Determinants of concern about falling in adults with age-related macular degeneration

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Purpose: To investigate the prevalence and level of concern about falling (CF) among older people with vision impairment due to age-related macular degeneration (AMD) compared to a visually normal control group, and to identify determinants of CF for the AMD group.

Methods: Participants included 133 older people: 77 with AMD (mean age = 80.5 ± 6.2 years), and 56 controls (mean age = 75.4 ± 5.3 years). Binocular visual acuity, contrast sensitivity and visual fields were measured, and CF was assessed using the Falls Efficacy Scale – International (FES-I). Data were also collected for sensorimotor function (postural sway, sit-to-stand, knee extensions, walking speed, proprioception), and neuropsychological function (reaction time, symptoms of anxiety and depression) using validated tests and scales.

Results: Concern about falling scores were higher for AMD participants compared to control participants (mean S.D. 24.6 ± 8.0 vs 21.6 ± 5.7, p = 0.02, respectively), although these findings failed to reach significance when adjusted for age (p = 0.16). Among AMD participants, multivariable models showed that greater CF was associated with reduced contrast sensitivity (p = 0.02), slower sit-to-stand times (p < 0.001) and higher anxiety scores (p < 0.001); these factors explained 40% of the variance in CF (p < 0.01).

Conclusion: Levels of CF in older people with AMD were not found to be elevated by their disease status alone, but rather by the extent of vision loss. Levels of CF in those with AMD were associated with various visual, sensorimotor and neuropsychological factors. These findings will assist clinicians in identifying those at greatest risk of developing high CF and inform the design of future intervention programmes for this population.

Introduction

Concern about falling (CF) is an important psychological factor that is frequently associated with falls in older people, and has far-reaching implications including activity restriction, depression, reduced quality of life and paradoxically an increased risk of falls. Between 12% and 65% of community-dwelling populations of older people without a history of falls report some level of CF. Concern about falling is even more common among those who have fallen in the previous year, between 29% and 92%. Around half of older people who report CF subsequently restrict their activities. While the prevalence of CF in older people with vision impairment (VI) is still largely unexplored, it has been reported to be three times higher among those with best corrected visual acuity (VA) equal to or worse than 6/12 (20/40) compared to people with best corrected VA of 6/6 (20/20) or better, with concomitant increases in levels of activity restriction.
A number of risk factors for CF have been identified in general populations, including a history of falls, older age, female gender, impaired balance, reduced physical function, neuroticism, generalised anxiety and depression. Importantly, many of these CF risk factors are prevalent in older people with VI, particularly among those with AMD, which is the most common cause of blindness in the developed world and the most common cause of vision impairment among low vision clinic populations in Australia. Older people with AMD may be more likely to experience significant CF since AMD occurs most commonly in older women, and has been associated with a history of falls and symptoms of depression. Concern about falling may negatively affect participation in daily activities, physical function, risk of falls and quality of life for these individuals. However, the risk factors for CF among VI populations in general, including AMD, are still unclear. Increased prevalence and severity of CF and greater CF-related activity restriction has been linked to more severe glaucomatous visual field loss, while for AMD, CF has been associated with reduced contrast sensitivity and visual acuity. In addition to visual function, associations have been identified between CF and poor balance, poor grip strength and depressive symptoms in older people with VI due to various eye diseases.

Since AMD is the most common cause of vision loss in older people utilising vision rehabilitation services, establishing whether CF is more prevalent among older people with AMD and understanding the associated risk factors is important, given the negative consequences of CF and its likely contribution to the increased demand on health and welfare services. Successful interventions for CF, tailored to older people with AMD, could support individuals in making lifestyle choices and changes that would minimise the risk of developing or worsening CF. Such interventions would take the form of falls prevention programmes (such as balance and exercise programmes to improve overall physical function) aimed at simultaneously addressing CF. In addition, such interventions could reduce the effects of the negative consequences associated with CF, such as activity restriction, depression and reduced quality of life, all of which are found more commonly among this population and create significant obstacles to the goal of healthy ageing.

The aim of this study was to compare the prevalence of CF among older people with AMD with that of a visually normal control group, using the validated and widely used Falls Efficacy Scale – International (FES-I). In addition, the study aimed to identify visual, sensorimotor and neuropsychological determinants of CF in older people with VI due to AMD.

Methods

Participants

Community-dwelling people over 65 years of age with VI due to AMD and a control group with normal vision were recruited from Queensland University of Technology Optometry and Low Vision clinics, private ophthalmology practices and from the local community via media advertising. Participants were excluded if they had any other significant ocular or visual pathway disease except normal age-related cataract changes. Other exclusions were a history of Parkinson’s disease, vestibular dizziness or disease, cognitive impairment or an inability to walk household distances without the assistance of another person. The Montreal Cognitive Assessment (MOCA) Blind was used to screen for cognitive impairment; participants scoring less than 14, which reflects moderate to severe cognitive impairment, were excluded. The research followed the tenets of the Declaration of Helsinki, and informed consent was obtained before participant assessment. The Queensland University of Technology Human Research Ethics Committee approved the research.

Vision assessment

All participants underwent an eye examination, which was performed by an experienced optometrist (UW). This included slit-lamp assessment and grading of lens opacities using the Lens Opacities Classification System (LOCSIII), and retinal examination performed using indirect ophthalmoscopy. Lens opacity scores were dichotomised into no or minimal lens opacities (LOC5 grade of zero to two, including intraocular lenses scored as zero), and moderate to severe (grade of three and higher), based on previous research. Participants were allocated to the AMD and control groups according to the Beckman classification scale based on drusen size, pigmentary abnormalities and presence/absence of geographic atrophy or neovascular AMD. Details were recorded regarding the prescription and type of habitual spectacle correction (e.g., single vision, bifocal, progressive).

Visual acuity was assessed binocularly using an Early Treatment for Diabetic Retinopathy Study (ETDRS) logMAR chart at a working distance of 3 m and luminance of 130 cd m⁻². Participants performed the assessment wearing their habitual distance correction. Testing distance was changed to 1m if a measure of visual acuity could not be obtained at 3m. Participants were encouraged to guess letters with a termination rule of four or more letters named incorrectly and letter-by-letter scoring, with each correctly identified letter scored as −0.02 log units. Contrast sensitivity was measured binocularly using the photographic printed version of the Melbourne Edge Test.
Concern about falling was assessed using the Falls Efficacy Scale – International (FES-I). The FES-I assesses CF across 16 common daily living activities (such as getting dressed, shopping and using stairs), using a four-point scale (1 = not at all concerned to 4 = very concerned). The score is determined by summing all responses, with higher scores indicating higher levels of CF (range 16–64). A score of 23 was classified as a high level of CF, and a score of ≥28 was classified as a very high level of CF, as used in community-dwelling older people. The FES-I has excellent psychometric properties and internal reliability (Cronbach’s alpha values of 0.96), with high test-retest reliability (0.96) and validity.

Health, demographic, and falls history
Demographic information was collected, including age, gender, years of education and current medications. Participants were asked to self-rate their balance on a 5-point response scale (poor to excellent), and to report how many falls they had experienced in the 12 months prior to entering the study, along with any injuries they had suffered as a result of these falls.

Sensorimotor assessment
Functional lower limb performance was assessed using the five times sit-to-stand test. Participants began seated and were instructed to rise to standing without the aid of their arms. The time taken to stand up and sit down five times was measured in seconds. Lower limb strength was assessed by measuring the isometric quadriceps strength (knee extensor muscles) in the dominant leg, using a spring gauge dynamometer. Participants were seated with the hip and knee joints positioned at 90 degrees and the spring gauge strap attached above the ankle. Participants were asked to push their dominant lower leg out as hard as they were able, and a strength measurement (in kg force) obtained; a mean value was calculated from three measurements.

Postural sway was measured while standing on a foam surface with the eyes open. Participants were positioned on a force platform (Hurlabs, www.hurlabs.com/), and instructed to stand as still as possible for a period of 30 s; the centre of pressure trace length was measured in mm. Participants wore their habitual distance correction and were instructed to look straight ahead towards a high contrast 20 × 30 cm distance fixation target during the test. Participants’ self-selected walking speed was measured along a 23 m, well-lit, indoor walkway with no obstructions, and recorded in m s⁻¹. Participants were instructed to walk to the far end of the corridor, touch the wall at the end, and immediately return to the starting point. Time taken was recorded in seconds using a stopwatch.

Neuropsychological assessment
Cognitive status was assessed using the MOCA-Blind; this measure is widely used as a screening tool in VI populations; the maximum possible score is 22. Simple hand reaction time was assessed using a hand-held electronic timer in the form of a modified computer mouse. Participants were seated during the test and asked to press the button on the mouse as soon as they observed the appearance of a bright LED light. After five practice tests, 10 measurements were recorded, and an average score calculated in seconds. Depressive symptoms were evaluated using the Patient Health Questionnaire-9 (PHQ-9), a validated measure used widely in previous research, including VI populations, higher score indicates more severe depression. Symptoms of anxiety were assessed using the Geriatric Anxiety Inventory (GAI), a well-validated measure, designed specifically for use in older people; higher scores indicate higher levels of anxiety.

Statistical analysis
Statistical analyses were performed using SPSS v25 software (www.ibm.com/uk-en/products/spss-statistics), and the
level of significance was set at \( p < 0.05 \). Descriptive statistics were used to report means and standard deviations of demographic, CF, visual, sensorimotor and neuropsychological data. Group differences between the AMD and control group for the FES-I, vision and other measures were assessed using linear regression models, unadjusted and adjusted for age given that there was a significant between group differences in age. Adjustment for multiple comparisons was not performed, given the exploratory nature of the research.\(^{42}\)

To explore the determinants of CF in the AMD group, the associations between CF (FES-I scores), visual function and other measures were examined using univariable linear regression analysis. The single variable most strongly correlated with FES-I score was then selected from each category of tests (vision, sensorimotor and neuropsychological), and entered into a multivariable regression analysis using forced entry to establish the relative contribution of each measure. This approach has been used in previous research,\(^{33,34}\) and was selected to avoid issues of overfitting (model optimism) and multicollinearity between the various predictor variables.

Several variables had missing data due to poor physical function of some participants, which limited their ability to perform the sit-to-stand and balance tests. These missing values were substituted with +3 S.D. for the group, to reflect poor performance; this comprised less than 10% of the participants. There was also missing data for visual field tests for three AMD participants, as they were considered unreliable based on visual field reliability indices; multiple imputation was used to calculate substitute values. The multiple imputation analysis for the missing visual field data was conducted in SPSS, using 10 imputed data sets from an imputation model using age, binocular contrast sensitivity, binocular visual acuity and the remaining visual field measures. Analyses on the imputed datasets were pooled based on Rubin’s rules.\(^{45}\)

**Results**

Participants included 77 older people with AMD (mean 80.5 ± 6.2 years) and 56 control participants (mean 75.4 ± 5.3 years). Characteristics of the study participants are shown in Table 1, and the range of Beckman classifications is presented in Table 2. The AMD group had significantly poorer visual function than the controls on all measures (\( p < 0.001 \)). Most participants in the AMD group were classified as having intermediate to late AMD. There were no differences in the proportion of participants with significant lens opacities in the better eye between groups (\( p = 0.16 \)). Participants with AMD were slightly older than the controls (80.5 ± 6.2 vs 75.4 ± 5.3, \( p < 0.001 \)), but the two groups did not differ significantly for any of the other health and demographic variables. There was a trend towards a higher likelihood of previous falls in the AMD group (\( p = 0.07 \) unadjusted; \( p = 0.05 \) adjusted). Similarly, a trend for poorer self-reported balance was identified for the AMD group, with 34 (44%) rating their balance as fair or poor, compared to 13 (23%) of the control group (\( p = 0.01 \) unadjusted; \( p = 0.08 \) adjusted).

Mean FES-I score for the AMD group was 24.6 ± 8.0 compared to a mean of 21.6 ± 5.7 for the control group, which was not significantly different after adjustment for age (unadjusted \( p = 0.02 \); adjusted \( p = 0.16 \)). 44% of AMD participants (\( N = 34 \)) expressed high levels of CF (FES-I ≥ 23) compared to 27% of control participants (\( N = 15 \)) (unadjusted \( p = 0.04 \); adjusted \( p = 0.11 \)). Similarly, a higher proportion of the AMD group (\( N = 25 \); 32%) reported very high CF (FESI ≥ 28) when compared to the control group (\( N = 10 \); 18%), but this difference was not significant (unadjusted \( p = 0.06 \); adjusted \( p = 0.19 \)).

In the unadjusted analyses, there were significant differences in physical performance measures between the two groups. The AMD group were slower on both sit-to-stand (unadjusted \( p = 0.02 \)) and habitual walking speed (\( p < 0.001 \)) assessments, and obtained lower scores for knee extension strength (unadjusted \( p = 0.03 \)) and longer trace lengths for postural sway (unadjusted < 0.001). However, none of these differences remained significant after adjustment for age. The AMD group had significantly slower reaction times than the control group (unadjusted \( p < 0.001 \); adjusted \( p = 0.003 \)). Symptoms of depression were significantly more common among AMD participants, even after adjustment for age (unadjusted \( p = 0.007 \); adjusted \( p = 0.03 \)). No significant difference was found between the groups for anxiety symptoms or cognitive impairment scores, adjusted or unadjusted.

For the AMD participants, univariable regression with FES-I scores was undertaken for all vision, sensorimotor and neuropsychological measures (see Table 3). Impaired visual function as assessed with all of the vision measures was significantly associated with higher FES-I scores (all \( p < 0.05 \)), with contrast sensitivity demonstrating the strongest association with FES-I scores (\( p = 0.002 \)). Of the sensorimotor measures, slower sit-to-stand, slower habitual walking speed and lower knee extension strength were significantly associated with higher FES-I scores, with the five times sit-to-stand test demonstrating the strongest associations (\( p < 0.001 \)). Higher levels of both anxiety and depression symptoms were also significantly associated with higher FES-I, with anxiety being the stronger of the two (\( p < 0.001 \)).

The tests that were most strongly associated with FES-I scores in the univariable regression from each of the vision, sensorimotor and neuropsychological categories (contrast sensitivity, sit-to-stand, GAI anxiety) were entered into a
multivariable regression analysis. Results are shown in Table 3. All three factors were independent predictors of CF, with anxiety being the strongest predictor. The final model explained 40% of the variance in FES-I scores ($R^2 = 0.40, F_{3,73} = 16.02; p < 0.01$).

**Discussion**

This study investigated levels of CF among a group of older people with mild to moderate levels of VI due to AMD compared to a visually normal control group, and demonstrated that CF was not significantly different between groups after adjustment for age. However, in further analysis for AMD participants, reduced contrast sensitivity, slower sit-to-stand time and more symptoms of anxiety were significant determinants of CF in multivariable analysis. Importantly, these findings demonstrate the holistic nature of CF, which can be associated with reduced vision function, sensorimotor and neuropsychological factors.
Concern about falling in macular degeneration

Table 2. Age-related Macular Degeneration (AMD) grading (Beckman classification) for AMD (n = 77) and control participants (n = 56)

| Beckman classification | Better eye n (%) | Worse eye n (%) |
|------------------------|------------------|----------------|
| Normal or no ageing    | AMD (6%)         | Control (100%) |
| Early AMD              | AMD (6%)         | Control (100%) |
| Intermediate AMD       | 18 (23%)         | 10 (13%)       |
| Late AMD               | 45 (58%)         | 62 (81%)       |
| Missing†               | 3 (4%)           | 3 (4%)         |
| Total                  | 77 (100%)        | 77 (100%)      |

†Data not obtained for 3 participants whose physical status prohibited slit-lamp examination. All 3 had longstanding diagnoses of bilateral AMD from their treating ophthalmologist, with significant bilateral vision loss and binocular visual acuities of worse than 0.30 logMAR.

AMD participants had higher levels of CF when compared to the control group; however, this difference was not significant after adjustment for age, indicating that levels of CF in those with AMD do not differ strongly from those found among sighted peers. Similarly, a previous study found no significant differences in levels of CF between a cohort of older people with AMD with mild to moderate vision loss and a visually normal control group.²² Collectively, these findings suggest that ocular disease status alone does not significantly affect levels of CF, but rather it is the severity of vision loss associated with the disease that affects CF levels.

In the current study, a higher proportion of the AMD group reported retrospective falls when compared to the control group (34% vs 20%); however, this difference did not quite reach statistical significance in either the adjusted or the unadjusted analysis. When compared to previous studies, the number of falls reported in the current study was relatively low for both AMD participants (34% in the current study vs 54% respectively) and controls (20% vs 32%).⁴⁶ This is not surprising, since the previous studies used prospective falls recording methods, rather than the retrospective recording of falls undertaken in the current study. Retrospective recall of falls is poor among older people; thus the levels recorded in this study were likely lower than actual falls rate.⁴⁷

For the AMD participants, contrast sensitivity was the visual function most strongly associated with CF, to a greater extent than visual acuity and visual fields. These findings concur with those of Van Landingham et al.,²² who reported that contrast sensitivity demonstrated the strongest association with CF levels, with weaker associations between CF and visual acuity for a group of older people with AMD.²² Similarly, Wang et al. reported associations between higher levels of CF-related activity restriction and reductions in contrast sensitivity among older people with AMD.¹⁰ Contrast sensitivity has previously been identified as the visual function measure best associated with gait changes, falls, and injurious falls in older people with AMD.¹⁸,²²,⁴⁸ Negotiation of obstacles, such as steps, curbs or detection of uneven surfaces requires interpretation of information over a wide range of spatial frequencies which

Table 3. Univariable associations between Falls Efficacy Scale—International (FES-I) scores with vision, sensorimotor and neuropsychological measures for the Age-related Macular Degeneration (AMD) participants (n = 77)

| Vision variables                  | Correlation | p       | Model Standardised β† | p       |
|-----------------------------------|-------------|---------|------------------------|---------|
| Binocular contrast sensitivity    | −0.34       | 0.002   | −0.23                  | 0.02    |
| Binocular visual acuity           | 0.23        | 0.04    |                        |         |
| Binocular mean deviation 30-2     | −0.29       | 0.009   |                        |         |
| Central visual field              | −0.32       | 0.004   |                        |         |
| Sensorimotor variables            |             |         |                        |         |
| Five times sit-to-stand           | 0.40        | <0.001  | 0.31                   | 0.001   |
| Knee extension strength           | −0.27       | 0.02    |                        |         |
| Habitual walk speed               | −0.30       | 0.008   |                        |         |
| Postural sway: trace length       | 0.15        | 0.18    |                        |         |
| Neuropsychological variables      |             |         |                        |         |
| GAI Anxiety†                      | 0.47        | <0.001  | 0.41                   | <0.001  |
| PHQ-9                             | 0.41        | <0.001  |                        |         |
| Depression§                       | 0.13        | 0.25    |                        |         |
| MOCA Blind§                       | −0.07       | 0.52    |                        |         |
| Reaction time                     |             |         |                        |         |
| Demographics                      |             |         |                        |         |
| Age                               | 0.21        | 0.07    |                        |         |
| Gender                            | 0.07        | 0.56    |                        |         |

†The multivariable model included one variable from each of the three categories. Bold values indicate significant values.

²²Final Model $F(3,73) = 16.02, R² = 0.40.$
²²Geriatric Anxiety Inventory.
²²Patient Health Questionnaire-9.
²²Montreal Cognitive Assessment Blind.
would be compromised in those with reduced contrast sensitivity. Thus, reductions in contrast sensitivity may be associated with a higher risk of falling, and in turn higher levels of CF.

The AMD and control participants exhibited similar levels of sensorimotor function, which is surprising, given that high levels of activity restriction and sedentary behaviour have previously been reported among older people with VI, which typically results in poorer physical function.49,50 After adjustment for age, the two groups performed similarly on sit-to-stand, knee extension, habitual walking speed and proprioception; these measures provide a good overall indication of physical function, as well as lower extremity and central strength.51,52 Similarly, no significant differences were found for self-reported or objective measures of balance.

For the AMD participants, CF was associated with all sensorimotor measures (slower sit-to-stand time, lower knee extension strength and slower habitual walking speed), which supports previous research in VI populations. Van Ladingham et al.22 identified significant associations between higher levels of CF and poorer grip strength in multivariable modelling,22 while results from another study indicated that CF had a mediating effect on the association between decreased contrast sensitivity and lower levels of physical activity measured with accelerometers.53

The significant associations between physical performance and CF are particularly relevant, given the high levels of activity restriction and increased sedentary behaviour reported previously among older people with VI which predispose them to physical decline.49,50 The finding that CF was not significantly associated with postural sway for this population is interesting, since balance has been associated with CF in non-VI populations.24,55 To date, no other research has investigated the association between postural sway and CF for older people with VI.

Symptoms of depression were significantly more common among AMD participants when compared to controls, while no difference was found for symptoms of anxiety. For AMD participants, higher levels of both anxiety and depression symptoms were associated with CF. These findings support previous studies that have consistently found higher levels of depression among older people with AMD, with mixed findings regarding anxiety.26-58 Furthermore, the associations between higher CF and higher levels of anxiety and depression found in the current study also supports previous studies. Among a population of VI older people including AMD, glaucoma and Fuchs corneal dystrophy, symptoms of depression measured with the Geriatric Depression Scale (GDS) were significantly more common among those who reported CF related activity restriction.10 Similarly, for a general population, associations were identified between CF and symptoms of depression measured with the GDS.34 These associations between CF and anxiety and depression are important given the significantly higher levels of anxiety and depression previously identified among older people with AMD.6,56-58; this serves to highlight CF as a significant issue for this population.

In univariable modelling, contrast sensitivity, sit-to-stand and anxiety levels were identified as the strongest determinants of CF, with each factor being independently associated with CF in the multivariable model. These findings highlight the multifactorial nature of CF, which is in support of findings from non-VI populations of older people.11 This indicates that successful interventions to reduce CF among older people with AMD should include an exercise component to reduce declines in physical function and psychological support to manage anxiety and depression, in addition to vision rehabilitation strategies, which can help minimise the effects of vision loss on daily function. Evidence from general populations indicates that exercise interventions can help to manage CF;59 such programmes need to be carefully tailored to VI populations to avoid increasing the incidence of falls because of increased exposure.60 To date, one study has been successful in safely piloting an exercise programme for VI older people, with further research required to establish the effects of the programme on levels of CF.23

The strengths of this study were the incorporation of a range of well-established and standardised measures of vision, sensorimotor, and neuropsychological function to explore the relationship with measures of CF, through use of a validated instrument used widely in previous research. The study was limited, however, by a relatively small sample size. A further limitation is that the control group was significantly younger than the AMD group, with adjustments made to analyses to address this age difference. Older people with more severe vision loss due to AMD were under-represented in the study, making it likely that the findings underestimate CF levels within this population more broadly. Similarly, it is likely that the study sample under-represented individuals with poor physical function, which could explain the low number of retrospective falls reported by both participant groups. A larger study would allow for more extensive investigation of a broader range of determinants of CF, including sensory declines in hearing and vestibular function, while a study design involving collection of data during planned visits to low vision clinics may improve access for those with more severe VI, resulting in a more representative sample.

Conclusion

In summary, this study demonstrated that reductions in contrast sensitivity, increased symptoms of anxiety and
slower sit-to-stand times are associated with higher levels of CF among older people with mild to moderate levels of VI due to AMD. The finding that there was no significant difference in the levels of CF between participants with AMD and visually normal controls suggests that it is reductions in visual, sensorimotor and neuropsychological function, rather than disease status, which increase the risk of high levels of CF. Identification of the key determinants of CF among older people with AMD in this study provides information to assist clinicians in identifying those at greatest risk of developing high CF, and will inform the design of future intervention programmes for this population.

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Conflict of interest

The authors report no conflicts of interest and have no proprietary interest in any of the materials mentioned in this article.

Author contributions

Ursula Ellen White: Conceptualization (lead); Data curation (lead); Formal analysis (equal); Investigation (lead); Methodology (lead); Project administration (lead); Writing-original draft (lead); Writing-review & editing (lead). Alex Black: Conceptualization (supporting); Formal analysis (equal); Investigation (equal); Methodology (equal); Supervision (lead); Writing-original draft (supporting); Writing-review & editing (supporting). Kim Delbaere: Conceptualization (supporting); Formal analysis (equal); Investigation (equal); Methodology (equal); Supervision (supporting); Writing-original draft (supporting); Writing-review & editing (supporting). Jo Wood: Conceptualization (supporting); Formal analysis (supporting); Investigation (equal); Methodology (equal); Supervision (supporting); Writing-original draft (supporting); Writing-review & editing (supporting).

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