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Research Article

# Prospective Study of Trajectories of Physical Performance and Mortality Among Community-Dwelling Older Japanese

**Yu Taniguchi,[1] Yoshinori Fujiwara,[1] Hiroshi Murayama,[2] Isao Yokota,[3] Eri Matsuo,[1] Satoshi Seino,[1] Yu Nofuji,[4] Mariko Nishi,[1] Yutaka Matsuyama,[5] and Shoji Shinkai[1]**

[1]Research Team for Social Participation and Community Health, Tokyo Metropolitan Institute of Gerontology, Japan. [2]Institute of Gerontology, The University of Tokyo, Japan. [3]Department of Biostatistics, Graduate School of Medical Science, Kyoto Prefectural University of Medicine, Japan. [4]Institute of Community Medical Practice, Health Promotion Research Center, Tokyo, Japan. [5]Department of Biostatistics, School of Public Health, The University of Tokyo, Japan.

Address correspondence to Yu Taniguchi, PhD, Research Team for Social Participation and Community Health, Tokyo Metropolitan Institute of Gerontology, 35-2 Sakae-cho, Itabashi-ku, Tokyo 173-0015, Japan. E-mail: yu0717@tmig.or.jp

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## Abstract

**Objective:** Physical performance measures (PPMs) are good predictors of adverse health outcomes in later life. This prospective study used repeated measures analysis to examine sex-specific age trends in PPMs, identify potential PPM trajectory patterns, and determine whether PPM trajectory patterns were associated with all-cause mortality among older Japanese.

**Methods:** Among 1,524 adults aged 65 years or older who participated in a baseline survey, 1,048 adults (mean [*SD*] age, 71.6 [5.4] years; women, 57.0%) were followed up at least once. The total number of observations was 4,747, and the average number of follow-up assessments was 4.5 during the period from 2002 through 2011. The PPMs studied were handgrip strength, usual gait speed, and one-leg standing time. We checked local registries to identify deaths from any cause; 89 (8.5%) participants died during follow-up.

**Results:** All PPMs significantly decreased with advancing age, and handgrip strength and usual gait speed showed sex-specific age trends. We identified three distinct trajectory patterns (high, middle, and low trajectory groups) for each PPM in adults aged 65–90 years, and the trajectories for handgrip strength and usual gait speed showed parallel declines in men and women, respectively. After adjusting for important confounders, the trajectory groups for handgrip strength and one-leg standing time were independent predictors of all-cause mortality.

**Conclusions:** Regardless of baseline level, the PPMs tended to show similar age-related changes in later life. However, individuals in low PPM trajectory groups had a higher mortality risk, which highlights the importance of interventions that maintain or improve physical performance, even among older adults with low physical performance.

**Keywords:** Physical performance—Trends—Trajectories—Mortality—Older persons

Physical performance measures (PPMs) for older adults are good predictors of adverse health outcomes such as disability, hospitalization, cognitive decline, and mortality (1–6). Previous cross-sectional studies have reported reference and/or normative PPM values to facilitate evaluation of physical performance of older adults in clinical and research settings (6–18).

Repeated measures analysis accounts for a period effect. A recent repeated measures analysis using data from longitudinal studies revealed PPM trends in aging. In a study of adults aged 64 years or older evaluated at baseline and at 2- and 4-year visits, Auyeung and colleagues (19) reported that the annualized decline in handgrip strength was 0.798 kg/y among men and 1.239 kg/y among women. Decline in usual gait speed was 0.019 m/s/y among men and 0.025 m/s/y among women. Buracchio and colleagues (20) reported a significant decline of 0.013 m/s/y in usual gait speed among 204 healthy participants aged 65 or older. This estimate conforms with reference values reported in cross-sectional studies (6–14,17,18). To our knowledge, however, no study has used multiple repeated measures data from a large-scale longitudinal study to investigate sex-specific age-related trends in PPMs. An attempt to identify sex-specific aging trends in PPMs by using repeated measured analysis of longitudinal data from a large group to compensate for the number of measurements might yield robust norms of physical performance.

A previous study (21) classified gait-speed trajectory patterns and found a significant association between trajectory pattern and mortality risk: Mortality risk was higher among those with a faster decline than among those with a slower decline. In addition to gait speed, initial PPMs such as grip strength and one-leg standing time are independent risk factors for all-cause mortality (5), which suggests that PPM trajectory patterns might be good predictors of all-cause mortality. Nevertheless, to date, no such investigation has been conducted.

In this prospective study of community-dwelling older adults, we used repeated measures data on handgrip strength, usual gait speed, and one-leg standing time from a 10-year longitudinal study launched in Kusatsu Town, Japan, in 2002. Thereafter, we checked local registries to ascertain deaths from any cause. This study had three objectives: to examine sex-specific age trends in PPMs, to identify PPM trajectories, and to determine whether potential PPM trajectories were associated with all-cause mortality after adjustment for important confounders among community-dwelling older Japanese.

## Methods

### Participants

The data for this study were collected as part of a comprehensive health examination conducted in Kusatsu Town, Gunma Prefecture, Japan. In addition to an annual preventive health checkup, for residents aged 40 years or older, participants aged 65 years or older underwent a geriatric assessment that included PPMs, from 2002 through 2011. Annual assessments were performed at the same local public health center in the same manner. The details of the study design have been previously reported (3,6,22). All participants provided written informed consent under conditions approved by the Ethics Committee at Tokyo Metropolitan Institute of Gerontology.

The data source for the present study was 1,449 adults aged 65 years or older who lived in Kusatsu Town at first participation, during the period from June 2002 through June 2010. In a sample of the 1,449 adults with valid and complete baseline data, 1,048 participated in at least one follow-up assessment by June 2011. The reasons for attrition (from 1,449 to 1,048 participants) included death ($n$ = 36), need for care under the long-term care insurance program ($n$ = 110), relocation ($n$ = 43), and unknown reasons ($n$ = 212). The average number of follow-up assessments among the 1,048 adults was 4.5, and the total number of observations was 4,747. Analysis of local registries showed 89 (8.5%) deaths from any cause among the 1,048 participants through June 2011.

### Physical Performance Measures

Handgrip strength (kilogram) of the dominant hand was measured using a standard hydraulic handgrip dynamometer (3,23). Participants were asked to squeeze the device as hard as they could. Usual gait speed was measured over a straight 11-m walkway marked with tape at 3 and 8 m, on a flat floor (3,6,24–26). Participants were requested to walk at their usual pace. The time required to walk 5 m was measured and gait speed (expressed as meter per second) was calculated. One-leg standing time (seconds) was assessed for the participant's preferred leg (1,3,6,27). Participants were requested to hold their hands to their waist while looking straight ahead, lift one-leg, and maintain a standing posture for as long as possible. The time until balance was lost (or the maximum of 60 seconds) was recorded. Usual gait performance was measured once. Grip strength and one-leg standing time were measured twice, and the better of the two results was recorded. Well-trained staff administered all PPMs. For safety, participants wore standard walking shoes during the assessment.

### Other Variables

The covariates included baseline age, sex, years of education, history of chronic diseases, self-rated health, body height and weight, body mass index (BMI), resting blood pressure, blood testing (white blood cell count, red blood cell count, hemoglobin, hematocrit, hemoglobin A1c, total cholesterol, high-density lipoprotein cholesterol, triglycerides, creatinine, and albumin), activities of daily living (ADLs) (1,28), Tokyo Metropolitan Institute of Gerontology Index of Competence (TMIG-IC), Geriatric Depression Scale (GDS) short-version score (29), and the Mini-Mental State Examination (MMSE).

Chronic diseases evaluated included clinically relevant medical conditions, namely, hypertension, hyperlipidemia, cerebral vascular disease, heart disease, diabetes mellitus, and cancer. For each of these conditions, participants were asked if they had received a physician diagnosis (yes or no). A summary variable (0–6) was created to indicate number of chronic diseases.

ADLs included bathing, dressing, walking, eating, and continence. Dependence in an ADL was defined as a need for help from someone else or inability to perform the activity. Scores ranged from 0 to 10, with lower scores indicating lower activity of daily living.

The TMIG-IC (30) is designed to measure higher-level competence in older community residents.

### Statistical Analyses

First, we calculated descriptive statistics to characterize the study population (Table 1). Second, to account for correlations within longitudinal measurements of PPMs, we utilized PROC MIXED in SAS, using the sandwich estimator for estimating errors (31). Sex-specific age trends in PPMs were estimated by a mixed-effects model that assumed unstructured covariance among repeated measurements and was adjusted by baseline year. The random effects were the intercept and baseline age (a continuous variable). Linear and quadratic terms for aging were included in the mixed-effects model to account for nonlinear trends in PPMs over time. The significance of the quadratic terms for aging was formally tested using likelihood ratios between a model with and without the quadratic term for aging. To investigate differences between sexes in age trends, we tested the interaction term between age and sex. Estimated PPM age trends for age 65–90, as of 2010, are shown in Figure 1 and Table 2. Third, we used a group-based semiparametric mixture model and the SAS macro PROC TRAJ to plot PPM trajectories for men and women aged 65–90 (Figure 2) (32). This approach applies a multinomial modeling strategy to identify relatively homogeneous clusters of developmental trajectories within a sample population, that is, the modeling strategy allows for the emergence of more than two trajectories. Trajectory parameters are derived by latent class analysis using maximum likelihood estimation (21). We selected the best-fitting model by comparing Bayesian information criterion values. To assess model fit, posterior probabilities of group membership

**Table 1.** Baseline Demographic and Health Characteristics of 1,048 Community-Dwelling Japanese Aged 65 Years or Older

| Variable | Men (*n* = 451, 43.0%) | Women (*n* = 597, 57.0%) | All Participants |
|---|---|---|---|
| Sex (%, women) | — | — | 57.0 |
| Age (y) | 71.3 ± 5.0 | 71.8 ± 5.7 | 71.6 ± 5.4 |
| Years of education (y) | 10.0 ± 2.8 | 9.1 ± 2.4 | 9.5 ± 2.7 |
| Chronic disease (%) | | | |
| Hypertension | 32.7 | 34.3 | 33.6 |
| Hyperlipidemia | 7.6 | 23.0 | 16.4 |
| Cerebral vascular disease (stroke, cerebral hemorrhage, subarachnoid hemorrhage) | 7.4 | 4.9 | 5.9 |
| Heart disease (angina, myocardial infarction, arrhythmia, other) | 11.6 | 7.9 | 9.5 |
| Diabetes mellitus | 13.2 | 6.7 | 9.5 |
| Cancer | 2.8 | 3.5 | 3.2 |
| Number of chronic diseases (%) | | | |
| 0 | 47.1 | 45.9 | 46.4 |
| 1 | 35.1 | 43.3 | 34.7 |
| ≥2 | 17.8 | 19.8 | 18.9 |
| Self-rated health (%, very good or good) | 83.9 | 83.7 | 83.8 |
| BMI (%) | 23.1 ± 2.8 | 23.3 ± 3.3 | 23.2 ± 3.1 |
| Blood pressure (mmHg) | | | |
| Systolic | 135 ± 20 | 132 ± 20 | 133 ± 20 |
| Diastolic | 80 ± 12 | 76 ± 11 | 77 ± 12 |
| Handgrip strength (kg) | 33.1 ± 6.9 | 20.0 ± 5.1 | 25.6 ± 8.8 |
| Usual gait speed (m/s) | 1.33 ± 0.24 | 1.26 ± 0.26 | 1.29 ± 0.26 |
| One-leg standing time (s) | 39.9 ± 23.0 | 33.9 ± 23.6 | 36.5 ± 23.5 |
| White blood cell count (*n*/μ) | 5,861 ± 1,614 | 5,691 ± 1,485 | 5,764 ± 1,543 |
| Red blood cell count ($10^4$/μL) | 456 ± 44 | 423 ± 34 | 437 ± 42 |
| Hemoglobin (g/dL) | 14.7 ± 1.3 | 13.3 ± 1.0 | 13.9 ± 1.3 |
| Hematocrit (%) | 43.4 ± 3.9 | 39.5 ± 3.1 | 41.2 ± 4.0 |
| Hemoglobin A1c (%) | 5.5 ± 1.1 | 5.4 ± 0.9 | 5.4 ± 1.0 |
| Total cholesterol (mg/dL) | 192 ± 33 | 215 ± 34 | 205 ± 35 |
| HDL cholesterol (mg/dL) | 56.4 ± 14.1 | 63.8 ± 14.7 | 60.7 ± 14.9 |
| Triglycerides (mg/dL) | 163 ± 100 | 149 ± 84 | 155 ± 91 |
| Creatinine (mg/dL) | 0.88 ± 0.19 | 0.68 ± 0.15 | 0.76 ± 0.20 |
| Albumin (g/dL) | 4.2 ± 0.2 | 4.2 ± 0.2 | 4.2 ± 0.3 |
| ADL score (%, ≥10 points) | 99.5 | 98.8 | 99.1 |
| TMIG-IC (%, ≥13 points) | 48.2 | 48.0 | 48.1 |
| GDS short-version (%, ≥6 points) | 19.6 | 22.1 | 21.0 |
| MMSE (%, ≥26 points) | 74.2 | 73.3 | 73.7 |
| Duration of follow-up (d) | 2,108 ± 942 | 2,248 ± 937 | 2,188 ± 941 |

*Note:* ADL = activities of daily living; BMI = body mass index; GDS = Geriatric Depression Scale; HDL = high-density lipoprotein; MMSE = Mini-Mental State Examination; TMIG-IC = Tokyo Metropolitan Institute of Gerontology Index of Competence. ± *SD*.

assignments were calculated for each individual. A high posterior probability of belonging to a single group represents a good fit (33). We compared baseline demographic and health characteristics with trajectory patterns for handgrip strength (Table 3). Fourth, we used Cox proportional hazards models to examine the associations of PPM trajectories with all-cause mortality, while controlling for potential confounders (Table 4). Model 1 was adjusted for sex, age, and baseline year. Model 2 was additionally adjusted for number of chronic diseases, ADL score, GDS short-version score, and MMSE score at baseline. Statistical analyses were conducted using SPSS (version 18.0; SPSS, Chicago, IL) and SAS (version 9.4; SAS Institute), and a $p$ value of less than .05 was considered to indicate statistical significance.

## Results

Subject demographic and health characteristics are summarized in Table 1. At baseline, 57.0% of participants were woman, average (*SD*) age was 71.6 (5.4) years, average number of years of education was 9.5 (2.7), 46.4% had no chronic diseases, 48.1% had a maximum score on the TMIG-IC, and 73.8% had a score of 26 or higher on the MMSE. Average handgrip strength was 25.6 (8.8) kg, usual gait speed was 1.29 (0.26) m/s, and one-leg standing time was 36.5 (23.5) seconds.

The mixed-effects model showed sex-specific age trends for each PPM (Figure 1; Table 2). All PPMs significantly declined with age in both men and women ($p < .001$). There was a significant difference ($p < .01$) between sexes in age trends for handgrip strength and usual gait speed but not one-leg standing time.

We identified three trajectory patterns for each PPM: high, middle, and low (Figure 2). Mean handgrip strength for men in the high trajectory group (24.0%) was 42.7 kg at age 65 and 39.4 kg at age 75. For the middle (50.9%) and low trajectory groups (25.1%), the values were 36.3 and 28.7 kg at 65 years and 32.1 and 25.0 kg at 75 years, respectively. For women, the corresponding values for the high (27.0%), middle (54.6%), and low trajectory groups (18.4%)

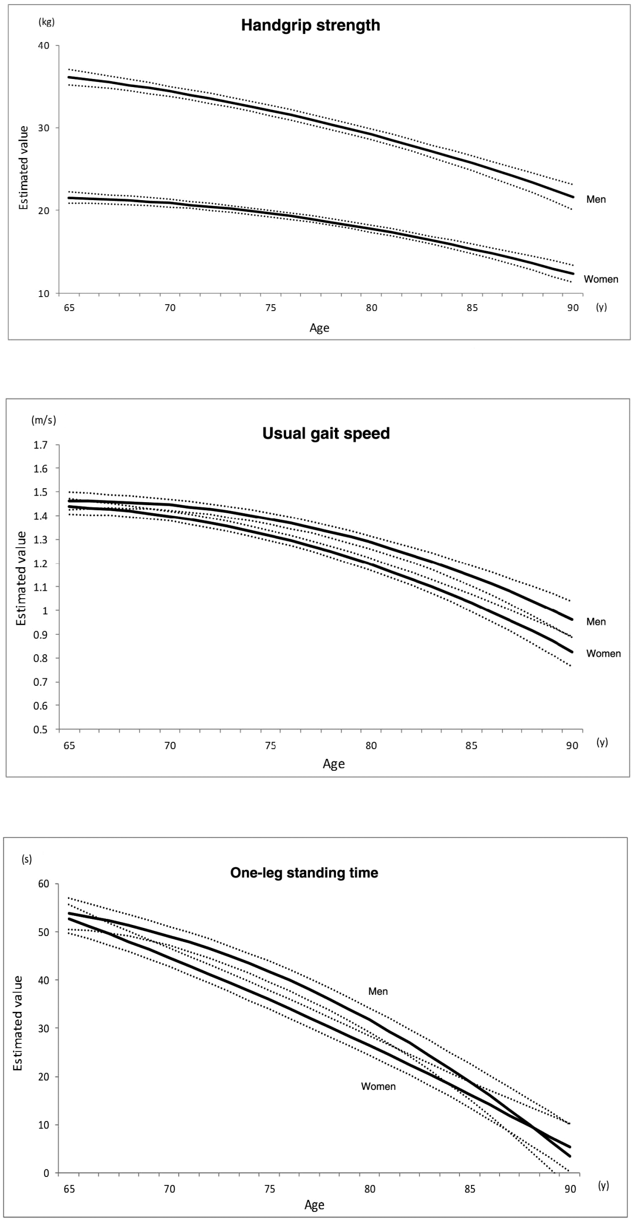


**Figure 1.** Age-related change in physical performance measures in the mixed-effects model. The solid lines are estimated values, and the dotted lines are 95% confidence intervals. Adjusted for baseline year.

were 25.6, 21.4, and 15.5 kg at age 65, and 24.2, 19.1, and 14.0 kg at age 75, respectively. Mean usual gait speed for men in the high trajectory group (42.8%) was 1.58 m/s at age 65 and 1.51 m/s at age 75. Men in the middle (50.9%) and low trajectory groups (6.4%) had usual gait speeds of 1.32 and 0.96 m/s at 65 years and 1.26 and 0.84 m/s at 75 years, respectively. For women, the values for the high (25.5%), middle (56.0%), and low trajectory groups (18.5%) were 1.60, 1.37, and 1.06 m/s at age 65 and 1.51, 1.26, and 0.98 m/s at age 75, respectively. Men and women in all three groups exhibited parallel declines in trajectories for handgrip strength and usual gait speed after age 65 years. Mean one-leg standing time in men was 59.9 seconds at age 65 and 58.9 seconds at age 75 in the high trajectory group (37.1%). Men in the middle trajectory group (21.0%) had a time of 45.8 seconds at 65 years and 49.5 seconds at 75 years, and those in the low trajectory group (41.9%) had times of 25.2 seconds at 65 years and 20.3 seconds at 75 years. For women, the corresponding values for the high (30.4%), middle (19.0%), and low trajectory groups (50.7%) were 59.9, 51.5, and 25.0 seconds at age 65, and 57.8, 44.9, and 16.5 seconds at age 75. The posterior probability of allocating each participant into the three groups was 0.84–0.97, indicating a good fit of the model of group trajectories to individual trajectories.

Table 3 shows the baseline demographic and health characteristics of individuals in relation to the three trajectory patterns for handgrip strength. At baseline, adults in the high trajectory group were more likely to be women, less likely to have diabetes mellitus, and had fewer chronic diseases, better self-rated health, higher BMIs, lower hemoglobin A1c values, higher albumin levels, higher TMIG-IC scores, lower GDS short-version scores, and higher MMSE scores.

In the high, middle, and low trajectory groups for handgrip strength, the cumulative incidence of all-cause death during a follow-up period of 10 years was 4.5% (median duration of follow-up, 5.1 years), 9.4% (5.2 years), and 10.9% (6.1 years), respectively. The corresponding values were 4.5% (5.1 years), 9.4% (5.2 years), and 10.9% (6.1 years) for usual gait speed and 2.8% (5.1 years), 6.2% (5.2 years), and 12.8% (7.8 years) for one-leg standing time. Compared with those in the high trajectory group during follow-up, participants in the middle and low trajectory groups for handgrip strength had hazard ratios (HRs) of 2.03 (95% confidence interval, 1.08–3.80) and 2.43 (1.21–4.88), respectively, for all-cause mortality, after controlling for sex, age, and baseline year (Table 4; Model 1). Even in the fully adjusted model (Model 2), participants in the middle and low trajectory groups had HRs of 1.93 (1.02–3.66) and 2.05 (0.99–4.27),

**Table 2.** Mean Values for Physical Performance Measures, by Age, in the Mixed-Effects Model

| | | Age (y) | | | | | |
|---|---|---|---|---|---|---|---|
| Variable | Sex | 65 | 70 | 75 | 80 | 85 | 90 |
| Handgrip strength (kg) | Men | 36.1 (0.5) | 34.4 (0.3) | 32.1 (0.3) | 29.2 (0.3) | 25.7 (0.4) | 21.7 (0.8) |
| | Women | 21.5 (0.3) | 20.9 (0.2) | 19.6 (0.2) | 17.8 (0.2) | 15.4 (0.3) | 12.3 (0.5) |
| Usual gait speed (m/s) | Men | 1.46 (0.02) | 1.44 (0.01) | 1.39 (0.01) | 1.29 (0.01) | 1.14 (0.02) | 0.96 (0.04) |
| | Women | 1.44 (0.02) | 1.40 (0.01) | 1.32 (0.01) | 1.19 (0.01) | 1.03 (0.02) | 0.83 (0.03) |
| One-leg standing time (s) | Men | 53.7 (1.7) | 49.1 (1.0) | 41.8 (1.1) | 31.7 (1.3) | 18.9 (1.9) | 3.5 (3.4) |
| | Women | 52.6 (1.5) | 44.6 (1.0) | 35.9 (1.0) | 26.4 (1.0) | 16.2 (1.4) | 5.3 (2.5) |

*Note:* Values are averages (standard error). Adjusted for baseline year.

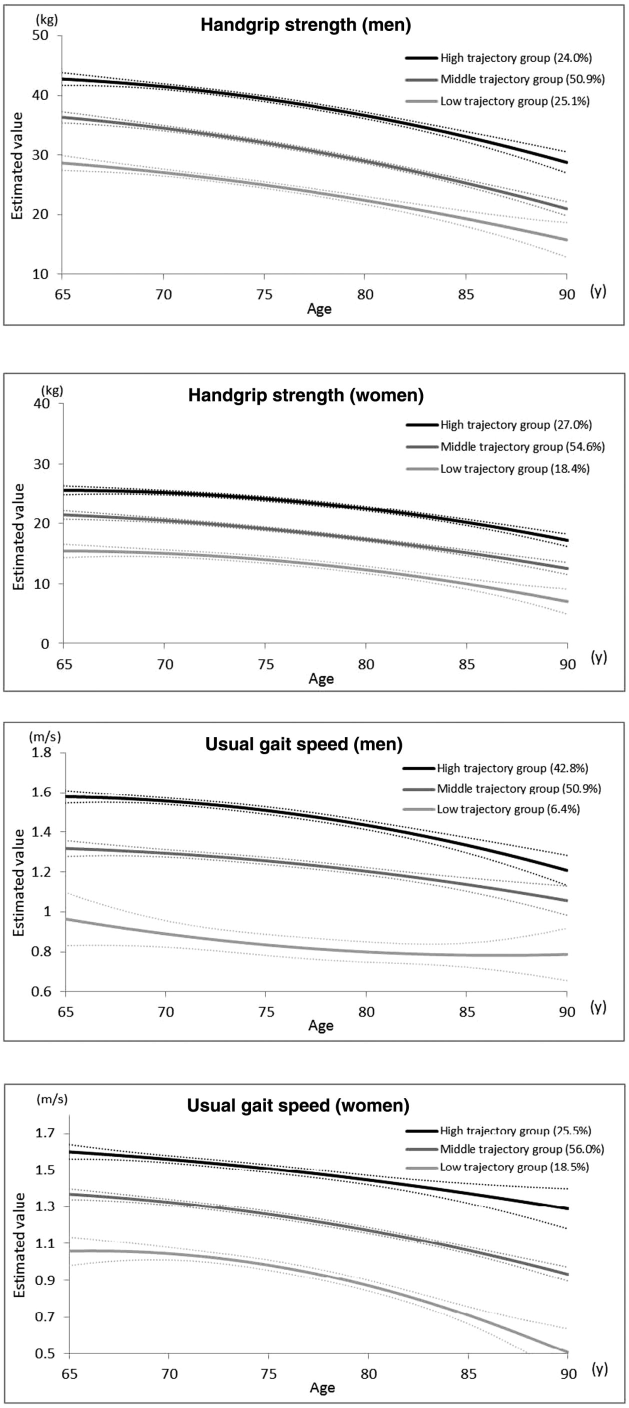


**Figure 2.** Trajectories for physical performance measures in a group-based semiparametric mixture model. The solid lines are estimated values, and the dotted lines are 95% confidence intervals.

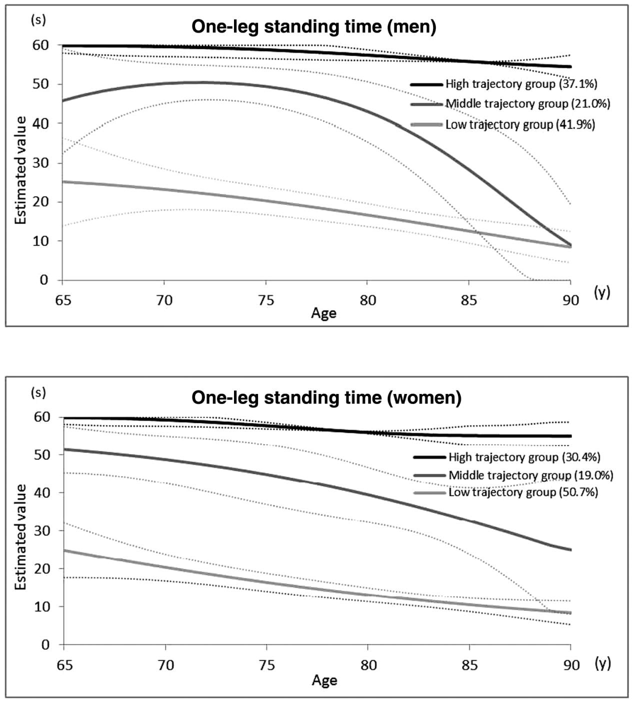


**Figure 2.** *Continued*

respectively, for all-cause mortality as compared with participants in the high trajectory group. For usual gait speed, the corresponding HRs were 1.40 (0.81–2.41) and 2.20 (1.12–4.35) in Model 1 and 1.20 (0.68–2.11) and 1.56 (0.73–3.34) in Model 2. For one-leg standing time, the corresponding HRs were 1.66 (0.71–3.86) and 2.46 (1.24–4.91) in Model 1 and 1.52 (0.63–3.63) and 2.06 (1.01–4.21) in Model 2. We divided baseline PPM data into tertiles by sex and examined associations with all-cause mortality after controlling for potential confounders. Although baseline PPMs were marginally associated with all-cause mortality, the associations with PPM trajectories were stronger in Models 1 and 2 (data not shown).

## Discussion

This prospective study using repeated measures analysis of data from community-dwelling older Japanese is the first to show that sex-specific age trends in PPMs, PPM trajectory patterns, and potential PPM trajectory pattern are independent predictors of all-cause mortality after adjustment for important confounders.

All PPMs in the present study significantly decreased as age increased, and age trends for handgrip strength and usual gait speed differed by sex. An age-related decrease in the sex difference in handgrip strength (16,18,19) and usual gait speed (6,19) is a common finding in previous studies. Although a sex difference in age trends for one-leg standing time has been reported for older Japanese (6), we did not find a significant difference between men and women, perhaps because we utilized a longitudinal mixed-effects model that used repeated measures analysis.

We identified three distinct trajectory patterns for each PPM (high, middle, and low) from age 65 to 90 years. These trajectories showed parallel declines in men and women for handgrip strength and usual gait speed. For one-leg standing time, men in the middle trajectory group had a large decrease around age 75, and the value at approximately age 90 was almost equal to that in the low trajectory group. The reason for this finding is not clear, but we believe the group-based semiparametric mixture model could not yield stable estimates of middle trajectories in one-leg standing time at age 90. Nevertheless, our findings indicate that, regardless of baseline level, PPMs show similar age-related changes in later

**Table 3.** Baseline Demographic and Health Characteristics of 1,048 Community-Dwelling Japanese Aged 65 Years or Older by Handgrip Trajectories

| Variable | High Trajectory Group (*n* = 265, 25.3%) | Middle Trajectory Group (*n* = 563, 53.7%) | Low Trajectory Group (*n* = 220, 21.0%) | *p* Value |
|---|---|---|---|---|
| Sex (%, women) | 59.6 | 59.0 | 48.6 | .02 |
| Age (y) | 71.2 ± 5.6 | 71.8 ± 5.5 | 71.5 ± 4.9 | .37 |
| Years of education (y) | 9.7 ± 2.5 | 9.5 ± 2.7 | 9.2 ± 2.6 | .21 |
| Chronic disease (%) | | | | |
| Hypertension | 33.6 | 32.7 | 35.9 | .70 |
| Hyperlipidemia | 17.0 | 15.5 | 17.8 | .70 |
| Cerebral vascular disease (stroke, cerebral hemorrhage, subarachnoid hemorrhage) | 4.2 | 6.1 | 7.8 | .24 |
| Heart disease (angina, myocardial infarction, arrhythmia, other) | 11.3 | 9.1 | 8.2 | .46 |
| Diabetes mellitus | 6.8 | 8.9 | 14.2 | .02 |
| Cancer | 3.6 | 3.9 | 0.7 | .15 |
| Number of chronic diseases (%) | | | | .04 |
| 0 | 46.0 | 49.6 | 38.6 | |
| 1 | 36.6 | 31.0 | 41.8 | |
| ≥2 | 17.4 | 19.4 | 19.5 | |
| Self-rated health (%, very good or good) | 85.9 | 85.7 | 76.3 | <.01 |
| BMI (%) | 23.8 ± 3.1 | 23.2 ± 3.1 | 22.5 ± 2.9 | <.01 |
| Blood pressure (mmHg) | | | | |
| Systolic | 133 ± 19 | 134 ± 20 | 132 ± 21 | .56 |
| Diastolic | 79 ± 11 | 77 ± 12 | 77 ± 13 | .13 |
| Handgrip strength (kg) | 31.2 ± 8.7 | 25.2 ± 7.6 | 20.1 ± 7.7 | <.01 |
| Usual gait speed (m/s) | 1.35 ± 0.22 | 1.29 ± 0.25 | 1.22 ± 0.28 | <.01 |
| One-leg standing time (s) | 42.9 ± 21.9 | 36.4 ± 23.4 | 29.0 ± 23.5 | <.01 |
| White blood cell count (*n*/μ) | 5,708 ± 1,285 | 5,730 ± 1,499 | 5,917 ± 1,894 | .25 |
| Red blood cell count ($10^4$/μL) | 442 ± 41 | 437 ± 40 | 433 ± 46 | .07 |
| Hemoglobin (g/dL) | 14.0 ± 1.3 | 13.9 ± 1.3 | 13.9 ± 1.5 | .69 |
| Hematocrit (%) | 41.4 ± 3.8 | 41.1 ± 3.8 | 41.0 ± 4.5 | .44 |
| Hemoglobin A1c (%) | 5.3 ± 0.7 | 5.4 ± 1.0 | 5.6 ± 1.3 | .03 |
| Total cholesterol (mg/dL) | 209 ± 35 | 204 ± 34 | 202 ± 37 | .05 |
| HDL cholesterol (mg/dL) | 60.8 ± 15.7 | 61.0 ± 14.5 | 59.7 ± 14.9 | .56 |
| Triglycerides (mg/dL) | 160 ± 96 | 154 ± 91 | 154 ± 87 | .67 |
| Creatinine (mg/dL) | 0.79 ± 0.22 | 0.75 ± 0.18 | 0.77 ± 0.19 | .22 |
| Albumin (g/dL) | 4.3 ± 0.2 | 4.2 ± 0.2 | 4.2 ± 0.2 | <.01 |
| ADL score (%, ≥10 points) | 98.9 | 99.6 | 98.1 | .11 |
| TMIG-IC (%, ≥13 points) | 58.0 | 49.3 | 32.7 | <.01 |
| GDS short-version (%, ≥6 points) | 18.0 | 17.4 | 34.0 | <.01 |
| MMSE (%, ≥26 points) | 79.4 | 73.4 | 67.0 | .01 |
| Duration of follow-up (d) | 2,177 ± 950 | 2,192 ± 942 | 2,190 ± 928 | .98 |

*Note:* ADL = activities of daily living; BMI = body mass index; GDS = Geriatric Depression Scale; HDL = high-density lipoprotein; MMSE = Mini-Mental State Examination; TMIG-IC = Tokyo Metropolitan Institute of Gerontology Index of Competence. ± *SD*. Analysis of variance, $\chi^2$ test.

life. Development of physical performance until senescence may therefore be important.

The present study is the first to show that, as compared with the high trajectory group, participants in the low trajectory group for handgrip strength and one-leg standing time had HRs of 2.05 and 2.06, respectively, for all-cause mortality in the fully adjusted model (Model 2). All-cause mortality was strongly associated with usual gait speed. As compared with participants in the high trajectory group, those in the middle and low trajectory groups had HRs of 1.40 and 2.20, respectively, for all-cause mortality, after adjustment for sex, age, and baseline year (Model 1). There was no significant association of trajectory with usual gait speed or all-cause mortality in the fully adjusted model (Model 2). Although we did not observe a clear association between trajectory of usual gait speed and all-cause mortality, an earlier study reported a significant association among older Americans (21). Additional studies are needed in order to increase data robustness. Our evidence suggests that trajectory groups for handgrip strength and one-leg standing time are independent predictors of all-cause mortality, after adjusting for important confounders. The present study is the first to show that PPM trajectory patterns are better than initial PPMs as predictors of all-cause mortality, after adjustment for important confounders.

This study has important strengths. First, our large sample of community-dwelling participants enabled analysis in a longitudinal mixed-effects model and group-based semiparametric mixture model, which revealed sex-specific trends and potential trajectory patterns for each PPM. Second, we assessed sociomedical factors and included them in the statistical models. The results revealed that PPM trajectory patterns were significantly associated with all-cause mortality, even after adjusting for sociodemographic factors, chronic

**Table 4.** Independent Associations of Trajectories of Physical Performance Measures With All-Cause Mortality Among Community-Dwelling Japanese Aged 65 Years or Older

| Independent Variable | Trajectory | Model 1 HR (95% CI) | Model 2 HR (95% CI) |
|---|---|---|---|
| Handgrip strength | | | |
| | High[a] (25.3%) | 1 | 1 |
| | Middle (53.7%) | 2.03 (1.08–3.80)* | 1.93 (1.02–3.66)* |
| | Low (21.0%) | 2.43 (1.21–4.88)* | 2.05 (0.99–4.27) |
| Usual gait speed | | | |
| | High[a] (33.1%) | 1 | 1 |
| | Middle (53.9%) | 1.40 (0.81–2.41) | 1.20 (0.68–2.11) |
| | Low (13.0%) | 2.20 (1.12–4.35)* | 1.56 (0.73–3.34) |
| One-leg standing time | | | |
| | High[a] (34.2%) | 1 | 1 |
| | Middle (18.6%) | 1.66 (0.71–3.86) | 1.52 (0.63–3.63) |
| | Low (47.3%) | 2.46 (1.24–4.91)* | 2.06 (1.01–4.21)* |

*Note:* ADL = activities of daily living; CI = confidence interval; GDS = Geriatric Depression Scale; HR = hazard ratio; MMSE = Mini-Mental State Examination. Cox hazard regression models were run separately. Model 1: adjusted for sex, age (65–69, 70–74, 75–79, 80–84, 85+ years) and baseline year. Model 2: Model 1 covariates plus number of chronic diseases (0, 1, 2+), ADL score (≥10 points), GDS short-version score (≥6 points), and MMSE score (≥26 points) at baseline. [a]Reference group. *$p < .05$.

diseases, depressive mood, and cognitive function. Third, we used PPM trajectory patterns and baseline PPM data, which enabled us to compare hazards with all-cause mortality.

Some limitations of this study should be noted. First, because of the healthy volunteer effect, the participants were healthier than the general elderly population. Although all residents aged 65 years or older were invited to participate in the annual surveys, those in poor health would have been excluded from the study. This limitation may have attenuated the association between PPM trajectory patterns and all-cause mortality. In practice, because older persons similar to our study population are the people who participate in community-based health checkups and interventions, the sex-specific age trends and three major PPM trajectory patterns in this study will be applicable to them. Second, the measurement protocol for PPMs was different from that used in previous studies in Western countries. Participants in Western countries were seated with elbows flexed at 90° during measurement of handgrip strength. In Japan, the protocol of standing with fully extended elbows is more common. For measurement of gait speed, a "static start" protocol is more common in Western countries, whereas a "dynamic start" protocol is used in Japan. Third, normative values for gait speed were faster for older Japanese women than for older American women, which suggests that a traditional lifestyle affects physical performance in later life (34). Sex-specific age trends or trajectory patterns for PPMs might differ between Japanese and Western populations. Fourth, only all-cause mortality was assessed. Further study is needed in order to explore the association of PPM trajectory patterns with cause-specific mortality, for example cardiovascular and other-cause mortality. Fifth, although baseline PPMs were marginally associated with all-cause mortality in this study, a previous study reported significant associations between baseline PPMs and mortality (5). Moreover, analysis of the demographic and health characteristics in relation to the three trajectory patterns for handgrip strength showed that the high trajectory group had fewer medical problems, as well as good physical function and mental and cognitive performance at baseline. Interestingly, adults in the high trajectory group had higher BMIs. A previous study reported that the reduced risk of death in overweight and obese older adults was attributable to the lack of discriminatory power of BMI in detecting age-related changes in body composition, particularly an increased ratio of fat mass to lean mass (35–37). Future studies will need to explore associations of baseline PPMs and potential PPM trajectory patterns with all-cause mortality, while controlling for important confounders such as body composition.

In conclusion, this prospective study identified sex-specific age trends and three major PPM trajectory patterns. Moreover, trajectory groups for handgrip strength and one-leg standing time were significantly associated with all-cause mortality among community-dwelling older Japanese, even after adjustment for potential confounders. Individuals in low PPM trajectory groups had a higher mortality risk, which highlights the importance of interventions that maintain or improve physical performance, even among older adults with low physical performance.

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## Conflict of Interest

The authors have no competing interests to declare.

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