Risk of Falls, Injurious Falls, and Other Injuries Resulting from Visual Impairment among Older Adults with Age-Related Macular Degeneration

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Purpose. Age-related macular degeneration (AMD) is the leading cause of irreversible visual impairment among older adults. This study explored the relationship between AMD, fall risk, and other injuries and identified visual risk factors for these adverse events.

Methods. Participants included 76 community-dwelling individuals with a range of severity of AMD (mean age, 77.0 ± 6.9 years). Baseline assessment included binocular visual acuity, contrast sensitivity, and merged visual fields. Participants completed monthly falls and injury diaries for 1 year after the baseline assessment.

Results. Overall, 74% of participants reported having either a fall or a non–fall-related injury. Fifty-four percent of participants reported a fall and 30% reported more than one fall; of the 102 falls reported, 63% resulted in an injury. Most occurred outdoors (52%), between late morning and late afternoon (61%) and when navigating on level ground (62%). The most common non–fall-related injuries were lacerations (36%) and collisions with an object (35%). Reduced contrast sensitivity and visual acuity were associated with increased fall rate, after controlling for age, sex, cognitive function, cataract severity, and self-reported physical function. Reduced contrast sensitivity was the only significant predictor of non–fall-related injuries.

Conclusions. Among older adults with AMD, increased visual impairment was significantly associated with an increased incidence of falls and other injuries. Reduced contrast sensitivity was significantly associated with both increased rates of falls and other injuries, while reduced visual acuity was only associated with increased fall rate. These findings have important implications for the assessment of visually impaired older adults. (*Invest Ophthalmol Vis Sci.* 2011;52:5088–5092) DOI: 10.1167/iovs.10-6644

Older adults have one of the highest injury-related mortality rates[1,2] and have a poorer prognosis and more complications after injury than their younger counterparts,[3] which has significant ramifications for associated health care costs.[4] It has been demonstrated that the risk of unintentional injury, especially resulting from falls, is higher for individuals with visual impairment compared with those with normal vision.[5–7] However, little is known about the relationship between visual impairment and injuries unrelated to falls, such as lacerations and burns.[8]

Of particular relevance are the effects of visual impairment resulting from age-related macular degeneration (AMD) on falls and other injuries, given that AMD is the most common cause of irreversible visual impairment in older adults. Age-related macular degeneration affects a range of visual functions that have been associated with increased fall risk, including visual acuity,[5,9–12] contrast sensitivity,[13] and visual fields.[6,10] There have also been numerous studies that have suggested that AMD is associated with impaired postural stability,[14,15] mobility and gait,[16–19] and a greater physiological fall risk profile.[20] Some of these studies have also demonstrated that visual measures including contrast sensitivity and visual fields[18,19,21] are better predictors of impaired balance and mobility performance in AMD than visual acuity. Despite these associations, only a limited number of studies have explored the relationship between AMD and falls, and none have identified the visual risk factors for falls and injuries specifically in this population.

Although earlier studies failed to find an association between AMD and increased fall risk,[9,22,23] possibly because of insufficient numbers of AMD patients in the study populations, a more recent study reported that the risk of injurious falls was doubled in older women with neovascular AMD compared with age-matched controls.[24] Importantly, the mean best eye visual acuity of the population at baseline was 20/80, representing a relatively advanced level of AMD, and other visual function measures were not reported. It is thus not possible to identify which visual function measures best predicted falls in this population, information that is critical for eye care providers.

In this study we aimed to better understand the prospective injury risk from falls and non–fall–related causes over a 12-month follow-up period in a sample of older adults with a range of levels of visual impairment due to AMD. In particular we were interested in identifying which visual factors best predicted prospective injury and falls in this population.

Methods

Participants

Eighty community dwelling older adults with retinal changes consistent with AMD who had no significant ocular or visual pathway disease leading to visual field loss, other than AMD, were included in the study and have been described in detail elsewhere.[19] Participants were recruited from the School of Optometry Clinic at the Queensland

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University of Technology, via the electoral roll, or from Brisbane-based members of the Macular Degeneration Foundation (Sydney, Australia).

Participants were excluded from the study if they were unable to walk unaided or had a history of Parkinson's disease, diabetes, or peripheral neuropathy. Participants were also screened for cognitive impairment using the Mini Mental State Examination (MMSE).[25] A small number of participants were unable to complete three of the 30 MMSE items due to visual impairment (vision-based items ["CLOSE YOUR EYES"], sentence writing, and design for copy) even with enlarged versions of these items (equivalent to 20/400); for these participants the relevant items were scored as correct.[25,26] Participants with any comorbid eye disease (other than AMD or cataract) were not included in the study.

The research followed the tenets of the Declaration of Helsinki, and informed consent was obtained before participant assessment. The research was approved by the Queensland University of Technology Human Research Ethics Committee.

Vision Assessment

All participants attended a baseline assessment where they underwent an eye examination, including assessment of the presence and severity of lens opacities, using the slit lamp-based Lens Opacities Classification System (LOCSIII),[27] and nonmydriatic, 45° slide photography of the posterior pole using a fundus camera (Canon CR6-45NM; Canon, Tokyo, Japan) to confirm the presence of retinal changes consistent with AMD. The severity of AMD was also independently graded from the fundus slide photographs, according to the AREDS classification scheme.[28] For the purpose of analysis, the highest LOCS score (either nuclear, posterior subcapsular, or cortical) in the eye with the better visual acuity was used as the level of cataract severity.

Binocular high-contrast visual acuity was measured with participants' habitual distance refractive correction using a Bailey-Lovie high-contrast letter chart at a working distance of 3.2 m and an average luminance of 195 cd/m^2. Participants were instructed to guess letters, even when they were unsure, until a full line of letters was incorrectly read. Visual acuity was scored letter by letter (each letter corresponded to 0.02 logMAR units). Contrast sensitivity was measured binocularly using the paper version of the Melbourne Edge Test (MET),[29] at a working distance of 40 cm and an average luminance of 65.5 cd/m^2, with an appropriate near correction. The MET is a four alternative forced-choice edge detection test that measures contrast sensitivity at around 3 c/deg,[29] has excellent test-retest reliability,[30] and has been used in a range of previous studies of vision and falls.[31,32] Participants were asked to identify the orientation of the edge within each circular patch until two consecutive incorrect responses were made, and the lowest contrast edge correctly identified was recorded as the participant's contrast sensitivity in dB.

Visual fields were assessed using the Humphrey Field Analyzer (Model HFA-II 750, Carl Zeiss Meditec, Dublin, CA). Monocular 24-2 SITA-Standard threshold tests were performed by an experienced optometrist. Where required, a large fixation target was used to ensure stable fixation during testing; in some cases where fixation errors were still high, fixation monitoring was disabled, and fixation was continuously monitored visually by the examiner. Field tests were considered reliable if false-positive and false-negative errors were <33%.[33] A binocular mean deviation score was derived by merging the right and left fields to create an integrated binocular visual field, based on the more sensitive of the two eyes at each visual field location[34]; the binocular field was also considered separately as field loss at locations above (superior to) and below (inferior to) the midline. Participants' habitual correction and spectacle type used for walking (e.g., multifocal, single vision, progressive) were also recorded.

Questionnaire

The SF-36 physical function scale was used as a self-reported measure of physical function. This provides an index of general physical functioning and health and has been shown to be an effective and valid health care measure in older community-based populations.[35]

Falls and Injury Diaries

After the baseline assessment, participants were asked to complete a monthly diary that recorded any falls and other injuries experienced over that period and to return the diary in the prepaid envelopes provided. A fall was defined as unintentionally coming to the ground or some lower level not as a result of a major intrinsic event (e.g., stroke) or overwhelming hazard[36]; participants were asked to detail any injuries resulting from any falls. Participants were asked to record which spectacle correction they were wearing at the time of the fall. The non-fall-related injuries included burns or scalds, collision with an object, collision and laceration, eye injury, laceration, lifting and twisting injury, pedestrian accident, or sporting injury. If participants failed to complete their monthly diaries, they were sent reminders by mail and contacted by telephone.

Statistical Analyses

Statistical analyses were performed using commercially available software (SPSS v. 17.0 for Windows; SPSS, Chicago, IL). Because falls accounted for the majority of adverse events incurred in this sample, the events were separated into fall and non-fall-related events for analysis, and injurious falls were also considered separately for comparison. The number of falls, injurious falls, and non-fall-related injuries per participant during the 12-month period were examined using both Poisson and negative binomial regressions, with the Lagrange multiplier test used to test for overdispersion. The distribution of non-fall-related injuries revealed significant overdispersion, and therefore the negative binomial model was used, while falls and injurious falls did not reveal significant overdispersion, and therefore the Poisson model was retained as is recommended.[37] For each outcome measure (falls, injurious falls, and other injuries), each visual function measure (visual acuity, contrast sensitivity, total mean deviation, superior mean deviation, inferior mean deviation) was examined in separate regression models. Separate models were conducted for each visual function measure because the visual measures were so highly correlated as to cause serious multicollinearity if they had been included in a simultaneous model (with correlations of around 0.7-0.8). All analyses controlled for the following potential confounding variables: age, MMSE, sex, physical function, and cataract severity; none of these variables were significantly related to any of the outcome measures in the models.

Results

Of the participants assessed at baseline, three participants did not complete any diaries, and a fourth completed only the first two diaries, and these were therefore not included in the analyses. The final sample consisted of 76 participants (mean age, 77.0 ± 6.9 years; range, 59-95 years) including 34 males (45%) and 42 females (55%). Participants had a range of severity of AMD, in terms of both visual function and their AREDs grades, with more participants exhibiting binocular visual loss and AREDS scores in the mild to moderate rather than the severe categories (Table 1). For the better eye, 24 participants (32%) were pseudophakic, 7 (9%) had a LOCS score of 0, 10 (13%) had a grade of 1, 17 (23%) a grade of 2, 10 (13%) a grade of 3, 7 (9%) a grade of 4, and 1 (1%) a grade of 5.

Overall, 74% (n = 56) of the sample reported at least one fall or injury event during the 12 month follow-up period. Falls were the most common event, with 54% of the participants (n = 41) reporting at least one fall and 30% (n = 23) reporting two or more falls. Seventeen participants reported three or more falls, with the highest incidence being eight during the one year follow-up period. Table 2 shows the characteristics of the reported falls and other injury events sustained by the sample over the follow-up period. Sixty-three percent of the falls (n = 64) resulted in an injury, but only 17% required medical treatment. Most falls occurred outdoors (52% of all

Table 1. Summary of the Visual Characteristics and AREDs Scores of Participants

Vision Characteristic	
Binocular visual acuity, logMAR	
Mean ± SD	0.28 ± 0.4
≤0.3 (20/40), *n* (%)	51 (67.1)
>0.3 (20/40) and ≤1 (20/200), *n* (%)	18 (23.7)
>1 (20/200), *n* (%)	7 (9.2)
Binocular contrast sensitivity, dB	
Mean ± SD	16.61 ± 4.52
≥18 dB, *n* (%)	41 (53.9)
<18 dB and ≥12 dB, *n* (%)	23 (30.3)
<12 dB, *n* (%)	12 (15.8)
Integrated visual fields, mean deviation, dB	
Mean ± SD	−2.79 ± 4.5
≥−2 dB, *n* (%)	44 (57.9)
<−2 dB and ≥−6 dB, *n* (%)	19 (25)
< −6 dB, *n* (%)	13 (17.1)
AREDS score (average of both eyes)	
Mean ± SD	2.32 ± 1.2
Early (<2), *n* (%)	26 (34)
Moderate (≥2 and <4), *n* (%)	35 (46)
Advanced (grade 4), *n* (%)	14 (19)
Missing, *n* (%)	1 (1)

falls compared to 35% indoors and 13% unspecified), between late morning and late afternoon (61%), and overall, falls occurred more often when navigating on level ground (62% of all falls) than when rising or reclining. The main reason reported for a fall was tripping (40%), followed by loss of balance (25%), with misplaced stepping being the least likely reason reported for falling (9%). We also examined whether falls were associated with the use of multifocal spectacles. The use of multifocal spectacles correction did not differ significantly between fallers and nonfallers (57% and 59%, respectively, χ^2 [1] = 0.015, $P = 0.9$), or between multiple fallers and nonmultiple fallers (60% and 52%, χ^2 [1] = 0.433, $P = 0.506$). Interestingly, 21% of those who fell were not wearing their habitual spectacle correction at the time of the fall.

There were 138 non–fall-related injuries, of which lacerations (36%) and collisions with an object (35%) were most common, followed by lifting or twisting injuries, and then burn or scald injuries (Table 2).

Table 3 shows the results of a series of regression analyses predicting falls and injury rates based on each of the visual function measures, controlling for age, MMSE, sex, physical function, and cataract severity. Reduced contrast sensitivity and visual acuity were significantly associated with an increased rate of falls. When only injurious falls were considered, reduced contrast sensitivity and visual acuity were still the only significant visual predictors. However, only reduced contrast sensitivity was significantly associated with an increased rate of other injury events.

Discussion

This study demonstrated among older adults with AMD who were free of ocular disease other than cataract that the presence of increased visual impairment is associated with a higher incidence of prospective falls and injuries recorded over a 12 month follow-up period. Of the visual function measures assessed, reduced contrast sensitivity was significantly associated with an increased rate of both falls and other injuries, while reduced visual acuity was significantly associated only with an increase in falls. Visual field loss within the central 24° was not significantly associated with either falls or other injuries in this sample.

The finding that contrast sensitivity was the strongest visual predictor of falls among older adults with AMD is in accord with previous studies that have demonstrated associations between reduced contrast sensitivity and increased postural sway on foam[14,19] and gait adaptations in older adults with AMD.[18,19,21] The findings also support those of general population studies where fall risk has been shown to be increased in the presence of reduced contrast sensitivity.[13,38] Avoidance of trip hazards and negotiating stairs are likely to be reliant on adequate visual information over a range of spatial frequencies, and hence measures of contrast sensitivity better predicted these adverse events in this population. The finding that reduced contrast sensitivity also predicts the propensity for other injuries is also highly relevant given that older adults in general, regardless of their visual status, have high injury-related mor-

Table 2. Characteristics of Prospective Falls and Injuries Sustained over the 12-Month Follow-up Period

	n	%
All falls	102	100
Injurious falls	64	63
Injury sustained		
Soft-tissue injury	55	86
Fracture	4	6
Head trauma	5	8
Fall location		
Inside		
Inside own home, on the one level	16	16
Inside own home, walking up or down stairs	6	6
Inside but not own home, on the one level	4	4
Inside own home, getting out of a chair	3	3
Inside own home, getting out of bed	2	2
Inside own home, accessing the toilet	2	2
Inside but not own home, accessing the shower/bath	2	2
Inside own home, accessing the shower/bath	1	<1
Outside		
On the one level	16	16
Garden/park/grassed area	10	10
On a footpath	9	9
Of own home, walking up or down stairs	6	6
On the one level	3	3
On a bus/train	2	2
Car park/driveway	2	2
On a step/escalator	2	2
On a curb	2	2
Getting into or out of a vehicle	1	<1
Other	13	13
Cause of fall		
Trip	41	40
Misplaced step	9	9
Slip	16	16
Loss of balance	26	25
Not reported	10	10
Fall time of day		
Night time (6 PM–5:59 AM)	11	11
Early morning (6 AM–10:59 AM)	19	19
Midday (11 AM–2:59 PM)	37	36
Afternoon (3 PM–5:59 PM)	26	25
Not indicated	9	9
Other injuries		
Laceration	49	36
Collision with object	48	35
Lifting or twisting injury	22	16
Burn or scald	12	9
Other	3	2
Sporting injury	1	<1
Eye injury	1	<1
Pedestrian accident	1	<1
Collision and laceration	1	<1

Table 3. Regression Predicting Prospective Falls and Injurious Falls (Poisson) and Other Injury (Negative Binomial) Based on Measures of Visual Function

	Falls (Poisson)			Injurious Falls (Poisson)			Other Injury Events (Negative Binomial)		
	B	Wald χ^2 (1 df)	P	B	Wald χ^2 (1 df)	P	B	Wald χ^2 (1 df)	P
Binocular contrast sensitivity, Melbourne Edge Test, dB	−0.092	13.332	<0.001	−0.081	6.031	0.014	−0.087	4.361	0.037
Binocular visual acuity, logMAR	0.631	6.947	0.008	0.629	4.173	0.041	0.377	0.831	0.362
Binocular visual fields, dB									
Mean defect (total)	0.009	0.123	0.726	0.048	1.675	0.196	−0.012	0.092	0.762
Mean defect (superior)	0.009	0.130	0.719	0.039	1.332	0.249	−0.012	0.111	0.739
Mean defect (inferior)	0.008	0.096	0.757	0.052	1.772	0.183	−0.009	0.052	0.820

Note: All analyses were performed controlling for age, MMSE, sex, physical function, and cataract severity. Each visual function measure was examined in a separate regression to avoid multicollinearity.

tality rates[1] and have a worse prognosis and more complications after injury than their younger counterparts.[3]

Visual acuity was also associated with an increased rate of falls but not with increased risk for other injuries. The role of reduced visual acuity in increased fall risk is not unexpected given previous studies that have shown collectively that those with reduced visual acuity are 1.7 times more likely to have a fall and 1.9 times more likely to have multiple falls compared with those with normal vision.[8] Although more recent general population studies have identified that visual field loss is the strongest visual predictor of falls,[6,7] this was not found to be the case for this sample. This may be because in our sample the participants were free of ocular diseases other than AMD and early cataract and hence had localized central rather than peripheral field loss; in addition, measurement of visual fields in this population tends to be less accurate due to fixation difficulties.[39] It is also important to note that the visual field measures in this study were confined to the central 24° of the visual field rather than in more peripheral locations.

In this study, a high proportion of participants reported a fall during the 12-month follow-up period; 54% reported at least one fall, and 30% reported two or more falls. These rates are higher than those previously reported among general population studies of older adults, which have reported annual fall rates of around 30%[7] and annual multiple fall rates around 16%.[6] Furthermore, our participants reported a mean of 0.84 injurious falls per person-year, which is higher than the rate of 0.37 injurious falls per person-year reported by a previous study of older women with neovascular AMD.[24] It is difficult, however, to directly compare rates between studies given the considerable variations in study designs, fall and injury definitions, and sample populations.

Falls were more common between late morning to late afternoon and on level surfaces, however this may simply be because older adults are more likely to be out and about at this time, and most walking occurs on level surfaces. Falls also tended to occur more often when walking outdoors rather than indoors and were the result of tripping or loss of balance rather than a misplaced step.

When we examined the pattern of non–fall–related injuries, the largest proportion were lacerations, followed by collisions with an object, which is consistent with previous studies that have examined home-based injuries.[2,40] Another study did not report collisions as a separate category, but in accord with our findings reported that lacerations were the most common non–fall–related injury.[41] It is difficult to compare our results with those of studies that report on more serious injuries resulting in hospital admissions or death,[42,43] given that they involved a higher degree of injury severity than that examined in the present study. Comparison of the rates of these falls and other injuries among larger populations of vision impaired and visually normal individuals would be informative.

Collectively, these findings have clinical implications for the management and advice that should be provided to patients with AMD and highlight the potential injury risks that these patients are exposed to in their daily activities, even when most of the sample had mild to moderate rather than severe levels of AMD. Importantly, contrast sensitivity was the strongest predictor of both the rates of falls and other injuries in this population. A larger-scale prospective study is required to establish the levels of AMD severity and visual impairment at which the injury risk begins to increase. An improved understanding of this would help eye care providers to identify at which stage patients should be referred to appropriate rehabilitation specialists for advice regarding modifiable risk factors (shoe wear, floor coverings, physical activity) and interventions, such as hip protectors, which reduce the risk of injury in the event of a fall.[44]

This study has a number of strengths including the use of prospective falls as one of our primary outcome measures, which are now considered the gold standard for recording falls rather than retrospective falls measures.[45] We adopted a similar prospective approach to recording other injury events. Furthermore, the study used a standardized battery of visual function measures that incorporated commercially available instrumentation, allowing replication of the study findings and application in a range of settings. The most important limitation of the study was the relatively small sample size, and future studies should include larger cohorts of patients with varying levels of visual impairment from AMD. Nevertheless, these preliminary findings suggest that reductions in contrast sensitivity are the most important predictors of increased risk of falls and other injuries in this population.

In summary, this study highlights the importance of contrast sensitivity screening among older adults with AMD, using easy-to-administer and reliable contrast sensitivity measures such as the MET. These measures can be performed by appropriately trained personnel in eye and health care settings and will allow clinicians to identify those older adults with AMD who are at risk of future falls and injuries.

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