Hilly environment and frequency of going out-of-home among older adults: Examining moderating effect of driving status

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Abstract

Aim: The health benefits of "going out-of-home" frequently among older adults are well known. A hilly environment would inhibit this habit. This study examined (1) longitudinal associations between a hilly environment and the frequency of going out-of-home and (2) the moderating effect of driving status on their association among older adults.

Methods: This study involved a longitudinal study design. Data on 856 older adults in Nada Ward, Kobe, Japan, was obtained from a three-wave questionnaire survey (Wave 1: December 2017 to January 2018; Wave 2: after one year; Wave 3: after three years). In each survey, the frequency of going out-of-home time was measured. The average land slope within 500m network buffers of each participant's home was calculated as the index of the hilly environment. Driving status was also measured.

Results: The latent growth model revealed that while a higher average land slope was not significantly associated with changes in the frequency of going out-of-home over time, it was significantly associated with a lower frequency of going out-of-home at the initial level. The interaction term in the latent growth model showed that driving status did not moderate the associations of the average land slope with the initial level of, and changes in, the frequency of going out-of-home.

Conclusions: Although it remains unclear whether a hilly environment would accelerate a decline in the frequency of going out-of-home over time, this study found that older adults living in a hilly environment were less likely to leave their homes.

Keywords*:* aged; environmental design; geographic information systems; homebound persons; public health

Introduction

The health benefits of leaving home during the day (or "going out-of-home") more frequently among older adults are well known. The concept of going out-of-home is similar to the notions of homebound status and life-space mobility. Homebound status generally represents the status in which older adults rarely go out-of-home [1]. Life-space mobility captures the frequency of going to various life spaces [2]. Along with "going out-of-home," the term "going outdoors" has been commonly used. Going out-of-home is associated with numerous health outcomes [3-5]. Thus, implementing effective strategies that encourage older adults to go out-of-home is important for promoting their health. To establish such strategies, identifying the determinants of the frequency of going out-of-home among them is essential.

The frequency of going out-of-home among older adults is determined by environmental factors. The ecological model of health behavior [6] proposes that multi-level factors are correlated with health behaviors. In particular, the ecological model underscores the importance of environmental factors [6]. The frequency of going out-of-home and homebound status are determined by environmental factors such as social networks [7], barriers upon entry to the home [8], mixed land use in neighborhoods [9], distance to retail stores [10], and perceived accessibility to parks [11].

In addition, a hilly environment would also determine the frequency of going out-of-home among older adults. Walking in a hilly environment entails exerting more physical effort—including energy expenditure [12] and muscle activities [13]—than traversing a flat environment. Thus, a hilly environment might inhibit older adults from going out-of-home frequently. The undesirable influences of a hilly environment indicate that more intensive support to promote going out-of-home should be provided to older adults living in such a landscape. Physical activity studies [14-16] imply that older adults living in a hilly environment are less likely to engage in physical activity. Since going out-of-home is associated with physical activity [17], a hilly environment would also influence the frequency of going out-of-home among older adults. However, few previous studies have examined the associations between a hilly environment and the frequency of going out-of-home in this population.

To better understand the influences of a hilly environment on the frequency of going out-of-home among older adults, it is helpful to explore moderators (effect modifiers). Moderators signal who may be more susceptible to the influences of a hilly environment compared to others. Driving status would be one moderator. It is reasonable to assume that traveling by car in a hilly environment requires less physical effort than walking and cycling, and that the undesirable effects of a hilly environment on the frequency of going out-of-home might be more relevant among non-drivers than drivers. Physical activity studies denote that driving status can moderate associations between the environment and physical activity among older adults [18-20]. However, these studies investigated the moderating effects of driving status in relation to other environmental factors.

The present study aimed to explore (1) longitudinal associations between a hilly environment and the frequency of going out-of-home and (2) the moderating effect of driving status on their associations among older adults. We employed a latent growth model—a statistical methodology of structural equation modeling—to analyze longitudinal data. The latent growth model can specify and treat the initial status of frequency of going out-of-home and the longitudinal change of it, separately. By employing this model, we posited that a hilly environment would be associated with a lower frequency of going out-of-home at the initial level (Hypothesis 1A) and would accelerate declines in its frequency over time (Hypothesis 1B). For the second purpose, the study conjectured that the associations of a hilly environment with the initial level of, and changes in, the frequency of going out-of-home would be more relevant among non-drivers than among drivers (initial level: Hypothesis 2A; change: Hypothesis 2B).

Methods

Participants and procedures (Figure 1)

The present study analyzed data obtained from a three-wave questionnaire survey by postal mail. The survey targeted older adults living in Nada Ward in the city of Kobe, Hyogo Prefecture. Nada Ward is a typical urban area in Japan. Since Nada Ward is at the base of Mt. Rokko and adjacent to the sea, it has both hilly and flat areas. From the official register of residents of Nada Ward, the survey identified all men who were 64, 69, and 74 years old on the first day of April 2017 (n=2,204), as well as their wives, whose age was within 10 years of the men's age (n=1,516). At the baseline (December 2017 to January 2018: Wave 1), the survey asked these 3,720 individuals to answer the questionnaire, and 1,784 individuals responded. Among them, 1,079 agreed to have further contact with our research group. After one year from the baseline (Wave 2), the survey asked 1,079 individuals to answer a one-year follow-up survey, and 919 individuals responded. After three years from the baseline (Wave 3), the survey asked 1,079 individuals to answer a three-year follow-up survey, and 854 individuals responded.

In this study, among the 1,784 respondents of Wave 1, 928 were excluded from the analyses due to the reasons shown in Figure 2. Thus, the present study scrutinized the data of 856 individuals.

We implemented the survey as part of a larger research project. We have already published one paper [21] and submitted several other papers using the data from the survey. None of the other papers analyzed a hilly environment.

Written informed consent was obtained from all participants. The survey received approval from the Ethics Committee of the Graduate School of Human Development and Environment at Kobe University (No. 549-2). All procedures were conducted in accordance with the principles of the Declaration of Helsinki.

Measures

Frequency of going out-of-home

Each wave of the survey asked respondents to indicate the frequency of going out of the house on usual non-working days (except for checking the mailbox and taking out the garbage) from five choices: *almost every day*; *once every 2–3 days*; *once every 4–5 days*; *once every 6–7 days*; and *hardly ever*. Similar to a previous study [5], to convert weekly frequencies and treat frequency as a continuous variable, the present study coded the choice of *almost every day* as 7, once every 2–3 days as 2.8, once every 4–5 days as 1.55, once every 6–7 days as 1.08, and *hardly ever* as 0, respectively.

Average land slope

Similarly to previous physical activity studies [14-16], the present investigation measured the average land slope as the index of a hilly environment. Using geographic information systems (ArcGIS for Desktop 10.5 Network Analyst and Spatial Analyst; ESRI Japan Corporation), the current study calculated the average land slope within 500m network buffers of each respondent's home. Physical activity studies have commonly employed 400–500 m or 800–1000 m buffer sizes [22]. We selected 500 m buffer because the hilliness around the home would be much more relevant to older adults' decision to go out than the hilliness at a 800–1000 m distance. Digital Elevation Model 5 m Grid, provided by the Geospatial Information Authority of Japan, and ArcGIS Geo Suite Road Network data (2019), provided by ESRI Japan Corporation, were utilized to calculate it.

Driving status

Similarly to a prior study [20], the survey at Wave 1 asked the respondents whether they usually drove a car and/or motorbike by themselves (*yes* or *no*).

Demographic factors

The present study explored the data of age, gender (*male*/*female*), education level (*junior to high school*/*more than high school*), living alone (*yes*/*no*), employment status (*yes*/*no*), perceived household economic status (a five-point Likert scale from 1 = *very poor* to 5 = *very good*), and frailty (*yes*/*no*) as demographic factors at Wave 1. The survey measured education level by four options: *junior school or junior high school*; *high school*; *2-year college or vocational school*; and *4-year college*. For convenience of analysis, we dichotomized the educational level to treat the ratio of each sample size as equal. The Kihon Checklist [23, 24] was utilized to evaluate frailty. This checklist has 25 items, and the sensitivity and specificity to screen for frailty by cut-off point as 7/8 are 89.5% and 80.7%, respectively [24].

Analyses

For the main analyses, the present study conducted latent growth modeling (Figure 2). Latent growth modeling estimated the intercept (the initial level) and slope (longitudinal change over time) of the frequency of going out-of-home. The factor loading for the slope was set as 0, 1, and 3 for Wave 1, Wave 2, and Wave 3, respectively. In Model 1, the current study investigated the paths from the average land slope to the intercept and the slope of the frequency of going out-of-home. In Model 2, the paths from driving status at Wave 1 and the paths from the interaction term of driving status with the average land slope were added. In Model 3, the paths from demographic factors at Wave 1 were added. Corresponding models included the correlations among the average land slope, driving status, the interaction term, and demographic factors. The average land slope was mean-centered prior to create the interaction term. If the path from the average land slope to the intercept of the frequency of going out-of-home and the path from it to the slope of the frequency of going out-of-home were negative and significant in all models, Hypotheses 1A and 1B would be supported, respectively. If the path from the interaction term to the intercept of the frequency of going out-of-home and the path from the interaction term to the slope of it were positive and significant in both models 2 and 3, Hypotheses 2A and 2B would be supported, respectively.

The present study also conducted multi-group modeling to improve the robustness of the findings for the moderating effect of driving status. First, the study developed the unconstrained model, which did not have any equality constraints for the parameters between non-drivers and drivers. Next, the study developed constrained models, which treated the path coefficients from the average land slope to the intercept and the slope of the frequency of going out-of-home as equal between non-drivers and drivers. The current study compared the model fit indices of the unconstrained and constrained models. If the chi-square of the model with an equality constraint on the path to the intercept of going out-of-home was significantly different from the unconstrained model, and the other model fit indices of the constrained model were worse than the unconstrained model, Hypothesis 2A would be supported. In the same vein, if the chi-square of the model with an equality constraint on the path to the slope was significantly different from the unconstrained model, and the other model fit indices of the constrained model were worse, Hypothesis 2B would be supported. Both the unconstrained and constrained models included paths from demographic factors to the intercept and the slope of the frequency of going out-of-home.

The missing data were handled using full information maximum likelihood estimation. The model fit indices were the chi-square, the comparative fit index (CFI), the Tucker-Lewis index (TLI), the root mean square error of approximation (RMSEA), and Akaike's information criterion (AIC). IBM SPSS AMOS 25.0 was utilized to develop both models. Statistical significance was set at $p<0.05$.

Results

The characteristics of the participants at Wave 1

Compared with individuals excluded from the analyses (Table 1), those included were more likely to be younger, to have a higher education level, to live with others, to perceive their household economic status as good, to be in a non-frail state, to drive cars and/or bikes, and to go out-of-home more frequently.

Longitudinal associations of the average land slope and driving status with the frequency of going out-of-home

The mean frequencies of going out-of-home per week at Wave 1 (n=842) were 5.3 days (SD, 2.4 days), Wave 2 (n=768) were 5.3 days (SD, 2.3 days), and Wave 3 (n=716) were 5.2 days (SD, 2.4 days), respectively.

In the latent growth model (Table 2), since the intercept variances were statistically significant in all models (p<0.001), individual variabilities were relevant for the initial level of frequency of going out-of-home. In contrast, the slope mean (p=0.099–0.860) and slope variance (p=0.083–0.114) of the frequency of going out-of-home were insignificant, indicating that the frequency did not change significantly across the waves, and the individual differences of its change were limited.

Across all models, the path from the average land slope to the intercept of the frequency of going out-of-home was negative and significant (Table 2;-0.05 to -0.07 [p=0.010–0.038]). However, the path from average land slope to the slope of the frequency of going out-of-home was insignificant (-0.01 to 0.00 [p=0.510–0.824]). All paths from the interaction term to the intercept (Model 2, 0.03 [p=0.456]; Model 3, 0.02 [p=0.588]) and slope of its frequency were insignificant (Model 2, 0.00 [p=0.821]; Model 3, 0.00 [p=0.824]). Thus, Hypotheses 1B, 2A, and 2B were not supported, whereas Hypothesis 1A was supported.

The multi-group modeling showed that the chi-squares of the constrained models (p=0.667–0.911) were not significantly different from the unconstrained model, and that the AIC of the constrained models (AIC=283.02–285.02) was better than that of the unconstrained model (AIC=286.84; Table 3). Thus, Hypotheses 2A and 2B were not supported.

Discussion

As Hypothesis 1A was supported, the present study found that a higher average land slope was associated with a lower frequency of going out-of-home at the initial level among older adults. However, since Hypothesis 1B was not supported, it was not associated with changes in the frequency of going out-of-home over time among older adults. These findings indicate that a hilly environment inhibits older adults from going out-of-home frequently, although it would not accelerate the decline in the frequency of going out-of-home over time. While previous studies have reported that certain environmental factors are associated with going out-of-home among older adults [7-11], they have not examined a hilly environment. The current study advances our understanding of the environmental determinants of the frequency of going out-of-home. The finding regarding the association of a hilly environment with a lower frequency of going out-of-home is consistent with the results of previous physical activity studies [4-16]. Regarding the potential mechanisms for their association at the initial level, traversing a hilly environment would require more effort than traveling in a flat environment; thus, older adults living in a hilly environment might refrain from going out-of-home frequently. For the null association of a hilly environment with changes in the frequency of going out-of-home over time, the insignificance of the slope mean and the slope variances in the latent growth modeling suggests that the habit of going out-of-home was stable, and that most respondents did not change their habit across the three-year period of the study. A more stable habit might lead to the null association of a hilly environment with changes in the frequency of going out-of-home. In other words, more observations longer than three years might be more desirable for detecting the influence of a hilly environment on changes in the frequency of going out-of-home.

Since hypotheses 2A and 2B were not supported, the moderating effect of driving status was not revealed in the present study. This finding indicates that a hilly environment would influence the initial level of the frequency of going out-of-home, regardless of older adults' driving status. One potential reason for its insignificant moderating effect might be because driving in a hilly environment requires more psychological effort than driving in a flat environment [25], and walking in a hilly environment requires more physical effort [12, 13] than walking in a flat environment. The other reason might be that a considerable number of drivers in urban areas commonly use the public transportation system, instead of using private cars. The present study did not measure the usage frequencies of public transportation and private cars, and a lack of them would influence the null-results. The current study does not align with the research trends of physical activity studies, which have shown the moderating effect of driving status [18-20]. Thus, more extensive studies are essential to confirm the moderating effect of driving status on the relationship between a hilly environment and the frequency of going out-of-home.

One strength of this study is its longitudinal design with three waves. However, the current study also has some limitations. First, the study has selection bias. The study analyzed data obtained from one urban city. Moreover, the participants excluded from this study, based on the criteria, were less likely to go out-of-home frequently than the participants included. Referring to Japanese nationwide data [26] of the frequency of going out-of-home (5.0 days per week, on average, among Japanese adults aged 65 to 74), the included participants (5.3 day per week, on average) would be more biased than the excluded participants (4.9 day per week, on average). The excluded participants might also be at higher risks for health problems. Selection bias weakens the generalizability (external validity) of the findings. There is a possibility that Hypotheses 2A and 2B will be observed if the selection bias is weakened. Further studies with lower selection bias are necessary. Second, the study measured the frequency of going out-of-home via a questionnaire only. Measuring the frequency of going out-of-home through diaries [19] or a global positioning system [5, 9] would provide more accurate data. Third, as mentioned above, more long-term observations would be better for detecting changes in the frequency of going out-of-home over time. Finally, we did not consider walkable distance and other environmental factors as potentially important confounders. Although walkable distance is associated with frequency of going out-of-home, car use, and land slope among older adults [27], we did not measure it. Environmental factors such as population density, the accessibility of public transportation, and mixed land use might also be confounders. We plan to report the relative influences of these environmental factors on the frequency of going out-of-home in another paper.

As for the practical implications of the findings, older adults living in a hilly environment would be a high-priority group for providing interventions to promote going out-of-home. Previous studies have reported several intervention programs such as an intergenerational volunteer program [28], a community-based educational program [29], and a self-monitoring program [30], which can encourage going out-of-home among older adults. These programs should preferentially be provided to older adults living in a hilly environment.

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Disclosure statement

The authors declare no conflict of interest.

Data availability statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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Figure captions

Figure 1. Flowchart of the participants and procedure

Figure 2. Conceptual diagram of latent growth modeling for the associations of average land slope and driving status with the frequency of going out-of-home. This conceptual diagram corresponds to the results presented in Table 2. The intercept and slope of frequency of going out-of-home represents the initial level of and longitudinal change in its frequency, respectively. If the paths from average land slope to the intercept and slope of frequency of going out-of-home were negative and significant, Hypotheses 1A and 1B would be supported, respectively. If the paths from the interaction terms of driving status with average land slope to the intercept and slope of the frequency of going out-of-home were positive and significant, Hypotheses 2A and 2B would be supported, respectively. The demographic factors were age, gender, education level, living alone, employment status, perceived household economic status, and frailty. Driving status (*no*=0, *yes*=1), gender (*male*=0, *female*=1), education level (*junior to high school* =0, *more than high school*=1), living alone (*no*=0, *yes*=1), current employment (*no*=0, *yes*=1), and frailty (*no*=1, *yes*=1) were dummy variables. Cross-sectional correlations among the demographic factors were included in the model.

Table 1. The characteristics of the participants in Wave 1

	Excluded from analyses		Included in analyses		
	n	M (SD) or %	*n*	M (SD) or %	*p*-value
Age (*years*), M (SD)	928	**68.4 (4.1)**	856	**67.8 (4.3)**	**0.008†**
Gender (*female*), %	928	39.1%	856	40.5%	0.540‡
Education level (*more than high school*), %	903	**42.3%**	853	**53.3%**	**<0.001‡**
Perceived household economic status (*score, 1–5*), M (SD)	911	2.8 (0.9)	855	3.1 (0.9)	**<0.001†**
Living alone (*yes*), %	916	**8.8%**	850	**6.2%**	**0.039‡**
Employment status, (*yes*), %	865	44.9%	824	49.4%	0.062‡
Frailty (*yes*), %	883	**14.5%**	848	**7.9%**	**<0.001‡**
Driving status (*yes*), %	908	**45.3%**	856	**55.8%**	**<0.001‡**
Average land slope (*degrees*), M (SD)	928	5.6 (4.2)	856	5.9 (4.2)	0.083†
Frequency of going out-of-home (*days per week*), M (SD)	894	**4.9 (2.5)**	842	**5.3 (2.4)**	**0.001†**

†*t*-test, ‡chi-square test

The sample size of each variable varies due to missing values.

Table 2. Parameter estimates of the latent growth model for associations of the average land slope with the frequency of going out-of-home (n=856).

	Model 1		Model 2		Model 3	
	Estimate (SE)	*p*-value	Estimate (SE)	*p*-value	Estimate (SE)	*p*-value
Mean and variance of the frequency of going out-of-home (days per week)						
Intercept mean	**5.29 (0.08)**	**<0.001**	**5.22 (0.12)**	**<0.001**	**4.35 (1.47)**	**0.003**
Intercept variance	**2.78 (0.28)**	**<0.001**	**2.78 (0.28)**	**<0.001**	**2.70 (0.27)**	**<0.001**
Slope mean	-0.05 (0.03)	0.099	-0.07 (0.05)	0.136	-0.11 (0.60)	0.860
Slope variance	0.15 (0.09)	0.114	0.15 (0.09)	0.105	0.16 (0.09)	0.083
Unstandardized path coefficients to the intercept of the frequency of going out-of-home						
Path from the average land slope	**-0.05 (0.02)**	**0.010**	**-0.07 (0.03)**	**0.038**	**-0.07 (0.03)**	**0.034**
Path from driving status at Wave 1	—		0.10 (0.15)	0.516	0.10 (0.17)	0.550
Path from driving status at Wave 1 × average land slope	—		0.03 (0.04)	0.456	0.02 (0.04)	0.588
Path from age at Wave 1	—		—		0.00 (0.02)	0.940
Path from gender at Wave 1	—		—		0.15 (0.18)	0.409
Path from education level at Wave 1	—		—		0.06 (0.16)	0.709
Path from perceived household economic status at Wave 1	—		—		**0.26 (0.09)**	**0.004**

Path from living alone at Wave 1	—		—		-0.03 (0.32)	0.918
Path from employment status at Wave 1	—		—		-0.07 (0.16)	0.642
Path from frailty	—		—		-0.46 (0.29)	0.111
Unstandardized path coefficients to the slope of the frequency of going out-of-home						
Path from the average land slope	-0.01 (0.01)	0.510	0.00 (0.01)	0.821	0.00 (0.01)	0.824
Path from driving status at Wave 1	—		0.04 (0.06)	0.567	0.02 (0.07)	0.798
Path from driving status at Wave 1 × average land slope	—		0.00 (0.02)	0.813	0.00 (0.02)	0.922
Path from age at Wave 1	—		—		0.00 (0.01)	0.669
Path from gender at Wave 1	—		—		-0.10 (0.07)	0.188
Path from education level at Wave 1	—		—		-0.05 (0.06)	0.428
Path from perceived household economic status at Wave 1	—		—		0.01 (0.04)	0.871
Path from living alone at Wave 1	—		—		-0.05 (0.13)	0.682
Path from employment status at Wave 1	—		—		-0.07 (0.06)	0.256
Path from frailty	—		—		0.03 (0.12)	0.810

SE: standard error. The intercept and slope of frequency of going out-of-home represents the initial level of and longitudinal change in its frequency, respectively. If the paths from average land slope to the intercept and slope of frequency of going out-of-home were negative and significant, Hypotheses 1A and 1B would be supported, respectively. If the paths from the interaction terms of driving status with average land slope to the intercept and slope of the frequency of going out-of-home were positive and significant, Hypotheses 2A and 2B would be supported, respectively. Driving status (*no*=0, *yes*=1), gender (*male*=0, *female*=1), education level (*junior to high school*=0, *more than high school*=1), living alone (*no*=0, *yes*=1), current employment (*no*=0, *yes*=1), and frailty (*no*=1, *yes*=1) were dummy variables. The model fit indices were $\chi^2(2)=1.80$, CFI>0.999, TLL>0.999, RMSEA<0.001, and AIC=25.80 in Model 1; $\chi^2(4)=2.92$, CFI>0.999, TLL>0.999, RMSEA<0.001, and AIC=48.92 in Model 2; and $\chi^2(11)=11.45$, CFI=0.999, TLI=0.998, RMSEA=0.007, and AIC=197.45 in Model 3.

Table 3. Model fit indices of the models with equality constraints of path coefficients between non-drivers and drivers.

	χ^2	$\Delta\chi^2$	*p* values	CFI	TLI	RMSEA	AIC
Unconstrained model	14.84	—		>0.999	>0.999	<0.001	286.84
Model with an equality constraint on the path from the average land slope to the intercept of the frequency of going out-of-home	15.02	0.19	0.667	>0.999	>0.999	<0.001	285.02
Model with an equality constraint on the path from the average land slope to the slope of the frequency of going out-of-home	14.87	0.03	0.854	>0.999	>0.999	<0.001	284.87
Model with equality constraints on the paths from the average land slope to both the intercept and the slope of the frequency of going out-of-home	15.02	0.19	0.911	>0.999	>0.999	<0.001	283.02

$\Delta\chi^2$, Changes in the chi-square
An equality constraint was placed between non-drivers and drivers.

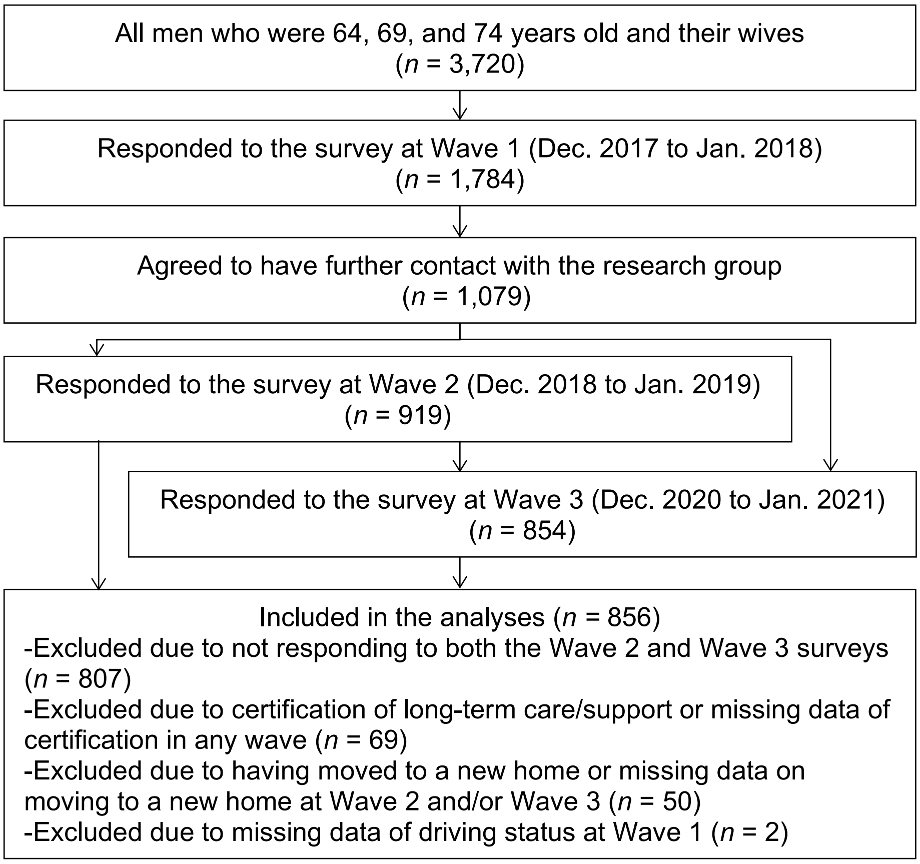
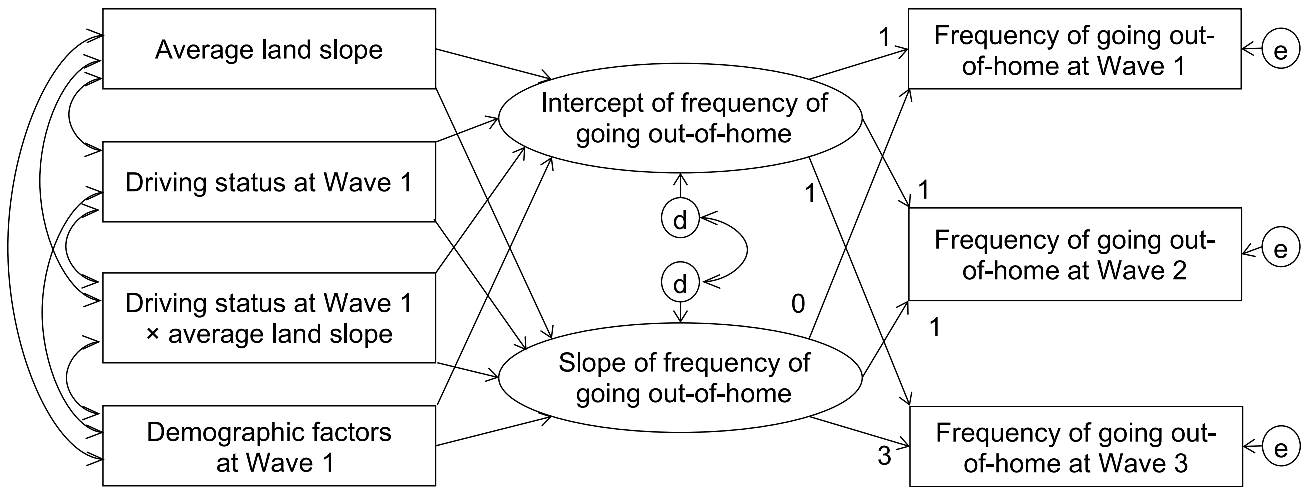

All men who were 64, 69, and 74 years old and their wives
(n = 3,720)
Responded to the survey at Wave 1 (Dec. 2017 to Jan. 2018)
(n = 1,784)
Agreed to have further contact with the research group
(n = 1,079)
Responded to the survey at Wave 2 (Dec. 2018 to Jan. 2019)
(n = 919)
Responded to the survey at Wave 3 (Dec. 2020 to Jan. 2021)
(n = 854)
Included in the analyses (n = 856)
-Excluded due to not responding to both the Wave 2 and Wave 3 surveys (n = 807)
-Excluded due to certification of long-term care/support or missing data of certification in any wave (n = 69)
-Excluded due to having moved to a new home or missing data on moving to a new home at Wave 2 and/or Wave 3 (n = 50)
-Excluded due to missing data of driving status at Wave 1 (n = 2)

Figure 1.


Average land slope
Driving status at Wave 1
Driving status at Wave 1 × average land slope
Demographic factors at Wave 1
Intercept of frequency of going out-of-home
Slope of frequency of going out-of-home
d
d
1
1
1
0
1
3
Frequency of going out-of-home at Wave 1
Frequency of going out-of-home at Wave 2
Frequency of going out-of-home at Wave 3
e
e
e
Figure 2.