SOURCES OF BINOCULAR SUPRATHRESHOLD VISUAL FIELD LOSS IN A COHORT OF OLDER WOMEN BEING FOLLOWED FOR RISK OF FALLS (AN AMERICAN OPHTHALMOLOGICAL SOCIETY THESIS)

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ABSTRACT

Purpose: To determine the sources of binocular visual field loss most strongly associated with falls in a cohort of older women.

Methods: In the Study of Osteoporotic Fractures, women with severe binocular visual field loss had an increased risk of two or more falls during the 12 months following the eye examination. The lens and fundus photographs of the 422 women with severe binocular visual field loss, plus a random sample of 141 white women with no, mild, or moderate binocular visual field loss—47 white women with no binocular visual field loss, 46 white women with mild binocular visual field loss, and 48 white women with moderate binocular visual field loss —were evaluated for lens opacities, glaucomatous optic nerve damage, age-related macular degeneration, and diabetic retinopathy.

Results: Eighty-four percent of the women with severe binocular visual field loss had ocular disease in one or both eyes. Bilateral cataracts and glaucomatous optic nerve damage were the most common sources of this severe binocular visual field loss. Approximately 15.2% of women had no evidence of lens opacities, glaucomatous optic nerve damage, age-related macular degeneration, or diabetic retinopathy.

Conclusion: Severe binocular visual field loss due primarily to cataracts, glaucoma, and age-related macular degeneration explains 33.3% of the falls among women who fell frequently. Because binocular visual field loss may be treatable and/or preventable, screening programs for binocular visual field loss and subsequent referral for intervention and treatment are recommended as a strategy for preventing falls among the elderly.

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INTRODUCTION AND LITERATURE REVIEW

Visual impairment increases with advancing age, detrimentally affecting health-related quality of life—including increased mortality risk,[1] nursing home admissions,[2] depression,[3,4] physician visits and hospitalizations,[5] and family stress,[6] as well as decreased self-rated health status.[7] One consequence of visual impairment that reduces quality of life is the increase of unintentional injuries, including falls and subsequent fractures.[8,9]

Falls and fractures among older adults present a serious public health problem.[10-12] They occur frequently[13] and increase morbidity and mortality in older adults.[14-17] Falls result in significant health care costs associated with hospitalization and treatment.[18-20] Hip fractures, which account for the highest morbidity and mortality of all fractures,[21] are commonly caused by falls.[22,23] Older women are more likely than men to experience falls and fractures.[24,25]

Although visual impairment may be a risk factor for falls and fractures, limited research exists. In the American Geriatrics Society's research agenda-setting program,[26] the relationship between visual problems and falls prevention was set as a high priority of future research in geriatric ophthalmology.

OCCURRENCE OF FALLS

More than a third of community-dwelling adults aged 65 years and older fall each year,[27-30] and older adults in poor health are more than twice as likely to fall as healthier individuals.[31] Approximately 30% of older adults who fall suffer serious injuries.[32]

Because falls in older adults can cause fractures,[33,34] fractures also present an important and growing public health concern. The most common fractures are of the hip, spine, upper arm, forearm, and bones of the pelvis, hand, and ankle.[35,36] Of these, hip fracture is the most serious injury and one of the leading causes of morbidity and excess mortality among older adults.[21]

Both falls and fractures increase exponentially with advancing age, and their occurrence is higher in older women than in men.[24,25] Because adults over age 65 represent a fast-growing segment in the United States,[37] it is expected that the number of individuals experiencing falls and fractures will also increase in the future.

Significance of Falls

Falls result in significant negative consequences for the individual as well as society, including increased mortality and morbidity, more hospital and nursing home admissions, more emergency department visits, and higher economic costs.

Increased Mortality

Falls are the leading cause of unintentional injury death in adults aged 65 and older in the United States.[38] In 2003, 13,701 deaths due to falls occurred in these adults, representing almost 40% of all unintentional injuries.[38] The majority (60%) of those who die from these injuries are older than 75 years of age.[39] Even falls that appear to be harmless can increase the risk of mortality.[40] The high rate of mortality associated with falls might be decreased using intervention strategies because falls are preventable through primary and secondary measures.[41]

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Injuries, Emergency Department Visits, and Hospitalizations

Falls are a common cause of nonfatal injuries.[42] They are a leading cause of traumatic brain injury emergency department visits.[43] Fall-related injuries were the cause of 860,000 hospitalizations per year from 1992 to 1994, and the majority of these hospitalizations involved older adults.[44] People who fall multiple times are more likely to be hospitalized for longer periods than individuals who have fallen once.[45] Women are twice as likely than men to be hospitalized for a fall-related injury.[42]

Institutionalization

Individuals 75 years and older who fall are four to five times more likely to be admitted to a long-term care facility compared to those who have experienced no falls.[46] As with hospitalizations, people who fall multiple times are more likely to be admitted to nursing homes than those experiencing a single fall.[45]

Economic Costs

In 2003, the acute-care costs of falls among older adults surpassed $8 billion.[47] Another study estimated that direct costs of fall-related injuries amounted to approximately $19 billion in 2000.[48]

In summary, falls are a major concern for older adults and have a significant financial and societal impact. Moreover, falls and fractures represent for the individual decreased quality of life and loss of independence. Studies have reported other detrimental consequences of these injuries, including depression,[49] anxiety,[50] and restriction of daily activities.[51]

VISUAL FUNCTIONING AND THE RISK OF FALLS

People with vision problems have a greater risk of sustaining an unintentional injury than those who are not visually impaired.[52] In a report by the American Geriatrics Society,[53] visual impairment was ranked as the sixth largest risk factor for falls when comparing the mean odds ratios of studies investigating the association between common risk factors and falls. These common risk factors included muscle weakness, history of falls, gait deficit, balance deficit, use of assistive devices, arthritis, impaired activities of daily living, depression, cognitive impairment, and age of 80 or older. Muscle weakness was ranked No. 1 and increased the odds of a fall fourfold, whereas visual impairment increased the odds of a fall more than twofold.

As would be expected, people who are visually impaired are susceptible to falls and injuries because they have fewer visual clues to alert them to risks in their environment, a factor exacerbated because older people can be more dependent on vision to retain vertical posture.[54] The visual system plays a vital part in helping an individual retain balance while standing still and to remain steady while moving.[54] Visual ability is essential in providing visual references on the location of obstacles and the self.[54] Adults aged 85 years and older experience increased postural instability with eye closure than those between the ages of 50 and 60 years when standing both on rigid and foam surface,[55] and body sway increases linearly when visual ability is decreasing.[56] Compromised balance could be due to age-related declines occurring in the vestibular system[57] and proprioception (ie, joint-position sense).[58]

Further, low contrast sensitivity can contribute to impaired sit-to-stand performance.[59] Older adults with reduced visual acuity have increased postural instability when controlling for other factors that might influence balance including range of motion and strength.[60] People with central visual field loss depend less on their vision to decrease postural sway.[61] Visual impairment due to cataract reduces postural stability.[62] Impaired depth perception may increase the risk of falling due to the possibility of inaccurate foot placement during activities such as negotiating stairs or avoiding obstacles.[63] In Templer's Stair Behavior Model,[63] visual input is necessary during the initial conceptual scan for sensory input, detection of hazards, choice of route, visual perception of step location, and continuous monitoring scans. Falls can occur if these processes are interrupted.

Visual Acuity and Falls

More than 70% of older adults admitted to an acute medical department who experience falls have reduced visual acuity.[64] Some studies investigating the relationship between falls and visual acuity have used self-reported measures to assess visual ability.[65-67] Studies using self-reported measures of visual acuity (such as the ability to recognize faces) have provided inconsistent findings[65-67]; differences might be attributable to variations in this measure since variations may be affected by various personal and cultural characteristics as discussed below.[68-71] Other studies have used ophthalmic assessments to investigate the effect of visual impairment on falls.[52,72-74]

Large cross-sectional population-based studies using ophthalmic assessments of vision have concluded that reduced visual acuity is significantly associated with falls. The Beaver Dam Eye Study[52] reported a lower percentage of falls in a group of participants with better visual acuity than with worse acuity. The Blue Mountains Eye Study[72] similarly concluded that people with reduced visual acuity were almost twice as likely to experience falls.

Prospective studies have also found an association between visual acuity and falls. This author and associates[73] found that older women having a visual loss of 10 letters or more had an increased likelihood of falling. Diminished visual acuity was also a significant risk factor for falls resulting in serious injury, in a 2-year prospective study of adults with disabilities aged 70 years and older.[74] The same study, however, found no statistically significant relationship between the risk of injurious falls and visual acuity among independently living adults. Other prospective studies did not show an association between falls and loss of distant vision,[28,66] but these studies were limited by smaller sample sizes.

Overall, despite some inconsistent findings, visual acuity is probably a risk factor for falls: larger studies using prospective designs have tended to show a strong significant association, and studies using self-reported measures may be biased by sociodemographic factors, cognition, and personality.[75]

Contrast Sensitivity and Falls

Contrast sensitivity measures a wide range of spatial frequencies and contrast levels.[54] Capability for avoiding trip hazards and negotiating stairs may be dependent on the visual system across spatial frequencies.[54] Contrast sensitivity is more strongly associated with performance in mobility tasks than visual acuity,[76,77] and contrast sensitivity is independently related to postural stability.[78] Older ambulatory individuals with reduced contrast sensitivity tend to walk significantly slower than those with normal levels of contrast sensitivity.[52]

Lord and colleagues,[79] using the Melbourne Edge Test, showed that people who fall frequently had better contrast sensitivity compared to people with no reported falls. The Blue Mountains Eye Study[72] reported that contrast sensitivity, as measured by the Vectorvision CSV-1000 chart, was significantly associated with frequent falls per 1 SD decrease. Prevalence ratios representing the risk of two or more falls in the past year were slightly higher for 6, 12, and 18 cycles per degree compared to 3 cycles. Controlling for age and depression, reductions in low-frequency contrast sensitivity increased the likelihood of frequent falls, as reported by de Boer and colleagues using the Vistech (VCTS 6000-1) chart.[80]

In contrast to these studies showing a consistent relationship between reduced contrast sensitivity and the higher risk for falls, other investigations found no significant increases in falls and fall-related fractures.[52,81-85] The Beaver Dam Study Eye[52] demonstrated no increase in the risk of falls using a contrast sensitivity Pelli-Robson scale. The conflicting results regarding contrast sensitivity and falls risk might be due to different contrast sensitivity tests used in the various studies as well as the different populations sampled. Moreover, postural stability might be more related to lower spatial frequency information,[86] which not all of the studies examined.

Visual Fields and Falls

Visual field loss is associated with slower walking speed and poorer mobility performance.[87] It also is associated with a 22% increase in tripping over obstacles after adjustments for age, gender, race, and other potential confounders.[88] Artificially restricted visual fields also reduced postural stability, according to one study.[89] Studies regarding the relationship between visual field loss and falls are limited.

The Rotterdam study[90] investigated the association between visual field loss and falls among 6280 participants. The investigators in this study used different techniques to assess the visual field. The Goldmann visual field test (a manual perimetry test) was used to assess the visual field in some participants, and the 52-point suprathreshold test (an automated perimetry test) was used in others. The definition of bilateral visual field loss was any visual field loss in both eyes. Approximately 6% of participants had visual field loss in at least one eye. According to the study, 3.4% of subjects having bilateral or unilateral visual field loss experienced frequent falls (defined as more than four falls in the past 2 years) compared to 0.55% of those with normal visual fields.

Other studies have investigated visual field loss in one eye as a predictor of falls. In the Blue Mountains Eye Study,[72] a cross-sectional study, a total of 2003 participants residing in the community reported their status of falling in the year prior to the eye examination. These participants had reliable results in the better eye using the 76-point suprathreshold visual field test. The categories of visual field loss were no points missed; 1 to 4 points missed; and 5 or more points missed. Of the 2003 study participants, 286 (14.3%) lost 5 or more visual field points in the better eye. In analyses adjusted for sex and age, individuals who missed 5 or more points had greater odds of frequent falls (defined as at least two falls in the past year) than those without visual field loss. There was an increased chance of falling with greater visual field loss (P = .015). Using the Henson perimeter, individuals in the Beaver Dam Eye Study with reduced visual field sensitivity had an increased likelihood of recurrent falls (defined as two or more falls) after adjustment for confounders. In this study of 3722 individuals, subjects were asked about their status of falling in the year prior to the eye examination.[83]

In a study of 489 older individuals (65 years and older) at a glaucoma clinic, the investigators studied the association between visual field loss and severe falls necessitating medical intervention or activity limitations.[91] Individuals provided information about such falls that occurred in the year prior to the eye examination. The visual field was not assessed consistently using the same testing technique among all participants. Individuals having 40% or greater loss in the visual field were more likely to report falls compared to those with less than 5% visual field loss, although the findings were not statistically significant.

In 148 participants, Lord and Dayhew[92] ascertained the number of falls subjects experienced by sending monthly questionnaires in the year following an eye examination, which included the assessment of the inferior visual field with a test described as lower visual field size. In this visual field test subjects are asked to look directly and continually at a circular target on the floor and to point to a black square card if they can see any part of it "out of the corner of their eye." According to the investigators, the reliability of this test was unclear. The investigators found that visual field assessment was not as a strongly associated with falls as were measurements of visual acuity, contrast sensitivity, and depth perception.

Recently, this author and colleagues93 reported that binocular visual field loss increases the risk of future falls in older women based on participants in the Study of Osteoporotic Fractures. Among 4071 women, 409 (10%) had severe binocular visual field loss at their baseline eye examination, and 643 (16%) experienced frequent falls within 1 year after eye examination. Severe binocular visual field loss was defined as the loss of 20 points or more on the binocular visual field and was significantly associated with frequent falls when adjusted for age, study site, and cognitive function. When binocular visual field loss was treated as a continuous variable, women with more points lost in the binocular visual field had an 11% higher chance of frequent falls in the analysis adjusted for age, study site, and cognition (OR, 1.11 per SD; 95% CI, 1.02-1.20). Among older white women with severe binocular visual field loss, a third of their frequent falls were attributable to their visual field loss. Reasons for the binocular visual field loss were unspecified in the Study of Osteoporotic Fractures because only a random sample of the cohort has had ophthalmic data evaluated for ocular conditions and diseases.

SOURCES OF VISUAL IMPAIRMENT

Uncorrected refractive error is a major source of visual impairment.[94] Other sources include age-related macular degeneration (ARMD), cataract, glaucoma, and diabetic retinopathy. Studies examining the relationship between uncorrected refractive error and falls were not found, although various types of spectacle corrections have been linked to an increased risk of falls, particularly among people wearing multifocal lenses (bifocals, trifocals, and progressive lenses). A prospective study[95]of 156 community-dwelling older subjects between the ages of 63 and 90 reported that people wearing multifocal spectacles were more than twice as likely to fall as those not wearing spectacles, controlling for age, compromised vision, and other characteristics.

After uncorrected refractive error, the Melbourne Visual Impairment Project[94] showed that the second most common source of visual impairment is ARMD, which can result in reduced visual acuity and contrast sensitivity.[96,97] Individuals with ARMD rely less on their vision to maintain stable posture; they tend to maintain balance by using information obtained through the kinesthetic and vestibular systems instead of the visual sensory system.[98] There is very little evidence to suggest that ARMD is a specific risk factor for falls; studies have failed to find an association of ARMD with falls[72] as well as with fractures that occur secondary to falls,[85] except for a recent article by this author and colleagues showing an association between ARMD (diagnosis codes) and hip fracture in the Medicare population.[99]

The third most common source of visual impairment shown by the Melbourne Visual Impairment Project was cataract.[94] In the Blue Mountains Eye Study, Ivers and colleagues[72] reported that posterior subcapsular cataracts increased the risk of falls, whereas nuclear or cortical cataracts did not. In the Melbourne Visual Impairment Project, McCarty and colleagues[100] reported that the presence of nuclear cataract significantly increased the risk of falls, but no other types of cataract had an effect.

Although glaucoma is the second leading cause of blindness worldwide,[101] in the Melbourne Visual Impairment Project it was the fifth most common source of visual impairment.[94] A retrospective study of 489 subjects with glaucoma showed that people taking nonmiotic and miotic glaucoma medications had an increased likelihood of falling.[91] Similarly, Ivers and associates[72] found that the use of nonmiotic medications increased the risk for multiple falls. The presence of glaucoma, however, was not significantly associated with falls in either the Blue Mountains Eye Study[72] or the Melbourne Visual Impairment Project.[100]

Diabetic retinopathy, the sixth reason for visual impairment demonstrated in the Melbourne Visual Impairment Project,[94] is associated with compromised visual function.[102,103] In a study by Richardson and colleagues,[104] severe polyneuropathy was a significant risk factor for multiple and injurious falls when adjusting for age, sex, medications, and comorbidities. In the Blue Mountains Eye Study, Ivers and colleagues[72] failed to find an association between diabetic retinopathy in any eye and falls.

Few studies have examined the independent association between specific eye disorders and falls, and data regarding the association of falls with cataract, ARMD, glaucoma, or diabetes are all inconclusive. Because of its patient numbers, scope, and multicenter infrastructure for measurement of falls as well as vision, the Study of Osteoporotic Fractures offered an excellent opportunity to evaluate the connection between visual functioning, various eye diseases, and risk for falls by looking at sources of binocular visual field loss.

PRIOR STUDY OF OSTEOPOROTIC FRACTURES RESEARCH ON BINOCULAR VISUAL FIELD LOSS AND FALLS

In my prior study regarding the association between binocular visual field loss and the risk of frequent falls,[93] older white women with binocular visual field loss had an increased likelihood of frequent falls (defined as at least two or more falls). A total of 4920 women had eye examinations between January 1997 and September 1998 as part of the study. The total number of women with reliable visual field tests in both eyes was 4216, and of these women, only 145 did not report sufficient information regarding their status of falling in the year after their eye examination. Thus, the final sample size of women included in the analysis of binocular visual field loss and falls was 4071.

The range of missed points on the binocular visual field test was 0 to 87, with a mean of 6.3 ± 11.5. A total of 1538 women (38%) missed no points on the test, and 1714 (42%) had mild binocular visual field loss. Four hundred ten women (10%) had moderate binocular visual field loss, and 409 (10%) had severe binocular visual field loss.

Six hundred forty-three of the 4071 women (16%) reported experiencing at least two falls. Thirteen percent of women with no binocular visual field loss reported frequent falling, compared with 16%, 19%, and 22% of women with mild, moderate, and severe binocular visual field loss, respectively. There was a trend of increased frequent falling with greater visual field loss that was statistically significant ($P < .001$).

In unadjusted and adjusted analyses, women with severe binocular visual field loss had greater odds of frequent falling than women with no binocular visual field loss. When age, study site, and cognitive function were controlled, women with severe binocular visual field loss had 50% greater odds of frequent falls (OR, 1.50; 95% CI, 1.11-2.02) than women with no binocular visual field loss. Both superior and inferior visual field loss were associated with increased odds of frequent falling. Women with severe inferior visual field loss had 91% greater odds of frequent falls than women with no inferior visual field loss (OR, 1.91; 95% CI, 1.46-2.51), whereas women with severe superior visual field loss had 74% greater odds of frequent falls (OR, 1.74; 95% CI, 1.36-2.23) than women with no superior visual field loss.

In unadjusted analysis, contrast sensitivity was a significant risk factor for two or more falls, although the association was not statistically significant when adjusting for age, study site, and cognition. There was no statistically significant association between visual acuity and at least two falls in unadjusted or adjusted analyses.

The Study of Osteoporotic Fractures[93] shows that severe binocular visual field loss increases the likelihood of older white women falling. However, because of the small numbers of women with severe binocular visual field loss in this vision case-cohort study, another case-control study was needed to determine the sources of severe binocular visual field loss in this cohort. This disease correlation study would include all of the women with severe binocular visual field loss in the whole cohort, and controls would be a random sample of women in the whole cohort without visual field loss or only mild or moderate binocular visual field loss.

METHODS

SUBJECTS

From 1986 to 1988, 9704 ambulatory white female volunteers aged 65 years or older, with no history of osteoporosis or bilateral hip replacement, were enrolled in the Study of Osteoporotic Fractures, a multicenter, prospective longitudinal cohort study for identifying potential risk factors of osteoporotic fractures.[105] These women were identified from 4 clinic centers nationwide: Baltimore, Maryland; Minneapolis, Minnesota; Portland, Oregon; and the Monongahela Valley, Pennsylvania. Beginning in January 1997 and continuing through September 1998, all surviving participants were invited to participate in a follow-up clinical examination (sixth clinic visit) that included an eye examination designed by this author. All individuals in the study gave informed consent to participate, and institutional review board approvals were obtained from all participating centers prior to the study. A total of 4820 white participants (63% of the surviving cohort) attended the sixth clinic visit (Figure 1).

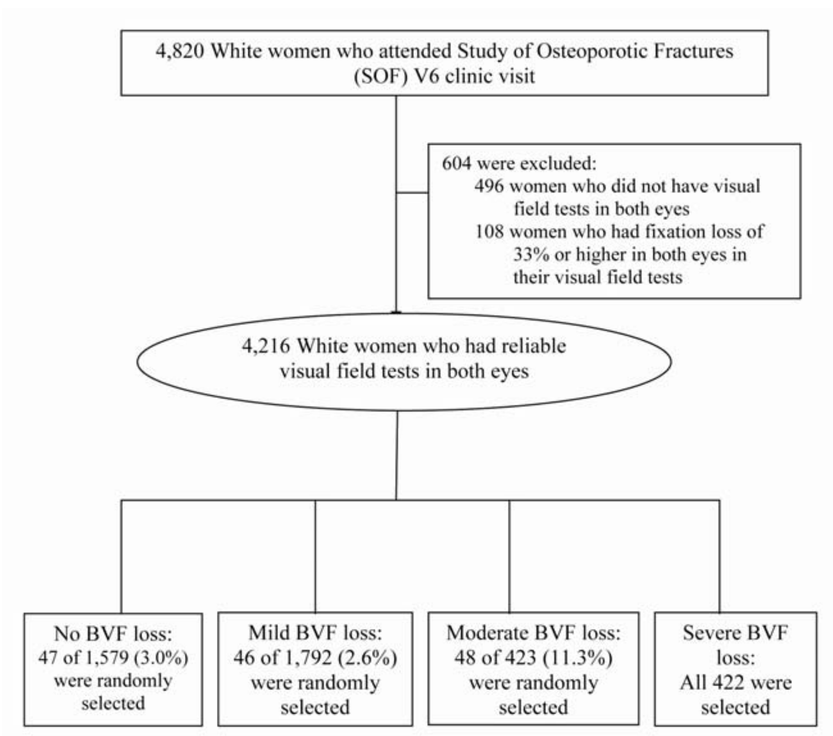

FIGURE 1

Flow chart of disease correlation study participants. BVF, binocular visual field.

At examination, subjects' eyes were measured for visual acuity, contrast sensitivity, refractive error, ocular pressures, and peripheral vision; in addition, dilated fundus photographs and lens photographs were taken. For the vision case-cohort, 1123 white women were selected for photograph grading by the Study of Osteoporotic Fractures eye study coordinating center using a random numbers generator program. All lens and fundus photographs of the women in this vision case-cohort sample were graded by two trained graders—utilizing the Wisconsin Age-Related Maculopathy Grading Scale[106] and the Wisconsin cataract grading system[107]—at the UCLA Center for Eye Epidemiology. This author adjudicated all disagreements among graders that could not be otherwise resolved.

MEASUREMENT OF VARIABLES

Assessment of Visual Acuity and Contrast Sensitivity

For each subject, distance visual acuity tests were performed in the clinic on both eyes separately, with habitual correction under standard illumination using Bailey-Lovie charts.[108] These charts are similar to the Early Treatment Diabetic Retinopathy Study charts in that the lines are of equal difficulty and there is geometric progression in letter size from line to line. The number of letters read correctly was recorded. Visual acuity was analyzed as a dichotomized variable (Snellen visual acuity of worse than 20/40 [less than 43 letters read correctly] vs 20/40 or better [43 or more letters read correctly]).

Distance contrast sensitivity (CS) was also performed in the clinic on both eyes of each participant separately, with habitual correction under standard illumination using the VCTS 6500 charts and light meters (Vistech Consultants, Inc, Dayton, Ohio).[109] These charts present a series of sine-wave gratings at calibrated levels of contrast at specific spatial frequencies (cycles per degree [cpd]). The number of gratings seen correctly in the CS chart at 5 spatial frequencies (1.5, 3, 6, 12, and 18 cpd) was recorded for each participant, and the number of gratings seen correctly was recorded and converted to a CS score at each spatial frequency according to the manufacturer's manual. Contrast sensitivity at low spatial frequency (1.5 cpd) was analyzed as both a continuous variable (CS score) and a dichotomized variable (CS score of 25 or greater vs CS score of 24 or less). When CS score was not available at 1.5 cpd, CS score at 3 cpd was used.

Assessment of Best-Corrected Visual Acuity and Uncorrected Refractive Error

In all subjects whose presenting visual acuity was 20/30 or worse in one eye, an objective autorefraction was measured in each eye using the READ sequence on the Humphrey Automatic Refractor Model 570 (Humphrey Automatic Refractor; Zeiss, Oberkochen, Germany). After the autorefraction measurement, best-corrected visual acuity in each eye was then assessed by asking the examinee to read the Snellen acuity chart (range, 20/15 to 20/200) with the new correction from the autorefractor. The best-corrected visual acuity was the smallest line of acuity in which the examinee could read all of the letters or missed no more than one letter. Uncorrected refractive error was then defined as present when the best-corrected visual acuity was 2 or more lines (10 or more letters) better than the presenting visual acuity.

Assessment of Visual Field Loss

Using the Humphrey Field Analyzer suprathreshold 76-point 30-degree visual field program (Humphrey Field Analyzer; Zeiss, Oberkochen, Germany), visual field tests were performed in the clinic on both eyes of each participant,[110] as described in a previous manuscript by this author and colleagues.[93] Given that the 76-point screening visual field test indicates only whether the light was detected in a certain area, a binocular visual field of each subject was created by overlapping the two 76-screening visual fields for each eye, using a method adapted from Esterman's binocular visual field functional scoring algorithm (Figure 2).[93,111]

Women who did not have visual field tests in both eyes (n = 496) or who had unreliable visual field tests, defined as fixation losses of 33% or higher in the visual field tests in at least one eye (n = 108), were excluded from the analysis (Figure 1). The total number of points missed in binocular visual field was obtained by summing the number of points missed in the binocular visual field. Due to the skewness of the distribution of binocular visual field loss, binocular visual field loss was analyzed within 4 groups: no points missed (no visual field loss), 1 to 9 points missed (mild visual field loss), 10 to 19 points missed (moderate visual field loss), and 20 or more points missed (severe visual field loss). Inferior- and superior-binocular visual field losses were evaluated in a secondary analysis. Inferior loss was defined as the number of points missed in the lower half of binocular visual field (48 points); superior loss was defined as the number of points missed in the upper half of binocular visual field (48 points). Each was categorized: no visual loss, 0 points missed; mild, 1 to 4 points missed; moderate, 5 to 9 points missed; and severe, 10 or more points missed.

Ascertainment of Falls

All participants were contacted by postcard or telephone approximately every 4 months to determine whether they had any new falls or fractures after the eye examination. Falls were recorded as having occurred if patients queried said they had fallen to the floor or hit an object when falling in the past 4 months.[73] In this study, frequent falling was defined as two or more falls within 1 year after clinical examination. Since the inception of the Study of Osteoporotic Fractures, there has been a cumulative completion rate of 98% for these contacts.[112]

Assessment of Cognitive Function

Cognitive function was measured using the Mini-Mental State Examination (MMSE) as described by Folstein and colleagues.[113] The scale focuses on the cognitive aspects of mental function and excludes questions regarding mood, abnormal mental experiences, and the form of thinking. At 24 hours, retest by single or multiple examiners resulted in relatively high retest reliability (r = 0.887, single examiner; r = 0.827, multiple examiner). At 28 days, retest in older individuals with dementia also revealed high retest reliability (correlation between test 1 and test 2 was 0.98).[114] Since its creation in 1975, various studies have examined the performance of the MMSE scale. In a study of 1600 adults aged 65 and older, the alpha internal consistency of the scale was 0.78.[115] The scoring system of the scale ranges from 0 to 30 points, and a score of 23 or less distinguishes between older adults with dementia, delirium, or psychoses from those without these conditions.

DESIGN OF DISEASE CORRELATION STUDY

This author reviewed the fundus and lens photographs of the 422 women with severe binocular visual field loss as well as a random sample of 141 white women—47 with no binocular visual field loss (3.0% randomly selected from 1,579 women with no binocular visual field loss); 46 with mild binocular visual field loss (2.6% randomly selected from 1,792 women with mild binocular visual field loss); and 48 with moderate binocular visual field loss (11.3% randomly selected from 423 women with moderate binocular visual field loss). The possible causes of severe binocular visual field loss were then determined using the following definitions.

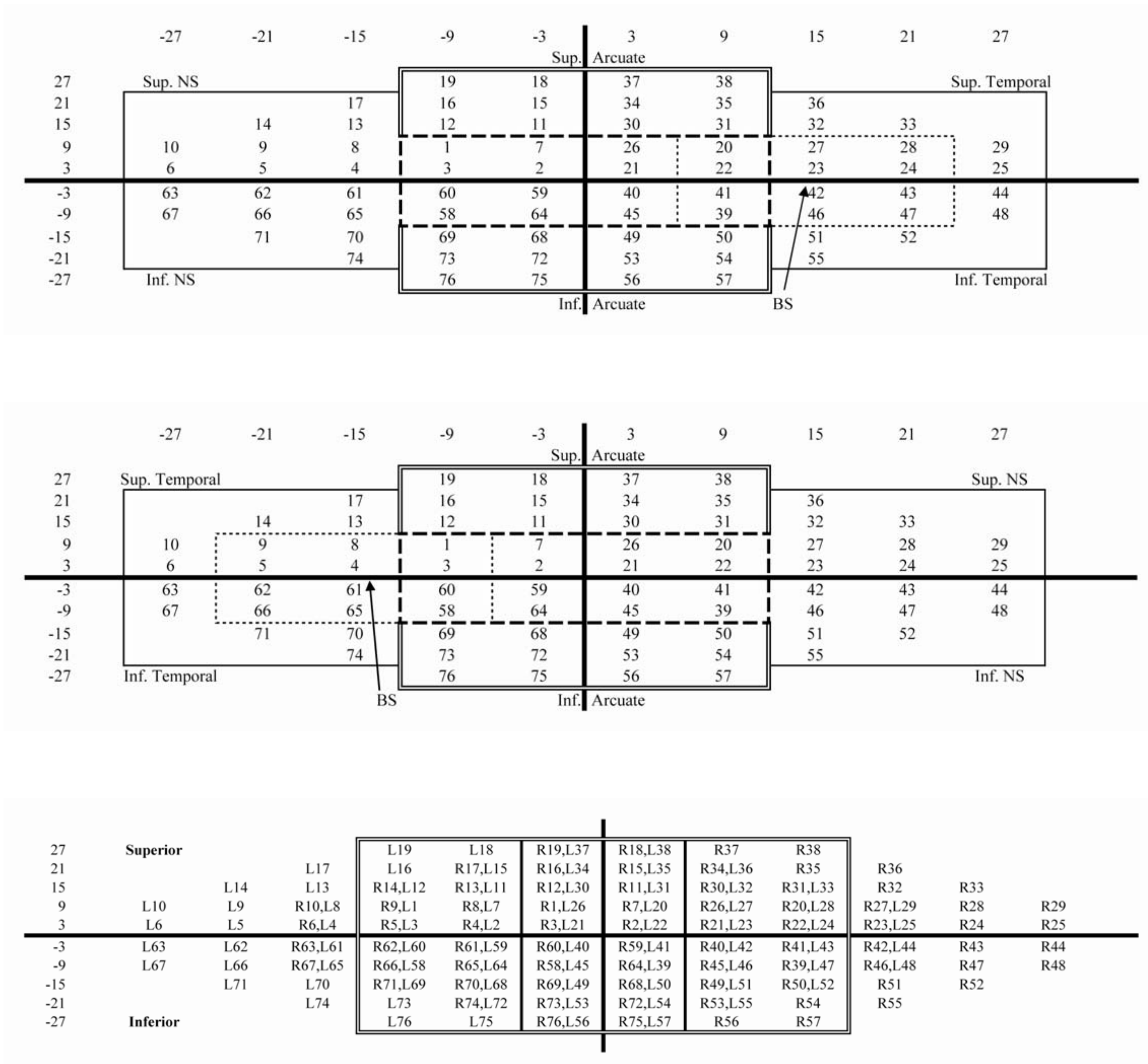

FIGURE 2

Creation of 96-point binocular visual field. Top panel depicts the Humphrey 76-point suprathreshold screening visual field test for the right eye. Middle panel depicts the Humphrey 76-point suprathreshold screening visual field test for the left eye. Bottom panel depicts the 96-point binocular visual field by overlapping visual fields at central and nasal areas from 2 eyes (shift left eyes 2 columns to the left), adapted from Esterman's 100-point binocular visual field functional scoring algorithm. A point lost in the binocular visual field in the overlapped area means that the location was missed by both eyes. BS, blind spot; NS, nasal; Inf, inferior; Sup, superior.

Cataract

Based on external or lens photographs, or both, aphakia or pseudophakia was first determined for all eyes. Among phakic eyes, cortical opacity, posterior subcapsular opacity, and nuclear sclerosis were measured using the Age-Related Eye Disease Study (AREDS) System for Classifying Cataracts,[115] which is an extension of the Wisconsin System for Classifying Cataracts from photographs.[107] The AREDS system used 3 additional standard photographs inserted into the intervals of the original 4 in the Wisconsin system for nuclear cataract grading, resulting in a linear scale of 0.9 to 6.1. Nuclear cataract was defined as the presence of nuclear sclerosis grade 4 or higher. Cortical cataract was defined as the presence of 5% or more cortical opacity within the central 5 mm of the lens, and posterior subcapsular cataract was defined as the presence of 5% or more opacity within the same confine.

Age-Related Macular Degeneration

Based on 45-degree stereoscopic fundus photographs, ARMD was determined using a modification of the Wisconsin Age-Related Maculopathy Grading System,[106] which was used in National Health and Nutrition Examination Surveys (NHANES) III.[116] The Wisconsin Age-Related Maculopathy Grading System was developed for use with 30-degree stereoscopic fundus photographs and uses a threshold of 63 μm diameter for classification of drusen as hard or soft. Because of the use of 45-degree stereoscopic fundus photographs in the NHANES III and Study of Osteoporotic Fractures V6 components, a threshold of 95 μm was used instead of 63 μm. Early ARMD was defined as the presence of soft drusen (drusen area ≥95 μm but <960 μm) with retinal pigment epithelium depigmentation or soft drusen (drusen area ≥960 μm) with or without pigmentary abnormalities. Late ARMD was defined as the presence of geographic atrophy or subfoveal choroidal neovascularization.

Glaucoma

Glaucoma was diagnosed by the appearance of the optic nerve head. The optic nerves were diagnosed as glaucomatous based on diffuse and localized thinning of the neuroretinal rim, loss of retinal fiber layer, increased cupping, and/or asymmetry of the optic nerve cup-to-disc ratios of greater than 0.3.[117]

Diabetic Retinopathy

Diabetic retinopathy was diagnosed when there were microaneurysms, retinal hemorrhages, and soft exudate, or intraretinal microvascular abnormalities, venous beading, neovascularization of the disc or retina, or laser scars secondary to photocoagulation.[116]

RESULTS

Among 422 white women who missed 20 or more points in the binocular visual field, optic nerve photographs were not available for 19 women and were not gradable in both eyes for 3 women. Sixty-three (15.8%) of 400 women with severe binocular visual field loss were pseudophakic and had no evidence of glaucoma, ARMD, diabetic retinopathy, or other retinal diseases. Two hundred thirty-one (68.5%) of the remaining 337 women had in both eyes the same eye disease, which accounted for their visual field loss (Table 1). One hundred nine (32.3%) had bilateral cataracts only, and 65 (19.3%) had bilateral glaucoma only. Of those 109 women with bilateral cataracts only, 89 (81.7%) had bilateral nuclear cataracts. The type of cataract could not be determined for an additional 11 women (10.1%), who most likely had nuclear cataracts. Of the 337 women, 41 (12.2%) had different eye diseases in both eyes; the majority of them had glaucoma in one eye and cataract in the other eye.

Women with severe binocular visual field loss were older, more likely to have worse visual acuity and contrast sensitivity in the better eye, and more likely to have worse cognition than women with no, mild, or moderate binocular visual field loss ($P < .001$) (Table 2).

Cataracts of any type were more common in women without binocular visual field loss compared to women with severe binocular visual field loss ($P < .001$) (Table 3), whereas posterior subcapsular cataracts were more common in women with severe binocular visual field loss than women without binocular visual field loss (Table 3). Early ARMD was more common in women with severe binocular visual field loss, and late ARMD was more common in women with moderate or severe binocular visual field loss, compared to women with no binocular visual field loss ($P < .001$) (Table 3). Glaucomatous optic nerve damage occurred more frequently in women with moderate or severe binocular visual field loss than in women with no or mild binocular visual field loss (P =.046). Although statistical significance was not seen with either uncorrected refractive error or diabetic retinopathy, there was a tendency for more uncorrected refractive error in women with any binocular visual field loss compared to women with no binocular visual field loss, and all 12 cases of diabetic retinopathy had severe binocular visual field loss (Table 3).

Among the women with severe binocular visual field loss, the women with ARMD lost more points centrally and had worse visual acuity and contrast sensitivity than did the women with other ocular diseases or those without ocular disease (Table 4). Women with glaucomatous optic nerve damage were more likely to report having noncataract eye surgery and to have a lower body mass index (Table 4). In addition, 41% of women with ARMD and 28% of women with glaucomatous optic nerve damage in both eyes fell two or more times during the year after the eye examination, whereas only 8% of the women who were pseudophakic and without ocular disease fell two or more times during the following year ($P = .092$). Concomitant factors—frequency of strokes; presence of two or more systemic diseases; cognitive function; depression; use of hypotensive or vasodilating agents, beta and alpha blockers, or anxiolytics; and self-rated health status—among those with ocular disease and those without did not reach statistical significance (Table 4).

TABLE 1. SOURCES OF SEVERE BINOCULAR VISUAL FIELD LOSS IN THE DISEASE CORRELATION STUDY

CATEGORY	NO. OF WOMEN
Women with bilateral eye diseases	**231**
Two or more eye diseases in both eyes	9
Bilateral ARMD and glaucoma	2
Bilateral glaucoma and cataract	6
Bilateral cataract and other eye diseases	1
Two or more eye diseases in one eye and one eye disease in the other eye	15
Bilateral glaucoma and unilateral ARMD	2
Bilateral glaucoma and unilateral cataract	4
Bilateral cataract and unilateral ARMD	1
Bilateral cataract and unilateral glaucoma	6
Bilateral cataract and unilateral diabetic retinopathy	1
Bilateral diabetic retinopathy and unilateral cataract	1
Single bilateral eye diseases	207
Bilateral ARMD	22
Bilateral glaucoma	65
Bilateral cataract	109
Bilateral diabetic retinopathy	4
Bilateral other eye diseases	7
Women with different eye diseases in both eyes	**41**
Unilateral ARMD and unilateral glaucoma	3
Unilateral ARMD and unilateral cataract	5
Unilateral ARMD and other eye disease	1
Unilateral glaucoma and unilateral cataract	21
Unilateral glaucoma and unilateral other eye disease	4
Unilateral cataract and unilateral diabetic retinopathy	2
Unilateral cataract and unilateral other eye disease	5
Women with known eye disease in only one eye*	**60**
Two or more eye diseases	2
Glaucoma and cataract	1
Cataract and other eye disease	1
Single eye disease	58
ARMD	13
Glaucoma	12
Cataract	26
Diabetic retinopathy	1
Other eye diseases†	6
No identifiable eye disease	**68**
Pseudophakic in both eyes	63
Pseudophakic in one eye and no cataract in other eye	5

ARMD, age-related macular degeneration.
*Optic nerve photographs were not gradable in the other eye or no eye disease can be determined by optic nerve photographs in the other eye.
†Other eye diseases included ischemic optic neuropathy, aphakic, macular hole, myopic degeneration, pale nerve, and retinal vein occlusion.

TABLE 2. CHARACTERISTICS OF WOMEN IN DISEASE CORRELATION STUDY BY SEVERITY OF BINOCULAR VISUAL FIELD LOSS

CHARACTERISTIC	NONE (0 POINT MISSED) (N = 47)	MILD (1-9 POINTS MISSED) (N = 46)	MODERATE (10-19 POINTS MISSED) (N = 48)	SEVERE (20 OR MORE POINTS MISSED) (N = 422)	*P* VALUE*
Age (yr), mean ± SD	78.5 ± 3.4	79.0 ± 3.5	81.4 ± 4.5	82.1 ± 4.6	<.001
VA in better eye					
Mean ± SD (No. of letters)	48.3 ± 5.1	44.5 ± 8.8	44.2 ± 7.8	42.6 ± 9.7	<.001

TABLE 2(continued). CHARACTERISTICS OF WOMEN IN DISEASE CORRELATION STUDY BY SEVERITY OF BINOCULAR VISUAL FIELD LOSS

20/40 or better	41 (87%)	33 (72%)	30 (63%)	261 (62%)	.003
Worse than 20/40	6 (13%)	13 (28%)	18 (37%)	159 (38%)	
Low-frequency CS score in better eye					
Mean ± SD	76.7 ± 50.0	57.7 ± 35.6	51.0 ± 34.2	49.1 ± 31.2	<.001
≥25	46 (98%)	41 (89%)	35 (73%)	305 (78%)	<.001
≤24	1 (2%)	5 (11%)	13 (27%)	87 (22%)	
MMSE					
Mean ± SD	28.5 ± 1.6	28.0 ± 2.0	27.4 ± 2.4	27.0 ± 2.6	<.001
≥24	46 (98%)	43 (96%)	44 (96%)	378 (92%)	.422
≤23	1 (2%)	2 (4%)	2 (4%)	34 (8%)	
Self-report stroke	0	2 (4%)	5 (10%)	33 (8%)	.115
Self-report 2 or more systemic diseases	14 (30%)	20 (43%)	23 (48%)	199 (47%)	.145
Use of hypotensive or vasodilating agents	12 (26%)	20 (43%)	23 (48%)	186 (44%)	.083
Use of beta and alpha blockers	11 (23%)	10 (22%)	16 (33%)	110 (26%)	.602
Use of anxiolytics	7 (15%)	8 (17%)	5 (10%)	42 (10%)	.325
Two or more falls within 1 yr after clinical exam	7 (16%)	9 (20%)	13 (28%)	92 (22%)	.633

CS, contrast sensitivity; MMSE, Mini-Mental State Examination; SD, standard deviation; VA, visual acuity.
*Fisher exact tests or Kruskal-Wallis tests.

TABLE 3. OCULAR CONDITIONS BY SEVERITY OF BINOCULAR VISUAL FIELD LOSS IN DISEASE CORRELATION STUDY

CONDITION	NONE (0 POINT MISSED) (N = 47)	MILD (1-9 POINTS MISSED) (N = 46)	MODERATE (10-19 POINTS MISSED) (N = 48)	SEVERE (20 OR MORE POINTS MISSED) (N = 422)
Lens status				
Lens photographs not available or not gradable	3	4	3	34
IOL in both eyes	10 (23%)	14 (33%)	12 (27%)	146 (38%)
Bilateral cataract (any type)*	24 (55%)	18 (43%)	17 (38%)	152 (39%)
IOL in one eye and cataract (any type) in the other eye	2 (5%)	4 (10%)	14 (31%)	63 (16%)
Bilateral PSC	8 (18%)	4 (10%)	5 (12%)	44 (12%)
IOL in one eye and PSC in the other eye	1 (2%)	2 (5%)	3 (7%)	18 (5%)
Age-related macular degeneration status*				
Fundus photographs not available or not gradable for retinal disease	4	8	7	45
Late ARMD in one or both eyes	1 (2%)	1 (3%)	5 (12%)	43 (11%)
Early ARMD in one or both eyes	10 (23%)	7 (18%)	8 (20%)	150 (40%)
No ARMD in either eye	32 (74%)	30 (79%)	28 (68%)	184 (49%)
Glaucoma status†				
Photographs not available or not gradable for glaucoma	4	6	4	32
Glaucoma in one or both eyes	9 (21%)	8 (20%)	16 (36%)	142 (36%)
No glaucoma in either eye	34 (79%)	32 (80%)	28 (64%)	248 (64%)
Diabetic retinopathy‡				
Diabetic retinopathy in one or both eyes	0	0	0	12 (3%)
None	44 (100%)	42 (100%)	44 (100%)	374 (97%)
Uncorrected refractive error‡				
VA or autorefraction not available	8	8	10	100
Uncorrected refractive error in one or both eyes	6 (15%)	3 (34%)	14 (37%)	102 (32%)
No uncorrected refractive error in either eye	33 (85%)	25 (66%)	24 (63%)	220 (68%)

ARMD, age-related macular degeneration; IOL, intraocular lens; PSC, posterior subcapsular cataract; VA, visual acuity.
*P < .001. (Statistical significance values calculated with chi-square tests or Fisher exact tests.)
†P < .05.
‡P > .1.

TABLE 4. CHARACTERISTICS OF WOMEN WITH SEVERE BINOCULAR VISUAL FIELD LOSS BY EYE DISEASE IN DISEASE CORRELATION STUDY

CHARACTERISTIC	IOL ONLY IN BOTH EYES (N = 63)	BILATERAL GLAUCOMA ONLY (N = 65)	BILATERAL CATARACT ONLY (N = 109)	BILATERAL ARMD ONLY (N = 22)	UNILATERAL EYE DISEASE (N = 60)	*P* VALUE*
Age (yr), mean ± SD	82.6 ± 4.4	82.2 ± 4.7	81.3 ± 4.2	83.6 ± 5.1	82.2 ± 4.5	.184
Binocular visual field loss area, mean No. of points missed ± SD						
Total (96 points)	32.5 ± 13.8	35.7 ± 14.8	35.3 ± 15.2	35.4 ± 16.3	36.8 ± 15.6	.568
Superior (48 points)	19.6 ± 8.9	20.4 ± 10.1	20.0 ± 9.4	18.5 ± 8.4	21.3 ± 8.8	.646
Inferior (48 points)	12.8 ± 8.4	15.4 ± 8.4	15.2 ± 8.6	16.9 ± 10.6	15.4 ± 10.1	.228
Central (16 points)	1.6 ± 2.6	2.4 ± 2.7	1.8 ± 2.5	3.7 ± 3.7	2.2 ± 3.4	.013
Peripheral (80 points)	30.9 ± 12.3	33.3 ± 13.1	33.5 ± 13.9	31.7 ± 14.3	34.5 ± 13.4	.521
Central (24 points)	2.6 ± 3.7	4.0 ± 4.0	3.1 ± 4.1	5.0 ± 5.2	3.7 ± 5.1	.037
Peripheral (72 points)	29.9 ± 11.2	31.8 ± 11.8	32.2 ± 12.5	30.5 ± 12.9	33.0 ± 12.0	.565
VA in better eye, mean ± SD (No. of letters)	46.2 ± 6.0	45.0 ± 6.5	42.9 ± 8.7	32.9 ± 15.1	44.6 ± 7.3	<.001
20/40 or better,	51 (81%)	48 (74%)	62 (57%)	5 (25%)	40 (67%)	<.001
Worse than 20/40	12 (19%)	17 (26%)	47 (43%)	15 (75%)	20 (33%)	
Low-frequency CS score in better eye, mean ± SD	50.1 ± 28.5	55.6 ± 39.9	49.5 ± 33.1	28.1 ± 14.5	50.0 ± 24.3	.002
≥25	54 (86%)	49 (77%)	83 (77%)	6 (37%)	47 (87%)	<.001
≥24	9 (14%)	15 (23%)	25 (23%)	10 (63%)	6 (11%)	
Uncorrected refractive error in at least one eye	15 (33%)	15 (28%)	29 (30%)	1 (8%)	13 (33%)	.472
Self-report any eye surgery (including laser treatment) other than cataract surgery	8 (13%)	19 (29%)	6 (6%)	3 (14%)	6 (10%)	<.001
MMSE						
Mean ± SD	27.1 ± 2.0	27.1 ± 2.6	27.0 ± 2.5	26.2 ± 2.4	27.1 ± 2.7	.384
≥24	58 (94%)	59 (92%)	100 (93%)	17 (94%)	55 (92%)	.980
≤23	4 (6%)	5 (8%)	7 (7%)	1 (6%)	5 (8%)	
Depression (GDS≥6), No. (%)	6 (10%)	8 (13%)	12 (11%)	4 (18%)	11 (18%)	.513
BMI (kg/m^2), mean ± SD	25.2 ± 4.5	24.5 ± 3.8	26.5 ± 4.5	26.7 ± 3.8	26.2 ± 4.4	.026
Walking speed (m/s), mean ± SD	0.82 ± 0.23	0.83± 0.21	0.79 ± 0.21	0.72 ± 0.18	0.80 ± 0.21	.121
Self-rated health status poor/fair	19 (30%)	13 (20%)	24 (22%)	7 (32%)	15 (25%)	.572
Self-report stroke	4 (6%)	2 (3%)	11 (10%)	2 (9%)	7 (12%)	.341
Self-report diabetes	4 (6%)	3 (5%)	7 (6%)	3 (14%)	2 (3%)	.510
Self-report 2 or more systemic diseases	31 (49%)	28 (43%)	47 (43%)	13 (59%)	32 (53%)	.492
Use of hypotensive or vasodilating agents	28 (44%)	27 (42%)	50 (46%)	11 (50%)	30 (50%)	.894
Use of beta and alpha blockers	19 (30%)	23 (35%)	24 (22%)	6 (27%)	15 (25%)	.391
Use of anxiolytics	5 (8%)	8 (12%)	9 (8%)	3 (14%)	9 (15%)	.566
Any falls in last 12 mo	25 (40%)	23 (36%)	38 (35%)	12 (55%)	26 (43%)	.443
History of any fractures	40 (63%)	38 (58%)	59 (54%)	14 (64%)	32 (53%)	.703
Two or more falls within 1 year after clinical exam	9 (14%)	18 (28%)	20 (20%)	8 (42%)	13 (22%)	.092

ARMD, age-related macular degeneration; BMI, body mass index; CS, contrast sensitivity, GDS, Geriatric Depression Scale; IOL, intraocular lens; MMSE, Mini-Mental State Examination; SD, standard deviation; VA, visual acuity.
*Fisher exact tests or Kruskal-Wallis tests.

DISCUSSION

Binocular visual field loss increases the risk of future frequent falls in older white females, and more severe visual field loss correlates with greater risk of recurrent falling. Women with severe binocular visual field loss were more likely to have cataracts or glaucomatous optic nerve damage than women without any visual field loss. Because visual field loss is the main consequence of glaucomatous optic nerve damage, it is not surprising that glaucomatous optic nerve damage was one of the main sources of binocular visual field loss in this population.

In the Rotterdam Eye Study,[90] glaucoma was the leading source of visual field loss in all age-groups. A 52-point suprathreshold testing of the visual field was performed on both eyes in 6250 individuals. The 52-point suprathreshold tests were repeated if they were abnormal the first time. If the suprathreshold test was abnormal a second time, then Goldmann kinetic perimetry was performed. Two hundred twenty-one subjects had visual field loss that was identified using the Goldmann perimetry, and 121 were identified using suprathreshold perimetry only. The overall prevalence of visual field loss was 5.6%, and bilateral visual field loss was present in 2% of participants. In individuals 85 years or older, the prevalence of visual field loss was 17.0%. Before age 75 years, other optic nerve diseases and stroke ranked second and third, respectively, and after age 75, ARMD and retinal vascular occlusive disease were second and third. In age- and sex-adjusted analyses, 3.4% of subjects with bilateral visual field loss had more than four falls within the 2 years after the eye examination vs 0.55% of subjects without visual field loss ($P < .05$).

Approximately 6 years after the Rotterdam Eye Study's initial assessment of bilateral field loss, suprathreshold perimetry was repeated in 3761 persons aged 55 years or older who had no visual field loss at baseline.[118] The overall incidence rate of visual field loss was 7.4 per 1000 person-years. In individuals aged 80 years or older, this rate increased to 21.1 per 1000 person-years. Glaucoma was the leading source of incident visual field loss in all age categories. After glaucoma, stroke was the second most common source in persons younger than 75 years, followed by ARMD and retinal vascular occlusive disease. Other sources of visual field loss included retinal vascular occlusion, optic nerve head diseases other than glaucoma, retinal disorder unspecified, glaucoma of other types, myopia, cataract, retinal detachment, trauma, amblyopia, and rare causes. In subjects 75 years or older, open-angle glaucoma, ARMD, and stroke were the main sources of visual field loss. In the Rotterdam Eye Study[90,118] visual field loss was calculated by eye, and investigators did not create a binocular visual field. In addition, the Rotterdam Eye Study's definition of glaucoma is not consistent with the definition used clinically,[117] and the type of classification used in the Rotterdam Eye Study does not reveal whether there were subjects in the study who had dense cataracts or no definite ocular disease but who had visual field loss.

Surprisingly, cataracts were shown to be the main source of severe binocular visual field loss in the Study of Osteoporotic Fractures disease correlation study. The women with severe binocular visual field loss and nuclear cataracts had nuclear opacities that were graded as 4 or higher using the Age-Related Eye Disease Study classification. Only 15% of the participants in the Age-Related Eye Disease Study had a nuclear opacity score of 4 or higher.[119] The greater prevalence of nuclear cataracts in this older white population is to be expected, since the incidence of lens opacities increases with age,[120]and the average age of the women in this study with severe binocular visual field loss was 82 years. Lam and colleagues[121] reported a fairly uniform depression of the automated Humphrey 30-2 visual field by cataracts, a condition that improved after cataract extraction. A generalized depression of visual fields by lens opacities has been reported by numerous investigators.[121-124] In the Blue Mountains Eye Study,[125] investigators reported in the abstract of their article that there were no statistically significant relationships between the total points missed on the 76-suprathreshold visual field test in one eye and the degree of cortical, posterior subcapsular or nuclear cataract after adjusting for confounders (age, sex, fixation losses, false-positive and false-negative errors, and the central decibel level of the visual field test). However, in unadjusted analyses, which were not reported in the abstract, there was a statistically significant trend for missing 10 points or more on the suprathreshold visual field test with greater nuclear cataract severity ($P < .05$). The loss of statistical significance in the adjusted analyses may result from overadjustment. The central decibel level of the visual field test may be a concomitant outcome; thus, treating it as if it is a background confounder may have masked a significant association between cataract severity and visual field loss.

In addition, a randomized, controlled clinical trial[126] showed that the removal of cataracts in the first eye reduced the subsequent rate of falling. Harwood and colleagues[126] randomly assigned 306 women aged over 70 to cataract surgery within 4 weeks (expedited) or 12 months later (delayed). Falls were ascertained by a daily diary, and the subjects were seen every 3 months. During the 12-month follow-up, there was a 34% reduction in the rate of falling in the group who had expedited cataract surgery compared to the group who had delayed cataract surgery (rate ratio, 0.66; $P = .03$). In a similar study,[127] 239 women over 70 years of age with one unoperated cataract were randomly assigned to expedited surgery or delayed cataract surgery in the unoperated eye. Although the rate of falling was reduced by 32% in the expedited surgery group, this result was not statistically significant (rate ratio, 0.68, $P = .18$). Thus, cataract surgery on the second eye does not appear to decrease the rate of falling as effectively as cataract surgery on the first eye. These findings are consistent with ours, which found that bilateral cataracts are a source of severe binocular visual field loss that increases the risk of frequent falls.

The source for severe binocular visual field loss could not be identified in 68 women from the lens and fundus photographs in the current series; 63 of these women were pseudophakic in both eyes. These bilaterally pseudophakic women without ocular disease but with severe binocular visual field loss had better visual acuity and contrast sensitivity than women with ARMD, which was the fifth most common reason identified for severe binocular visual field loss. However, these bilaterally pseudophakic women had a visual acuity that was on average 2 letters less than that of women with no binocular visual field loss; their contrast sensitivity in the better eye was worse than the contrast sensitivity of women with no binocular visual field loss (50.1 ± 28.5 vs 76.7 ± 50, respectively). In addition, these women had poorer cognition and were more likely to use [hypotensive or vasodilating agents than women with no binocular visual field loss. Since abnormal screening visual field tests in this subject population were not repeated, these women may be false positives, although they had less than 33% fixation losses in the visual field tests in both eyes.

Because 76-point suprathreshold tests have been used in prior studies,[125,128] there is information on the false-positive rate. In the Thessaloniki Eye Study,[128] 88 participants underwent a 76-point suprathreshold visual field test followed by a 30-2 full-threshold test on the Humphrey field analyzer. One eye per subject was randomly selected and included in the analysis. Visual field loss on the suprathreshold test was classified as present when at least 3 points were missed. With this criteria, 16.7% of the subjects were erroneously identified by the suprathreshold test to have visual field loss (false positives), and 21.4% of the subjects were erroneously identified to have no visual field loss on the suprathreshold test (false negatives). Whether or not eyes with borderline results in the full-threshold test were classified as having visual field loss, the sensitivity rates of the suprathreshold visual field test decreased as more points were missed while the specificity increased. When borderline results on the full-threshold visual field test were classified as being normal, the suprathreshold test had 78.6% sensitivity and 83.3% specificity. Extrapolation from these findings suggests that as the number of points missed increases from 3 points to 10 points, the specificity would increase and the number of false positives would decrease. Thus, subjects missing at least 20 points on a binocular suprathreshold visual field test would be more likely to have visual field loss and less likely to be false positives than subjects who missed less than 10 points. Conversely, there would be subjects who would have visual field loss with other testing strategies but who would be false negatives with suprathreshold testing.

Because the 63 bilaterally pseudophakic subjects without definite ocular disease in this study had decreased contrast sensitivity, there is the possibility that they had a retinal disease such as cystoid macular edema, which may not have been detectable with fundus photographs. Ibanez and colleagues[129] evaluated the effect of pseudophakic cystoid macular edema on contrast sensitivity. They found that despite good Snellen visual acuity, subjects with pseudophakic cystoid macular edema could have reduced contrast sensitivity.

Age-related macular degeneration in both eyes was the fifth highest source of severe binocular visual field loss. These women had the worst visual acuity and contrast sensitivity in the better eye compared with other women with severe binocular visual field loss. Given the prevalence of ARMD in the Study of Osteoporotic Fractures population,[93] it was surprising that ARMD did not seem to correlate with more severe binocular visual field loss, since the visual field tested central and peripheral vision. Women with ARMD did lose more points centrally than the other groups. In addition, the frequency of late and early ARMD increased as the binocular visual field worsened ($P < .001$).

A potential limitation of the Study of Osteoporotic Fractures is that the binocular visual field loss was calculated using Esterman's binocular visual field scoring algorithm rather than directly measuring the binocular visual field in each subject. However, because several studies have reported that results from calculated binocular visual fields are consistent with the results from an Esterman binocular visual field test, it is doubtful that this biased the study.[130-132] A limitation that may have confounded this study is that the abnormal suprathreshold visual field tests could not be repeated; subjects without cataracts, glaucomatous optic nerve damage, ARMD, or diabetic retinopathy but with severe binocular visual field loss may thus be false positives. Despite inclusion of these potential false positives in the analyses, an increased risk of frequent falling was demonstrated in women with severe binocular visual field loss compared to those with no binocular visual field loss.

The findings of the current study imply that the majority of severe binocular vision field loss is secondary to treatable ocular diseases (cataracts and glaucoma). Screening for severe binocular visual field loss might, therefore, have the potential for decreasing falls and fall-related injuries if the ocular diseases resulting in the visual field loss are treated. Although there are several risk factors for falls and fractures in older people, poor vision is an important contributor.[71,79-83,133] Because there have been very few studies about which vision interventions reduce falls and fall-related injuries, Lee and Coleman[26] made studying the relationship between treatment of visual problems and falls prevention a high priority in the research agenda for geriatric ophthalmology. Since 33.3% of the women who fell frequently did so due to severe binocular visual field loss—the majority of which was treatable and/or preventable—future research should focus on the potential benefits of screening for binocular visual field loss and referral of patients for appropriate intervention or treatment.

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