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Higher Risk of Multiple Falls among Elderly Women Who Lose Visual Acuity

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Objective: To determine the association between changes in visual acuity (VA) and frequent falls in older women.

Design: Prospective cohort study.

Participants: Two thousand two elderly community-residing women participating in the Study of Osteoporotic Fractures with measurements of VA at baseline and a follow-up examination 4 to 6 years later (mean of 5.6 years).

Methods: Binocular VA with habitual correction was measured under standard illumination using Bailey–Lovie charts at baseline and fourth examinations. Change in VA was stratified into 5 categories: no change or VA gain, loss of 1 to 5 letters, loss of 6 to 10 letters, loss of 11 to 15 letters, and loss of >15 letters. A separate analysis considered decline in VA as the loss of ≥10 letters (≥2 lines) on the Bailey–Lovie acuity measure between baseline and follow-up examinations.

Main Outcome Measures: Data on falls were obtained from postcards sent every 4 months after the follow-up examination. Frequent falling was defined as ≥2 falls during a 1-year period after the follow-up examination.

Results: Compared with women with stable or improved VA, women with declining acuity had significantly greater odds of experiencing frequent falling during the subsequent year. Odds ratios after adjustment for baseline acuity and other confounders were 2.08 (95% confidence interval [CI]: 1.39–3.12) for loss of 1 to 5 letters, 1.85 (95% CI: 1.16–2.95) for loss of 6 to 10 letters, 2.51 (95% CI: 1.39–4.52) for loss of 11 to 15 letters, and 2.08 (95% CI: 1.01–4.30) for loss of >15 letters. In the analysis of visual decline defined as a loss of ≥10 letters, heightened risk of frequent falling was evident in each of 2 subgroups defined by splitting the sample on baseline VA, with borderline significant evidence of a more pronounced effect in those women with baseline VA of 20/40 or worse (*P* value for interaction, 0.083).

Conclusions: Loss of vision among elderly women increases the risk of frequent falls. Prevention or correction of visual loss may help reduce the number of future falls. *Ophthalmology 2004;111:857–862 © 2004 by the American Academy of Ophthalmology.*

Falls are a common cause of morbidity and mortality in the elderly.[1] Approximately one third of older individuals fall each year,[2,3] and 7% of individuals older than 75 years have an emergency room visit for a fall-related injury each year.[4,5] Approximately 6% of urgent hospital admissions among older individuals are secondary to fall-related injuries.[3,5]

Impaired vision may increase the risk of falls in older individuals.[2,6–8] However, a number of previous studies[6,7] examining the relationship between impaired vision and risk of falls have utilized cross-sectional and retrospective designs and have been limited in their ability to control for potential confounding factors. Lord and Dayhew reported in a prospective study of 148 community-dwelling individuals[8] that impaired vision is an important and independent risk factor for falls. Although prior authors[8] have reported

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that there is an increased risk of falling in subjects with binocular visual acuity (VA) of 6/10 or worse, no prior study, to our knowledge, has investigated the association between declines in VA and the risk for falls in elderly individuals. Although recently measured VA is relevant for screening purposes, declines in VA may be scientifically interesting as a reflection of adaptation. That is, there may be an increased risk of falling if VA has recently declined, as elderly subjects may not be as successful in adapting to changes in their VA, whereas subjects with worse baseline acuity may have adapted at a time when their coordination and reflexes were better.

To test the hypothesis that declines in VA are associated with greater risk for frequent falls in elderly community-dwelling women, we prospectively measured decline in VA (mean of 5.6 years between examinations, standard deviation [SD] of 0.35 years) in 2002 older women and followed them up for 1 year for incident falls.

Materials and Methods

Subjects

From September 1986 through October 1988, a volunteer sample of 9704 women 65 years or older was recruited from population-based listings to participate in the Study of Osteoporotic Fractures (SOF).[9] Women received a letter and brochure inviting them to participate in the study. The SOF excluded black women, because of their lower incidence of hip fractures[10]; women unable to walk without the help of another person; and women with bilateral hip replacements.

Beginning in August 1992, all surviving participants were invited to participate in a follow-up examination completed in July 1994. A total of 6330 women (72% of survivors as of July 31, 1994) attended the clinic examination. Of these, 2002 women, a convenience sample of the study population, had measurements of VA performed at both baseline and follow-up examinations and are included in this analysis. Institutional review board/ethics committee approval was obtained from the University of California at San Francisco; University of California at Los Angeles; University of Minnesota; The Kaiser Permanente Center for Health Research in Portland, Oregon; University of Maryland; and University of Pittsburgh. All participants provided written informed consent for participation in baseline and subsequent examinations and ancillary studies.

Visual Acuity

Binocular distance VA with habitual correction was measured under standard illumination with Bailey–Lovie charts.[11] The lines on the Bailey–Lovie chart are of equal difficulty, and there is geometric progression in letter size from line to line similar to that of Early Treatment Diabetic Retinopathy Study charts. The number of letters correct was recorded for each participant. Changes in VA from baseline to the follow-up examination were stratified into 5 categories: no change or VA gain, loss of 1 to 5 letters, loss of 6 to 10 letters, loss of 11 to 15 letters, and loss of >15 letters. Declining VA was defined as a loss of ≥10 letters (≥2 lines) of VA between baseline and the follow-up examination.

Other Measurements

At the time of the follow-up examination, participants were asked to rate their health relative to others. Their responses were categorized into 3 groups: (1) poor or very poor, (2) fair, and (3) good or excellent. Exercise level (total kilocalories per week burned in the past year) was examined with a modified Paffenbarger survey, which has been validated in postmenopausal women.[12] All participants attending the follow-up examination were asked to bring all current prescription and nonprescription medications with them to the clinic. A computerized dictionary was used to categorize type of medication from product brand and generic names obtained from containers or from a participant report. Tandem stand balance with eyes open was categorized as poor, fair, or good. Women were categorized as poor if they could not hold either the tandem stand or the semitandem stand for 10 seconds, fair if they could not hold the tandem stand for 10 seconds but were able to hold the semitandem stand for at least 10 seconds, and good if they could hold the tandem stand for at least 10 seconds. Walking speed was determined by measuring the time in seconds needed to walk 6 m at a rapid pace. Ability to rise from a chair was assessed by determining whether the participant could rise up from a chair (without using her arms) 5 times. The average torque of the right quadriceps was measured twice with the knee extended to 125° during the last 3 of 4 seconds of pushing. Maximum grip strength was measured twice with a grip dynamometer in both hands[13] and averaged. Interrater reliability was assessed in 15 subjects at each clinic who were tested 15 minutes apart by 2 examiners and averaged for all clinics ($r = 0.93$). Depressed mood was assessed with the 15-item Geriatric Depression Scale, using a cutpoint of ≥6.[14–16] Smoking was summarized as current usage compared with never having smoked or former smoking. Alcohol consumption was summarized as the number of drinks per week. Weight change was calculated by subtracting the weight at the baseline examination from the weight at the follow-up examination and expressed as a percentage of the baseline value. Women with a decrease of ≥5% since the baseline examination and those with an increase of ≥5% since the baseline examination were compared with those who had a <5% change in baseline weight.

Outcome Variables

After the follow-up examination, we contacted participants every 4 months by postcard or telephone and were able to complete 98% of these follow-up contacts in surviving women. A fall was defined as falling all the way down to the floor or ground, or falling and hitting an object like a chair or stair. All falls reported on the first 3 postcards returned after the follow-up examination (covering approximately 1 year) were included in the analysis. The mean (± SD) follow-up interval for assessing falls was 11.86±1.25 months.

Data Analyses

Participant characteristics were compared between the vision cohort and the rest of the SOF participants who had a clinic visit but did not participate in the vision cohort. Subjects with questionnaire data only, home visits, or minimal data only were excluded from the analysis. Means and SDs for continuous covariates and proportions for categorical covariates were compared across the 5 VA change groups using analysis of variance or chi-square tests, respectively. In addition, the Cochran–Armitage test for trend and the Jonckheere–Terpstra trend test were used for binary covariates and for categorical covariates with >2 levels, respectively. Logistic regression analyses were performed to determine the relationship between loss of VA (loss of 1–5 letters, loss of 6–10 letters, loss of 11–15 letters, and loss of >15 letters vs. VA gain) and the subsequent report of frequent falling (≥2 falls vs. one fall or none) in the subsequent year. Potential covariates examined for inclusion in our multivariate model of the association between decline in VA (defined as a loss of ≥10 letters) and frequent falling were known

risk factors for falls in our cohort[17,18] and included age (per 5-year increase), self-rated health relative to others, total kilocalories per week burned in the past year, any falls in the past 12 months, ≥2 falls in the past 12 months, tandem stand balance with eyes open (poor, fair, good), trouble with dizziness, walking speed (meters per second), use of arms to stand, average of right quadriceps force trials, average of right/left grip strength, depression, chronic systemic diseases (arthritis, Parkinson's disease, stroke, and/or dementia), sedative/hypnotic/anxiolytic drug use, smoking, alcohol use (drinks per week), and weight change (gain or loss of ≥5% of baseline weight vs. stable weight). To obtain adjusted risk estimates for our outcome of frequent falling, we first examined the univariate associations between each potential covariate and decline in VA and univariate associations between each potential covariate and frequent falling. Potential confounders that were associated with both decline in VA and frequent falling at $P \leq 0.20$ were included in the multivariate models. In addition, age, baseline VA, bifocal use, chronic eye diseases (cataract, glaucoma, retinal disease), and chronic systemic diseases (arthritis, Parkinson's disease, stroke, dementia) were included in all multivariate models.

To evaluate whether the effect of declining VA on risk of falls depended on baseline level of acuity, subgroup analyses of decline in VA (defined as a loss of ≥10 letters) were performed with subjects stratified into 2 groups based on their baseline VA with habitual correction: (1) better than 20/40 and (2) 20/40 or worse. In addition, the interaction between baseline VA category and change in VA was tested.

Table 1. Comparison of Vision Cohort to the Rest of the Study of Osteoporotic Fractures (SOF) Cohort Who Completed the Follow-up Clinic Visit

Risk Factor	Vision Cohort (N = 2002)	Rest of the SOF Participants Who Completed the Clinic Visit (N = 4275)	P
Age at visit in 1992–1994 (years)	76.4±4.8	76.6±4.7	0.198*
Self-reported poor health status at visit in 1992–1994	1.55%	1.59%	0.77†
Any hip fracture since age 50 at visit in 1992–1994	2.7%	3.0%	0.41†
Self-report of frequent falls (≥2) at visit in 1992–1994	10.3%	11.7%	0.099†
Average of right/left grip strength	18.1±3.9	18.4±4.2	0.009*
Alcohol consumption (drinks/wk)	1.45±3.33	1.29±3.00	0.06‡
Chronic systemic diseases§	61.6%	65.8%	0.001†
Self-reported eye condition‖	53.8%	54.1%	0.805†

*t test.
†Chi-square test.
‡Wilcoxon rank sum test.
§History of arthritis, Parkinson's disease, stroke, and/or dementia.
‖History of cataracts, glaucoma, or retinal disease.

Results

Visual acuity data at both vision visits were available for 2002 of 2055 women (97.4%) who originally volunteered to be in the vision cohort. The 53 women who volunteered for but did not complete measurement of VA at the follow-up examination were more likely to have a baseline VA of 20/40 or worse than the 2002 for whom there was vision data at that visit (35.85% vs. 19.73%, $P = 0.004$). Of the 2002 subjects, 1975 (98.7%) returned 3 postcards within the first year after the visit in 1992 to 1994. The women who did not return 3 postcards the first year were more likely to have a baseline VA of 20/40 or worse than the women who returned the postcards (37.04% vs. 19.49%, $P = 0.023$).

There were differences in clinical characteristics between the subgroup of women in the vision cohort (n = 2002) and the rest of the women in the SOF who completed the clinic visit but did not have VA measured (n = 4275) at the time of the visit in 1992 to 1994. Subjects in the vision cohort had a weaker average right/left grip strength ($P = 0.009$) and showed borderline significant evidence of consuming more drinks of alcohol during the week ($P = 0.06$). In addition, they had fewer chronic medical conditions ($P = 0.001$) (Table 1).

At the baseline visit, there were 1607 subjects in the vision cohort whose VA with habitual distance correction was better than 20/40, 385 whose VA was 20/40 to better than 20/80, and 10 whose VA was 20/80 or worse. Of women in the vision cohort, 72.2% reported no falls during the 1-year period after the follow-up examination, whereas 16.4% reported 1 fall, and 11.4% reported ≥2 falls during the first year after the follow-up examination.

From baseline to fourth cohort examinations, 699 women (34.9%) had no change or a gain in VA, 638 (31.9%) lost 1 to 5 letters, 419 (20.9%) lost 6 to 10 letters, 154 (7.7%) lost 11 to 15 letters, and 92 (4.6%) lost >15 letters (Table 2). Women who experienced no change or a gain in VA had worse baseline VA than those who experienced a loss. Seventy-five percent of women who lost >15 letters of VA (more than a 3-line loss) reported the presence of cataract, glaucoma, or age-related macular degeneration, compared with 52.7% of women who had no change or an improvement in their VA ($P = 0.0006$). Except for baseline VA, women with a loss of 11 to 15 letters or >15 letters were worse off for each of the risk factors listed in Table 2 than women in the first 3 categories.

After adjustment for potential confounders, point estimates of the odds ratios (ORs) for frequent falling ranged from 1.85 to 2.51 across groups of subjects who lost VA, compared with subjects who had no change or gained VA (Table 3). Age; self-reported poor health; walking speed; sedative/hypnotic and/or anxiolytic medication use; bifocal use; and self-report of cataracts, glaucoma, or retinal disease were not associated with greater odds of frequent falling in the fitted model.

A loss of ≥2 lines in VA (≥10 letters) was associated with 43% higher adjusted odds of frequent falling, compared with a loss of <10 letters (OR, 1.43; 95% confidence interval [CI], 1.17–1.75; $P = 0.0004$). In stratified analyses, among women with baseline VA of 20/40 or worse, the impact of vision loss had a marked effect on the risk of subsequent multiple falls. Among women with VA of 20/40 or worse, those who lost ≥2 lines of acuity had 1.74-fold (95% CI, 1.23–2.45) greater odds of frequent falling compared with women with less than a 2-line loss of acuity. Among women with a baseline VA of better than 20/40, those with loss of ≥2 lines of acuity had 1.31-fold (95% CI, 1.01–1.70) greater odds of frequent falling compared with those with a loss of <2 lines. The P value for the interaction term between decline in VA and baseline VA was 0.083.

Discussion

Community-dwelling, elderly women who lost one or more letters of VA over approximately a 5-year period had substantially greater adjusted odds of frequent falling during

Table 2. Characteristics of Participants in the Vision Cohort across Categories of Change in Visual Acuity (VA)

Risk Factors	No Change or Vision Gain (N = 699 [34.9%])	Loss of 1–5 Letters (N = 638 [31.9%])	Loss of 6–10 Letters (N = 419 [20.9%])	Loss of 11–15 Letters (N = 154 [7.7%])	Loss of >15 Letters (N = 92 [4.6%])	*P*
Baseline VA (letters read correctly)	47.2±6.1	51.5±5.2	52.3±4.7	52.7±5.6	50.8±7.2	0.0001*
Self-report of eye condition[†]	52.7%	52.2%	51.8%	58.4%	75.0%	0.004[‡]
Bifocal use	77.5%	78.5%	74.7%	70.8%	71.7%	0.03[‡]
Worse self-reported health relative to others (3 categories for health)	1.0%	1.4%	2.2%	2.6%	2.2%	0.002[§]
Chronic systemic diseases[‖]	60.8%	60.5%	64.0%	57.8%	71.7%	0.19[‡]
Weight loss of ≥5% of weight at baseline (3 categories for weight change)	25.8%	23.7%	27.5%	27.3%	40.2%	0.25[§]
Age (yrs)	76.1±4.7	76.2±4.9	76.7±4.7	76.9±4.8	78.3±4.9	0.0002*
History of frequent falling	11.6%	9.9%	8.1%	13.6%	7.6%	0.31[‡]
Poor ability to do tandem stand balance with eyes open (3 categories for tandem stand)	8.4%	10.7%	10.9%	13.3%	13.5%	0.0003[§]
Walking speed (m/sec)	0.97±0.21	0.95±0.22	0.93±0.23	0.91±0.21	0.90±0.22	0.0003*
Sedative, hypnotic, and/or anxiolytic use[¶]	7.4%	7.2%	6.4%	9.7%	12.0%	0.26[‡]

*Analysis of variance.
[†]History of cataracts, glaucoma, or retinal disease.
[‡]Cochran–Armitage trend test.
[§]Jonckheere–Terpstra test.
[‖]History of arthritis, Parkinson's disease, stroke, and/or dementia.
[¶]List available on request.

the subsequent 12 months of follow-up than women who did not lose VA or had an improvement in their VA over the same time period. In addition, a loss of ≥10 letters of VA was associated with 43% greater odds of frequent falls during the subsequent year. The effect of acuity decline was most pronounced in the women with poorer baseline acuity, which is consistent with prior publications on the association of low VA and falls.[2,6–8] These findings suggest that elderly people with impaired acuity and/or declining acuity should be prioritized for interventions to evaluate and correct vision to minimize risk for future falls. Even a decline of 1 to 5 letters in VA over a 5-year period is associated

Table 3. Adjusted Odds of Falling ≥2 Times (from Multivariate Logistic Regression)

Risk Factors Included in Model	OR	95% CI Limits	*P*
Baseline VA (per letter increase)	0.96	0.94–0.99	0.01
Change in VA from baseline			
No change or gain in VA	1.0 (referent group)		
Loss of 0–5 letters	2.08	1.39–3.12	0.0004
Loss of 6–10 letters	1.85	1.16–2.95	0.01
Loss of 11–15 letters	2.51	1.39–4.52	0.002
Loss of >15 letters	2.08	1.01–4.30	0.05
Gain of ≥5% of baseline weight versus stable weight	0.83	0.52–1.31	0.42
Loss of ≥5% of baseline weight versus stable weight	1.40	0.99–1.98	0.06
Age (per 5-year increase)	0.87	0.72–1.05	0.14
Bifocal use	0.79	0.56–1.13	0.20
Eye condition*	1.17	0.84–1.61	0.35
Chronic systemic disease[†]	1.60	1.14–2.25	0.007
Self-reported health relative to others (1 = poor, very poor; 2 = fair; 3 = good, excellent)	1.05	0.74–1.48	0.80
History of frequent falling at follow-up examination	5.54	3.88–7.92	<0.0001
Ability to do tandem stand balance with eyes open (poor, fair, good)	0.69	0.55–0.88	0.002
Walking speed (m/sec)	0.65	0.29–1.47	0.30
Sedative, hypnotic, and/or anxiolytic use[‡]	1.15	0.68–1.93	0.60

*History of cataracts, glaucoma, or retinal disease.
[†]History of arthritis, Parkinson's disease, stroke, and/or dementia.
[‡]List available on request.
CI = confidence interval; OR = odds ratio; VA = visual acuity.

with roughly 2-fold greater adjusted odds of frequent falling compared with no change or a gain in VA over the same time period.

In the SOF cohort, decreased contrast sensitivity and depth perception were associated with an elevated risk of hip fractures,[19] whereas poor VA was not significantly associated with an elevated risk of hip fractures. Impaired VA was associated with an elevated risk of wrist and humerus fractures in the SOF.[20] In the Beaver Dam Eye Study,[6] approximately 11% (943/2365) of subjects who were 60 years or older and had binocular distance VA of 20/25 or less had a history of a fall in the past year, compared with 4.4% of those with a VA of 20/20 or better.

The finding that a loss of VA of ≥10 letters corresponds to elevated risk of frequent falls underscores the fact that losing ≥10 letters (2 lines of acuity) is not a trivial loss. Ten letters of loss represents a 1.6-times increase in the size of the letters that can be read at 20 feet. This means that women described here as having a decline in VA could no longer see letters at a distance of 20 feet unless the letters were 1.6 times larger than the letters they correctly identified 5 years earlier. For a baseline VA of 20/40, a decrease in VA of ≥10 letters would result in crossing the threshold that 42 states (84%) in the United States use in allowing unrestricted private driver's licenses.[21]

Several limitations should be considered when interpreting the results of this study. The major limitation is that this study may not be generalizable to men, women of non-Caucasian ancestry, or those in poorer health or living in institutions, because the participants were community-dwelling white women over the age of 70 years. Because the women were community dwelling and ambulatory when initially recruited to participate in the SOF, they were initially healthier than the population as a whole. It is plausible that in a less healthy population women may have even greater odds of falling than we reported.

Success in retaining women in the cohort, as reflected in the high percentage of follow-up, suggests that the risk of substantial nonresponse bias is not large. Data on falls from the postcards were collected every 4 months. Despite the greater frequency and corresponding diminished risk of recall bias compared with biannual surveys, there remains the potential for some recall bias.[22] Although the 4-month follow-ups are apt to be less accurate than monthly diaries, which are the current standard in research on falls, the convergent findings from both postcard and survey data collection from the SOF (results not reported here) enhance our confidence that the results do not reflect spurious associations. In addition, it is unlikely that errors in the measurement of VA accounted for our results, because the average difference in scores between logarithm of the minimum angle of resolution acuity tests when retested in the same subjects was less than 0.5 letters.[23]

In conclusion, a change in VA over approximately a 5-year period is an important risk factor for frequent falls. Thus, to decrease the risk of frequent falls and fall-related injuries, older individuals should be referred to eye care providers not only when there is loss of VA, but also when the VA can be improved with cataract surgery or correction of uncorrected refractive error, such as with new eyeglasses or contact lenses.

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