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Visual Field Loss and Risk of Fractures in Older Women

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OBJECTIVES: To evaluate the associations between visual field loss and nonspine fractures.

DESIGN: Prospective cohort study.

SETTING: Community.

PARTICIPANTS: Four thousand seven hundred seventy-three community-dwelling white and African-American women aged 65 and older with no previous history of hip fracture at the time of recruitment.

MEASUREMENTS: Radiographically confirmed hip and nonspine, nonhip fractures identified from September 1997 to April 2008. Visual field loss was measured using a Humphrey Field Analyzer suprathreshold screening test of the peripheral and central vision of each eye and was classified into an ordinal rating of no, mild, moderate, or severe binocular visual field (BVF) loss.

RESULTS: For hip and nonspine, nonhip fractures and in unadjusted and covariate-adjusted analyses, the highest incidence of fractures was seen in women with the most-severe BVF loss. In covariate-adjusted analysis, women with mild, moderate, and severe BVF loss had a 49% (hazard ratio (HR) = 1.49, 95% confidence interval (CI) = 1.18–1.88), 25% (HR = 1.25, 95% CI = 0.87–1.80), and 66% (HR = 1.66, 95% CI = 1.19–2.32) greater risk, respectively, for hip fractures than women without BVF loss. Similarly, women with mild visual field loss had a 12% (HR = 0.88, 95% CI = 0.75–1.04) lower risk for nonspine, nonhip fractures, whereas women with moderate and severe visual field loss had a 18% (HR = 1.18, 95% CI = 0.92–1.52) and 59% (HR = 1.59, 95% CI = 1.24–2.03) greater risk of nonspine, nonhip fractures than women without BVF loss.

CONCLUSION: BVF loss is independently associated with hip and nonspine, nonhip fractures in older female volunteers. **J Am Geriatr Soc 57:1825–1832, 2009.**

Key words: fractures; visual field loss; visual acuity

Poor vision has long been recognized as a potential risk factor for fractures in older people.[1–4] Findings from the Study of Osteoporotic Fractures (SOF) that visual impairment as measured according to depth perception and contrast sensitivity was associated with higher risk of hip fractures[5] and that poorer visual acuity was associated with higher risk of wrist fractures in older women[6] has previously been reported on. Another readily available clinical measure is the evaluation of central and peripheral vision. Such vision is measured by testing for visual field deficits. In visual field testing, patients indicate when they perceive objects or points of light presented in different locations associated with central and peripheral vision. In automated visual field testing, this information is translated into pixels showing a map of the areas in the eye where perception occurs. Visual field loss is a measure of low or no perception of light across one or more pixels. Visual field measurement is a standard diagnostic tool for disorders within the visual pathway from the photoreceptor cells in the retina to the occipital lobe. Studies have reported a prevalence of visual field loss ranging from 5.6% to 17% in adults aged 40 and older.[7,8]

Recently, it was reported that binocular visual field (BVF) loss was associated with greater risk of frequent falls in older white women.[9] In the limited research conducted, longitudinal studies have reported conflicting results on the link between visual field loss and risk of hip fracture.[8,10]

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One study reported that older white people with visual field loss did not have a higher risk of hip fracture,[8] whereas another found that the relationship between visual field loss and hip fracture in white people waned with longer follow-up time since the clinical examination.[10] Another prior study failed to find an association between visual field loss and wrist fractures in white people.[11]

To test the hypothesis that BVF loss is an independent risk factor for fracture, a comprehensive eye examination including visual field testing was performed in a cohort of 4,773 older women enrolled in the SOF,[12–14] and they were followed prospectively for 8 years.

METHODS

Subjects

From 1986 to 1988, 9,704 ambulatory white female volunteers aged 65 and older with no history of bilateral hip replacement were enrolled in the SOF, a multicenter, prospective, longitudinal cohort study for identifying potential risk factors of osteoporotic fractures.[12–14] Beginning in January 1997 and continuing through September 1998, all surviving participants were invited to participate in a follow-up clinical examination (6th clinic visit; V6) that included a comprehensive eye examination. In addition, a cohort of 662 women who identified themselves as African Americans were recruited from population listings at each of the four clinic centers to participate in the SOF and the eye examination. The same recruitment strategy was used to recruit African American and white participants. The two cohorts were pooled in a prior SOF study.[12] All individuals in the study gave informed consent to participate. Institutional review board approvals were obtained from all participating institutions. A total of 5,482 women, including 662 African-American and 4,820 white participants, attended V6. This sample of white women represented 63% of the surviving cohort. The analyses excluded 552 women who did not have visual field tests in both eyes. They also excluded 157 women who had unreliable visual field tests (tests with fixation losses of 33% or higher in both eyes), leaving a final sample of 4,773 women (87% of those with a clinic visit permitting visual field testing) (Figure 1). Visual field testing could not be conducted in participants who were unable to attend the clinic-based examinations.

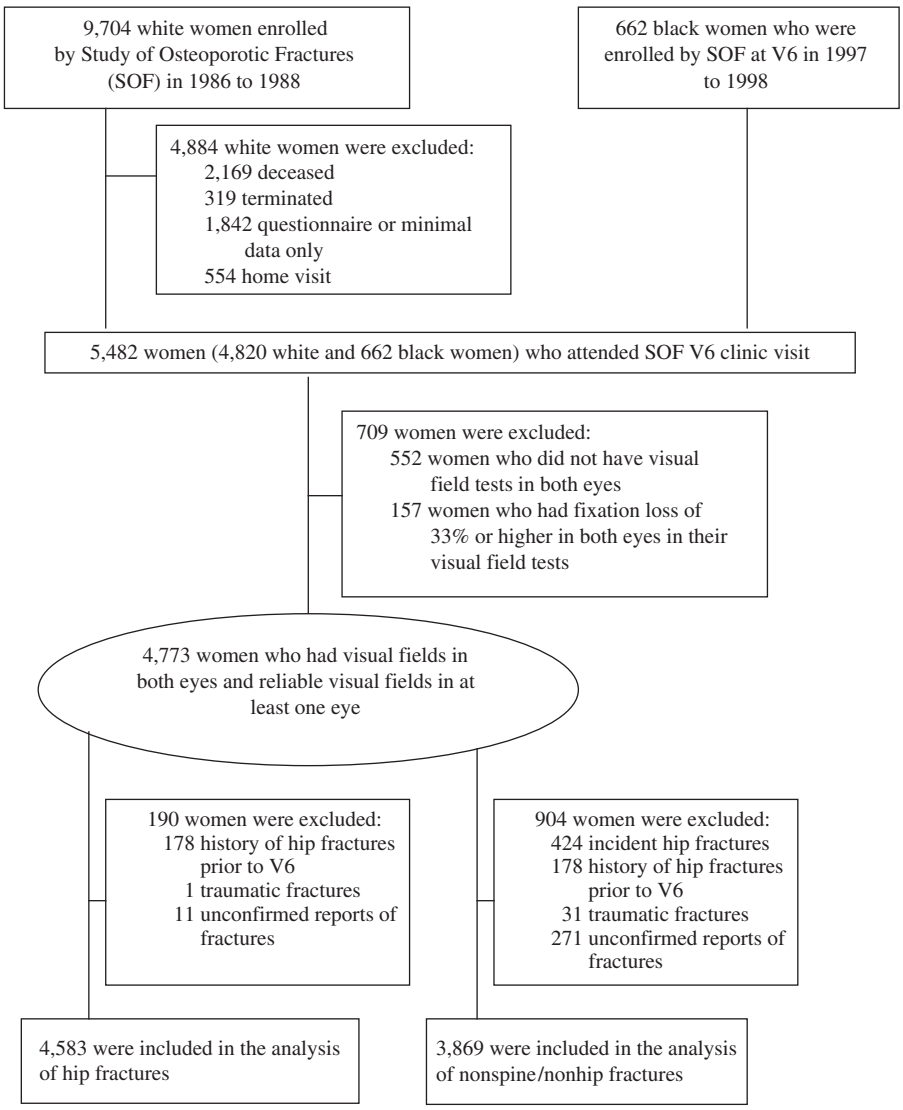

Figure 1. Study participant flow chart.

Ascertainment of Fractures

All participants were contacted by postcard or telephone approximately every 4 months from September 1997 to April 2008 to determine whether they had a new fracture after V6. There has been a cumulative completion rate of 98% for these contacts since the inception of SOF.[14] To distinguish clearly between fracture and nonfracture cases, cases with reports of fractures that were not confirmed according to X-ray records were excluded. Separate analyses were conducted for incident hip fractures and incident nonspine, nonhip fractures. A total of 4,583 women were included in the analysis of hip fractures, and after separating out hip and spine fractures, 3,869 women were included in the nonspine, nonhip fractures analysis (Figure 1).

Assessment of Vision

Visual field tests were performed on each eye of a participant with the Humphrey Field Analyzer suprathreshold 76-point 30° visual field program (Zeiss, Oberkochen, Germany).[15,16] The suprathreshold 76-point program is a screening visual field test measuring whether the eye's visual pathway detects a light 6 dB brighter than light that an eye of a healthy subject of the same age could detect. Seventy-six points of light are presented in the central and peripheral fields of each eye. Examiners were trained for half a day in the use of the Humphrey Field Analyzer. The training session covered calibration of the perimeter, the choice of the corrective lenses used for the test, and the explanation of the test to subjects. Examiners performed screening visual field tests on volunteers until the study coordinator or investigators could certify them as proficient.

A BVF for each participant was created by overlapping two 76-screening visual fields for each eye, using a method adapted from a BVF functional scoring algorithm.[9,16] The total number of points missed out of the 96 possible points in the BVF was recorded. BVF loss was categorized into four groups: no loss (0 points missed), mild loss (1–9 points missed), moderate loss (10–19 points missed), and severe loss (≥20 points missed).[9]

Distance visual acuity was measured in each eye separately with habitual correction under standard illumination using Bailey-Lovie charts,[17] which feature geometric progression in letter size from line to line. The number of letters seen correctly was recorded. Contrast sensitivity was also measured in each eye with habitual correction under standard illumination using the VCTS 6,500 charts (Vistech Consultants, Inc., Dayton, OH),[18] which present a series of sine-wave gratings at calibrated levels of contrast at specific spatial frequencies (cycles per degree). The number of gratings seen correctly was recorded and converted to a contrast sensitivity score at each spatial frequency according to the manufacturer's manual.

Other Measurements

Vision-related and other clinical characteristics reported to be risk factors or confounders for fractures were incorporated into the analyses. As described in prior SOF publications,[5,6,9,12–14] all risk factors and confounders were collected at V6 except for history of any fractures since age 50, which was obtained at V1 on the original cohort and V6 in the black cohort because V6 was their first (baseline) visit.

Statistical Analysis

The primary objective of the analysis was to determine the extent to which visual field loss was associated with risk of incident hip and nonspine, nonhip fractures in older white and African-American women. Visual acuity in the better-seeing eye was dichotomized into Snellen visual acuity levels of 20/40 or better versus worse than 20/40. Contrast sensitivity (CS) in the better-seeing eye at low spatial frequency (1.5 cycles/degree) was categorized into a CS score of less than 25 versus 25 or greater. When information was not available for at least one eye at 1.5 cycles/degree, the contrast sensitivity values for 3 cycles/degree was used. Because certain distributions were skewed, Spearman correlation coefficients were used to characterize associations between the continuous vision variables: BVF loss, visual acuity, and contrast sensitivity.

Cox proportional hazards analysis was used to determine whether BVF loss was a risk factor for time until occurrence of a fracture. The following potential confounding variables were considered: age, study site, race, self-rated health status, current smoking status, alcohol use, self-reported diabetes mellitus, self-reported hyperthyroidism, self-reported osteoporosis, current use of anticonvulsant drugs, current use of long-acting benzodiazepines, average grip strength, used arms to stand up, body mass index, depression, cognitive function, walking speed, falls in the previous year (≥1 falls within 12 months before the examination), hip bone mineral density (BMD), and history of any fractures since age 50. Separate models considered different subsets of potential confounders, as described in further detail in the Results section.

Interactions between BVF loss and age and between BVF loss and race were also evaluated. The percentage attributable risk (the proportion of fractures in women who had BVF loss that is attributable to this loss, calculated using the formula $100 \times (RR - 1)/RR$, where RR is the risk ratio estimate) and the population attributable risk percentage (the proportion of fractures in the total population that is attributable to BVF loss, calculated using the formula $100 \times P(e) \times (RR - 1)/(1+P(e) \times (RR - 1))$, where $P(e)$ is the prevalence of severe BVF loss in the population) were calculated.[19] To evaluate predictors of fractures, Akaike's information criterion (AIC)[20] was used to compare different models. Larger AIC values indicate better fit.

In secondary sensitivity analyses, BVF loss, visual acuity in the better eye, and CS at low spatial frequency in the better eye were analyzed as continuous variables in regression models adjusted for the same covariates as above. To control for skewness and extreme values, the continuous BVF loss variable was analyzed as the number of points lost up to 40 points, with any greater value fixed at 40 to improve linearity in a manner similar to rank transformations. The continuous visual acuity variables were analyzed as the number of letters read correctly, which is a logarithmic transformation of Snellen visual acuity. The continuous CS variables were analyzed as a logarithmic transformation of CS score at low frequency. All continuous vision variables were then standardized by dividing by their respective

standard deviations (SDs) after transformation, and the results were presented as risk ratios of incident fractures per 1-SD change in specific vision parameter.

All statistical analyses were performed using SAS version 9.1 software (SAS Institute Inc., Cary, NC). A *P*-value $<.05$ was considered statistically significant.

RESULTS

The 4,773 volunteers included in this analysis were slightly younger and had better self-rated health status, experienced less depression, and had better visual acuity in the better eye than the 709 women who were excluded. A total of 1,773 women (37%) had no BVF loss, 2,015 (42%) had mild BVF loss, 485 (10%) had moderate BVF loss, and 500 (11%) had severe BVF loss. The range of points lost across both eyes was from 0 to 87, with a mean of 6.4 ± 11.7. The Spearman correlation coefficients were -0.17 ($P<.001$) between BVF loss and visual acuity, -0.17 ($P<.001$) between BVF loss and contrast sensitivity, and 0.38 ($P<.001$) between visual acuity and contrast sensitivity. Table 1 summarizes characteristics of the study sample according to BVF loss.

During a mean of 8.1 ± 2.7 years of follow-up, 424 of 4,583 (9.3%) women suffered a first hip fracture (incidence rate of 11.4 per 1,000 person-years, 95% confidence interval (CI) = 10.4–12.6); 1,720 women without BVF loss had 115 (6.7%) hip fractures (incidence = 7.7 per 1,000 person-years, 95% CI = 6.4–9.3 per 1,000 person-years), 1,938 women with mild BVF loss had 205 (10.6%) hip fractures (incidence = 13.2 per 1,000 person-years, 95% CI = 11.5–15.1 per 1,000 person-years), 455 women with moderate BVF loss had 43 (9.5%) hip fractures (incidence = 12.8 per 1,000 person-years, 95% CI = 9.5–17.3 per 1,000 person-years), and 470 women with severe BVF loss had 61 (13.0%) hip fractures (incidence = 18.4 per 1,000 person-years, 95% CI = 14.3–23.7 per 1,000 person-years). Women with a first hip fracture missed a mean of 8.3 ± 13.5 points on the BVF test, whereas women who did not have any fractures missed a mean of 6.1 ± 11.3 points ($P<.001$). Figure 2 shows the Kaplan-Meier curves of time to hip fracture according to BVF loss. In analyses adjusted for age, race, study site, and cognitive function, women with severe BVF loss had a risk of hip fracture estimated to be 66% greater than that of women with no visual field loss (hazard ratio (HR) = 1.66, 95% CI = 1.19–2.32) (Table 2). The association between severe visual field loss and risk of hip fracture was borderline significant in the fully adjusted model (HR = 1.37, 95% CI = 0.97–1.95) (Table 2) and was not significant when hip BMD was included in the fully adjusted model (HR = 1.24, 95% CI = 0.86–1.77).

Of the 3,869 women included in the analysis examining the association between visual field loss and risk of nonspine, nonhip fracture, 770 (19.9%) experienced a nonspine, nonhip fracture during a mean of 8.0 ± 2.8 years of follow-up; 1,494 women without BVF loss had 307 (20.5%) nonspine, nonhip fractures (incidence = 23.9 per 1,000 person-years, 95% CI = 21.3–26.7 per 1,000 person-years), 1,615 women with mild visual field loss had 285 (17.6%) nonspine, nonhip fractures (incidence = 22.1 per 1,000 person-years, 95% CI = 19.7–24.9 per 1,000 person-years), 378 women with moderate visual field loss had 80 (21.2%) nonspine, nonhip fractures (incidence = 29.0 per 1,000 person-years, 95% CI = 23.3–36.1 per 1,000 person-years), and 382 women with severe visual field loss had 98 (25.7%) nonspine, nonhip fractures (incidence = 37.5 per 1,000 person-years, 95% CI = 30.7–45.7 per 1,000 person-years). Women with at least one incident nonspine, nonhip fracture missed a mean of 7.3 ± 13.4 points on the BVF test, whereas women who did not have any fractures missed a mean of 5.9 ± 10.8 points ($P=.30$). Women with severe BVF loss had roughly a 1.6 times greater risk of a nonspine, nonhip fractures than women without any visual field loss in analyses adjusted for age, race, study site, and cognitive function (HR = 1.59, 95% CI = 1.24–2.03) (Table 3). This higher risk remained significant in the fully adjusted model (HR = 1.46, 95% CI = 1.13–1.89) (Table 3) and when hip BMD (HR = 1.44, 95% CI = 1.11–1.86) was included in the fully adjusted model.

The number of incident hip fractures was not large enough for reliably examining the interaction effects in the hip fracture models, and no evidence was found of an interaction between age and visual field loss ($P=.48$) or between race and visual field loss ($P=.15$) in the nonspine, nonhip fracture models.

Visual acuity worse than 20/40 was not significantly associated with risk of hip fracture (Table 2) but was associated with a 19% greater risk (HR = 1.19, 95% CI = 1.00–1.41) of nonspine, nonhip fracture when the model was adjusted for age, race, study site, and cognitive function (Table 3). Women with poor contrast sensitivity (CS score <25) had a higher risk of nonspine, nonhip fracture in the fully adjusted model (Table 3) that remained present when hip BMD was included in the model (HR = 1.27, 95% CI = 1.09–1.49).

Using the estimate of 1.37 in the fully adjusted model as the relative risk of hip fracture for severe BVF loss compared with no loss, the percentage attributable risk for severe BVF loss was 27%. Assuming that 10% of older women had severe loss, similar to the SOF population, the population attributable risk percentage for severe BVF loss for hip fracture was 3.7%. Using the estimates of 1.46 for severe BVF loss in the fully adjusted models for nonspine, nonhip fractures, the percentage attributable risk for severe BVF loss was 31.5%, and the population attributable risk percentage was 4.6% (assuming that 10% of older women have severe BVF loss).

In secondary sensitivity analyses in which continuous vision variables were used, women who missed more points on the BVF had a higher risk of hip fracture (HR = 1.11 per SD, 95% CI = 1.01–1.21) and nonspine, nonhip fracture (HR = 1.18 per SD, 95% CI = 1.10–1.27). Women who recognized more letters (better visual acuity) with the better-seeing eye had less risk of hip (HR = 0.90 per SD, 95% CI = 0.82–0.99) and nonspine, nonhip fracture (HR = 0.87 per SD, 95% CI = 0.81–0.94). Women with higher contrast sensitivity scores in the better eye had less risk of nonspine, nonhip fractures (HR = 0.87 per SD, 95% CI = 0.80–0.93) and no risk of hip fracture (HR = 0.98 per SD, 95% CI = 0.89–1.09).

The test for trend in which risk was posited to increase linearly across severity categories of BVF loss was statistically significant for nonspine, nonhip fractures (trend

Table 1. Baseline Characteristics of Women Who Participated in the Study of Osteoporotic Fractures (SOF) Clinic Visit According to Binocular Visual Field Loss (N = 4,773)

Characteristic	Binocular Visual Field Loss			
	None (0) (n = 1,773)	Mild (1–9) (n = 2,015)	Moderate (10–19) (n = 485)	Severe (≥20) (n = 500)
Study site, n (%)				
1	440 (24.8)	489 (24.3)	114 (23.5)	99 (19.8)
2	625 (35.3)	582 (28.9)	129 (26.6)	98 (19.6)
3	412 (23.2)	517 (25.7)	121 (25.0)	122 (24.4)
4	296 (16.7)	427 (21.2)	121 (25.0)	181 (36.2)
Age				
Mean ± SD	78.2 ± 3.8	79.5 ± 4.3	80.4 ± 4.7	81.4 ± 4.9
<80, n (%)	1,210 (68.3)	1,115 (55.3)	232 (47.8)	192 (38.4)
80–84, n (%)	460 (25.9)	645 (32.0)	161 (33.2)	176 (35.2)
≥85, n (%)	103 (5.8)	255 (12.7)	92 (19.0)	132 (26.4)
Race, n (%)				
White	1,579 (89.1)	1,792 (88.9)	423 (87.2)	422 (84.4)
Black	194 (10.9)	223 (11.1)	62 (12.8)	78 (15.6)
Habitual visual acuity in the better eye (number of letters 0–70), n = 4,769				
Mean ± SD	47.5 ± 6.6	46.5 ± 7.0	44.9 ± 8.0	42.9 ± 9.6
Worse than 20/40, n (%)	352 (19.9)	467 (23.2)	161 (33.2)	185 (37.2)
Low-frequency (1.5 or 3 cycles/degree) contrast sensitivity in the better eye (range 0–220), n = 4,755				
Mean ± SD	37.9 ± 20.7	34.9 ± 19.9	31.1 ± 17.5	29.4 ± 16.4
<25, n (%)	545 (30.8)	743 (37.0)	242 (50.0)	256 (52.1)
Mini-Mental State Examination score (range 6–30), mean ± SD, n = 4,708	28.3 ± 1.8	27.8 ± 2.1	27.4 ± 2.4	26.7 ± 2.7
Current smoker, n (%), n = 4,768	63 (3.6)	92 (4.6)	26 (5.4)	30 (6.0)
Current alcohol use, n (%), n = 4,766	877 (49.5)	867 (43.1)	176 (36.4)	152 (30.4)
Self-rated health status, n (%), n = 4,768				
Fair, poor, or very poor	273 (15.4)	409 (20.3)	105 (21.7)	137 (27.4)
Excellent or good	1,499 (84.6)	1,603 (79.7)	379 (78.3)	363 (72.6)
Self-reported diabetes mellitus, n (%), n = 4,766	100 (5.7)	119 (5.9)	32 (6.6)	43 (8.6)
Self-reported hyperthyroidism, n (%), n = 4,768	62 (3.5)	89 (4.4)	13 (2.7)	23 (4.6)
Self-reported osteoporosis, n (%), n = 4,767	336 (19.0)	391 (19.4)	90 (18.6)	92 (18.4)
Depression (Geriatric Depression Scale score ≥6), n (%); n = 4,767	113 (6.4)	196 (9.7)	60 (12.4)	73 (14.6)
Current use of anticonvulsant drugs, n (%), n = 4,768	27 (1.5)	32 (1.6)	9 (1.9)	16 (3.2)
Current use of long-acting benzodiazepines, n (%), n = 4,768	36 (2.0)	43 (2.1)	15 (3.1)	18 (3.6)
Body mass index, kg/m^2, mean ± SD, n = 4,726	26.9 ± 5.0	27.1 ± 5.2	26.7 ± 5.1	26.3 ± 4.7
Walking speed, m/s, mean ± SD, n = 4,734	0.96 ± 0.20	0.90 ± 0.20	0.84 ± 0.20	0.79 ± 0.22
Average grip strength, kg, mean ± SD, n = 4,687	18.2 ± 4.2	17.2 ± 4.3	16.5 ± 4.1	16.0 ± 4.3
Use arms to stand up, n (%), n = 4,768	177 (10.0)	283 (14.1)	97 (20.0)	121 (24.3)
Self-reported ≥1 falls in previous year, n (%), n = 4,765	503 (28.4)	583 (29.0)	172 (35.5)	177 (35.5)
History of any fractures, n (%), n = 4,751	827 (46.8)	966 (48.2)	244 (50.3)	261 (52.6)
Hip bone mineral density, g/cm^2, mean ± SD, n = 4,653	0.75 ± 0.14	0.74 ± 0.14	0.74 ± 0.15	0.70 ± 0.13
Self-reported glaucoma in at least one eye, n (%)	168 (9.5)	228 (11.3)	80 (16.5)	104 (20.8)
Self-reported treatment for glaucoma, n (%)	157 (8.9)	221 (11.0)	79 (16.3)	102 (20.4)
Self-reported AMD in at least one eye, n (%)	119 (6.7)	197 (9.8)	51 (10.5)	70 (14.0)
Self-reported treatment for AMD, n (%)	4 (0.2)	6 (0.3)	2 (0.4)	1 (0.2)
Self-reported cataract in at least one eye, n (%)	1,179 (66.5)	1,457 (72.3)	372 (76.7)	378 (75.6)
Self-reported cataract surgery in at least one eye, n (%)	539 (30.4)	824 (40.9)	236 (48.7)	260 (52.0)

SD = standard deviation; AMD = age-related macular degeneration.

$P < .001$) and was of borderline significance for hip fractures (trend $P = .05$) after adjustment for age, site, race, and cognitive function. Using AIC values, the inclusion of BVF loss in the fully adjusted models for hip and nonspine, non-hip fracture improved model fit more than the inclusion of visual acuity or contrast sensitivity. The inclusion of hip BMD in the fully adjusted models decreased the AIC scores of all models, suggesting poorer predictive ability. The

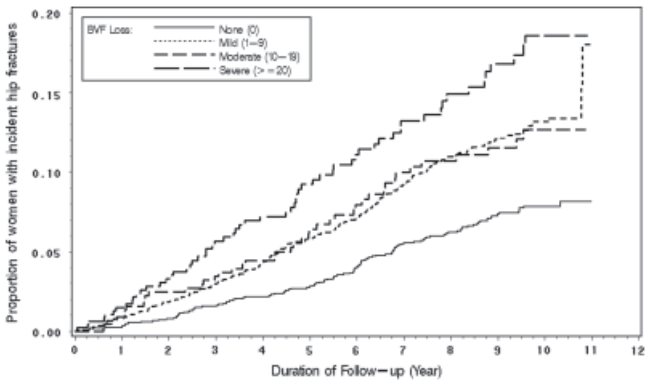

Figure 2. Estimated incidence of hip fractures according to binocular visual field (BVF) loss from Kaplan-Meier analysis.

highest AIC values were obtained in the models adjusted for age, race, study site, and cognitive function.

DISCUSSION

Older women with BVF loss have a greater risk of subsequent hip and nonspine, nonhip fracture. The association between visual field loss and risk of fracture was graded in nature. It was estimated that 3.7% of hip fractures and 4.6% of nonspine, nonhip fractures were attributable to severe visual field loss using standard epidemiological estimation procedures.

Ocular diseases such as glaucoma, cataracts and retinal disease;[21] a tumor[22] or vascular occlusion[8] along the cerebral visual pathway; or cognitive factors such as inattention during the visual field test[21] can induce visual field loss. The leading cause of visual field loss in persons aged 55 and older is glaucoma,[8] which is the second leading cause of preventable blindness worldwide.[23] Because vision loss from glaucoma can be prevented or slowed down with treatment[24] and half or more of individuals with glaucoma in the population are undiagnosed,[25,26] screening tests can identify not only patients at risk for subsequent fractures, but also patients who have potentially blinding yet treatable ocular diseases.

Technicians or nurses in the offices of clinicians can screen for visual field loss with a suprathreshold screening test, as was used in this study. The test takes 4 minutes per subject and is straightforward to administer. Fewer than 13% of subjects visiting the clinic were unable to complete the visual field testing in this study. The sensitivity and specificity of suprathreshold testing were 87% and 89%, respectively, in a study evaluating the use of suprathreshold testing in screening for neuroophthalmic diseases such as glaucoma.[27] Once visual field loss is detected on a screening test, subjects should be referred for an eye evaluation by an eye doctor especially if the visual field loss is present on repeat visual field testing.[21]

Prior studies have not evaluated whether BVF loss is associated with risk of fracture in older women but have evaluated the association between visual field loss in at least one eye and fracture in younger white subjects.[8,10,11] Both studies had younger cohorts and did not have as many incident fractures as the SOF. Their findings contrast with those of the current study that suggest that the greater risk of hip and nonspine, nonhip fractures in older women secondary to visual field loss persists for at least 8 years after visual field testing.

A prior SOF study[5] found that women with poor contrast sensitivity have greater risk of hip fracture, whereas reductions in visual acuity were not associated with greater

Table 2. Associations Between Risk of Hip Fracture and Vision Risk Factors (N = 4,583)

Vision Risk Factors*	Women Who Had Incident Hip Fractures/ Subjects in the Study Population, n/N (%)	Crude Incidence per 1,000 Person-Years (95% CI)	Hazard Ratio (95% CI) *P*-Value	
			Model Adjusted for Age, Race, Study Site, and Cognitive Function	Fully Adjusted Model†
Binocular visual field loss:				
None (0)	115/1,720 (6.7)	7.7 (6.4–9.3)	1.00; referent	1.00; referent
Mild (1–9)	205/1,938 (10.6)	13.2 (11.5–15.1)	1.49 (1.18–1.88) <.001	1.40 (1.11–1.78) .006
Moderate (10–19)	43/455 (9.5)	12.8 (9.5–17.3)	1.25 (0.87–1.80) .23	1.11 (0.77–1.62) .57
Severe (≥20)	61/470 (13.0)	18.4 (14.3–23.7)	1.66 (1.19–2.32) .003	1.37 (0.97–1.95) .08
P-value for trend			.05	.44
Visual acuity				
20/40 or better	306/3,481 (8.8)	10.6 (9.5–11.9)	1.00; referent	1.00; referent
Worse than 20/40	116/1,098 (10.6)	14.1 (11.8–16.9)	1.12 (0.90–1.41) .31	1.01 (0.80–1.27) .96
Contrast sensitivity score				
≥25	254/2,868 (8.9)	10.6 (9.4–12.0)	1.00; referent	1.00; referent
<25	165/1,698 (9.7)	12.7 (10.9–14.8)	1.11 (0.90–1.36) .34	1.09 (0.88–1.35) .42

* Each vision risk factor was examined in a separate model.

† Adjusted for age, race (black vs white), study site (four sites), cognitive function (Mini-Mental State Examination score), current smoker (yes vs no), alcohol use (yes vs no), self-reported health status (good or excellent vs poor or fair), self-reported diabetes mellitus (yes vs no), self-reported hyperthyroidism (yes vs no), self-reported osteoporosis (yes vs no), depression (yes vs no), current use of anticonvulsant drugs (yes vs no), current use of long-acting benzodiazepines (yes vs no), body mass index, walking speed, average grip strength, uses arms to stand up (yes vs no), ≥1 falls in previous year (yes vs no), and history of any fractures (yes vs no).

CI = confidence interval.

Table 3. Associations Between Risk of Nonspine, Nonhip Fracture and Vision Risk Factors (N = 3,869)

Vision Risk Factors*	Women Who Had Incident Nonspine, Nonhip Fracture/Subjects in the Study Population, n/N (%)	Crude Incidence per 1,000 Person Years (95% CI)	Hazard Ratio (95% CI) *P*-Value	
			Model Adjusted for Age, Race, Study Site, and Cognitive Function	Fully Adjusted Model†
Binocular visual field loss				
None (0)	307/1,494 (20.6)	23.9 (21.3–26.7)	1.00; referent	1.00; referent
Mild (1–9)	285/1,615 (17.7)	22.1 (19.7–24.9)	0.88; (0.75–1.04) .12	0.89; (0.75–1.05) .16
Moderate (10–19)	80/378 (21.2)	29.0 (23.3–36.1)	1.18; (0.92–1.52) .19	1.13; (0.87–1.47) .35
Severe (≥20)	98/382 (25.7)	37.5 (30.7–45.7)	1.59; (1.24–2.03) <.001	1.46; (1.13–1.89) .004
P-value for trend			<.001	<.001
Visual acuity				
20/40 or better	578/2,949 (19.6)	23.8 (21.9–25.8)	1.00; referent	1.00; referent
Worse than 20/40	192/918 (20.9)	28.4 (24.6–32.7)	1.19; (1.00–1.41) .046	1.12; (0.94–1.33) .21
Contrast sensitivity score				
≥25	465/2,420 (19.2)	23.0 (21.0–25.2)	1.00; referent	1.00; referent
<25	304/1,437 (21.2)	28.0 (25.0–31.3)	1.28; (1.10–1.49) .001	1.28; (1.09–1.50) .002

* Each vision risk factor was examined in a separate model.

† Adjusted for age, race (black vs white), study sites (four sites), cognitive function (MMSE), current smoker (yes vs no), alcohol use (yes vs no), self-reported health status (good or excellent vs poor or fair), self-reported diabetes mellitus (yes vs no), self-reported hyperthyroidism (yes vs no), self-reported osteoporosis (yes vs no), depression (yes vs no), current use of anticonvulsant drugs (yes vs no), current use of long-acting benzodiazepines (yes vs no), body mass index, walking speed, average grip strength, uses arms to stand up (yes vs no), ≥1 falls in previous year (yes vs no), and history of any fractures (yes vs no).

CI = confidence interval; MMSE = mini mental state examination.

risk of fractures. The current study found that contrast sensitivity was not as strong of a predictor for hip fractures as BVF loss. These results are not surprising because cataracts,[28–30] glaucoma,[29,31] and age-related macular degeneration[29,32] may cause poor contrast sensitivity and visual field loss.

Strengths of the current study include large sample size, a long follow-up period, a well-defined cohort, radiographically adjudicated fractures, assessment of different vision components, and the use of standardized protocols for all measurements. A potential limitation of this study is that the BVF loss was calculated using a BVF scoring algorithm rather than directly measuring visual fields with both eyes. This method of assessing BVF is accepted in vision research and is consistent with the results found when a BVF scoring algorithm is used.[33–35]

The study population comprised older volunteer women initially living in communities; therefore, the results might not apply to other populations such as men, younger women, or those with poorer health or living in institutions. It is possible that, in a less-healthy population, women may have even greater risk of fractures than reported here, especially because the women in the current study are survivors and most likely are healthier than women who did not continue in the SOF because of death or illness. In addition, the women in this study were highly motivated. Fewer than 13% of the women in the SOF were excluded from this analysis because of inability to perform visual field tests or unreliable visual field tests. Women who participated only in home visits were excluded from the analyses; their visual field loss could not be assessed, because visual field testing cannot be performed in the home. Women participating only in home visits were slightly older and had worse self-rated health status. The women excluded from the analysis may be more likely to be immobile and thus may have lower risks of fracture; alternatively, excluded women may be at greater risk of fracture, because they are likely to have worse vision than the women whose visual fields were assessed.

A limitation of this study is that spine fractures were not assessed at V6, and baseline and follow-up spine X-rays are needed to diagnose radiographic spine fractures. In addition, although cognitive impairment was adjusted for using the Mini-Mental State Examination (MMSE), the MMSE may not detect all types of dementia that may be associated with the presence of visual field loss. Another limitation of this study is that all risk factors and confounders were assessed at V6 and may have changed over time. This is especially true for the assessment of BVF loss, which was only done at V6. Continued visual field loss may be detected a mean of 7.5 years after the first glaucomatous visual field loss is detected.[36]

Because visual field loss is an independent risk factor for subsequent fractures, clinicians are advised to evaluate patients' vision when they report recurrent falling.[37] This recommendation does not specify a method for evaluating vision from among the multitude of tests that could be performed. The data suggest that future guidelines for the care of older patients should consider recommending evaluations of the visual fields in patients at heightened risk of fractures by recommending that clinicians refer their patients who are recurrent fallers for visual field loss assessment or screen for visual field loss themselves using suprathreshold tests such as was done in the SOF. Potential areas for future research include study of interventions to prevent fractures by managing visual field loss or through mobility training, as well as further research of the effect of visual field loss on ability to function and quality of life.

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