RESEARCH ARTICLE

Effects of visual impairment on mobility functions in elderly: Results of Fujiwara-kyo Eye Study

Kimie Miyata¹, Tadanobu Yoshikawa¹, Akihiro Harano², Tetsuo Ueda¹, Nahoko Ogata¹*¹

¹ Department of Ophthalmology, Nara Medical University, Kashihara, Nara, Japan, ² Department of Orthopedics, Yamatotakada Municipal Hospital, Yamatotakada, Japan

* ogata@naramed-u.ac.jp

Abstract

The aim of this study was to determine whether there is a significant association between a visual impairment (VI) and mobility functions in an elderly Japanese cohort. The subjects of this study were part of the Fujiwara-kyo Eye Study, a cross sectional epidemiological study of elderly individuals conducted by Nara Medical University. Participants were ≥70-years who lived in the Nara Prefecture. All underwent comprehensive ophthalmological examinations, and a VI was defined as a best-corrected visual acuity (BCVA) worse than 20/40 in the better eye. The associations between the BCVA and walking speed and one-leg standing time were determined. The medical history and health conditions were evaluated by a self-administered questionnaire. A total of 2,809 subjects whose mean age was 76.3 ± 4.8 years (± standard deviation) were studied. The individuals with a VI (2.1%) had significantly slower walking speeds and shorter one-leg standing times than that of the non-VI individuals (1.5 ± 0.4 vs 1.7 ± 0.4 m/sec, P < 0.01; 17.1 ± 19.6 vs 27.6 ± 21.3 sec, P < 0.01, respectively). Univariate logistic regression found that the odds ratio (OR) for the slower walking speed (<1 m/sec) in the VI individuals was significantly higher at 7.40 (3.36–16.30; 95% CI, P < 0.001) than in non-VI individuals. It was still significantly higher at 4.50 (1.87–10.85; 95% CI, P = 0.001) in the multivariate logistic regression model after adjusting for the BCVA, age, sex, current smoking habit, and health conditions. Our results indicate that the walking speed and one-leg standing times were significantly associated with VI.

Introduction

It has been reported that the risk of the risk of mobility difficulties increase after 65-years-of-age [1], and mobility difficulties may lead to higher risks for more disabilities, difficulties in activities of daily living (ADLs), institutionalization, and survival [2,3]. Chronic health diseases are the most common causes for physical disabilities that arise at older ages [3, 4], and visual impairments (VIs) have also been considered to be associated with the functional difficulties [4].

In earlier studies, we found that VIs affected the cognitive function of the elderly subjects [5,6]. Our next question was whether the VIs would also affect the physical functions of older
individuals. Earlier studies examined the effect of VI on physical mobility, and they reported that individuals with VIs had slower walking speeds, had more falls, and had more mobility difficulties than non-visually impaired individuals [7–11]. Thus, VI is not only a sensory disability but a significant deterrent to mobility functions. However, many previous studies identified mobility difficulty by self-reporting [7–11].

The Salisbury Eye Evaluation Studies reported that individuals with VIs had greater mobility disabilities than the non-VIs individuals [12,13]. However, how VI effects on mobility has not been fully examined.

The walking speed is a strong predictor of disability and death in older adults [14–17], and is used as a criterion for sarcopenia and frailty in the evaluation of health and mobility functions in elderly populations [18–21]. A shorter one-leg standing time is believed to indicate a weakness of the leg muscles which then enhances the risk of falling and locomotor disabilities [22,23].

The purpose of this study was to determine the effect of VIs on the physical capabilities. To accomplish this, we measured the walking speed and the one-leg balancing times in an elderly population whose VIs were also measured.

**Subjects and methods**

**The Fujiwara-kyo Study**

A detailed description of the Fujiwara-kyo Study has been published [24,25]. Briefly, this was a cohort study whose purpose was to identify factors related to the maintenance of a healthy life, prevention of physical weakness, and improve the functional capacities and quality of life (QOL) of an elderly population in Japan [24,25]. The subjects consisted of residents in the Nara Prefecture who were ≥65 years and living independently in their homes. The first examinations were performed in 2007, and the second survey was conducted in 2012. The examinations included a basic interview to obtain socio-demographic data, overall medical conditions, and histories of medical treatments. Participants brought filled-in self-administered questionnaires which had been mailed to their homes in advance of the live examination. The answers of all questions to the participants were checked by a nurse in a face-to-face during the live interviews, and the missing items were collected and written answers were confirmed.

**The Fujiwara-kyo Eye Study**

An ophthalmological survey, the Fujiwara-kyo Eye study, was conducted for the first time as part of the Fujiwara-kyo Study at the second survey during February to November 2012. The data presented in this manuscript were collected from the examinations done in 2012 [5,6]. The subjects recruited at the initial survey in 2007 were ≥65-years-old and were 5-years older in 2012.

The surveys were conducted in accordance with the tenets of the Declaration of Helsinki, and the protocol was approved by the Ethics Review Board of Nara Medical University. A signed informed consent form was obtained from all participants.

**Ophthalmological examinations.** Visual acuity. The refractive error (spherical equivalent) was determined by an auto refractometer and keratometer (ARK-700A, Nidek, Aichi, Japan). The data of the refractive errors were used as useful references to obtain the best-corrected visual acuity (BCVA). The uncorrected and the BCVA of both eyes were measured with a Landolt ring chart at 5 m by well-trained orthoptists. To obtain the BCVA, orthoptists used corrective lenses placed in trial frames for each participant. A VI was defined as BCVA worse than 20/40 in the better-seeing eye for the statistical analyses. This cut-off BCVA corresponded to the American Association of Ophthalmology categorization of a visual impairment...
which was defined as the distance BCVA worse than 20/40 in the better-seeing eye [26]. The decimal BCVA was converted to the logarithm of the minimum angle of resolution (logMAR) units for the statistical analyses.

**Walking speed test**

The walking speed was assessed over a distance of 10 m after 2 m for acceleration. Participants were required to walk as fast as possible at their maximal speed. Participants walked on a flat floor wearing walking shoes or sneakers. An attendant followed each participant during the speed walking test and one-leg standing test to protect the participants from an unexpected occurrences and avoid injuries from falls. In all tests, no accidental falls happened, and all participants finished the mobility tests safely. The walking time in 0.1 sec periods was measured with an automatic measurement system (10 m Walking Speed Measurement Model T.K. K.5801 and 5807; Takei Scientific Instruments, Niigata, Japan), and the walking speed (m/s) was calculated by dividing distance (10 m) by the time. The mean results of two trials was used for the statistical analysis. We defined a slow walking speed as <1 m/sec according to the sarcopenia criteria of Japanese version of the CHS (J-CHS criteria) [18], the International Waterlily & Water Gardening Society (IWGS) [20], and the new criteria of Asian Working Group for Sarcopenia (AWGS) of 2019 [21]. We also analyzed a slow walking speed of ≤0.8 m/sec according to the European Working Group on Sarcopenia in Older People (EWGSOP) criteria for sarcopenia [19].

**One-leg standing time**

Participants were instructed to stand on their preferred leg for as long as possible with their eyes opened and hands on their waist. The duration of the one-leg stand was until balance was lost. The one-leg standing time represents the static balance of the body, and a shorter one-leg standing time suggests an increased risk of falling [22,23]. If the participant exceeded 60 s, the time was recorded as 60 s. The mean of two trials was used for the statistical analyses.

**General information and health conditions**

The medical history and medication information were obtained by a self-administered questionnaire. The presence of systemic hypertension was based on a self-reported diagnosis and current antihypertensive therapy. The presence of diabetes mellitus was based on a self-reported diagnosis, current anti-diabetic therapy, and fasting plasma glucose and glycated hemoglobin levels. The presence of hip arthritis, knee arthritis, leg pain, ankle and foot pain, low back and buttock pain, and sciatica were defined base on self-administered questionnaire and self-reported previous diagnosis.

We also determined the presence of covariates; body mass index (BMI), smoking status, and a number of comorbid conditions. BMI was calculated as body weight (kg) divided by height (m) squared, and it was categorized into three groups: low (<18.5 kg/m²), normal (18.5 to <25 kg/m²), and high (≥25 kg/m²).

**Statistical analyses**

The significance of the differences of the findings in the VI and non-VI participants was determined by unpaired t tests and chi-square tests. The significance of the association between walking speed or one-leg standing time and other parameters was determined by linear regression analyses. The multivariate analyses were adjusted for age, sex, BMI, current smoking, and the number of other health conditions (Table 1). The odds ratios (OR) and 95% confidence
intervals (CI) for slow walking speed (<1 m/sec and ≤0.8 m/sec), the visual impairments, age, sex, BMI, current smoking, and the health conditions were calculated by logistic regression models. The results of earlier research have indicated that the risk of both VIs and disability increases nonlinearly with age [7]. To take this nonlinear association into consideration, the age at baseline was grouped into 5 years periods, e.g., 65 to 69, 70 to 74, 75 to 79, and over 80 years. The statistical analyses were performed with the SPSS (version 22.0; SPSS Inc., Chicago, IL). A \( P < 0.05 \) was taken to be significant.

## Results

### Demographics of participants

A total of 2,809 subjects whose mean age was 76.3 ± 4.8 years (mean ± standard deviation, SD) were studied. There were 1,482 men and 1,327 women, and 60 (2.1%) of the participants were categorized as VI, and 2,749 (97.9%) were categorized as non-VI. The VI participants were significantly older but there was no significant difference in the sex distribution, BMI, smoking habit, and general health conditions between the two groups (Table 1).

| Characteristics | All | VI | Non-VI | \( P \) |
|-----------------|-----|----|--------|-------|
| Number (%)      | 2809| 60 | 2749   |       |
| Age, mean ± SD, years | 76.3 ± 4.8 | 79.2 ± 6.2 | 76.2 ± 4.8 | <0.01 |
| Sex (men), number (%) | 1482 (52.8) | 26 (43.3) | 1456 (53.0) | 0.13 |
| BCVA, mean ± SD, logMAR units | -0.02 ± 0.14 | 0.53 ± 0.18 | -0.03 ± 0.11 | <0.01 |
| Walking speed, mean ± SD, m/seconds | 1.7 ± 0.4 | 1.5 ± 0.4 | 1.7 ± 0.4 | <0.01 |
| Average one-leg standing time with eyes opened, mean ± SD, seconds | 27.4 ± 21.3 | 17.1 ± 19.6 | 27.6 ± 21.3 | <0.01 |
| BMI, mean ± SD, kg/m² | 22.7 ± 2.9 | 22.5 ± 3.3 | 22.7 ± 2.9 | 0.62 |
| Current smoking, number (%) | 1171 (42.3) | 21 (36.2) | 1150 (42.4) | 0.34 |
| Number of other health conditions, number (%) | | | | |
| 0 | 503 (17.9) | 12 (20.0) | 491 (17.9) | |
| 1 | 623 (22.2) | 12 (20.0) | 611 (22.2) | |
| 2 | 616 (21.9) | 9 (15.0) | 607 (22.1) | |
| 3 | 657 (23.4) | 17 (28.3) | 640 (23.3) | |
| over 4 | 410 (14.6) | 10 (16.7) | 400 (14.6) | 0.66 |
| Health conditions | | | | |
| Hip arthritis, number (%) | 45 (1.6) | 0 (0.0) | 45 (1.7) | 0.31 |
| Knee arthritis, number (%) | 580 (20.7) | 11 (18.3) | 569 (20.7) | 0.65 |
| Leg pain, number (%) | 1328 (47.3) | 29 (48.3) | 1299 (47.3) | 0.87 |
| Ankle and foot pain, number (%) | 132 (4.7) | 4 (6.7) | 128 (4.7) | 0.47 |
| Low back and buttock pain, number (%) | 553 (19.7) | 16 (26.7) | 537 (19.5) | 0.17 |
| Sciatica, number (%) | 99 (3.5) | 2 (3.3) | 97 (3.5) | 0.94 |
| arrhythmia, number (%) | 232 (8.3) | 3 (5.0) | 229 (8.3) | 0.35 |
| Ischemic heart disease, number (%) | 77 (2.7) | 1 (1.7) | 76 (2.8) | 0.61 |
| Diabetes, number (%) | 414 (14.7) | 10 (16.7) | 404 (14.7) | 0.67 |
| Hypertension, number (%) | 1435 (51.8) | 30 (51.7) | 1405 (51.8) | 0.99 |
| COPD, number (%) | 129 (4.7) | 1 (1.7) | 128 (4.7) | 0.28 |
| Stroking, number (%) | 172 (6.1) | 6 (10.0) | 166 (6.0) | 0.21 |
| Cancer, number (%) | 420 (15.0) | 14 (23.3) | 406 (14.8) | 0.07 |

SD, standard deviation; BMI, Body mass index; BCVA, the best-corrected visual acuity; COPD, chronic obstructive pulmonary disease.

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The participants in the VI group had significantly slower walking speeds of 1.5 ± 0.4 m/sec than did the non-VI group at 1.7 ± 0.4 m/sec (P <0.05; Table 1). In addition, the individuals with VI had a significantly shorter one-leg standing time of 17.1 ± 19.6 sec than that of the non-VI group at 27.6 ± 21.3 sec (P <0.05; Table 1).

Associations between walking speed or one-leg standing time and other demographic parameters

The visual acuity, age, sex, current smoking habit, and the number of other health conditions were significantly associated with the walking speed and one-leg standing time (both P <0.001) as determined by linear regression analyses of univariate models. In the multivariate analyses, the visual acuity, age, sex, and the number of other health conditions were significantly associated with the walking speed and one-leg standing time (P <0.001; Tables 2 and 3). The BMI was significantly associated with one-leg standing time but not significantly associated with the walking speed.

Odds ratio for slow walking speed (≤1 m/sec and ≤0.8 m/sec) in participants with and without visual impairment

We set the cut-off for slow walking speed at 1.0 meter/sec [18,20,21] or ≤0.8 m/sec [19]. In the univariate logistic regression model, the OR for slow walking speed in the VI group was

Table 2. The associations between walking speed and parameters.

|                       | Univariate model | Multivariate model |
|-----------------------|------------------|--------------------|
|                       | B                | P value            | B                  | P value            |
| BCVA                  | -0.554           | <0.01              | -0.266             | <0.01              |
| Age                   | -0.029           | <0.01              | -0.028             | <0.01              |
| Sex (male)            | -0.199           | <0.01              | -0.223             | <0.01              |
| BMI                   | -0.001           | 0.786              | -0.006             | 0.008              |
| Current smoking       | 0.137            | <0.01              | -0.021             | 0.22               |
| Number of other health conditions | -0.051 | <0.01              | -0.036             | <0.01              |

BCVA, the best corrected visual acuity; BMI, Body mass index.
Multivariate model; Adjusted for age, sex, BMI, current smoking, and number of other health conditions.

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Table 3. The associations between average one-leg standing time and parameters.

|                       | Univariate model | Multivariate model |
|-----------------------|------------------|--------------------|
|                       | B                | P value            | β                  | P value            |
| BCVA                  | -32.09           | <0.01              | -17.11             | <0.01              |
| Age                   | -1.78            | <0.01              | -1.71              | <0.01              |
| Sex (male)            | -4.68            | <0.01              | -6.09              | <0.01              |
| BMI                   | -0.71            | <0.01              | -0.98              | <0.01              |
| Current smoking       | 3.19             | <0.01              | -0.65              | 0.54               |
| Number of other health conditions | -2.61 | <0.01              | -1.44              | <0.01              |

BCVA, the best corrected visual acuity; BMI, Body mass index.
Multivariate model; Adjusted for age, gender, BMI, current smoking, and number of other health conditions.

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significantly higher (OR; 7.40 at <1.0 m/sec, 95% CI; 3.36–16.30, \( P < 0.001 \); OR; 6.49 at <0.8 m/sec, 95% CI; 2.46–17.11, \( P < 0.001 \), respectively) than for the non-VI group (Table 4).

In the multivariate logistic regression model, adjustments were made for the BCVA, age, sex, current smoking habit, and the health conditions which were significant parameters in the univariate models. The OR for slow walking speed in the VI group was significantly higher (OR; 4.50 at <1.0 m/sec, 95% CI; 1.87–10.85, \( P = 0.001 \); OR; 3.51 at <0.8 m/sec, 95% CI; 1.21–10.15, \( P = 0.021 \), respectively) than for non-VI group (Table 4). These data indicate that there is a specific association between VA and walking speed.

**Discussion**

The population of older individuals has been rapidly increasing in advanced countries which have increased the cost of medical care and social security burdens for the government. To try to reduce or minimize the medical costs, governments must determine the factors associated with the increased medical care. One factor we have been concentrating on is the role played by the visual functions on the quality of life of older individuals.

The walking speed and standing one leg balance has been proposed to be strong predictors of disabilities and death of older adults [2,14–17,22,23,27,28].

Earlier studies suggested that older adults with VIs were more likely to report mobility difficulties and have slower walking speeds than their non-VIs individuals [7–11,29,30]. However, many of these studies identified the mobility difficulties by self-reporting [7–11]. For our study, we measured the walking speed and one-leg standing time, and our results clearly demonstrated that individuals with VIs had significantly slower walking speeds and significantly shorter one-leg standing times than did the non-VI individuals.

An earlier cohort study of Japanese rural individuals ages > 65 years reported that the average walking speed over 10 meters was 1.33 meters/sec [16]. Our participants demonstrated relatively faster walking speed than that cohort, but the participants with VIs had a significantly slower walking speed than non-VIs participants. We suggest that the individuals with VI have a greater fear of falling than do the non-VI individuals. Thus, older adults with VI walk more slowly to avoid falling. Ayaki et al. reported a significant correlation between the walking

| Participants with visual impairment (n = 60) | without visual impairment (n = 2749) |
|---------------------------------------------|-----------------------------------|
| Slow walking speed (<1m/sec)                |                                   |
| Unadjusted OR (95% CI)                      | 7.40 (3.36, 16.30)                |
| P value                                     | <0.001                            |
| Adjusted OR (95% CI)                        | 4.50 (1.87, 10.85)                |
| P value                                     | 0.001                             |
| Slow walking speed (<0.8m/sec)              |                                   |
| Unadjusted OR (95% CI)                      | 6.49 (2.46, 17.11)                |
| P value                                     | <0.001                            |
| Adjusted OR (95% CI)                        | 3.51 (1.21, 10.15)                |
| P value                                     | 0.021                             |

BCVA, best corrected visual acuity; OR, Odd ratio; CI, confidence intervals.

Adjusted OR is adjusted for variables (age, sex, BMI, smoking, and health conditions). BMI was categorized by underweight (<18.5 kg/m²), normal weight (18.5–24.9 kg/m²), and overweight or obese (≥25.0 kg/m²).

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speed and visual acuity, and they confirmed that a healthy binocular function is important for normal gait [31]. They compared the pre- and postoperative walking speed in cataract patients and reported a significant improvement in the walking speed after cataract surgery [31]. It is possible that the slowing of the walking speed is an adaptation at the onset of VIAs, and that individuals with VIAs walk slowly to maintain or improve their mobility safety.

The Salisbury Eye Evaluation Study reported that the interaction between age and VI status was not significant which indicated that the mobility speeds decreased at a similar rate in individuals with VIAs and non-VIs [32]. However, the results of our study demonstrated that the unadjusted OR for slow walking speed of <1 m/sec was significantly high at 7.40 in individuals with VI, and after adjustments for the age and health conditions, the OR was still significantly high at 4.50. These results indicate that the VI status affected the walking speed more likely than age.

A shorter one-leg standing time indicates low overall body balancing ability which is a greater risk for falling. When the walking speed slows, it reduces the daily walking activity which then leads to a weakening of the leg muscles and reduces static balance of the body. Thus, shorter one-leg standing times indicate a weakness of the leg muscles which would increase the risk of falling and enhance locomotor disability [22,23].

Falls and fall-related fractures are a major public health problem among the older adults [33]. It has been reported that 30% of community-dwelling adults older than 65 years fall at least once annually with 5% of falls resulting in fractures and 10% resulting in other serious injuries [34]. We demonstrated that the walking speed and one-leg standing time were significantly associated with the BCVA. Further studies are warranted to confirm the effects of visual improvements on the walking speeds and one leg standing times.

There are some limitations in this study. This was a cross-sectional study which precludes assessments of causality, and this was a survey study in which extensive examinations of mobilities were limited.

In conclusion, our results demonstrate the negative effects of VIAs on the mobility of older individuals. Thus, it is important for older individuals to have comprehensive ophthalmological examinations, and have all visual deficits corrected as best as they can.

Supporting information
S1 Dataset.
(XLSX)

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Author Contributions
Conceptualization: Nahoko Ogata.
Data curation: Kimie Miyata, Tadanobu Yoshikawa, Akihiro Harano.
Formal analysis: Kimie Miyata.
Investigation: Kimie Miyata, Akihiro Harano.
Methodology: Nahoko Ogata.
**Project administration:** Tadanobu Yoshikawa, Nahoko Ogata.

**Software:** Tadanobu Yoshikawa, Akihiro Harano.

**Supervision:** Tetsuo Ueda, Nahoko Ogata.

**Validation:** Tadanobu Yoshikawa.

**Writing – original draft:** Kimie Miyata.

**Writing – review & editing:** Nahoko Ogata.

**References**

1. Guralnik JM, LaCroix AZ, Abbott RD, Berkman LF, Satterfield S, Evans DA, et al. Maintaining mobility in late life. I. Demographic characteristics and chronic conditions. Am J Epidemiol. 1993; 137: 845–857. https://doi.org/10.1093/oxfordjournals.aje.a116746 PMID: 8494376

2. Guralnik JM, Ferrucci L, Simonsick EM, Salive ME, Wallace RB. Lower-extremity function in persons over the age of 70 years as a predictor of subsequent disability. N Engl J Med. 1995; 332: 556–561. https://doi.org/10.1056/NEJM199509233321102 PMID: 7838189

3. Fried LP, Guralnik JM. Disability in older adults: Evidence regarding significance, etiology, and risk. J Am Geriatr Soc. 1997; 45: 92–100. https://doi.org/10.1111/j.1532-5415.1997.tb00986.x PMID: 8994996

4. Centers for Disease Control and Prevention. Prevalence and most common causes of disability among adults—United States, 2005. MMWR Morb Mortal Wkly Rep. 2009; 58: 421–426. PMID: 19407734

5. Mine M, Miyata K, Morikawa M, Nishi T, Okamoto N, Kawasaki R, et al. Association of Visual Acuity and Cognitive Impairment in Older Individuals: Fujiwara-kyo Eye Study. Biorep Open Access. 2016; 5: 228–234. https://doi.org/10.1089/biores.2016.0023 PMID: 27610269

6. Miyata K, Yoshikawa T, Morikawa M, Mine M, Okamoto N, Kurumitani N, et al. Effect of cataract surgery on cognitive function in elderly: Results of Fujiwara-kyo Eye Study. PLOS One. 2018; 13: e0192677 https://doi.org/10.1371/journal.pone.0192677 PMID: 29462175

7. West SK, Munoz B, Rubin GS, Schein OD, Bandeen-Roche K, Zeger S, et al. Function and visual impairment in a population-based study of older adults. The SEE Project. The Salisbury Eye Evaluation. Invest Ophthalmol Vis Sci. 1997; 38: 72–82. PMID: 9008632

8. West SK, Rubin GS, Broman AT, Muñoz B, Bandeen-Roche K, Turano K. How does visual impairment affect performance on tasks of everyday life? The SEE Project. The Salisbury Eye Evaluation. Arch Ophthalmol. 2002; 120: 774–780. https://doi.org/10.1001/archopht.120.8.774 PMID: 12049833

9. Turano KA, Broman AT, Bandeen-Roche K, Munoz B, Rubin GS, West S, SEE Project Team. Association of visual field loss and mobility performance in older adults: Salisbury Eye Evaluation Study. Optom Vis Sci. 2004; 81: 298–307. https://doi.org/10.1097/01.optx.0000134903.13651.8e PMID: 15181354

10. Patel I, Turano KA, Broman AT, Bandeen-Roche K, Muñoz B, West SK. Measures of visual function and percentage of preferred walking speed in older adults. The Salisbury Eye Evaluation Project. Invest Ophthalmol Vis Sci. 2006; 47: 65–71. https://doi.org/10.1167/iovs.05-0582 PMID: 16385485

11. Freeman EE, Muñoz B, Rubin G, West SK. Visual field loss increases the risk of falls in older adults: The Salisbury Eye Evaluation. Invest Ophthalmol Vis Sci. 2007; 48: 4445–4450. https://doi.org/10.1167/iovs.07-0326 PMID: 17898264

12. Swenor BK, Muñoz B, West SK. Does visual impairment affect mobility over time? The Salisbury Eye Evaluation Study. Invest Ophthalmol Vis Sci. 2013; 54: 7683–7690. https://doi.org/10.1167/iovs.13-12869 PMID: 24179902

13. Swenor BK, Bandeen-Roche K, Muñoz B, West SK. Does walking speed mediate the association between visual impairment and self-report of mobility disability? The Salisbury Eye Evaluation Study. J Am Geriatr Soc. 2014; 62: 1540–1545. https://doi.org/10.1111/jgs.12937 PMID: 25040870

14. Studenski S, Perera S, Patel K, Rosano C, Faulkner K, Inzitari M, et al. Gait speed and survival in older adults. JAMA. 2011; 305: 50–58. https://doi.org/10.1001/jama.2010.1923 PMID: 21205966

15. Guralnik JM, Ferrucci L, Pieper CF, Leveille SG, Markides KS, Ostir GV, et al. Lower extremity function and subsequent disability: consistency across studies, predictive models, and value of gait speed alone compared with the short physical performance battery. J Gerontol A Biol Sci Med Sci. 2000; 55: M221–M231. https://doi.org/10.1093/gerona/55.4.m221 PMID: 10811152

16. Shinkai S, Watanabe S, Kumagai S. Walking speed as a good predictor for the onset of functional dependence in a Japanese rural community population. Age Aging. 2000; 29: 441–446.
17. Studenski S, Perera S, Patel K, Rosano C, Faulkner K, Inzitari M, et al. Gait speed and survival in older adults. JAMA 2011; 305: 50–58. https://doi.org/10.1001/jama.2010.1923 PMID: 21205966
18. Satake S. Research report: Factors which affects the progression of frailty (Japanese). 2019. http://www.nccg.go.jp/nccgkenkyu/documents/27/25xx-11.pdf.
19. Cruz-Jentoft AJ, Baeyens JP, Bauer JM, Boirie Y, Cederholm T, Landi F, et al. Sarcopenia: European consensus on definition and diagnosis: Report of the European Working Group on Sarcopenia in Older People. Age Ageing 2010; 39: 412–423. https://doi.org/10.1093/ageing/afq034 PMID: 20392703
20. Fielding RA, Vellas B, Evans WJ, Bhasin S, Morley JE, Newman AB, et al. Sarcopenia: An Undiagnosed Condition in Older Adults. Current Consensus Definition: Prevalence, Etiology, and Consequences. International Working Group on Sarcopenia. J Am Med Dir Assoc. 2011; 12: 249–256. https://doi.org/10.1016/j.jamda.2011.01.003 PMID: 21527165
21. Chen LK, Woo J, Assantachai P, Auyeung TW, Chou MY, Iijima K, et al. Asian Working Group for Sarcopenia: 2019 Consensus Update on Sarcopenia Diagnosis and Treatment. J Am Med Dir Assoc. 2020; 21: 300–307. https://doi.org/10.1016/j.jamda.2019.12.012 PMID: 32033882
22. Drusini AG, Eleazer GP, Caiazzo M, Veronesi E, Carrara N, Ranzato C, et al. One-leg standing balance and functional status in an elderly community-dwelling population in northeast Italy. Aging Clin Exp Res. 2002; 14: 42–46. https://doi.org/10.1007/BF03324416 PMID: 12027151
23. Sakamoto K, Nakamura T, Hagino H, Endo N, Mori S, Muto Y, et al. Effects of unipedal standing balance exercise on the prevention of falls and hip fracture among clinically defined high-risk elderly individuals: A randomized controlled trial. J Orthop Sci. 2006; 11:467–72. https://doi.org/10.1007/s00776-006-1057-2 PMID: 17013734
24. Nezu S, Okamoto N, Morikawa M, Saeki K, Obayashi K, Tomioka K, et al. Health-related quality of life (HRQOL) decreases independently of chronic conditions and geriatric syndromes in older adults with diabetes: the Fujiwara-kyo Study. J Epidemiol. 2014; 24: 259–266. https://doi.org/10.2188/jea.je20130131 PMID: 24814506
25. Okamoto N, Morikawa M, Tomioka K, Yanagi M, Amano N, Kurumatani N. Association between tooth loss and the development of mild memory impairment in the elderly: the Fujiwara-kyo Study. J Alzheimers. 2015; 44: 777–786. https://doi.org/10.3233/JAD-141665 PMID: 25362033
26. American Academy of Ophthalmology (AAO). Preferred Practice Pattern: Vision Rehabilitation for Adults 2010.7. www.aao.org.
27. Laukkonen P, Heikkinen E, Kauppinen M. Muscle strength and mobility as predictors of survival in 75-84-year-old people. Age Ageing 1995; 24: 468–473. https://doi.org/10.1093/ageing/24.6.468 PMID: 8588534
28. Ostr G, Markides S, Black SA, Goodwin JS. Lower body functioning as a predictor of subsequent disability among older Mexican Americans. J Gerontol A Biol Sci Med Sci.1998; 53A: M491–495. https://doi.org/10.1093/gerona/53a.6.m491 PMID: 9823755
29. Reuben DB, Mui S, Damesyn M, Moore AA, Greendale GA. The prognostic value of sensory impairment in older persons. J Am Geriatr Soc.1999; 47: 930–935. https://doi.org/10.1111/j.1532-5415.1999.tb01286.x PMID: 10443852
30. Jacobs JM, Hammerman-Rozenberg R, Maaravi Y, Cohen A, Steissman J. The impact of visual impairment on health, function and mortality. Aging Clin Exp Res. 2005; 17: 281–286. https://doi.org/10.1007/BF03324611 PMID: 16285193
31. Ayaki M, Muramatsu M, Negishi K, Tsubota K. Improvements in sleep quality and gait speed after cataract surgery. Rejuvenation Res. 2013; 16: 35–42. https://doi.org/10.1089/rej.2012.1369 PMID: 23145881
32. Swenor BK, Muñoz B, West SK. A longitudinal study of the association between visual impairment and mobility performance in older adults: the Salisbury eye evaluation study. Am J Epidemiol. 2014; 179: 313–22. https://doi.org/10.1093/aje/kwt257 PMID: 24148711
33. Niihata Kakuya, Fukuma Shingo, Hiratsuka Yoshinume, Ono Koichi, Yamada Masakazu, Sekiguchi Miho. Association between vision-specific quality of life and falls in community-dwelling older adults: LOHAS. PLoS One.2018; 13: e0195806. https://doi.org/10.1371/journal.pone.0195806 PMID: 29689064
34. Tinetti ME, Speechley M, Ginter SF. Risk factors for falls among elderly persons living in the community. N Engl J Med. 1988; 319: 1701–1707. https://doi.org/10.1056/NEJM1988122919812764 PMID: 32052676