increased disease burden owing to musculoskeletal disorders and injuries caused by falls[6–8]. In Japan, fall-related fractures are a major reason for older adults being certified to require assistance or long-term care to perform activities of daily living (ADLs)[9]. Preventing falls in older adults is an urgent issue in this country—a "super-aged society", setting it apart from other countries worldwide—that should be addressed for residents in ru-

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ral areas of the country, particularly those in farming and mountain villages, where societal aging is progressing more rapidly than that in urban areas.

Epidemiological studies have identified a variety of putative risk factors for falls in older adults[10–12]. The underlying causes of falls can be broadly divided into intrinsic and extrinsic factors. The former refers to problems with the physical and psychological characteristics of an individual, including age-related changes (e.g., age, physical functioning), physical illnesses, medications, and fear of falling. The latter refers to problems with an individual's physical environment, including land slope, steps, and other structural elements ("built environment") and even footwear. These factors are mutable and controllable; in fact, several systematic reviews have reported that fall prevention interventions aimed at reducing fall risk factors can effectively prevent falls among older adults[13–15].

Conversely, the environmental conditions that are found around an individual's place of residence, or "neighborhood environmental factors", are significantly difficult or even impossible to modify or control in the case of community-dwelling older adults. Evidence indicates that older adults' health and physical function are affected by their neighborhood environment[16]. Several studies have found that living in unsafe or low socioeconomic status areas was significantly associated with ADL limitations and reduced physical capacity[17–20]. Other studies have revealed that neighborhood environmental factors related to the ease of walking, such as residential density and road connectivity, have consistently strong associations with physical activity in older adults[21, 22]. All of these studies suggest that neighborhood environmental factors can influence physical capacity and activity levels, which are closely associated with falling in older adults. However, to the best of our knowledge, none of the epidemiological data reported thus far have explored the direct associations between falls and neighborhood environment in older populations. Previous studies focusing on neighborhood environmental factors that are related to gerontological health and physical functioning have predominantly considered urban settings, primarily in the United States and Europe. Few studies have considered environmental factors specific to rural older populations. There is a dearth of epidemiological studies in rural environments, particularly those related to older residents thereof, although the older population tends to account for a greater percentage of the population of these areas than the national average in countries worldwide[23]. In Japan, it is rare for the scope of gerontological research on the characteristics of neighborhood living environment to be limited exclusively to urban areas; rural areas are included in most studies[24–31]. These studies have identified several environmental factors, including access to public transportation, altitude, residential density, and land slope, which were found to be associated to varying degrees with physical activity and functioning, weight change, hypertension, and diabetes mellitus[26–31].

The neighborhood environment could hold the key to effective fall prevention at the population level, as older adults tend to spend a significantly longer amount of time in their place of residence than younger adults, thus making their living environment particularly significant[32]. The natural environment is thought to greatly influence people's health, and research interest in evaluating it alongside built environments to identify unique qualities of rural environments, which do not apply in urban settings, has increased[33]. Steep terrain is an intrinsic quality of Japan's geography that creates hilly neighborhoods, especially in rural parts of the country[34], thus making it critically important to identify environmental factors in these regions that predispose individuals to falling and threaten the lives of older residents. Several previous studies in Japan have reported the potential for a rural hilly neighborhood environment to influence health outcomes, but its association with falls in older adults has not been clarified[28–31]. This study aimed to explore the associations between hilly neighborhood environmental factors and falls in a Japanese population of rural older adults using a cross-sectional study design.

Materials and Methods

Study design

This cross-sectional study utilized data from the *Long Term Care Prevention Cohort Study Focusing on the Characteristics of Agricultural and Rural Areas*, a collaborative research project involving Unnan City (Shimane Prefecture, Japan), the Japanese Association of Rural Medicine, and Shimane University. The research project is a longitudinal survey intended to identify factors that lead to lifestyle-related diseases and long-term care in older adults aged 65 years or older based on survey data related to health status and lifestyle habits such as agricultural activities obtained during annual health checkups. The data used in this study were baseline data from 2017 for the project. Informed consent was obtained from the participants before they participated. The study protocol was approved by the ethics committee of Physical Education and Medicine Research Center UNNAN (H30-6-28-1), the Japanese Association of Rural Medicine (No. 20180507-15), and Shimane University (No. 20180920-8).

Participants

The study area was Unnan City (population: 39,614, aging rate: ≥35%, area: 553.4 km^2 [April 2017]), a rural area of Shimane Prefecture in Japan. The data included were obtained from 1,066 community-dwelling older adults (age ≥65 years) who had received a health checkup sponsored by the city government. Participants for whom data were

missing (n=101) were excluded from the analysis; finally, data obtained from 965 participants were used for the final analyses.

Outcome variables

The 1-year fall incidence (yes/no) that occurred during the past year was investigated as the primary outcome and was determined by asking participants whether they had fallen in the past year using a self-report questionnaire. Questions that ask participants to recall falls that occurred in the past year have been shown to have good screening accuracy, demonstrating relatively good sensitivity (80–89%) and high specificity (91–95%)[35]. Fear of falling (yes/no) was investigated as the secondary outcome and was determined by asking participants whether they felt anxious or worried about falling in their daily life using a self-report questionnaire. This psychological factor, defined as continual anxiety regarding falling that leads individuals to avoid routine daily activities despite having the physical ability to perform them[36], is known to increase the risk of fall incidence in older adults. Previous studies have indicated that this fear affects approximately half of community-dwelling older adults, including those who have never experienced an incidence of falling[37]; other studies have noted that the likelihood of the incidence of falling can be affected by residential (built) environments, such as conditions at home[38].

Main exposure variables

Two geographic variables were used for the analysis: mean elevation (m) and mean land slope (°). Elevation and slope values in the vicinity of each participant's home address were obtained using the geographic information system software (ArcGIS 10.5.1, ESRI Japan Co., Ltd., Japan) and averaged using road network buffers, a spatial range deemed suitable for assessing physical activity levels in preceding neighborhood environment research[39].

These values were calculated by averaging the corresponding National Land Numerical Information data for five-dimensional mesh data consisting of several 50×50-m grid squares within the road network buffer extending 1,000 m from the participant's place of residence; these data are managed by the National Land Information Division, National Spatial Planning and Regional Policy Bureau of Japan.

Data for both variables were divided into quartiles to explore potential associations with falling.

Covariates

Data for potential confounding and effect-modifying variables reflecting associations between the main exposure variables and outcome variables were obtained using a self-report questionnaire. Sex (men/women), age (65–74/≥75 years), household status (single/one/two/three or four households), days spent engaging in agricultural activities (0/1–59/60–149/≥150+ days/year), occupation (unemployed/farmer/non-farmer), body mass index (<18.5/18.5–24.9/≥25 kg/m^2), physical activity level (high/low/inactive), cognitive function decline risk (yes/no), depression symptom risk (yes/no), self-rated health (excellent/fairly good/average/not very good/poor), smoking habit (yes/no), and alcohol drinking habit (yes/no) were assessed. Statistical models evaluating the associations between mean elevation or land slope and falls and fear of falling were adjusted using these covariates.

Statistical analyses

One-year fall incidence (%) and fear-of-falling prevalence (%) rates were calculated separately by covariate subgroup.

Associations between these epidemiological factors and the mean elevation and land slope were explored using binomial logistic regression analysis, with covariates inserted into models by forced entry. In addition, the dose–response associations between exposure variables and outcomes were investigated using trend analysis.

The findings reported below correspond to the full analysis set population consisting exclusively of patients with complete data after excluding those with missing values.

Statistical significance was set at $P<0.05$. The International Business Machines Corporation Statistical Package for the Social Sciences version 25.0 was used for all statistical analyses.

Results

One-year fall incidence that occurred during the past year and fear-of-falling prevalence rates for the 965 participants in the final analysis dataset (men: 430, women: 535) are presented in Table 1, shown separately by participant attributes (covariates). The 965 participants had a mean (standard deviation) age of 74.2 (5.9) years; the mean age of males was 74.6 (6.1) years, and that of females was 73.9 (5.8) years.

Overall, 16.8% had fallen within the past year, whereas 43.2% reported a fear of falling. Having fallen in the past year was significantly associated with cognitive function decline risk ($P=0.03$), depressive symptom risk ($P=0.01$), and self-rated health ($P=0.02$). Fear of falling was significantly associated with sex ($P<0.01$), age ($P<0.01$), household status ($P=0.03$), number of days spent engaging in agricultural activities ($P=0.02$), working status ($P=0.01$), physical activity level ($P<0.01$), depressive symptom risk ($P<0.01$), self-rated health ($P<0.01$), and alcohol drinking habit ($P<0.01$).

The results of the logistic regression analysis of neighborhood geography and falling-related outcomes are shown in Table 2. The median (interquartile range) of the neighbor-

Table 1 Participants' characteristics

Variables	Total	Falls			Fear of falling		
		No	Yes	*P* value	No	Yes	*P* value
n (%)	965	803 (83.2)	162 (16.8)		548 (56.8)	417 (43.2)	
Sex							
Male	430 (44.6)	352 (81.9)	78 (18.1)		281 (65.3)	149 (34.7)	
Female	535 (55.4)	451 (84.3)	84 (15.7)	0.34	267 (49.9)	268 (50.1)	<0.01
Age							
65–74 years	525 (54.4)	441 (84.0)	84 (16.0)		332 (63.2)	193 (36.8)	
75 years and above	440 (45.6)	362 (82.3)	78 (17.7)	0.49	216 (49.1)	224 (50.9)	<0.01
Household status							
Single	108 (11.2)	90 (83.3)	18 (16.7)		47 (43.5)	61 (56.5)	
One household	313 (32.4)	253 (80.8)	60 (19.2)		187 (59.7)	126 (40.3)	
Two households	316 (32.7)	276 (87.3)	40 (12.7)		184 (58.2)	132 (41.8)	
Three or four households	228 (23.6)	184 (80.7)	44 (19.3)	0.10	130 (57.0)	98 (43.0)	0.03
Days Engaging in agriculture							
No	154 (16.0)	128 (83.1)	26 (16.9)		70 (45.5)	84 (54.5)	
1–59 days/year	193 (20.0)	159 (82.4)	34 (17.6)		109 (56.5)	84 (43.5)	
60–149 days/year	247 (25.6)	203 (82.2)	44 (17.8)		145 (58.7)	102 (41.3)	
≥150 days/year	371 (38.4)	313 (84.4)	58 (15.6)	0.89	224 (60.4)	147 (39.6)	0.02
Current working status							
Unemployed	466 (48.3)	392 (84.1)	74 (15.9)		250 (53.6)	216 (46.4)	
Non-farmer	245 (25.4)	200 (81.6)	45 (18.4)		133 (54.3)	112 (45.7)	
Farmer	254 (26.3)	211 (83.1)	43 (16.9)	0.70	165 (65.0)	89 (35.0)	0.01
BMI, kg/m^2							
<18.5	106 (11.0)	91 (85.8)	15 (14.2)		55 (51.9)	51 (48.1)	
18.5–24.9	709 (73.5)	592 (83.5)	117 (16.5)		411 (58.0)	298 (42.0)	
≥25	150 (15.5)	120 (80.0)	30 (20.0)	0.43	82 (54.7)	68 (45.3)	0.42
Physical activity level							
High	328 (34.0)	274 (83.5)	54 (16.5)		227 (69.2)	101 (30.8)	
Low	625 (64.8)	520 (83.2)	105 (16.8)		317 (50.7)	308 (49.3)	
Inactive	12 (1.2)	9 (75.0)	3 (25.0)	0.74	4 (33.3)	8 (66.7)	<0.01
Cognitive function decline risk							
No	717 (74.3)	608 (84.8)	109 (15.2)		420 (58.6)	297 (41.4)	
Yes	248 (25.7)	195 (78.6)	53 (21.4)	0.03	128 (51.6)	120 (48.4)	0.06
Depressive symptoms risk							
No	622 (64.5)	532 (85.5)	90 (14.5)		405 (65.1)	217 (34.9)	
Yes	343 (35.5)	271 (79.0)	72 (21.0)	0.01	143 (41.7)	200 (58.3)	<0.01
Self-rated health							
Excellent/fairly good	369 (38.2)	320 (86.7)	49 (13.3)		246 (66.7)	123 (33.3)	
Average/not very good/poor	596 (61.8)	483 (81.0)	113 (19.0)	0.02	302 (50.7)	294 (49.3)	<0.01
Smoking habit							
No	905 (93.8)	752 (83.1)	153 (16.9)		507 (56.0)	398 (44.0)	
Yes	60 (6.2)	51 (85.0)	9 (15.0)	0.86	41 (68.3)	19 (31.7)	0.08
Alcohol drinking habit							
No	711 (73.7)	588 (82.7)	123 (17.3)		382 (53.7)	329 (46.3)	
Yes	254 (26.3)	215 (84.6)	39 (15.4)	0.50	166 (65.4)	88 (34.6)	<0.01

BMI: body mass index. *Differences between fall status were examined using the χ^2 test.

hood hilliness variables, that is, elevation and land slope, were, 75 (134–112) meters and 10 (7–14) degrees, respectively. After adjusting for all confounding variables, fall incidence during the past year was significantly associated with both mean elevation (Q2: OR=1.99, *P*=0.01; Q3: OR=2.02, *P*=0.01) and mean land slope (Q3: OR=1.74, *P*=0.04; Q4:

Table 2 Logistic regression for the association between neighborhood environmental factors and fall status

	n (%)	Crude model			Adjusted model[a]		
		OR	95% CI	*P* value	aOR	95% CI	*P* value
During the past 1-year fall incidence							
Mean elevation[b]							
Q1	27 (11.2)	(ref)			(ref)		
Q2	44 (18.3)	**1.79**	**(1.07–3.00)**	**0.03**	**1.99**	**(1.17–3.37)**	**0.01**
Q3	46 (19.1)	**1.88**	**(1.12–3.14)**	**0.02**	**2.02**	**(1.19–3.44)**	**0.01**
Q4	45 (18.6)	**1.82**	**(1.09–3.04)**	**0.02**	1.65	(0.97–2.83)	0.07
p for trend				**0.03**			0.10
Mean land slope[c]							
Q1	29 (12.0)	(ref)			(ref)		
Q2	39 (16.2)	1.42	(0.85–2.38)	0.19	1.53	(0.90–2.59)	0.12
Q3	45 (18.7)	**1.69**	**(1.02–2.80)**	**0.04**	**1.74**	**(1.04–2.93)**	**0.04**
Q4	49 (20.3)	**1.87**	**(1.14–3.09)**	**0.01**	**1.74**	**(1.04–2.93)**	**0.04**
p for trend				**0.01**			**0.03**
Fear of falling							
Mean elevation[b]							
Q1	91 (37.6)	(ref)			(ref)		
Q2	101 (42.1)	1.21	(0.84–1.74)	0.32	1.35	(0.91–2.00)	0.14
Q3	110 (45.6)	1.39	(0.97–2.00)	0.07	**1.78**	**(1.19–2.65)**	**<0.01**
Q4	115 (47.5)	**1.50**	**(1.05–2.16)**	**0.03**	1.45	(0.97–2.16)	0.07
p for trend				**0.02**			**0.03**
Mean land slope[c]							
Q1	93 (38.4)	(ref)			(ref)		
Q2	101 (41.9)	1.16	(0.80–1.66)	0.44	1.31	(0.88–1.94)	0.18
Q3	105 (43.6)	1.24	(0.86–1.78)	0.25	1.46	(0.99–2.17)	0.06
Q4	118 (49.0)	**1.54**	**(1.07–2.21)**	**0.02**	**1.51**	**(1.01–2.25)**	**0.04**
p for trend				**0.02**			**0.04**

aOR: adjusted odds ratio; CI: confidence interval; p for trend: trend test. Each neighborhood environmental factor was included separately. Boldface indicates significance, $P<0.05$. [a]Sex, age, household status, days engaging in agriculture, current working status, BMI, physical activity level, cognitive function decline risk, depressive symptoms risk, self-rated health, smoking habit, and alcohol drinking habit were adjusted. [b]Mean elevation was categorized into "Q1" (<59.2 m), "Q2" (59.2 to <75.1 m), "Q3" (75.1 to < 193.5 m), and "Q4" (≥193.5 m). [c]Mean land slope was categorized into "Q1" (<6.9°), "Q2" (6.9 to <10.0°), "Q3" (10.0 to <13.6°), and "Q4" (≥13.6°).

OR=1.74, $P=0.04$) when compared to those of group Q1 (the lowest category). In addition, a significant dose–response trend was observed for mean land slope (p for trend=0.03). After adjusting for all confounding variables, fear of falling was significantly associated with both mean elevation (Q3: OR=1.78, $P<0.01$) and mean land slope (Q4: OR=1.51, $P=0.04$) when compared to those of group Q1 (the lowest category). In addition, significant dose–response trends were observed for both mean elevation (p for trend=0.03) and mean land slope (p for trend=0.04).

Discussion

Our findings demonstrated that residents living in areas with a higher degree of land slope were significantly and positively associated with fall incidence during the past year. For the secondary outcome, significant positive associations between higher elevations and land slope and a greater fear of falling were also observed. Our findings suggest that older adults residing in hilly neighborhoods have a higher rate of fall incidence than their peers living in flatter parts of the same area.

Tripping (stumbling) is known to be the primary proximate cause of falls[40–42] and occurs when a swinging foot contacts an object or the ground[43]. A fall can be defined as "unintentionally coming to rest on ground, floor, or other lower level and excludes coming to rest against furniture, wall, or other structures". Slipping is also implicated as a direct cause of falls[44]. Generally, one would expect higher rates of exposure to earth, sloping land, and other natural topographies to be present in significantly hilly neighborhood environments, given the lower percentage of land oc-

cupied by manmade surfaces such as pavement and roads. We can hypothesize that extended exposure to more natural environments, which often involve hilly terrain, increases people's risk of directly encountering the type of conditions in which they are prone to stumbling or slipping while walking around or doing other routine activities, increasing their risk of falling. Compared to younger adults, older adults are more prone to stumbling because of their lower *toe clearance*, that is, the distance from the toes of the trailing leg to the floor while walking or to a stair or other obstacles when stepping over it[43]. Reduced mobility is a major risk factor for falls in older adults, as lower physical activity levels combined with the aging process cause a functional decline in physical abilities such as strength and balance[10–12]. Given their lower physical capacity relative to younger adults, their fall risk may increase because they disproportionately feel the effects of living physically proximate to (or even in the middle of) hilly neighborhoods.

Fear of falling in older adults is known to be influenced by the presence of environmental hazards that increase fall risk[45] and the physical environments of daily living spaces such as homes, frequently used facilities, and nearby areas where they walk daily. In some cases, sufferers can be afraid of falling, even regarding activities performed in their own homes[46]. A Malaysian study of middle-aged and older adults found that people with a greater fear of falling may face greater *functional home hazards* connected to living behaviors than their less fearful peers, such as the inability to safely ascend stairs[38]. In New Zealand, researchers have observed that fear of falling is independently associated with difficulties walking near home because of factors such as the presence or absence of footpaths, including their width, condition, obstruction, and slope as well as the presence of puddles leaves, and steps or stairs[47]. When considered together, these findings suggest that exposure to natural environments, which often involve hilly terrain, may increase an individual's fear of falling by boosting psychological anxiety in regard to its occurrence. It is widely known that fall-related fractures increase the likelihood of needing long-term nursing care. Therefore, it seems plausible that older adults who live in mountainous, hilly terrain in places with low accessibility to medical and welfare resources would be particularly prone to having higher psychological anxiety regarding falling than their peers living in flatter parts of the country. When older adults are fearful of falling, they often curtail routine activities despite being fully able to perform them in a physical sense, thus leading to disuse, reduced physical capacity, and counterproductivity, which, in turn, increases their fall risk[36]. Enhancing approaches to reducing the fear of falling in older adults may be especially important for rural populations living in hilly neighborhoods.

With the rapid aging of the population, the Japanese government is aiming to create a 'community-based Integrated Care System' as a social system that will allow older adults to live the rest of their lives in their own ways in familiar environments[48]. The findings of this study suggest that a fall prevention approach that considers the neighborhood environment of older adults is important in realizing this social system.

Our findings should be interpreted carefully because of several limitations. First, the study participants were not randomly selected from each residential district in Unnan City. Our data came from older adults who participated in an annual health checkup sponsored by the city, who may be healthier or more conscious of their health than the older population at large. Second, participants' reporting of falls may have been affected by recall bias because the self-report questionnaire we used required them to recall their occurrence over an entire year. A prior study recommended that study participants keep records of falls daily using a calendar or other means, particularly in the case of interventional research, to allow researchers to collect that information every month[49]. However, critics have noted that response rates can be greatly reduced when this approach is adopted[50]. No definitive conclusion regarding the optimum method for monitoring falls has yet been reached[35]. Third, our regression models were not adjusted for physical capacity; reduced strength, mobility, and impaired balance are typical risk factors for falls[10–12]. Fourth, this study did not consider chronic diseases or related medications. A previous study has shown that fall risk can be exacerbated by chronic disease, drug side effects, and polypharmacy[10–12]. People living in rural areas are generally at higher risk of chronic diseases[51, 52], which means we cannot rule out the possibility that they influenced fall incidence in our study population. However, we believe we were able to control for chronic disease to a certain extent by including self-rated health as a covariate in our models as it is an established measure of individuals' subjective perceptions of their general health that is widely used in observational epidemiological studies.

Nevertheless, our study has many strengths. First, it is the first to explore how falls and fear of falling are associated with elevated, hilly terrain of the neighborhoods in which older Japanese adults live in rural parts of the country. To date, studies assessing the associations between extrinsic and environmental factors and falling in older adults have focused on aspects of the built environment, including conditions present in homes and building interiors[38], or other physical environments, such as steps in walkable neighborhoods[47]. None investigated how falls were associated with exposure to natural environments. Our findings provided a follow-up question for further study that can be stated as follows: Does living in a natural environment act as a major correlate for falls and fear of falling, or is this a spurious "pseudo-relationship" that can be explained by other confounding variables?

Second, the geographic data applied in this study pro-

vide an objective measurement of the neighborhood environment. Subjective measures are important, but they are subject to individual variation[53], making them less accurate than quantitative methods. The quantification of neighborhood environments using objective data will be highly beneficial in designing effective intervention strategies that account for conditions specific to rural communities.

Our study's third advantage is its setting: a rural area of Japan where the proportion of the population aged 65 years or older already exceeds 35%. Although people living in rural areas tend to be at a greater risk of chronic diseases than people living in urban areas due to the limited availability of medical resources[51, 52], research on their residents, especially older adults, has been limited. Roughly half of the world's population lives in rural environments, despite the increasing percentage of urban residents[54]. Given that a large segment of the rural population consists of older adults[23], a study in rural gerontology is of special significance not only for local communities but also for global public health broadly. One could argue its importance to be even greater in Japan, a country at the forefront of societal aging where roughly 70% of the total land area is occupied by mountainous and hilly terrain.

Conclusion

This study identified significant positive associations between elevation, hilliness, and falls in older adults living in a rural community. A steeper local terrain was associated with a greater rate of the 1-year fall incidence that occurred during the past year, whereas both greater elevation and hilliness were associated with the prevalence of fear of falling.

Although further longitudinal observational studies are needed, our findings suggest that older adults living in hilly parts of rural areas are at greater risk of falling than their peers living in flatter areas. In the future, fall prevention interventions aimed at reducing fall incidence risk in older rural populations may need to be adjusted to account for hilly neighborhood environmental factors.

Conflict of interest: The authors declare that they have no conflicts of interest.

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