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Original Study

Dose-Response Relationship Between Life-Space Mobility and Mortality in Older Japanese Adults: A Prospective Cohort Study

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A B S T R A C T

Objectives: Some epidemiological studies of older American adults have reported a relationship between life-space mobility (LSM) and mortality. However, these studies did not show a dose-response relationship and did not include individuals from other countries. Therefore, we evaluated the dose-response relationship between LSM and mortality in older adults.
Design: Prospective cohort study.
Setting and Participants: We used the data of 10,014 older Japanese adults (aged ≥65 years) who provided valid responses to the Life-Space Assessment (LSA) in the Kyoto-Kameoka study in Japan.
Methods: LSM was evaluated using the self-administered LSA consisting of 5 items regarding life-space from person's bedroom to outside town. The LSM score was calculated by multiplying life-space level by frequency score by independence score, yielding a possible range of 0 (constricted life-space) to 120 (broad life-space). These scores were categorized into quartiles (Qs). Mortality data were collected from July 30, 2011 to November 30, 2016. A multivariate Cox proportional hazards model that included baseline covariates were used to evaluate the relationship between LSM score and mortality risk.
Results: A total of 1030 deaths were recorded during the median follow-up period of 5.3 years. We found a negative association between LSM score and overall mortality even after adjusting for confounders [Q1: reference; Q2: hazard ratio (HR) 0.81, 95% CI 0.69-0.95; Q3: HR 0.70, 95% CI 0.59-0.85; Q4: HR 0.68, 95% CI 0.55-0.84, *P* for trend < .001]. Similar results were observed for the spline model; up to a score of 60 points, LSM showed a strong dose-dependent negative association with mortality, but no significant differences were observed thereafter (L-shaped relationship).
Conclusions and Implications: Our findings demonstrate an L-shaped relationship between LSM and mortality. This study will be useful in establishing target values for expanding the range of mobility among withdrawn older adults with a constricted life-space.

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The authors declare no conflicts of interest.
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Maintaining mobility, a vital component of active aging, is crucial in older adults who wish to continue to lead independent and dynamic lives.[1] Optimum mobility is defined as an individual's ability to reach a destination safely and reliably and is impeded by gait disturbance or the need for assistance to be mobile.[2] Often overlooked even in clinical practice,[3] immobility is an important public health target in countries and communities with rapidly aging populations.

Life-space mobility (LSM) refers to the size of the spatial area that an individual intentionally moves through during daily activities and the frequency of such movement.[4,5] The University of Alabama at Birmingham's Life-Space Assessment (LSA) evaluates mobility based on the frequency at which the individual leaves the confines of their bedroom, home, property, neighborhood, or town and evaluates mobility based on the individual's independence in doing so.[4] Unlike the measurement of functional mobility offered by gait tests in hypothetical or experimental settings,[6] the LSA may more accurately reflect actual mobility as it considers both the individual's range of mobility in the community and his or her independence during those movements.[4,6] Owing to its close association with reduced physical performance[4,7,8] and social participation,[9] LSM evaluated by the LSA has been associated with cognitive function,[7,10] reduced health-related quality of life (HRQoL),[11] and fall risk.[12]

Epidemiologic studies of older adults in the United States have shown a negative association between overall mortality risk and LSM as evaluated by the LSA[13–16] and other questionnaires.[17] However, to our knowledge, these associations have only been examined in American community-dwelling older adults and have not been investigated in people residing in other countries or communities. As a 5-year change in LSA-evaluated mobility has been found to differ by race,[18] it is vital to evaluate the relationship between mortality risk and LSM in other countries. Moreover, no studies have examined a dose-response relationship between mortality risk and LSM. Therefore, in this study, we aimed to evaluate the dose-response relationship between LSM and mortality risk using data from a community-based longitudinal cohort study of older Japanese adults. We hypothesized that there would be a negative association between mortality risk and LSM.

Methods

Study Design and Population

The Kyoto-Kameoka study is a prospective cohort study of older adults aged ≥65 years (range: 65-102 years) residing in Kameoka City, Kyoto Prefecture, Japan. Details of the study are explained elsewhere.[19–22] To survey all residents of Kameoka City who were aged ≥65 years as of July 1, 2011, qualified candidates were selected based on their name, sex, date of birth, and other information obtained from the basic residency register maintained by Kameoka City Hall (Figure 1). Among the candidates selected (n = 19,424), those who required long-term care at level 3 or above (n = 1170), and those who died between July 1 and July 28, 2011 (n = 23), were excluded. The remaining 18,231 candidates participated in the Needs in the Sphere of Daily Life Survey (baseline survey), which includes the LSA that evaluates LSM, on July 29, 2011. Of these participants, 13,294 responded to the survey (response rate: 72.9%).

Of those who participated in the baseline survey (n = 13,294), we excluded participants with an incomplete LSA (n = 2218). We confirmed the validity of the LSM score against independence assessed by the long-term care insurance system in 11,076 older adults. Furthermore, to avoid the possibility of a reverse causal relationship between LSM and mortality, we excluded those who required support level 1 or 2 (n = 555) or long-term care level 1 or 2 (n = 499), and who moved out of the city on an unknown date (n = 8). Ultimately, 10,014 participants were included in the analysis.

This study was approved by the Research Ethics Committee. We obtained informed consent from all participants at the time of their response to the mail survey. Our report adheres to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.[23]

LSM Score Evaluation

We evaluated LSM using Baker et al's self-administered LSA questionnaire.[4] Average LSM for the past month was evaluated using the following questions on the range of mobility: Have you been to other rooms of your home besides the room where you sleep? (Level 1); Have you been to an area outside your home? (Level 2); Have you been to places in your neighborhood? (Level 3); Have you been to places outside your neighborhood, but within your town? (Level 4); Have you been to places outside your town? (Level 5). Mobility frequency was evaluated for life-space levels 1 through 5 as follows: less than once a week = 1 point, 1 to 3 times a week = 2 points, 4 to 6 times a week = 3 points, daily = 4 points. A uniform value was used to represent independence across the full range of mobility (no equipment or personal assistance = 2 points, required equipment = 1.5 points, required personal assistance = 1 point). Participants who responded that they required assistance with daily activities or hospital visits were defined as "requiring personal assistance," whereas participants who responded that they used a wheelchair, electric wheelchair, walker, or cane were defined as "requiring equipment." The LSM score was calculated by multiplying life-space level by frequency score by independence score, yielding a possible range of 0 (constricted life-space) to 120 (broad life-space).

Evaluation of Death Events

Participant survival during the follow-up period was evaluated using the basic resident register maintained by Kameoka City Hall.

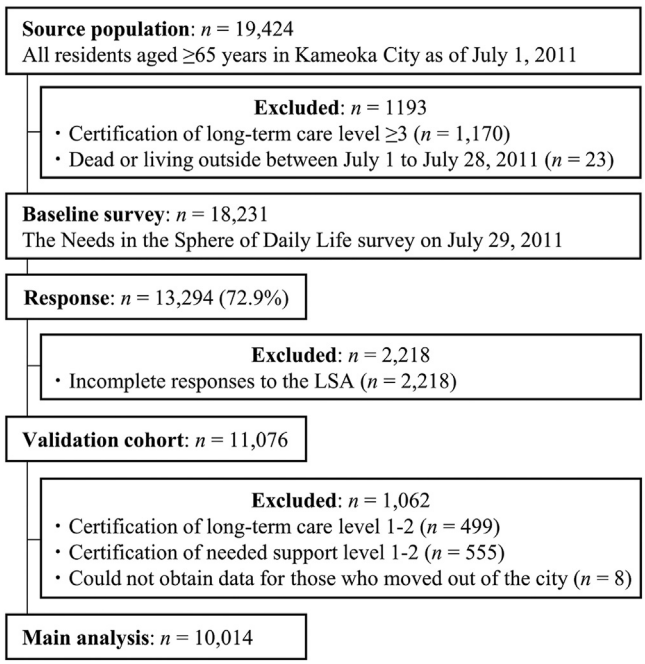

Fig. 1. Participant flow diagram for the analysis of life-space mobility and mortality in the Kyoto-Kameoka study. LSA, life-space assessment.

Kameoka City Hall provided data from July 30, 2011, to November 30, 2016. Data for residents whose registration had been revoked or who had moved out of the country or municipality were censored.

Evaluation of Independence by the Long-Term Care Insurance System

Under the Japanese long-term care insurance system, older adults (aged ≥65 years) or middle-aged adults (aged 40-64 years) with specific illnesses are eligible for financial assistance based on the severity of their physical and cognitive disorders.[24] To determine eligibility for this system, candidates undergo an in-person assessment of everyday functioning by officials dispatched from the local government using a 74-item questionnaire based on activities of daily living. Based on questionnaire results and a physician's opinion, a candidate's long-term care level is determined by the Long-Term Care Insurance Certification Committee, which consists of academic experts in health care and welfare. Certification is classified into 7 levels beginning with support levels 1 and 2 and advancing to long-term care levels 1 (least disabled) through 5 (most disabled). This information was provided by the officials of Kameoka City Hall.

Statistical Analysis

To confirm the validity of the LSM score, median (interquartile range) LSM scores are shown for those without long-term care certification, those who required support level 1 or 2, and those who required long-term care level 1 or 2. In addition, the Jonckheere-Terpstra trend test and Spearman rank correlation analysis were used to test trends among these values. Using Meng et al's equation,[25] a correlation coefficient was compared between independence as assessed by the long-term care insurance system and the LSM score with (0-120 point) or without (0-60 point) incorporating subjectively assessed independence.

The LSM scores were divided into quartiles. For continuous variables, descriptive statistics of mean and SD were calculated, and analysis of variance was performed for between-groups comparisons. Categorical variables are shown as the number of participants and percentage, and Pearson χ^2 test was performed for between-group comparisons. Missing data for covariates were supplemented using 5 data sets generated through multivariate imputation by chained equation (MICE) package using the statistical software R.[26] All missing values were assumed to be missing at random.

The absolute risk of overall mortality for each LSM score quartile is expressed as the number of events per 1000 person-years. We used a multivariate Cox proportional hazards model including baseline covariates to adjust for the effect of confounders on the association between LSM score and overall mortality. Multivariate analysis was performed using the following 2 models. Model 1 adjusted for age (continuous), sex (female or male), and population density (≥1000 or <1000 individuals/km^2). The population density of residential neighborhoods was defined by a small administrative unit called Cho using population and area as of October 1, 2010. Model 2 adjusted for body mass index (continuous), living alone (yes or no), socioeconomic status (high or low), educational attainment (<9, 10-12, or ≥13 years), smoking status (never smoker, past smoker, or current smoker), alcohol drinker (yes or no), self-reported general health (good or poor), number of drugs (continuous), and number of chronic diseases (continuous) in addition to the adjustments included in model 1. These variables were selected for adjustment based on previous studies.[13–17] Analytic results are expressed as hazard ratios (HRs) and 95% CIs. HRs were calculated using the first quartile as a reference. Furthermore, HR (95% CI) for overall mortality with each 10-point increase in LSM score was estimated by stratifying the sample by the median LSM score for the cohort (<60 points or ≥60 points).

We used multiple logistic regression analysis including the variables from model 2 to estimate the probability of being assigned to each quartile of LSM scores (propensity score). Inverse probability weighting was used to create adjusted Kaplan-Meier survival curves.[27] We performed a sensitivity analysis using the following 2 methods: (1) we excluded death events recorded in the first 2 follow-up years (205 men, 97 women) to rule out the possibility of a reverse causal relationship; (2) we performed a similar analysis using a complete case data set without missing values.[28]

We also evaluated the curvature of the relationship between LSM score and overall mortality risk using a restricted cubic spline model with 3 knots based on the distribution of LSM scores.[20,21] The results are expressed as HRs and 95% CIs, with HRs calculated using an LSM of zero as a reference point.

A P value of <.05 (2-tailed) was considered statistically significant. All analyses were performed using R software 3.4.3 for multiple imputation analyses (R Core Team, Vienna, Austria) and/or Stata MP, version 15.0, for other analyses (StataCorp LP, College Station, TX, USA).

Results

Baseline participant characteristics of the LSM score validation group are shown in Supplementary Table 1. Those certified as needing support or long-term care were older and included a higher percentage of women than those without such certification. LSM score validation is shown in Table 1. Independence assessed by the long-term care insurance system showed a significantly stronger correlation with the LSM score that incorporated independence than the LSM score that did not incorporate independence (−0.373 vs −0.313, Meng Z test: $P < .001$).

Participants' baseline characteristics are shown by the LSM score quartile for the analyzed cohort in Table 2. Participants with higher LSM scores were more educated, more likely to be alcohol drinkers, less likely to use medication, and showed higher physical activity. These participants were also younger, less likely to be female, and had better self-reported health. Those excluded from the study were older and included more women than those included in the study (Supplementary Table 2).

The relationship between LSM score and overall mortality risk is shown in Figure 2 and Table 3. The median follow-up period was 5.3 years (50,311 person-years). A total of 1030 participants (10.3%) died during the follow-up period. We found a significant negative association between LSM score and overall mortality risk even after adjusting for confounders (Q1: reference; Q2: HR 0.81, 95% CI 0.69–0.95; Q3: HR 0.70, 95% CI 0.59-0.85; Q4: HR 0.68, 95% CI 0.55-0.84, P for trend < .001). The HR (95% CI) for overall mortality when the LSM score was 10 points higher was 0.90 (0.86-0.94) for those with LSM <60 points and 1.00 (0.92-1.07) for those with LSM ≥60 points. Moreover, stratified and sensitivity analyses showed similar results (Supplementary Tables 3 and 4). In the analysis of the dose-response relationship between LSM score and mortality risk using a restricted cubic spline model with an LSM score of zero as a reference point, LSM showed a strong dose-dependent negative association with mortality up to a score of 60 points, but no significant differences were observed thereafter (L-shaped relationship). In other words, when LSM became higher, mortality risk became lower until a score of 60 LSM. This spline analysis model fits the data well compared with the linear regression analysis (Akaike information criterion: 17,752 vs 17,759). In addition, the adjusted model for transportation statuses such as the use of public transportation and cars showed similar results (Supplementary Figure 1).

The relationship between LSM score and overall mortality risk stratified by LSA subdomains is shown in Supplementary Table 5. LSM was associated with a higher mortality risk for those who did not

Table 1
Validation of Life-Space Mobility Score Against Objective Dependency Level

	Healthy	Dependency Levels*					
		Requiring Help		Long-Term Care		*P* for Trend	*r*†
		Level 1	Level 2	Level 1	Level 2		
Total, n	10,022	409	146	259	240		
LSM score (0-60)	31 (18-41)	12 (0-24)	9 (0-22)	4 (0-15)	4 (0-12)	<.001	−0.313‡
LSM score (0-120)	60 (32-80)	12 (0-26)	10 (0-22)	4 (0-16)	4 (0-12)	<.001	−0.373‡
Sex							
Women, n	5344	282	109	192	153		
LSM score (0-60)	30 (18-40)	12 (0-22)	9 (0-21)	4 (0-15)	3 (0-10)	<.001	−0.346‡
LSM score (0-120)	56 (28-78)	12 (0-24)	10 (0-22)	4 (0-16)	3 (0-10)	<.001	−0.410‡
Men, n	4678	127	37	67	87		
LSM score (0-60)	32 (20-42)	12 (0-27)	9 (0-26)	4 (0-14)	4 (0-14)	<.001	−0.252‡
LSM score (0-120)	62 (36-84)	15 (0-30)	9 (0-27)	4 (0-15)	4 (0-14)	<.001	−0.311‡
Age, y							
<75, n	6268	63	30	32	27		
LSM score (0-60)	34 (24-42)	26 (10-36)	27 (10-40)	17 (1-34)	8 (0-35)	<.001	−0.087‡
LSM score (0-120)	64 (44-84)	28 (12-40)	28 (10-44)	17 (1-34)	8 (0-36)	<.001	−0.173‡
≥75, n	3754	346	116	227	213		
LSM score (0-60)	24 (12-36)	10 (0-20)	7 (0-16)	4 (0-14)	3 (0-10)	<.001	−0.371‡
LSM score (0-120)	42 (16-66)	12 (0-22)	7 (0-18)	4 (0-14)	4 (0-10)	<.001	−0.435‡
Family structure							
Living alone, n	1172	120	30	35	34		
LSM score (0-60)	31 (18-40)	18 (4-28)	11 (3-27)	4 (0-14)	8 (0-23)	<.001	−0.314‡
LSM score (0-120)	56 (30-78)	18 (4-31)	11 (3-27)	4 (0-18)	8 (0-23)	<.001	−0.426‡
Others, n	8850	289	116	224	206		
LSM score (0-60)	31 (18-41)	10 (0-21)	8 (0-20)	4 (0-15)	3 (0-9)	<.001	−0.313‡
LSM score (0-120)	60 (32-80)	12 (0-22)	10 (0-21)	4 (0-16)	4 (0-9)	<.001	−0.364‡

LSM, life-space mobility; *r*, correlation coefficient.
The LSM scores were calculated using with (0-120 points) and without (0-60 points) independence level for each question [personal assistance (1 point), equipment only (1.5 point), or no equipment or personal assistance (2 points)]. The values are expressed as a number, median (interquartile range), and correlation coefficients. The trend test and correlation analysis were performed by the Jonckheere-Terpstra trend test and Spearman rank correlation analysis, respectively.
*The objectively evaluated dependency level shows the severity in the order of requiring help at level 1 and level 2 and long-term care at level 1 and level 2.
†To compare the ranking of an individual's LSM score with and without the consideration of dependency determined from the life-space assessment, we used the Meng et al equation.[25] If the results presented significant differences ($P < .05$), these relationships were interpreted as not being equivalent.
‡Statistically significant ($P < .05$).

move within the home, outside the home, in the neighborhood, or within town compared to those who did move in these areas. However, there was no significant difference in mortality risk between those who went outside of town and those who did not.

Discussion

This population-based cohort study examined the dose-response relationship between overall mortality risk and LSM score in older adults. We identified an L-shaped relationship, specifying that LSM showed a strong dose-dependent negative association with mortality up to a score of 60 points, but no significant differences were observed thereafter. To our knowledge, this is the first study to verify the dose-response relationship between validated LSM score and mortality risk in older adults.

Validation of the LSA

Participants tend to report socially acceptable responses in self-reported assessments, regardless of their actual behaviors.[29] This necessitates LSM score validation, as this systematic error may increase the variance of the self-reported variables.[30] Several studies have demonstrated the validity of the LSA with physical performance,[4,7,8] cognitive functions,[7,8,11] and psychosocial status[4,7,8,11] evaluated by subjective questionnaires. LSA validity has also been confirmed with objective indices including motor status as evaluated by the Timed Up-and-Go Test[11,31] and walking speed[11] and physical activity[11] as evaluated by a wearable sensor. We demonstrated that independence evaluated by the long-term care insurance system was more strongly correlated with the LSA-evaluated LSM score that incorporated independence than the LSM score that did not incorporate independence. This suggests that the LSM score reflected subjective independence and indicates the effectiveness of subjectively evaluated independence.

Main Outcome and Mechanism

Previous studies have shown an association between LSM and overall mortality risk in samples of 599 to 3892 older American adults aged ≥65 years who were followed up for an average of 2.7-8.5 years.[13–17] We found similar results using data from 10,014 participants, a sample more than 2.5 times the size of previous studies. Considering some previous studies,[4,7–9,11] LSM may have significant associations not only with physical performance but also with social relationships and behaviors.[9] Two popular theoretical models suggest the potential effects of social relationships on health outcomes, including mortality risk.[32] One is the stress-buffering model.[33] This theory suggests that social relationships provide information and emotional experiences that promote adaptive behavior or neuroendocrine responses in response to acute or chronic stressors.[34] Lockdowns and physical distancing in response to the COVID-19 pandemic have been associated with increased stress, including mental health problems and loneliness, in older adults,[35] suggesting that poor social relationships may be associated with the negative effects of stressors on health. The second theory that may explain this is the main effect model,[36] which suggests that social relationships are directly associated with health-protective effects through unexpected emotional and behavioral changes. Longitudinal studies have reported associations between LSM and HRQoL[37] as well as the frequency of health care use (eg, hospitalization).[38] Although the above may be potential causes of the negative association between LSM and mortality risk,

Table 2
Baseline Participant Characteristics According to Life-Space Mobility Score Quartiles

	Tota (n = 10,014)	Life-Space Mobility Score				*P* Value
		Q1 (n = 2490)	Q2 (n = 2449)	Q3 (n = 2748)	Q4 (n = 2327)	
Age, y*	73.3 (6.3)	76.7 (7.0)	73.6 (6.2)	72.0 (5.2)	71.1 (4.8)	<.001
Women†	5340 (53.3)	1460 (58.6)	1351 (55.2)	1441 (52.4)	1088 (46.8)	<.001
PD ≥1000 people/km^2†	4512 (45.1)	1089 (43.7)	1076 (43.9)	1276 (46.4)	1071 (46.0)	.11
Body mass index*	22.6 (3.5)	22.4 (4.0)	22.6 (3.5)	22.6 (3.3)	22.6 (2.9)	.018
Living alone†	1171 (11.7)	295 (11.9)	312 (12.7)	335 (12.2)	229 (9.8)	.009
HSES†	3220 (32.2)	714 (28.7)	782 (31.9)	929 (33.8)	795 (34.2)	<.001
Education ≥13 y†	2064 (20.6)	356 (14.3)	478 (19.5)	616 (22.4)	614 (26.4)	<.001
Current smoker†	1142 (11.4)	286 (11.5)	252 (10.3)	329 (12.0)	275 (11.8)	<.001
Alcohol drinker†	6501 (64.9)	1377 (55.3)	1563 (63.8)	1888 (68.7)	1673 (71.9)	<.001
Poor self-reported health†	2015 (20.1)	898 (36.1)	488 (19.9)	385 (14.0)	244 (10.5)	<.001
Physical activity, MET-min/wk*	739 (1543)	387 (1153)	697 (1449)	849 (1616)	1029 (1817)	<.001
No medication†	2146 (21.4)	383 (15.4)	490 (20.0)	664 (24.2)	609 (26.2)	<.001
Hypertension†	3703 (37.0)	942 (37.8)	917 (37.4)	1009 (36.7)	835 (35.9)	.52
Stroke†	365 (3.6)	133 (5.3)	86 (3.5)	77 (2.8)	69 (3.0)	<.001
Heart disease†	1182 (11.8)	386 (15.5)	301 (12.3)	280 (10.2)	215 (9.2)	<.001
Diabetes†	1009 (10.1)	280 (11.2)	254 (10.4)	265 (9.6)	210 (9.0)	.06
Hyperlipidemia†	912 (9.1)	167 (6.7)	216 (8.8)	281 (10.2)	248 (10.7)	<.001
Digestive disease†	485 (4.8)	175 (7.0)	102 (4.2)	106 (3.9)	102 (4.4)	<.001
Respiratory disease†	811 (8.1)	224 (9.0)	204 (8.3)	220 (8.0)	163 (7.0)	.08
Urologic diseases†	593 (5.9)	163 (6.6)	150 (6.1)	151 (5.5)	129 (5.5)	.33
Cancer†	366 (3.7)	129 (5.2)	81 (3.3)	81 (3.0)	75 (3.2)	<.001
No. of chronic diseases*,‡	0.94 (0.98)	1.04 (1.03)	0.94 (0.97)	0.90 (0.96)	0.88 (0.95)	<.001
Life-space mobility score*	55.3 (31.5)	12.2 (10.8)	45.2 (7.8)	69.5 (6.7)	95.2 (10.4)	<.001

HSES, high socioeconomic status; PD, population density; Q, quartiles.
Data for participants with missing values were imputed by multiple imputation: body mass index (n = 531, 5.3%); family structure (n = 725, 7.2%); socioeconomic status (n = 450, 4.5%); education (n = 1149, 11.5%); smoking status (n = 415, 4.1%); alcohol status (n = 355, 3.5%); self-reported health (n = 368, 3.7%); physical activity (n = 185, 1.8%); and medications (n = 761, 7.6%). Q1, Q2, Q3, and Q4 include the life-space mobility score of ≤31.5, 32.0-58.5, 60.0-80.0, and ≥82.0, respectively.
*Continuous variables are shown in terms of mean with SD and were analyzed using variance analysis. Physical activity was evaluated by validating the International Physical Activity Questionnaire—Short Form.
†Categorical variables are shown in terms of the number of cases with percentage and were analyzed using Pearson χ^2 test.
‡From the data obtained on the disease status (including the presence of hypertension, stroke, heart disease, diabetes, hyperlipidemia, digestive disease, respiratory disease, urologic diseases, and cancer), the comorbidity scores were summed to obtain a total score ranging from 0 (no comorbidity) to 9 (poor status).

basic and interventional research is needed to elucidate the underlying mechanisms in detail.

Dose-Response Relationships

In a previous study on mortality risk and LSA-evaluated LSM, 5 groups were analyzed. Older women from the United States with LSM scores between 0 and 60 were associated with a higher risk of all-cause mortality than those with higher scores (81-120 points), but not those with midlevel scores (61-80 points).[13] These results were similar to the results in American older men.[16] In addition, a previous study of American older adults reported an association between LSA-evaluated LSM and fall events.[12] Similar to our results regarding mortality risk, their findings showed that changes in LSM caused

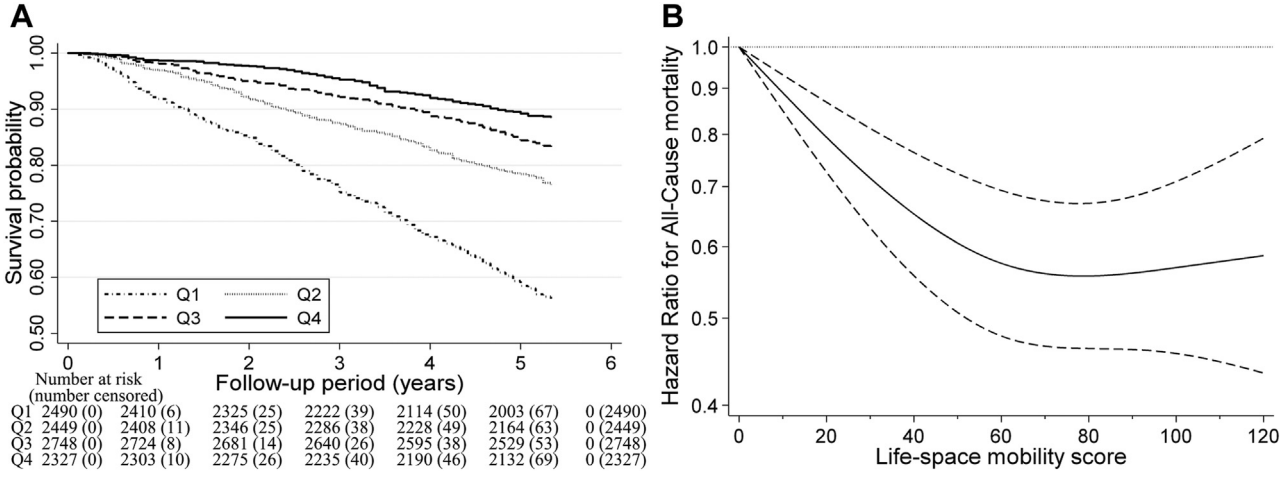

Fig. 2. The association between life-space mobility score and all-cause mortality using a multivariate regression model among older adults. (A) Multivariate adjusted Kaplan-Meier survival curves using inverse probability weighting according to quartile (Qs). (B) Restricted cubic spline model. Solid lines represent hazard ratios, and dashed lines represent 95% CIs. As a reference, we calculated the hazard ratio using 0 points for life-space mobility scores. We estimated that $P < .05$ when the 95% CI of the hazard ratio did not exceed 1.00, and $P \geq .05$ when the 95% CI of the hazard ratio exceeded 1.00. Adjustment factors included the patients' age, sex, population density, body mass index, family structure, economic status, educational attainment, smoking status, alcohol consumption status, self-reported health, physical activity, number of drugs, and the number of chronic diseases.

Table 3
Hazard Ratios for Physical Activity and Sedentary Time Status and All-Cause Mortality Calculated Using the Multivariate Cox Proportional Hazards Model

	n	Event	PY	Events/1000 PY	Crude	Model 1*	Model 2†
				Rate (95% CI)	HR (95% CI)	HR (95% CI)	HR (95% CI)
LSM quartiles							
Q1	2490	458	11,968	38.3 (34.9, 41.9)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
Q2	2449	246	12,286	20.0 (17.7, 22.7)	0.52 (0.45, 0.61)	0.67 (0.58, 0.79)	0.81 (0.69, 0.95)
Q3	2748	187	14,118	13.2 (11.5, 15.3)	0.34 (0.29, 0.41)	0.54 (0.45, 0.65)	0.70 (0.59, 0.85)
Q4	2327	139	11,939	11.6 (9.9, 13.7)	0.30 (0.25, 0.36)	0.50 (0.41, 0.61)	0.68 (0.55, 0.84)
P for trend‡				<.001	<.001	<.001	<.001
10-point increment							
Total	10,014				0.84 (0.82, 0.86)	0.90 (0.88, 0.92)	0.94 (0.92, 0.96)
<60 points	5260				0.79 (0.75, 0.83)	0.86 (0.82, 0.90)	0.90 (0.86, 0.94)
≥60 points	4754				0.96 (0.88, 1.04)	0.98 (0.90, 1.05)	1.00 (0.92, 1.07)

HR, hazard ratio; LSM, life-space mobility; PY, person-years; Q, quartiles; Ref, reference.
Q1, Q2, Q3, and Q4 include the life-space mobility score of ≤31.5, 32.0-58.5, 60.0-80.0, and ≥82.0, respectively.
*Model 1: Adjusted for age, sex, and population density.
†Model 2: In addition to the factors listed in model 1, adjusted for body mass index, family structure, economic status, educational attainment, smoking status, alcohol consumption status, self-reported health status, physical activity, number of drugs, and number of chronic diseases.
‡Linear trend *P* values were calculated using the likelihood ratio test and a continuous variable of LSM score.

greater changes in the risk of fall events in those with low LSM scores than in those with high LSM scores, and these previous studies support our findings. Therefore, our results may be able to generalize the target values of the LSM score of ≥60 points in older adults.

Even those with complete independence in LSM need to go to town at least 1 to 3 times per week to reach an LSA-evaluated LSM score of 60. In our analysis of the mobility space subdomains of LSA, we showed that there was a negative association with mortality risk for those who were mobile at levels 1 (home) through 4 (within town) compared to those who were not mobile at these levels. However, there was no association between mortality risk and the presence or absence of LSM outside of town (level 5). Therefore, our results suggested that mobility not only in one's neighborhood but also within one's town at least once a week may be necessary to achieve the maximum effectiveness of LSM on mortality risk among older adults. Our results concerning the dose-response relationship between mortality risk and LSM score should provide useful information for establishing target values for expanding life-space, particularly in withdrawn older adults. Given that the global COVID-19 pandemic is decreasing LSM for many people,[39] our findings are likely to be of particular use in supporting withdrawn older adults.

Strengths and Limitations

One strength of this research is that we were able to confirm the validity of LSA-evaluated LSM scores in a large-scale cohort study of community-dwelling older adults. This is evidence of a more accurate estimation of the dose-response relationship between mortality risk and LSM score. The LSA is the most commonly used method for evaluating LSM around the globe,[40] and using the LSA to investigate the association between LSM and mortality risk makes our results more accurate and generalizable.

However, this study has some methodologic limitations. First, self-reported LSM scores may introduce systematic reporting bias. In addition, the independence measure included on the LSA was evaluated using a single index, rather than an assessment for each life-space level. Although this is different from the original LSA method, our results are likely accurate because we validated the LSM score against independence assessed by the long-term care insurance system. Second, although this study was a complete survey of older adults aged ≥65 years residing in Kameoka City, baseline participant characteristics differed between participants who were included and those who were excluded from the present study, which may reflect selection bias. Third, the follow-up period of this study was relatively short. Furthermore, because of the unavailability of data on mortality causes, we could not examine the relationship between the LSM score and the cause of death. Lastly, although the present study adjusted for confounders, there is still a possibility of residual confounding bias in the association between LSM score and overall mortality risk. The LSM score is associated with risk factors for adverse events other than mortality risk and is related to the same social factors and lifestyle habits as other adverse events.[40] These limitations may limit the generalization of our results. Careful interpretation of our results is necessary because we could not elucidate the causal relationships between the LSM score and mortality. For example, to determine whether going outside the city in the passenger seat of a car could reduce the risk of death for high-risk older adults, an intervention study would be necessary. As such, there is a need to reevaluate our results through prospective studies that are better designed and have longer follow-up periods.

Conclusion and Implications

Our results showed an L-shaped relationship between LSM score and mortality risk. These results suggest that even a slight expansion of the mobility range of older adults with a constricted life-space can reduce mortality risk. These findings may encourage many withdrawn older adults whose life-spaces are restricted for various reasons and provide useful information for establishing target values to aim for when increasing life-space.

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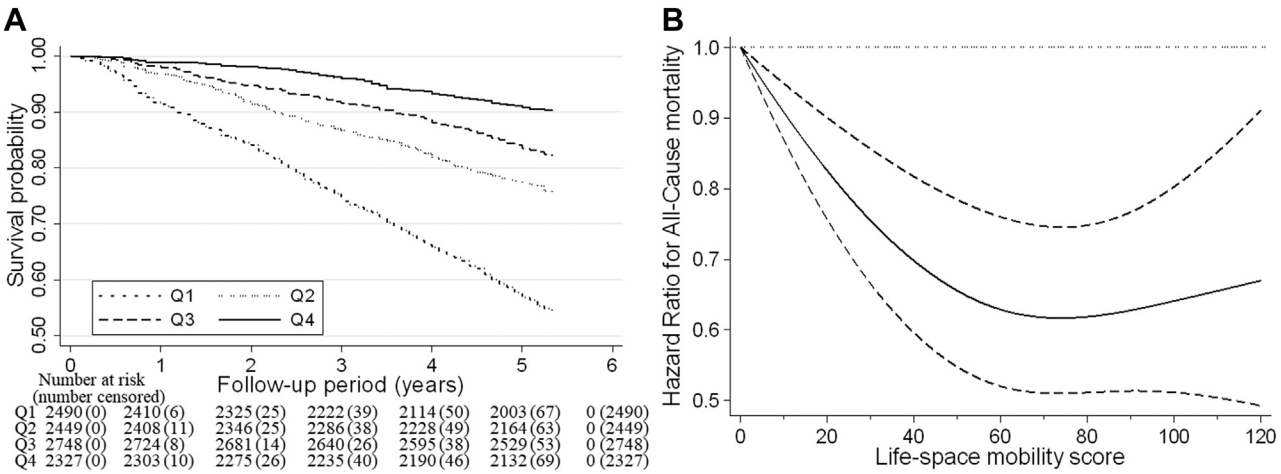
References

1. World Health Organization. *Global Age-friendly Cities: A Guide*. World Health Organization; 2007.
2. Satariano WA, Guralnik JM, Jackson RJ, et al. Mobility and aging: New directions for public health action. *Am J Public Health*. 2012;102:1508–1515.
3. Cummings SR, Studenski S, Ferrucci L. A diagnosis of dismobility—giving mobility clinical visibility: A Mobility Working Group recommendation. *JAMA*. 2014;311:2061–2062.

4. Baker PS, Bodner EV, Allman RM. Measuring life-space mobility in community-dwelling older adults. *J Am Geriatr Soc*. 2003;51:1610–1614.
5. May D, Nayak US, Isaacs B. The life-space diary: A measure of mobility in old people at home. *Int Rehabil Med*. 1985;7:182–186.
6. Glass TA. Conjugating the "tenses" of function: discordance among hypothetical, experimental, and enacted function in older adults. *Gerontologist*. 1998;38:101–112.
7. Curcio CL, Alvarado BE, Gomez F, et al. Life-Space Assessment scale to assess mobility: Validation in Latin American older women and men. *Aging Clin Exp Res*. 2013;25:553–560.
8. Ji M, Zhou Y, Liao J, et al. Pilot study on the Chinese version of the Life Space Assessment among community-dwelling elderly. *Arch Gerontol Geriatr*. 2015;61:301–306.
9. Thomson R, Yuki M, Talhelm T, et al. Relational mobility predicts social behaviors in 39 countries and is tied to historical farming and threat. *Proc Natl Acad Sci U S A*. 2018;115:7521–7526.
10. Ullrich P, Eckert T, Bongartz M, et al. Life-space mobility in older persons with cognitive impairment after discharge from geriatric rehabilitation. *Arch Gerontol Geriatr*. 2019;81:192–200.
11. Ullrich P, Werner C, Bongartz M, et al. Validation of a modified life-space assessment in multimorbid older persons with cognitive impairment. *Gerontologist*. 2019;59:e66–e75.
12. Lo AX, Rundle AG, Buys D, et al. Neighborhood disadvantage and life-space mobility are associated with incident falls in community-dwelling older adults. *J Am Geriatr Soc*. 2016;64:2218–2225.
13. Mackey DC, Lui LY, Cawthon PM, et al. Life-space mobility and mortality in older women: Prospective results from the study of osteoporotic fractures. *J Am Geriatr Soc*. 2016;64:2226–2234.
14. Boyle PA, Buchman AS, Barnes LL, et al. Association between life space and risk of mortality in advanced age. *J Am Geriatr Soc*. 2010;58:1925–1930.
15. Kennedy RE, Sawyer P, Williams CP, et al. Life-space mobility change predicts 6-month mortality. *J Am Geriatr Soc*. 2017;65:833–838.
16. Mackey DC, Cauley JA, Barrett-Connor E, et al. Life-space mobility and mortality in older men: A prospective cohort study. *J Am Geriatr Soc*. 2014;62:1288–1296.
17. Xue QL, Fried LP, Glass TA, et al. Life-space constriction, development of frailty, and the competing risk of mortality: The Women's Health And Aging Study I. *Am J Epidemiol*. 2008;167:240–248.
18. Choi M, O'Connor ML, Mingo CA, et al. Gender and racial disparities in life-space constriction among older adults. *Gerontologist*. 2016;56:1153–1160.
19. Yamada Y, Nanri H, Watanabe Y, et al. Prevalence of frailty assessed by Fried and Kihon checklist indexes in a prospective cohort study: Design and demographics of the Kyoto-Kameoka longitudinal study. *J Am Med Dir Assoc*. 2017;18:733.e7–733.e15.
20. Watanabe D, Yoshida T, Nanri H, et al. Association between the prevalence of frailty and doubly labeled water-calibrated energy intake among community-dwelling older adults. *J Gerontol A Biol Sci Med Sci*. 2021;76:876–884.
21. Watanabe D, Yoshida T, Watanabe Y, et al. Objectively measured daily step counts and prevalence of frailty in 3,616 older adults. *J Am Geriatr Soc*. 2020;68:2310–2318.
22. Nanri H, Yamada Y, Yoshida T, et al. Sex difference in the association between protein intake and frailty: Assessed using the Kihon checklist indexes among older adults. *J Am Med Dir Assoc*. 2018;19:801–805.
23. von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: Guidelines for reporting observational studies. *PLoS Med*. 2007;4:e296.
24. Yamada M, Arai H. Long-term care system in Japan. *Ann Geriatr Med Res*. 2020;24:174–180.
25. Meng X, Rosenthal R, Rubin DB. Comparing correlated correlation coefficients. *Psychol Bull*. 1992;111:172–175.
26. van Buuren S, Groothuis-Oudshoorn K. mice: Multivariate imputation by chained equations in R. *J Stat Softw*. 2011;45:1–67.
27. Xie J, Liu C. Adjusted Kaplan-Meier estimator and log-rank test with inverse probability of treatment weighting for survival data. *Stat Med*. 2005;24:3089–3110.
28. Sterne JA, White IR, Carlin JB, et al. Multiple imputation for missing data in epidemiological and clinical research: Potential and pitfalls. *BMJ*. 2009;338:b2393.
29. Taber DR, Stevens J, Murray DM, et al. The effect of a physical activity intervention on bias in self-reported activity. *Ann Epidemiol*. 2009;19:316–322.
30. Berkman LF, Blumenthal J, Burg M, et al. Effects of treating depression and low perceived social support on clinical events after myocardial infarction: The Enhancing Recovery in Coronary Heart Disease Patients (ENRICHD) Randomized Trial. *JAMA*. 2003;289:3106–3116.
31. Mumken SA, Gellert P, Stollwerck M, et al. Validation of the German Life-Space Assessment (LSA-D): Cross-sectional validation study in urban and rural community-dwelling older adults. *BMJ Open*. 2021;11:e049926.
32. Holt-Lunstad J, Smith TB, Layton JB. Social relationships and mortality risk: A meta-analytic review. *PLoS Med*. 2010;7:e1000316.
33. Cohen Sheldon WTA. Stress, social support, and the buffering hypothesis. *Psychol Bull*. 1985;98:310–357.
34. House JS, Landis KR, Umberson D. Social relationships and health. *Science*. 1988;241:540–545.
35. van Tilburg TG, Steinmetz S, Stolte E, et al. Loneliness and mental health during the COVID-19 pandemic: A study among Dutch older adults. *J Gerontol B Psychol Sci Soc Sci*. 2021;76:e249–e255.
36. Hartley C, Coffee P. Perceived and received dimensional support: Main and stress-buffering effects on dimensions of burnout. *Front Psychol*. 2019;10:1724.
37. Bentley JP, Brown CJ, McGwin G Jr, et al. Functional status, life-space mobility, and quality of life: A longitudinal mediation analysis. *Qual Life Res*. 2013;22:1621–1632.
38. Kennedy RE, Williams CP, Sawyer P, et al. Life-space predicts health care utilization in community-dwelling older adults. *J Aging Health*. 2019;31:280–292.
39. Rantanen T, Eronen J, Kauppinen M, et al. Life-space mobility and active aging as factors underlying quality of life among older people before and during COVID-19 lockdown in Finland—a longitudinal study. *J Gerontol A Biol Sci Med Sci*. 2021;76:e60–e67.
40. Johnson J, Rodriguez MA, Al Snih S. Life-space mobility in the elderly: Current perspectives. *Clin Interv Aging*. 2020;15:1665–1674.



Supplementary Fig. 1. Association between life-space mobility score and all-cause mortality using a multivariate regression model adjusted of transportation status among older adults. (A) Multivariate adjusted Kaplan-Meier survival curves using inverse probability weighting according to quartile (Qs). (B) Restricted cubic spline model. Solid lines represent hazard ratios, and dashed lines represent 95% CIs. The hazard ratio based on 0 point for life-space mobility score as reference was calculated. We estimated that $P < .05$ when the 95% CI of the hazard ratio did not exceed 1.00, and $P \geq .05$ when the 95% CI of the hazard ratio exceeded 1.00. The adjustment factors are age, sex, population density, body mass index, family structure, economic status, educational attainment, smoking status, alcohol consumption status, self-reported health, physical activity, number of drugs, number of chronic diseases, use public transportation, get in car, and drive car myself.

Supplementary Table 1
Characteristics of Participants With and Without Certification of Requiring Help and Long-Term Care

	Healthy (n = 10,022)	Dependency Levels				*P* Value
		Requiring Help		Long-Term Care		
		Level 1 (n = 409)	Level 2 (n = 146)	Level 1 (n = 259)	Level 2 (n = 240)	
Age, y*	73.3 (6.3)	81.6 (6.6)	81.6 (7.9)	83.5 (7.2)	84.0 (7.6)	<.001
Women†	5344 (53.3)	282 (69.0)	109 (74.7)	192 (74.1)	153 (63.8)	<.001
PD ≥1000 people/km^2†	4517 (45.1)	185 (45.2)	61 (41.8)	115 (44.4)	105 (43.8)	.94
Body mass index*	22.6 (3.5)	21.9 (3.9)	22.1 (5.3)	21.7 (4.1)	21.8 (6.0)	<.001
Living alone†	1172 (11.7)	120 (29.3)	30 (20.6)	35 (13.5)	34 (14.2)	<.001
HSES†	3222 (32.2)	124 (30.3)	53 (36.3)	89 (34.4)	71 (29.6)	<.001
Education ≥13 y†	2064 (20.6)	63 (15.4)	20 (13.7)	38 (14.7)	28 (11.7)	<.001
Current smoker†	1142 (11.4)	20 (4.9)	8 (5.5)	10 (3.9)	9 (3.8)	<.001
Alcohol drinker†	6506 (64.9)	187 (45.7)	53 (36.3)	80 (30.9)	95 (39.6)	<.001
Poor self-reported health†	2017 (20.1)	225 (55.0)	94 (64.4)	150 (57.9)	152 (63.3)	<.001
Physical activity, MET-min/wk*	739 (1543)	176 (670)	103 (475)	148 (614)	45 (174)	<.001
No medication†	2148 (21.4)	24 (5.9)	3 (2.1)	24 (9.3)	23 (9.6)	<.001
Hypertension†	3707 (37.0)	165 (40.3)	63 (43.2)	98 (37.8)	75 (31.3)	.10
Stroke†	365 (3.6)	51 (12.5)	23 (15.8)	44 (17.0)	44 (18.3)	<.001
Heart disease†	1185 (11.8)	81 (19.8)	32 (21.9)	52 (20.1)	41 (17.1)	<.001
Diabetes†	1010 (10.1)	56 (13.7)	18 (12.3)	37 (14.3)	36 (15.0)	.003
Hyperlipidemia†	913 (9.1)	31 (7.6)	11 (7.5)	18 (7.0)	9 (3.8)	.028
Digestive disease†	485 (4.8)	38 (9.3)	12 (8.2)	19 (7.3)	20 (8.3)	<.001
Respiratory disease†	811 (8.1)	43 (10.5)	7 (4.8)	20 (7.7)	11 (4.6)	.05
Urologic diseases†	594 (5.9)	47 (11.5)	11 (7.5)	25 (9.7)	27 (11.3)	<.001
Cancer†	366 (3.7)	23 (5.6)	3 (2.1)	13 (5.0)	8 (3.3)	.15
No. of chronic diseases*,‡	0.94 (0.98)	1.31 (1.06)	1.23 (1.04)	1.26 (1.33)	1.13 (1.13)	<.001

HSES, high socioeconomic status; PD, population density.
Data for participants with missing values were imputed by multiple imputation: body mass index (n = 684, 6.2%); family structure (n = 786, 7.1%); socioeconomic status (n = 502, 4.5%); education (n = 1346, 12.2%); smoking status (n = 448, 4.0%); alcohol status (n = 385, 3.5%); self-reported health (n = 410, 3.7%); physical activity (n = 204, 1.8%); and medications (n = 811, 7.3%).

*Continuous variables are shown in terms of mean with SD and were analyzed using variance analysis.

†Categorical variables are shown in terms of the number of cases with percentage and were analyzed using Pearson χ^2 test.

‡From the data obtained on disease status (including the presence of hypertension, stroke, heart disease, diabetes, hyperlipidemia, digestive disease, respiratory disease, urological diseases, and cancer), the comorbidity scores were summed to obtain a total score ranging from 0 (no comorbidity) to 9 (poor status).

Supplementary Table 2
Characteristics of the Included and Excluded Participants

	Included Participants (n = 10,014)	Excluded Participants (n = 3280)	*P* Value
Age, y*	73.3 (6.3)	78.1 (7.6)	<.001
Women†	5340 (53.3)	1997 (60.9)	<.001
PD ≥1000 people/km^2†	4512 (45.1)	1405 (42.8)	.026
Body mass index*	22.6 (3.5)	22.3 (4.0)	<.001
Living alone†	1171 (11.7)	524 (16.0)	<.001
HSES†	3220 (32.2)	1008 (30.7)	.13
Education ≥13 y†	2064 (20.6)	503 (15.3)	<.001
Current smoker†	1142 (11.4)	255 (7.8)	<.001
Alcohol drinker†	6501 (64.9)	1776 (54.2)	<.001
Poor self-reported health†	2015 (20.1)	1130 (34.5)	<.001
Physical activity, MET-min/wk*	739 (1543)	321 (1033)	<.001
No medication†	2146 (21.4)	458 (14.0)	<.001
Hypertension†	3703 (37.0)	1200 (36.6)	.69
Stroke†	365 (3.6)	252 (7.7)	<.001
Heart disease†	1182 (11.8)	477 (14.5)	<.001
Diabetes†	1009 (10.1)	381 (11.6)	.013
Hyperlipidemia†	912 (9.1)	210 (6.4)	<.001
Digestive disease†	485 (4.8)	182 (5.6)	.11
Respiratory disease†	811 (8.1)	232 (7.1)	.06
Urological diseases†	593 (5.9)	224 (6.8)	.06
Cancer†	366 (3.7)	121 (3.7)	.93
No. of chronic diseases*,‡	0.94 (0.98)	1.00 (1.05)	.004

HSES, high socioeconomic status; PD, population density.
Data for participants with missing values were imputed by multiple imputation [n = (n in included participants) and (n in excluded participants)]: body mass index (n = 531 and 507); family structure (n = 725 and 394); socioeconomic status (n = 450 and 280); education (n = 1149 and 745); smoking status (n = 415 and 287); alcohol status (n = 355 and 251); self-reported health (n = 368 and 218); physical activity (n = 185 and 369); and medications (n = 761 and 379).

*Continuous variables are shown in terms of mean with SD and were analyzed using variance analysis.

†Categorical variables are shown in terms of the number of cases with percentage and were analyzed using Pearson χ^2 test.

‡From the data obtained on disease status (including the presence of hypertension, stroke, heart disease, diabetes, hyperlipidemia, digestive disease, respiratory disease, urologic diseases, and cancer), the comorbidity scores were summed to obtain a total score ranging from 0 (no comorbidity) to 9 (poor status).

Supplementary Table 3
Results of Sensitivity Analysis for the Relationship Between Life-Space Mobility Score and All-Cause Mortality

	Life-Space Mobility Score				*P* for Trend*
	Q1	Q2	Q3	Q4	
Complete case					
n	1513	1760	2021	1744	
LSM score	13.1 (10.7)	45.2 (7.8)	69.6 (6.7)	95.0 (10.5)	
Events/PY	256/7326	161/8871	127/10,435	97/8932	
Events/1000 PY	34.9 (30.9-39.5)	18.1 (15.6-21.2)	12.2 (10.2-14.5)	10.9 (8.9-13.3)	
Crude	1.00 (Ref)	0.52 (0.42-0.63)	0.34 (0.28-0.43)	0.31 (0.24-0.39)	<.001
Model 1†	1.00 (Ref)	0.65 (0.53-0.79)	0.52 (0.42-0.65)	0.48 (0.38-0.61)	<.001
Model 2‡	1.00 (Ref)	0.79 (0.65-0.97)	0.70 (0.55-0.88)	0.69 (0.53-0.89)	<.001
Only ≥2 y events					
n	2348	2370	2694	2300	
LSM score	12.4 (10.8)	45.2 (7.8)	69.6 (6.7)	95.2 (10.5)	
Events/PY	316/11,827	167/12,193	133/14,054	112/11,911	
Events/1000 PY	26.7 (23.9-29.8)	13.7 (11.8-15.9)	9.5 (8.0-11.2)	9.4 (7.8-11.3)	
Crude	1.00 (Ref)	0.50 (0.42-0.61)	0.35 (0.28-0.42)	0.34 (0.28-0.43)	<.001
Model 1†	1.00 (Ref)	0.67 (0.55-0.81)	0.57 (0.46-0.70)	0.60 (0.48-0.76)	<.001
Model 2‡	1.00 (Ref)	0.76 (0.63-0.92)	0.69 (0.55-0.86)	0.76 (0.59-0.96)	<.001

HR, hazard ratio; LSM, life-space mobility; PY, person-years; Q, quartiles; Ref, reference.
Q1, Q2, Q3, and Q4 include the life-space mobility score of ≤31.5, 32.0-58.5, 60.0-80.0, and ≥82.0 in participants with complete case, respectively; life-space mobility score of ≤31.5, 32.0-58.5, 60.0-80.0, and ≥82.0 in participants with only ≥2 years' events, respectively.

*Linear trend *P* values were calculated using the likelihood ratio test and a continuous variable of LSM score.

†Model 1: Adjusted for age, sex, and population density.

‡Model 2: In addition to the factors listed in model 1, adjusted for body mass index, family structure, economic status, educational attainment, smoking status, alcohol consumption status, self-reported health status, physical activity, number of drugs, and number of chronic diseases.

Supplementary Table 4
Subgroup Analysis for Association Between Life-Space Mobility Score and All-Cause Mortality

	Life-Space Mobility Score				*P* for Trend*
	Q1	Q2	Q3	Q4	
Men, n	1157	1138	1194	1185	
LSM score	14.4 (12.1)	48.6 (7.9)	71.6 (6.5)	96.6 (10.6)	
Events/PY	274/5364	150/5668	106/6062	94/6043	
Events/1000 PY	51.1 (45.4-57.5)	26.5 (22.5-31.1)	17.5 (14.5-21.2)	15.6 (12.7-19.0)	
Crude	1.00 (Ref)	0.55 (0.45-0.67)	0.35 (0.28-0.44)	0.28 (0.22-0.36)	<.001
Model 1†	1.00 (Ref)	0.65 (0.53-0.80)	0.50 (0.40-0.63)	0.46 (0.36-0.59)	<.001
Model 2‡	1.00 (Ref)	0.78 (0.64-0.96)	0.66 (0.52-0.83)	0.64 (0.50-0.82)	<.001
Women, n	1302	1340	1328	1370	
LSM score	10.2 (9.5)	42.0 (8.0)	65.7 (5.7)	91.2 (10.8)	
Events/PY	198/6394	93/6807	61/6880	54/7093	
Events/1000 PY	31.0 (26.9-35.6)	13.7 (11.1-16.7)	8.9 (6.9-11.4)	7.6 (5.8-9.9)	
Crude	1.00 (Ref)	0.45 (0.35-0.58)	0.29 (0.22-0.39)	0.27 (0.19-0.37)	<.001
Model 1†	1.00 (Ref)	0.64 (0.50-0.82)	0.56 (0.41-0.76)	0.58 (0.42-0.81)	<.001
Model 2‡	1.00 (Ref)	0.79 (0.61-1.02)	0.72 (0.53-0.99)	0.77 (0.54-1.09)	.031
<75 years, n	1529	1660	1708	1366	
LSM score	21.2 (14.6)	55.7 (6.8)	76.4 (5.8)	99.1 (9.3)	
Events/PY	126/7716	88/8527	75/8853	57/7041	
Events/1000 PY	16.3 (13.7-19.4)	10.3 (8.4-12.7)	8.5 (6.8-10.6)	8.1 (6.2-10.5)	
Crude	1.00 (Ref)	0.68 (0.51-0.91)	0.45 (0.33-0.60)	0.49 (0.36-0.66)	<.001
Model 1†	1.00 (Ref)	0.67 (0.51-0.88)	0.54 (0.40-0.71)	0.52 (0.38-0.71)	<.001
Model 2‡	1.00 (Ref)	0.81 (0.61-1.07)	0.65 (0.49-0.87)	0.68 (0.49-0.94)	.001
≥75 years, n	938	931	958	924	
LSM score	4.5 (5.6)	28.9 (6.9)	54.6 (7.6)	85.9 (13.0)	
Events/PY	267/4284	166/4503	137/4734	114/4654	
Events/1000 PY	62.3 (55.3-70.3)	36.9 (31.7-42.9)	28.9 (24.5-34.2)	24.5 (20.4-29.4)	
Crude	1.00 (Ref)	0.59 (0.49-0.72)	0.50 (0.41-0.63)	0.41 (0.31-0.54)	<.001
Model 1†	1.00 (Ref)	0.62 (0.51-0.75)	0.54 (0.43-0.66)	0.46 (0.37-0.58)	<.001
Model 2‡	1.00 (Ref)	0.68 (0.56-0.82)	0.67 (0.54-0.84)	0.63 (0.50-0.81)	<.001
Living alone, n	293	282	296	300	
LSM score	12.2 (10.7)	43.1 (7.0)	66.3 (5.8)	91.4 (11.9)	
Events/PY	37/1433	24/1425	24/1488	16/1539	
Events/1000 PY	25.8 (18.7-35.6)	16.8 (11.3-25.1)	16.1 (10.8-24.1)	10.4 (6.4-17.0)	
Crude	1.00 (Ref)	0.57 (0.34-0.95)	0.60 (0.36-0.98)	0.38 (0.20-0.73)	.013
Model 1†	1.00 (Ref)	0.67 (0.40-1.12)	0.78 (0.46-1.32)	0.55 (0.30-1.32)	.14
Model 2‡	1.00 (Ref)	0.76 (0.45-1.30)	0.90 (0.52-1.58)	0.64 (0.34-1.21)	.43
Others, n	2195	2137	2413	2098	
LSM score	12.1 (10.8)	45.3 (7.8)	69.5 (6.8)	95.2 (10.4)	
Events/PY	420/10,526	222/10,710	160/12,421	127/10,769	
Events/1000 PY	39.9 (36.3-43.9)	20.7 (18.2-23.6)	12.9 (11.0-15.0)	11.8 (9.9-14.0)	
Crude	1.00 (Ref)	0.52 (0.44-0.61)	0.32 (0.27-0.38)	0.29 (0.24-0.36)	<.001
Model 1†	1.00 (Ref)	0.69 (0.58-0.81)	0.52 (0.43-0.63)	0.50 (0.40-0.61)	<.001
Model 2‡	1.00 (Ref)	0.82 (0.70-0.98)	0.68 (0.55-0.83)	0.68 (0.55-0.85)	<.001

HR, hazard ratio; LSM, life-space mobility; PY, person-years; Q, quartiles; Ref, reference.
Q1, Q2, Q3, and Q4 include the life-space mobility score of ≤35.0, 36.0-61.5, 62.0-82.5, and ≥84.0, respectively, in men; ≤27.0, 28.0-55.5, 56.0-76.0, and ≥78.0, respectively, in women; ≤43.5, 44.0-64.0, 66.0-84.0, and ≥86.0, respectively, in participants <75 years old; ≤16.5, 17.0-40.5, 42.0-66.0, and ≥68.0, respectively, in participants ≥75 years old; ≤30.0, 31.5-54.0, 56.0-76.0, and ≥78.0, respectively, in participants living alone; and ≤31.5, 32.0-58.5, 60.0-80.0, and ≥82.0, respectively, in participants with other family structures.

*Linear trend *P* values were calculated using the likelihood ratio test and a continuous variable of LSM score.

†Model 1: Adjusted for age, sex, and population density.

‡Model 2: In addition to the factors listed in model 1, adjusted for body mass index, family structure, economic status, educational attainment, smoking status, alcohol consumption status, self-reported health status, physical activity, number of drugs, and number of chronic diseases.

Supplementary Table 5
Hazard Ratios for Life-Space Assessment Subdomains and All-Cause Mortality Calculated Using the Multivariate Cox Proportional Hazards Model

Mobility Level	n	Event	PY	Events/1000 PY	Crude	Model 1*	Model 2†
				Rate (95% CI)	HR (95% CI)	HR (95% CI)	HR (95% CI)
Within home							
Case	8398	755	42,528	17.8 (16.5, 19.1)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
Noncase	1616	275	7783	35.3 (31.4, 39.8)	2.00 (1.74, 2.30)	1.56 (1.36, 1.79)	1.37 (1.19, 1.58)
Outside home							
Case	7458	629	37,824	16.6 (15.4, 18.0)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
Noncase	2556	401	12,487	32.1 (29.1, 35.4)	1.94 (1.71, 2.20)	1.57 (1.38, 1.79)	1.35 (1.18, 1.54)
Neighborhood							
Case	8354	716	34,963	16.9 (15.7, 18.2)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
Noncase	1660	314	16,020	39.5 (35.4, 44.2)	2.36 (2.06, 2.69)	1.69 (1.48, 1.94)	1.41 (1.23, 1.62)
Within town							
Case	8477	712	40,694	16.6 (15.4, 17.8)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
Noncase	1537	318	10,290	43.6 (39.1, 48.7)	2.66 (2.33, 3.03)	1.76 (1.53, 2.03)	1.50 (1.30, 1.73)
Outside town							
Case	5796	453	29,470	15.4 (14.0, 16.9)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
Noncase	4218	577	20,841	27.7 (25.5, 30.0)	1.81 (1.60, 2.04)	1.24 (1.09, 1.41)	1.07 (0.94, 1.23)

HR, hazard ratio; PY, person-years; Ref, reference.
Average LSM for the past month was evaluated using the following questions on range of mobility: Have you been to other rooms of your home besides the room where you sleep? (level 1: within home); Have you been to an area outside your home? (level 2: outside home); Have you been to places in your neighborhood? (level 3: neighborhood); Have you been to places outside your neighborhood, but within your town? (level 4: within town); Have you been to places outside your town? (level 5: outside town). Participants who responded "no" to these questions were defined as "noncase" for each life-space level.

*Model 1: Adjusted for age, sex, and population density.

†Model 2: In addition to the factors listed in model 1, adjusted for body mass index, family structure, economic status, educational attainment, smoking status, alcohol consumption status, self-reported health status, physical activity, number of drugs, and number of chronic diseases.