Visual Impairment and the Incidence of Falls and Fractures Among Older People: Longitudinal Findings From the Blue Mountains Eye Study

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PURPOSE. We assessed the impact of visual impairment on the incidence of falls and fractures in older persons.

METHODS. Of 3654 baseline participants, 2334, 1952, and 1149 were re-examined after 5, 10, and 15 years. Presenting visual acuity (VA) was measured at each examination. Bilateral and unilateral visual impairment was defined as VA worse than 20/40 in the better and worse eye, respectively. Incident visual impairment was defined in eyes with VA 20/40 or better at baseline, which subsequently developed visual impairment. Incidence of falls was assessed over the 12 months before each visit, whereas incidence of fractures was assessed over the 5 years between two visits. Discrete logistic-regression models with time-dependent variables were used to assess associations between visual impairment and subsequent falls and fractures after adjusting for potential confounding variables.

RESULTS. The proportions of participants reporting ≥2 falls ranged between 10% and 14%, and proportions reporting fractures ranged between 12% and 21%, across the three follow-up visits. Participants with incident visual impairment were more likely to report ≥2 falls in 5 years, OR (odds ratio) 1.46, 95% confidence interval (CI) 1.04 to 2.04 (bilateral), and OR 1.22, 95% CI 0.98 to 1.51 (unilateral). Compared to participants with normal vision, those with incident unilateral visual impairment had a higher incidence of fractures over 5 years (OR, 1.27; 95% CI, 0.98–1.51). No increased incidence of falls or fractures was evident after 5+ years among participants with visual impairment.

CONCLUSIONS. In this older cohort, recent development of visual impairment was associated with increased likelihood of subsequent falls and fractures in the next 5 years, independent of other confounding variables.

Keywords: visual impairment, falls, fractures

In this report we aimed to assess the impact of bilateral and unilateral VI, and the duration a person lived with VI, on subsequent falls and fractures over 5- and 10-year periods in a population-based cohort of older Australians, the Blue Mountains Eye Study (BMES).

METHODS

Study Population

The BMES is a population-based study of vision and common eye diseases in a suburban Australian population 49+ years, residing in the Blue Mountains area, west of Sydney, Australia. Detailed methods of the baseline survey were reported previously.30 In brief, at baseline we recruited and examined 3654 participants between 1992 and 1994. Survivors of baseline participants were invited to participate in the 5-, 10-, and 15-year follow-up examinations. Of those, 2334 returned after 5 years (75.8% of survivors), 1952 after 10 years (76.5% of survivors), and 1149 after 15 years (56.1% of survivors).
the period between the 10- and 15-year visits, 496 had died, leaving in 2048 eligible participants. A total of 899 participants had moved or refused to return for examination.

All BMES visits were approved by the Human Research Ethics Committees of the University of Sydney and the West Sydney Area Health Service, and were conducted adhering to the tenets of the Declaration of Helsinki. Signed informed consent was obtained from all participants at each examination visit.

**Measures**

At each visit, the visual acuity (VA) of each eye was measured using a logMAR and modified Early Treatment Diabetic Retinopathy Study (ETDRS) methods. Visual impairment was defined as presenting VA worse than 20/40 (39 letters or less read), and severe VI (blindness) was defined if VA was worse than 20/200 (4 letters or less read). An eye was at risk of developing VI if VA was 20/40 or better, or at risk of developing blindness if VA was 20/200 or better at baseline. Incident bilateral VI was defined as developing VI in one or both eyes of participants who had at least one eye at risk of developing VI at baseline. The severity of bilateral VI was defined according to VA of the better eye at the latest follow-up visit. Incident unilateral VI was defined as VA worse than 20/40 (39 letters or less read) in the worse eye when both eyes were at risk of developing VI at baseline. Best-corrected VA also was measured at each examination by means of subjective refraction at each examination.

Participants were asked the following question to determine the occurrence of falls over a 12-month period before the study examination; “During the past 12 months, have there been any falls where you have landed on the ground or floor?” If the response was yes, additional questions were asked, including how many falls they had suffered. We determined the incidence of falls over a 12-month period before each visit among all participants who were examined at the visit.

Participants were asked the following question at the 5-, 10-, and 15-year follow-up visits to determine the incidence of fractures over a 5-year period between the visit when VI was detected and the subsequent visit after VI was detected; “Have you broken or fractured a bone since the last examination?”

In addition, a comprehensive interview-administered questionnaire was conducted detailing sociodemographic characteristics, past histories of angina, acute myocardial infarct, stroke, arthritis, hypertension, diabetes, the presence of a walking disability (the use of a cane, crutch, walking frame or wheelchair), and any hospital admissions (at least overnight) in the 12 months before each visit.

**Statistical Analysis**

The SAS 9.2 software (SAS Institute, Cary, NC, USA) was used for statistical analyses. Discrete logistic models (PROC PHREG) with time-dependent study (VI) and outcome (any falls and fractures) variables, were used to assess associations between VI and subsequent falls and fractures. The incidence of falls was categorized into 2 groups; persons who reported 2 or more falls versus persons who reported one or no falls. The incidence of fractures also was categorized into 2 groups; any fractures versus no fracture.

Persons with incident VI detected at each visit were assessed for falls and fractures at subsequent visits with a 5-year interval. This analysis used discrete logistic regression model and time-dependent variables to include VI detected at 5-year follow-up and outcome events reported at 10-year follow-up, and VI detected at 10-year follow-up and outcome events reported at 15-year follow-up visits. Persons with bilateral and unilateral VI were compared to persons without VI in either eye over the 15-year follow-up period.

Logistic regression models (PROC LOGISTIC) were used to assess the associations between incident bilateral or unilateral VI detected at the 5-year follow-up and subsequent falls and fractures at the 15-year follow-up visit (a 10-year interval). As falls were self-reported events, the exact time when each event occurred was not known, and events that occurred during the follow-up period, but outside the 12-month period before the follow-up visit could have been omitted. Therefore, we used dichotomous variables (had or did not have) for fall and fracture outcomes, and logistic regression models to assess the longitudinal associations.

All models were adjusted for potential confounding variables known to be associated with having a fall or fracture, including the presence of a walking disability, home ownership, living arrangements, cataract surgery within the follow-up period, having 3 or more comorbidities (angina, acute myocardial infarct, stroke, arthritis, hypertension, and diabetes), use of medications that could result in falls or fractures (tranquilizer, sedatives, and antidepressants), bifocal/multifocal spectacle correction, and having any hospital admissions over the 12 months before the visit when VI was detected. We used a $P$ value < 0.05 as the selection criterion for variables to be included in the final parsimonious, multivariable models, unless variables needing to be adjusted for based on content knowledge. We cross-checked all variables excluded from the final models and confirmed that each of these variables did not change the association between VI and the outcome variables by more than 10%. Supplementary analysis using best-corrected VA measured after subjective refraction in place of presenting VA also was performed. Odds ratios (OR) and 95% confidence intervals (CI) are presented.

**Results**

Baseline characteristics by the presence or absence of self-reported ≥2 incident falls or self-reported fractures at any follow-up visit (5-, 10-, and 15-year) are presented in Table 1. Compared to participants without subsequent events of ≥2 falls or fractures, those with ≥2 falls were more likely to be women, to have had a hospital admission within the last 12 months before baseline visit, to live alone, and have a walking disability at baseline. Participants with subsequent fractures were more likely to be women and to have had a hospital admission within the last 12 months before baseline. The proportion of persons reporting ≥2 falls at the 5-, 10-, and 15-year follow-up examinations was 10.4%, 13.9%, and 10.4%, respectively, and the corresponding proportion of persons reporting a fracture was 20.9%, 13.2%, and 11.6%, respectively.

**Baseline VI and Subsequent Falls and Fractures Reported at the 5-Year Follow-up Visit**

At baseline, bilateral VI was detected in 397 persons (10.9%) and unilateral VI was detected in 1075 (29.4%) persons, of which 150 and 535 had complete data at the 5-year follow-up. Two or more falls in the year before the 5-year follow-up visit were reported by 16.0% and 14.2% of participants with bilateral and unilateral VI at baseline, respectively, compared to 9.72% of those without VI in either eye at baseline (adjusted OR, 1.46; 95% CI, 0.86–2.47, and OR, 1.37; 95% CI, 0.59–1.44 for persons presented with bilateral and unilateral VI at baseline, respectively). History of fractures in the past 5 years was reported at the 5-year follow-up by 26.0% and 27.1% of baseline participants with bilateral and unilateral VI, respectively, compared to 19.8% of participants who had no VI in...
either eye at baseline (adjusted OR, 0.94; 95% CI, 0.61–1.44) and OR, 1.29; 95% CI, 1.00–1.67 for persons with bilateral and unilateral VI at baseline, respectively; Table 2).

### Incident VI, and Subsequent Falls and Fractures Within 5-Year Intervals

Of the 2799 persons without VI at baseline, 81 developed bilateral VI at any follow-up visit (5-, 10-, or 15 years). Due to small numbers of incident bilateral blindness at all follow-up visits, incidence of bilateral and unilateral blindness was grouped together as incidence of any blindness, and was found in 69 persons over the 15-year follow-up period.

Persons with incident bilateral VI during the follow-up period were more likely to report ≥2 subsequent falls in 5 years (adjusted OR, 1.46; 95% CI, 1.04–2.04), but were not more likely to report a subsequent fracture (adjusted OR, 1.07; 95% CI, 0.77–1.50; Table 3).

Persons with incident unilateral VI during the follow-up period also were more likely to report ≥2 subsequent falls in 5 years (adjusted OR, 1.22; 95% CI, 0.98–1.51), although this association was marginally nonsignificant. In addition, they were significantly more likely to report a subsequent fracture in 5 years (adjusted OR, 1.27; 95% CI, 1.04–1.55).

Supplementary analyses using best-corrected VA measured after subjective refraction in place of presenting VA did not significantly change the associations between incident bilateral and unilateral VI and subsequent report of ≥2 falls or fractures in 5 or less years (data not shown).

Persons with incident blindness (unilateral or bilateral) during the follow-up period were not more likely to report ≥2 falls or a fracture in 5 years (adjusted OR, 0.99; 95% CI, 0.35–2.77 and OR, 0.71; 95% CI, 0.25–1.98, respectively).

### Incident VI, and Subsequent Falls and Fractures in More Than 5 Years

Persons with incident bilateral VI detected at the 5-year follow-up visit were not more likely to report ≥2 subsequent falls or a fracture in 10 years; that is, at the 15-year follow-up visit (OR, 1.10; 95% CI, 0.45–2.69) and OR, 1.27; 95% CI, 0.53–3.06 for long-term incident falls and fracture, respectively; Table 3). There were only 2 persons with incident blindness at the 5-year follow-up (n = 2), and, therefore, the association between incident blindness and incident falls or fractures over 10 years was not assessed.

### Discussion

We found that older persons who developed bilateral or unilateral VI during the follow-up period (had experienced VI recently) were more likely to report ≥2 falls within 5 years of VI being detected, compared to persons who remained free of VI over the same follow-up period. However, this association diminished after 5 or more years. While incident bilateral VI was not associated with subsequent self-reported fracture at any point in time, incident unilateral VI was associated increased likelihood of subsequent self-reported fractures in 5 years, after adjusting for potential confounders.

The lack of positive association between incident bilateral VI and subsequent fractures could have been a result of insufficient study power due to relatively small numbers.

Our finding of longitudinal association between VI and subsequent falls complement previous cross-sectional findings from the baseline examination of the same population, which also reported an increased likelihood of reporting ≥2 falls during the 12-month period before the study baseline (OR, 1.4; 95% CI, 1.1–2.0) among persons with mild VI (VA 20/40–20/60) at baseline. The nonsignificance of the longitudinal association between baseline VI and self-reported falls at the 5-year follow-up examination found in this current study may be due to the fact that some of these baseline participants had been living with VI for a long duration, as we do not have information about when VI developed before the baseline examinations for these participants.

Similar observations were reported by other population-based, cross-sectional studies of older people, including the Shihpai Eye Study (OR, 2.0; 95% CI, 1.0–4.3) and the Singapore Malay Eye Study (OR, 1.3; 95% CI, 1.0–1.6). However, a clinic-based study by Lamoureux et al. did not

### Table 2. Associations Between Baseline Bilateral or Unilateral VI and Subsequent Falls (≥2) and Fractures Reported at the 5-Year Follow-Up Examination, Shown as OR With 95% CI

<table>
<thead>
<tr>
<th>Baseline Visual Impairment Status</th>
<th>n (% Subjects Reporting ≥2 Falls at the 5-Year Follow-Up)</th>
<th>OR* (95% CI)</th>
<th>P Value</th>
<th>n (% Subjects Reporting a Fracture at the 5-Year Follow-Up)</th>
<th>OR* (95% CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bilateral, n = 150</td>
<td>24 (16.0)</td>
<td>1.46 (0.86–2.47)</td>
<td>0.16</td>
<td>39 (26.0)</td>
<td>0.94 (0.61–1.44)</td>
<td>0.77</td>
</tr>
<tr>
<td>Unilateral, n = 535</td>
<td>76 (14.2)</td>
<td>1.37 (0.98–1.90)</td>
<td>0.07</td>
<td>145 (27.1)</td>
<td>1.29 (1.00–1.67)</td>
<td>0.05</td>
</tr>
<tr>
<td>Male, n = 982</td>
<td>89 (9.1)</td>
<td>1.03 (0.63–1.75)</td>
<td>0.12</td>
<td>149 (15.2)</td>
<td>0.51 (0.41–0.64)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Walking disability, n = 74</td>
<td>24 (32.4)</td>
<td>0.58 (0.34–2.44)</td>
<td>0.45</td>
<td>24 (32.4)</td>
<td>1.29 (0.77–2.17)</td>
<td>0.33</td>
</tr>
<tr>
<td>3+ Co-morbidities, n = 154</td>
<td>19 (12.3)</td>
<td>3.32 (1.97–5.59)</td>
<td>&lt;0.01</td>
<td>34 (22.1)</td>
<td>0.95 (0.64–1.43)</td>
<td>0.81</td>
</tr>
</tbody>
</table>

* Adjusted for age, sex, presence of a walking disability, 3 or more co-morbidities.
find significant cross-sectional associations between falls and VI, contrast sensitivity, stereopsis, or visual field loss. A review by Ambrose et al.31 on risk factors of falls among older persons reported that older persons at high risk of falls were more frail, more likely to have other comorbidities and mobility problems, all that could have reduced their physical activities and, therefore, might also reduce the chance of falls.31

Previous longitudinal reports from the Auckland Hip Fracture Study56 showed an increased risk of hip fractures in 2.5 years (OR, 1.3; 95% CI, 1.0–1.8) among persons with VA < 20/30 in at least one eye. A study by Javitt et al.29 found that progressive vision loss in the better eye was associated with an increased risk of injury over a 4-year follow-up period. These previous findings support our observations of a short- to mid-term association between unilateral VI and fractures, that is, persons with baseline and incident unilateral VI had approximately a 30% increased risk of fractures in subsequent 5 years, but not 10 years. The significant associations found between unilateral, but not bilateral VI and risk of fractures in this report may be due to the deficiency in stereo acuity among unilateral VI cases that affects depth perception needed for navigating.17,56

The Framingham Study28 reported a nonsignificantly increased risk of fractures over a 10-year period retrospectively (adjusted relative risk [RR] 1.5; 95% CI, 0.95–2.5) among persons with moderate VI in at least one eye (VA 20/50–20/80). In contrast, we found weakening or no associations between VI and falls and fractures over the long-term. There are many potential reasons that may explain a diminishing risk of falls and fractures associated with VI over the long-term. Individualized rehabilitation programs may have been implemented that addressed the potential risk of further falls.37 Admission to aged-care facilities, when older people became frail and had developed other comorbidities and disabilities, could have led to a selection bias in this surviving cohort sample. This also may explain our failing to detect the associations over the long-term.

Strengths of our study include its large population-based sample with reasonable follow-up rates and the use of standardized methods to assess VA. We have specified incidence, duration and a clear temporal relationship. Limitations include the inability to adjust for all confounding variables that may influence the risk of falls or fractures. Relatively small number of participants with bilateral VI at each follow-up visit may have limited the power of our study. A major limitation is survival bias. Persons who did not attend follow-up visits could have been frailer, had more comorbid conditions including VI, and, thus, would have had more falls or fractures than persons who did attend, resulting in an under-reporting event rate of falls and fractures and potential underestimation of the associations. Additionally, falls and fractures were self-reported and could have been subject to recall bias.39 The causes of fractures were not confirmed by radiology reports or hospital discharge summaries.

Previous studies have consistently shown that visual field loss is associated with an increased risk of falls.39–41 Visual field, however, was not consistently measured at each follow-up examination in our cohort study. At baseline visit, we measured visual fields on over 80% of the participants. There was no single blindness case that was due to the criterion of visual field defect (visual field of less than 20° from the point of fixation).42

In Australia, it was estimated that the average cost was $3906 per injury resulting from falls.55 Over the 1-year period from 2010 to 2011, the number of hospitalized injury cases due to falls in persons aged 65+ years was over 92,000.54 Findings from previous and our current studies indicate that a period with a high risk of falls is within the first 5 years after the onset of VI. Measures to minimize risk of falls should be taken soon after VI develops.37 Our findings also reinforce the need for regular eye examinations to detect and intervene VI early among older persons, to avoid adverse events such as falls and fractures and maintain their independent living status as long as possible.

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References

8. Lamoureux EL, Fernwick E, Moore K, et al. Impact of the severity of distance and near-vision impairment on depression

<table>
<thead>
<tr>
<th>Duration of VI</th>
<th>Subsequent Falls</th>
<th>Subsequent Fractures</th>
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<tbody>
<tr>
<td></td>
<td>OR (95% CI)</td>
<td>P Value</td>
</tr>
<tr>
<td></td>
<td>OR (95% CI)</td>
<td>P Value</td>
</tr>
<tr>
<td>Incident bilateral VI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–5 y†</td>
<td>1.10 (0.45–2.69)</td>
<td>0.84</td>
</tr>
<tr>
<td>&gt;5–10 y‡</td>
<td>1.27 (0.53–3.06)</td>
<td>0.59</td>
</tr>
<tr>
<td>Incident unilateral VI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–5 y†</td>
<td>1.26 (0.79–2.01)</td>
<td>0.33</td>
</tr>
<tr>
<td>&gt;5–10 y‡</td>
<td>1.51 (0.96–2.37)</td>
<td>0.08</td>
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</table>

* Adjusted for age, sex, presence of a walking disability, 3 or more co-morbidities.
† PROC PHREG.
‡ PROC LOGISTIC.
Visual Impairment and Subsequent Falls and Fractures


