REVIEW

Are we blind to injuries in the visually impaired? A review of the literature

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Objectives: To review the literature on the risks and types of injuries associated with visual impairment, and to identify pertinent areas for future research.

Methods: A search of bibliographic databases was conducted in April 2000 for studies published since 1980 and selected studies that met two or more of the following criteria: formal ophthalmic assessment was used; adjustment for confounding variables; large sample size including numbers of visually impaired; and clear definitions and outcomes.

Results: Thirty one studies were selected. The majority of these studies (20) assessed falls (including eight on hip fracture and four on multiple falls), eight studies reported traffic related injuries, and three studies assessed occupational injury. The evidence on falls, which relate predominantly to older people, suggests 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 fully sighted populations. The odds of a hip fracture are between 1.3 and 1.9 times greater for those with reduced visual acuity. Studies of less severe injuries and other causes of injury were either poorly designed, underpowered, or did not exist.

Conclusions: There are substantial gaps in research on both injuries to which people with visual impairment are especially susceptible and in evaluating interventions to reduce these injuries. It is recommended that in future studies the minimum data captured includes: formal ophthalmic assessment of visual fields and visual acuity, outcome measurement, control for confounders, and the costs of health care resource use and any interventions.

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The risk of having an unintentional injury is higher for people who are visually impaired compared with the fully sighted population.[1] It is critical that in planning and implementing measures to reduce the risk of injuries occurring in the home, workplace, and the general environment, specific consideration is given to those with visual impairment.

In England in 1999–2000, an estimated 240 000 people were blind and another 421 000 people were partially sighted (that is, 0.48% and 0.85% of the population respectively).[2 3] Because these estimates exclude undiagnosed cases the true blind and partially sighted populations are likely to be much greater.

Intuitively, there are two main reasons why people with visual impairment are more susceptible to injury: they have fewer visual clues to alert them to potential hazards such as oncoming traffic, and home environments and workplaces have not been suitably adapted, for example, with adequate lighting. Also, the risk of falling is exacerbated in certain groups, such as older people, who tend to be more dependent on vision to maintain vertical posture.[4]

The aim of this study is to review the epidemiological literature on events that can lead to injury, the risk of injury, and the types of injuries sustained due to visual impairment. This study considers English language articles of unintentional injuries in those with visual impairment and excludes injuries associated with visual deficiencies, such as colour blindness or poor night vision.

Because we are interested in epidemiological studies on the incidence of injury due to visual impairment, the associated risk factors, and studies of interventions to reduce the risk of injury associated with visual impairment, we cannot strictly adhere to the guidelines for systematic reviews.[5] That guideline focuses on the review and meta-analysis of randomised controlled trials, which only form a small part of this review.

METHODS

Literature search

The database search was conducted in April 2000. The databases searched were: Cumulative Index to Nursing and Allied Health Literature (CINAHL), Embase, Enviroline, Health Promis, Health Management Information Consortium (HMIC), Incidence and Prevalence Database (IPD), Medline, Occupational Safety and Health (OSHrom), Sociological Abstracts, and Transportation Research and Information Services (TRIS). All were searched for articles published between 1980 and 2000.

MeSH headings and free text were searched using the terms injuries (including accidents*, burn*, drowning*, fracture*, trauma*, occupational-accident*, home-accident*, traffic-accident*) and visual impairment (including blindness*, visual acuity*, visual-impairment*, vision-disorders, partial* sight*).

Selection and validity assessment

The in-depth review took place between April 2000 and July 2000. Initially, two reviewers read the titles and abstracts of all the articles. Studies assessing the causes and treatment of visual impairment due to an injury, and injuries sustained in the absence of any eye condition (for example, injuries associated with factors such as helmets and visors obscuring visual fields or due to poor lighting) were excluded. Case reports and qualitative studies were also excluded.

Appropriately designed analytical studies (including observational studies) and cross sectional surveys were

Abbreviations: CI, confidence interval; OR, odds ratio; PR, prevalence ratios; RR, relative risk reviewed in depth. For inclusion, all met two or more of the following criteria:

- Objective ophthalmic assessment.
- Adjustment for confounding variables.
- Large numbers of visually impaired.
- Clear reporting of definitions and outcomes.

Objective ophthalmic assessment includes measurement of visual acuity, visual fields, contrast sensitivity, depth perception, or diagnosis of specific eye conditions such as cataract and glaucoma. Subjective reports of visual assessment show low correlations with objective measures such as visual acuity.[6–8]

When comparing the risk of injuries occurring in the visually impaired with the fully sighted, there are likely to be other factors associated with visual impairment that increase the chances of injury (that is confounders). For example, as people age they are more likely to have impaired vision and they are more likely to have a fall.[9 10] Therefore, age is a confounding factor for falls. When assessing the risk of falling, it is important that estimates are corrected for the effects of confounding variables.

Outcomes

The outcomes identified in the articles are measures of association between the risk of injury and visual impairment. Statistical measures of association used in the studies include relative risk (RR), odds ratios (OR), and prevalence ratios (PR).

RESULTS

After removing duplicate records across the databases, 471 articles were identified. A manual search of the titles and abstracts identified 250 of these articles as irrelevant. Exclusion at this stage included studies that investigated an injury causing blindness or visual impairment.

Of the remaining 221 articles, only 31 were identified that met two or more of the selection criteria. Many articles were excluded, as although they mentioned injury in the visually impaired, they were review or discussion articles where no analytical study had been undertaken. The 31 studies were separated into categories according to cause and setting. Injury categories used are falls and fall related fractures (20), occupational injuries (3), and traffic injuries (8). No analytical studies were identified that assessed the risk of injury in other areas including the home, poisoning, burns, and electrical injuries.

Falls and visual impairment

The studies on falls vary with respect to the type of fall. Some include all people who had had any type of fall within a specific period. Others explore the characteristics of people who have fallen more than once within a specified time period. Finally, there are studies that assess serious fall injury, such as fracture to the wrist or hip.

General falls

Of the 20 studies, 14 addressed visual impairment and all falls, irrespective of injury (table 1). Of these, only one adjusted for confounding variables and measured visual impairment across a large cohort.[11] It found a positive association between falling and visual impairment in people over 75 years of age, with the adjusted RR 1.7 (95% confidence interval (CI) 1.2 to 2.3).[11]

Multiple falls

The Blue Mountains Eye Study is the only large cohort study we identified with multiple falls as an outcome that adjusted for confounding variables and used formal ophthalmic assessment to measure visual impairment.[9] It revealed significant associations between posterior subcapsular cataract PR 2.1 (95% CI 1.0 to 4.3), the use of non-miotic glaucoma medication PR 2.0 (95% CI 1.1 to 3.6), visual acuity worse than 20/30 PR 1.9 (95% CI 1.2 to 3.0), and poor contrast sensitivity PR 1.2 (95% CI 1.1 to 1.3) with multiple falls.

The Arfken *et al* study predominantly used subjective reports of visual impairment and showed no difference between those with visual impairment and those without.[6] This study illustrates the need for objective measures of visual impairment as it also showed a low correlation between objectively measured visual acuity and self reported visual disabilities (for example, a correlation coefficient of 0.12 for visual acuity and difficulty watching television).

The use of glaucoma medication was identified as a significant proxy risk factor for falls.[9 12] However, this is a crude proxy for reduced visual fields or loss of peripheral vision. In future studies it would be better to objectively measure functional impairment (for example, visual fields), in both patients who are treated for glaucoma and in those who are undiagnosed/untreated.

Multiple fallers are an important subset as there are implications for resources. These are more likely to be transferred to nursing homes after falling compared with single fallers and, in addition, are likely to be hospitalised for longer periods.[13]

Fall related fracture

Seven studies were identified that assessed the risk of hip fracture and one assessed the risk of Colles fracture. Falls account for approximately 90% of hip fractures.[14 15] Therefore, the hip fracture studies may include events other than falls.

Hip fracture

Studies with hip fracture as the outcome are intrinsically methodologically more sound than many of the studies described earlier. These studies do not rely on subjective recall of previous injury since hip fracture almost always requires admission to hospital.

There were four cohort studies that assessed the risk of hip fracture due to impaired vision that adjusted for confounding variables and used formal ophthalmic assessment.[16–19] A significant association was found between visual acuity and risk of hip fracture in three out of the four studies (95% CI's range 1.3 to 1.9). In a study of women aged 65 years and older, both poor depth perception and reduced ability to perceive contrast (but not poor visual acuity) were found to increase the risk of hip fracture independently.[17] The relative risk of hip fracture for the low distant depth perception was 1.4 (95% CI 1.0 to 1.9) and low contrast sensitivity RR 1.2 (95% CI 1.0 to 1.5).[14]

In a further three case-control studies, which either did not use formal ophthalmic assessment or did not adjust for confounders, statistically significant associations between visual impairment and hip fracture were found.[20–22]

Colles fracture (fractured wrist)

No studies were identified that assessed the risk of Colles fracture due to impaired vision, that adjusted for confounding variables, and used formal ophthalmic assessment. However, one was identified that assessed the unadjusted association between having a wrist fracture for people with impaired vision.[23] The authors found that the wrist fracture group had better eyesight than the control group ($p=0.022$). The authors suggest that individuals with better eyesight may be more likely to stretch their arm back to break a fall, and hence have an increased risk of sustaining a fractured wrist. However, not only was there no adjustment for confounding factors, the power of this study was low.

Risk of occupational injury due to visual impairment

No studies were identified that assessed the risk of occupational injuries due to impaired vision, that adjusted for

Table 1 Falls and visual impairment

Reference	Study design	Study group	Ophthalmic assessment	Adjustment for confounding variables	Key results
6	Cohort (R)	n=875, elderly	Formal	Yes	Risk of first, multiple, and injurious falls: was not significantly associated with visual impairment
48	Cohort (P)	n=761, aged 70+	Formal	Age only	Risk of fall: was not significantly associated with visual impairment
17	Cohort (P)	n=9516, aged 65+	Formal	Yes	Risk of hip fracture: increased with poor depth perception RR 1.4 (95% CI 1.0 to 1.9) and/or low contrast sensitivity RR 1.3 (95% CI 1.0 to 1.5)
18	Cohort (P)	n=7575, aged 75+	Formal	Yes	Risk of hip fracture: increased with poor visual acuity RR 1.9 (95% CI 1.1 to 3.1). In subjects with very poor visual acuity the risk of hip fracture was even higher RR 2.0 (95% CI 1.1 to 3.7)
49	Cohort (P)	n=1947, aged 70+	Medical history	Yes	Odds of fall: increased in patients with a medical history of glaucoma OR 1.63 (95% CI 1.13 to 2.37)
19	Cohort (R)	n=2633	Formal	Yes.	Risk of hip fracture: increased in subjects with any visual impairment RR 1.73 (95% CI 1.13 to 2.65)
13	Cross section	n=50, 50	Medical notes	NA	Risk of fall: was significantly associated with blindness and poor vision
12	Cohort (R)	n=489, aged 65+	Formal	Yes	Risk of serious falls: increased in subjects with 40% or greater visual field loss RR 3.0 (95% CI 0.94 to 9.8) and use of non-miotic eye medications 5.4 (95% CI 1.8 to 16.4)
20	Case-control	n=174	Self report/ medical history	Yes	Odds of hip fracture: was increased in women with low distant vision (self reported) OR 4.8 (95% CI 1.4 to 16.2)
23	Case-control	n=24, 24	Formal	No	Risk of wrist fracture: was lower in the group with poorer vision
9	Cross section	n=3299, aged 49+	Formal	Yes	Risk of multiple falls: posterior subcapsular cataract prevalence ratio* (PR) 2.1 (95% CI 1.0 to 4.3); use of non-miotic glaucoma medication PR 2.0 (95% CI 1.1 to 3.6) low visual acuity PR 1.9 (95% CI 1.2 to 3.0); low contrast sensitivity PR 1.2 (95% CI 1.1 to 1.3). No significant association with other vision variables studied. *(*The prevalence ratio is similar to relative risk)*
16	Case-control	n=991, 910, aged 60+	Formal	Yes	Odds of hip fracture: increased in the visually impaired. OR 1.3 (95% CI 1.0 to 1.8)
37	Survey (P)	n=200, aged 65+	Formal	No	Risk of fall: significant difference between low vision of patients attending for falls compared with other those attending for other medical problems
50	Cross section	n=143, aged 65+	Questionnaire	NA	Risk of fall: among patients with diabetic retinopathy and glaucoma the vision questionnaire had a 100% sensitivity in identifying patients with a history of falls
1	Cohort (R)	n=3722, adults	Formal	Yes	Risk of fall and hip fracture: was significantly associated with visual acuity in the over 60s, in the under 60s risk was only associated with some vision measures
21	Case-control	n=129, aged 65+	Case notes	Yes	Odds of in hospital hip fracture: were higher in the visually impaired OR 1.97 (95% CI 1.18 to 3.30)
51	Cohort (P)	n=341, aged 65+	Formal	Age only	Risk of multiple falls: significantly increased in subjects with poor visual acuity and/or a low ability to perceive contrast
22	Cohort (R)	n=53, 530	Case notes	Age/sex only	Risk of second hip fracture: was significantly increased in the blind/ and those with low vision
11	Cohort (P)	n=336, aged 75+	Formal	Yes	Risk of fall: was higher in the visually impaired subjects RR 1.7 (95% CI 1.2 to 2.3)
52	Cohort (P)	n=927, aged 72+	Formal	No	Risk of multiple falls: was higher in visually impaired RR 1.6 (95% CI 1.1 to 2.4)
4	Cohort (R)	n=165	Blind	No	Risk of fall: the blind demonstrated a higher risk than the deaf or non-impaired populations

Abbreviations: (P) prospective study, (R) retrospective study; CI, confidence interval; OR, odds ratio; RR, relative risk.

confounding variables and used formal ophthalmic assessment. The evidence from the studies that used self reported vision gave equivocal evidence about an association between occupational injuries and visual impairment (table 2).[24 25]

Risk of traffic related injuries due to visual impairment

No studies assessed the risk of pedestrian injuries, or of injuries sustained while using public transport that met our criteria. One was identified that assessed the risk of pedestrian injuries in children due to visual impairment where vision was self reported (table 3).[26] This study found children with poor vision had a fourfold greater risk of pedestrian injury than those with full vision. However, whether the child's vision was corrected or uncorrected was not reported.

Seven studies were identified that evaluated the association between visual impairment and risk of traffic injuries (table 3).[27–33] Associations were found between crash risk and visual field loss,[27 31 32] minimal visual acuity and lack of binocularity,[28] and glaucoma.[31] Cataract was associated with increased at-fault traffic crashes,[27–30] but diminished visual acuity alone and contrast sensitivity were not found to be associated with crash risk.[28 29 31 32] The associations were weak largely due to the studies being underpowered to detect significant effects,[29] to selection bias,[34] or to risk compensation.[33 35]

The full effect of visual impairment on driving performance may not be recognised, because many studies have reported that certain features of visually impaired individuals' driving

Table 2 Occupational injuries and visual impairment

Reference	Research methods	Study group	Ophthalmic assessment	Adjustment for confounding variables	Key results
25	Cohort (R) using the Health and Retirement Study (HRS)	n=6854, aged 51–61	Self report	Yes	Odds of occupational injury: increased for those with poor sight OR 1.53 (95% CI 1.11 to 2.09)
24	Cohort (R) using the National Health Interview Survey (NHIS)	n=459, 827, aged 18–65	Self report	Yes	Odds of occupational injury: increased for the blind OR 3.21 (95% CI 1.32 to 7.85), but not for the visually impaired OR 1.37 (95% CI 0.87 to 2.17)
53	Cohorts (R) reanalysis	Participants in the NHIS and HRS	Self report	Yes	Odds of occupational injury: increased in subjects with poor vision in HRS study OR 1.48 (95% CI 1.07 to 2.06), but not in NHIS study OR 2.42 (95% CI 0.77 to 7.60)

Abbreviations: (P) prospective study, (R) retrospective study; CI, confidence interval; OR, odds ratio.

behaviour may compensate for risk. People who were visually impaired were reported to drive less, take fewer risks when driving, only drive in daylight and in familiar areas.[30 36] Although poorer driving performance is recognised in drivers with impaired vision, this does not translate into increased crash rates or injuries compared with other drivers.

DISCUSSION

The most salient feature is the lack of sound epidemiological studies of injury associated with visual impairment. Even more conspicuous is the absence of intervention studies. Intervention studies, such as screening or detection of visual impairment, appropriate treatment, and environmental modifications are needed. To judge the effectiveness of an intervention study, the outcome should be injuries (or injuries averted) rather than improvement in vision. These types of studies are an obvious omission from public health research agendas—a point we return to later.

Studies that investigated the association between visual impairment and the risk of injury, which adjusted for confounding variables and formally measured visual impairment, were identified primarily in the falls literature. These varied in the types of visual impairment measured and the eye disorders investigated. Poor depth perception and reduced ability to perceive contrast are prevalent in conditions such as cataracts, glaucoma, and diabetic retinopathy. Some studies that used formal ophthalmic assessment investigated the risk of injury by specific eye condition. The prevalence of potentially reversible impaired vision in hospital inpatients admitted after a fall is high.[3 37] Therefore, diagnosis and treatment of ocular disease is a prevention strategy that deserves further investigation.

Evidence on the association of diabetes with falls and hip fractures is inconclusive. The primary reason for this was poor case selection. In some studies, subjects with diabetes were included irrespective of the degree of retinopathy or visual impairment.[38] In another study, subjects with diabetic retinopathy were compared with fully sighted controls without measuring the severity of retinopathy or visual impairment.[10]

Where appropriate measures of severity of eye disease were used, for example visual acuity, the sample size was too small to draw conclusions.[19] Sample size is a major problem. For example, in a study of over 2000 subjects, there were four hip fractures in 47 patients with diabetic retinopathy.[19] This, and other similar studies are typically underpowered to detect significant effects. Unless large initial samples are obtained, subgroup analyses are insufficiently powered.

A further issue is the need to control for confounders within subgroups. For example, there are many complications with diabetes other than visual, such as peripheral neuropathy. Consequently, in future subgroup analyses (for example, for

Table 3 Traffic injuries and visual impairment

Reference	Research methods	Study group	Opthalmic assessment	Adjustment for confounding variables	Key results
27	Cohort (R)	n=294, aged 55+	Formal	Age/crash frequency only	Driver crash risk: drivers with substantial visual field loss were 6 times more likely to have incurred 1 or more crashes. Other vision measures were poor predictors of crash risk
28	Case-control	n=1400, 2636, aged 70+	Formal	Yes	Driver crash odds: visual acuity was not a significant predictor of accident risk
29	Cohort (P)	n=2739, aged 49+	Formal	Yes	Driver crash risk: neither visual acuity nor ability to see contrast in the best eye were significantly associated
30	Case-control (review)	aged 55+	Formal	Yes	Driver crash odds: useful field of view between 41%-60%, the injurious crash risk OR 16.5 (95% CI 5.8 to 47.3), glaucoma OR 3.6 (95% CI 1.0 to 12.6). Other vision measures were not significantly associated
31	Case-control	n=279 cases, aged 55+	Formal	Yes	Driver crash risk: relative risk of being a crasher in the prior 5 years compared to non-crasher with cataract RR 2.48 (95% CI 1.00 to 6.14)
26	Case-control	n=177, 471, children	Reported abnormal vision	Yes	Pedestrian injury odds: the adjusted odds ratio for the risk of injury abnormal vision was OR 4.25 (95% CI 1.68 to 10.8)
32	Cohort (R)	n=1878, aged 65+	Formal	Yes	Driver crash risk: visual field was the only vision variable associated with crash involvement OR 1.33 (conference abstract only available)
33	Case-control	n=107, adults	Informal	Yes	Driver crash odds: did not have significantly higher on-road accident rates

Abbreviations: (P) prospective study, (R) retrospective study; CI, confidence interval; OR, odds ratio; RR, relative risk.

people with diabetes), confounding factors (such as complications), as well as levels of visual impairment, should be measured and controlled.

This issue of confounders is reflected in studies of occupational injuries. The studies reviewed here were inconclusive, as results from two major studies were contradictory.[24 25] Although differences in the measures of self reported poor vision may go some way to explaining the differences in results, it is more likely to be the result of differing risks in various workplaces. There was a lack of information about the environmental adaptations of workplaces to meet the need of people with visual impairment. These need to be considered in studies of occupational injuries.

Ivers *et al* found a significant association between increased risk of falling and posterior subcapsular cataract PR 2.1 (95% CI 1.0 to 4.3) compared with no opacity in best eye, but no association with other types of cataract.[9] Drivers with cataracts were four times more likely to report difficulty with challenging driving situations and were 2.5 times more likely to have a history of at-fault crash involvement.[30] Posterior subcapsular cataract is the most common type of cataract in patients presenting for cataract surgery (60.6% of patients), and therefore, this is a treatable risk factor.[39]

Studies of hip fracture showed differences in visual risk factors, such as visual acuity. Dargent-Molina *et al*[18] hypothesise that the discrepancy between their findings and that of Cummings *et al*[17] may be due to the difference in mean age in the two cohorts (80.5 *v* 72.0). Dargent-Molina *et al* suggest that in a younger cohort the decline in depth perception and contrast sensitivity may be early indicators of visual impairment—before visual acuity is affected, whereas in an older cohort the decline in visual acuity may be the factor that best shows the cumulative effect of both age related and disease related visual deficits.[18]

There is a wide body of research that has investigated preventative interventions to reduce the risk of falling,[40 41] but not specifically in relation to the population with visual impairment. There is strong evidence that visual impairment is a risk factor for falls, and the recent UK guidelines submitted to the UK Department of Health[42] and the American and British Geriatric Societies[43] guidelines on fall prevention advocate assessment of visual impairment. However, there is no trial evidence that reducing visual impairment reduces falls, although there does exist a multifactorial intervention trial, which was successful in reducing falls, where assessment of multiple risk factors with tailored intervention included visual impairment.[44]

In the population aged 65 years and over, 30% are visually impaired.[3 45] Visual impairment is potentially treatable in 75% of cases, but, in the UK, only one quarter of those with visual impairment have contact with eye services.[46] Therefore, many of the consequences of visual impairment, such as injurious falls, could be prevented and the economic and human impact reduced.

Effective vision screening programmes with appropriate treatment are required to adequately identify and treat the target population. A recent systematic review of randomised controlled trials of vision screening concluded that there is no evidence that community based screening of older people results in improvements in vision.[8] The use of questions about visual problems as a screening tool, and the lack of clear plans for intervention were proposed as explanations for the lack of effectiveness.[8] Furthermore, the cost of spectacles may deter people from attending an optometrist or from obtaining glasses.[47] Therefore, a vision screening programme requires careful design with objective measures and appropriate treatment to be available.

There is need for further research into the epidemiology of the relative risk of injury for the visually impaired in many injury prevention areas such as pedestrians and work place injuries. Where there is evidence of increased risk to those with visual impairment there is a need to develop and assess the effectiveness of interventions. Interventions may include visual screening/assessment, treating the visual impairment where possible, and modifying the environment.

Key points

- The risk of unintentional injury, especially due to falls, is higher for those with visual impairment than the general population.
- Other than the falls literature, there are few sound epidemiological studies on visual impairment and occupational injury or traffic related injury; and there are none relating to other cause/settings categories.
- No single intervention studies were identified that developed and evaluated interventions to reduce the risk of injuries in those with visual impairment.
- The effects of vision testing and appropriate referral/treatment in multifactorial intervention studies cannot be disentangled from non-vision related interventions.
- Studies on vision interventions that use injury as the end point are needed.

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