

REVIEW

Vision and falls

Clin Exp Optom 2005; 88: 4: 212–222

Alex Black BAppSc (Hons)

GradCertHlthSc

Joanne Wood BSc (Hons) PhD

MCOptom FAAO

School of Optometry, Queensland

University of Technology, Brisbane,

Australia

Submitted: 30 August 2004

Revised: 13 April 2005

Accepted for publication: 13 May 2005

Falls occur in about one third of older people living independently in the community every year. This can lead to significant physical, psychological and financial costs to the individual and the community. While the risk factors for falls in older people are multifactorial, poor vision is considered to be an important contributing factor. The aim of this review is to evaluate current research linking impaired visual function with falls and to review current intervention strategies for the prevention of falls in older individuals.

The evidence from the current literature indicates that impairment of visual functions, such as visual acuity, contrast sensitivity, visual fields and depth perception, is associated with an increased risk of falls. Recent studies have also demonstrated that falls can be reduced following cataract surgery as a visual intervention.

Optometrists need to be aware of these associations and through appropriate treatment, referral and/or education, they can play a major role in optimising visual function in older people, as part of a multidisciplinary approach to falls prevention.

Key words: elderly, falls, fractures, visual function

Falls are one of the most serious health problems for older people. More than one third of those aged 70 years and above and living independently in the community report a fall at least once a year, with up to half of these experiencing multiple falls on an annual basis.¹⁻³ Falls also occur more frequently in nursing home settings, with up to 60 per cent of residents reporting at least one fall per year.⁴ This increased rate of falls in nursing home residents is likely to result from them being older and having higher levels of chronic illness and cognitive impairment and greater limitations in their activities of daily living than their community dwelling counterparts.⁵

Importantly, the proportion of older people who fall each year increases with

their advancing age.^{3,6} This is significant in our ageing population, where it is projected that the over-65 age group could represent one quarter of the population over the next 20 years and the over-85 age group will increase nearly four-fold.⁷ Thus, prevention of falls is an important public health issue that needs to be addressed by all health professionals.

Falls account for more than 40 per cent of injury-related deaths and approximately one per cent of all deaths in Australians aged 65 and over. Falls are the leading cause of injury-related deaths, followed by motor vehicle accidents and suicide.⁸ Fifteen to 24 per cent of falls result in serious injury requiring medical treatment,^{9,10} while hip fractures are associated with high

mortality rates (20 to 30 per cent within 12 months of the fall)¹¹⁻¹³ and those who recover from a fall often have persistent pain and reduced mobility.¹¹ In 2002, more than 1,300 Australians aged 65 or older died as a result of a fall¹⁴ and more than 55,000 older Australians were hospitalised for injuries sustained from falling during the financial year 1999-2000.¹⁵

There are important psychological consequences associated with falling, even in the absence of physical injury. Fear of falling may produce anxiety and depression about self-sufficiency and independence¹⁶ and is associated with deteriorating health,¹⁷ leading to reduced quality of life and reduction of independence. About one quarter of older individuals report

restricting their activities following a fall^{18,19} and 26 per cent of nursing home admissions are directly attributable to falls.²⁰ On a financial level, it has been estimated that the cost per patient per fall in Australia is about \$4,500, of which 80 per cent comprises hospital costs, 16 per cent community costs and four per cent personal costs.²¹ Overall the cost of falls to the Australian health care system in 2001 was estimated to be nearly \$500 million and is projected to increase three-fold by 2051.²²

Falls are seldom due to a single cause and numerous risk factors have been identified. Close²³ reviewed the main intrinsic risk factors that have consistently been shown to be associated with falls. These include:

1. general factors, such as age, female gender, history of falls, living alone
2. physiological or functional factors, such as visual problems, impaired muscular strength and problems with mobility
3. medical risk factors, including Parkinson's disease, stroke, depression, cognitive impairment and arthritis
4. use of medications, such as sedatives and antidepressants or multiple medications.

In addition, there are many environmental risk factors (extrinsic factors) that are associated with increased risk of falls. These include the use of inappropriate footwear, poor environmental lighting and slippery or uneven surfaces.

The strength of the associations between each of the numerous risk factors and falls varies. For instance, a history of previous falls moderately increases risk by a factor of 2.5,^{18,24} while female gender approximately doubles the risk of falls²⁴⁻²⁶ and the use of multiple medications increases risk by around 1.3 times.^{24,27} Importantly, there is a moderate association between impaired visual function and falls, with estimates that impaired visual function (such as reduced visual acuity) can approximately double the risk of a fall.^{6,26} This is an important association that warrants higher levels of awareness, given that the highly publicised association between smoking and the incidence of late age-related macular degeneration is of a similar order, about 2.35 times.²⁸

The aim of this review is to evaluate current research into falls to inform optometrists of recent evidence that links impaired visual function with falls, to review current intervention strategies and suggest potential strategies for prevention of falls in our older population.

VISUAL FUNCTION AND BALANCE

The visual system plays an integral role in both maintaining balance while standing still and remaining stable while moving within the environment. Visual information provides a visual reference of self-position and the position of obstacles within an individual's surrounds and is integrated with input from the vestibular balance and proprioceptive or somatosensory (muscle receptors and joint nerves) systems.

A deficit in any of these three balance systems results in an increased reliance on the other systems to maintain stability. For example, the removal of visual cues by eye closure has been shown to increase body sway by a factor of three.²⁹ In addition, case reports have shown that patients with severe vestibular and somatosensory deficits rely on visual cues to a greater extent than normal subjects and will lose their balance and fall following eye closure.³⁰ Conversely, individuals with central visual field losses rely more on their non-visual balance systems to maintain stable posture than those with normal visual fields.³¹

The reliance on visual information for maintenance of postural stability increases with age, with adults aged 85 years or more swaying up to 38 per cent more on eye closure than those aged 50 to 60 years.³² This can be attributed to the age-related changes that occur in both the vestibular³³ and somatosensory systems.³⁴ Recent studies have shown that this increased reliance on vision for the maintenance of postural stability occurs in women as early as 50 years.³⁵ If the balance system does not adapt to increased visual reliance, balance may be compromised. Indeed, those who fall have less reliance on visual information for balance than those who do not.³⁶

Accurate visual information is vital for maintenance of stable posture in older adults. Impaired vision, in the form of

defocus reduces postural stability, especially in the presence of disruptions to the vestibular and somatosensory systems, for both young^{29,37} and older^{38,39} individuals. Likewise, degrading visual input by simulating cataract also reduces postural stability.³⁸ Individuals with reductions in contrast sensitivity and stereopsis have reduced postural stability and these visual functions are independent predictors of stability, while standing on foam (which acts to disrupt the somatosensory system).⁴⁰ Again, older individuals with moderately impaired visual acuity (6/18 to 6/60) demonstrate poorer postural stability compared to those with normal vision or early visual impairment.⁴¹

This increased reliance on visual information for maintenance of postural stability with increasing age has important implications given the increased prevalence of visual impairment with advancing age. Australian population studies have shown that the main causes of visual impairment are uncorrected refractive error⁴² and age-related eye diseases (such as cataract, age-related macular degeneration and glaucoma).⁴³ In addition, age-related changes in the visual system occur even in those free of eye disease.⁴⁴ Therefore, the age-related changes in the visual system, along with reductions in the other two balance systems (vestibular and somatosensory), result in impaired balance control in older individuals, which can ultimately lead to falls.

VISUAL FUNCTION AND FALLS

Early studies reported associations between vision and falls.^{10,18} Since then, the relationship between specific visual functions and falls has been investigated in a range of studies to determine which aspects of vision are important. They have considered visual acuity, contrast sensitivity, visual fields, stereopsis (depth perception) and the type of spectacle correction as risk factors for falls, using a range of study designs, outcome measures (single falls, multiple falls, injurious falls or hip fractures over a period) and study populations. Studies of hip fracture rates are commonly incorporated within falls research, as 90 per cent of hip fractures

occur as a result of falls.⁴⁵

The study designs used in falls research can include:

1. Prospective cohort studies that are considered the gold standard. A group of participants is followed over a specified time, typically for 12 months.
2. Retrospective studies that are often performed as part of a population cross-sectional study, in which a group of participants is questioned on previous falls that have occurred.
3. Case-control studies, in which a specific group of participants is assessed and compared to an age-matched control group.

A key difference between these methodologies is the accuracy of reporting, as 13 to 32 per cent of participants will often not recall a previous fall.⁴⁶ Prospective study designs maximise the accuracy of reported falls. Ideally, the measures of visual performance should reflect the visual status of an individual at the time of the fall. Measures of visual performance taken before any falls are recorded are considered the most precise. Measures taken after a fall may not be as accurate due to further changes in the visual system, such as the development of cataract. Furthermore, often it cannot be established with certainty whether visual changes, such as retinal detachment, were a result of a fall, rather than being a causative factor.

A range of statistical analyses has been used to investigate different risk factors in relation to falls. Odds ratios (OR), risk ratios (RR), prevalence ratios (PR) and hazard ratios (HR, survival analysis) are used to provide an indication of the likelihood of an event, such as a fall. These ratios are multiplying factors, where a ratio of one indicates that there is no increased or decreased likelihood of the event associated with the risk factor, while a ratio of two indicates that there is a doubling of the likelihood of the event occurring. Furthermore, the significance of these ratios needs to be adjusted for possible confounding variables, such as age and gender, which may be related to both the outcome event and the hypothesised risk factor. Multivariate analysis is often used to control for the effects of these confounding variables and provides an accurate indication of

whether a specific risk factor is associated with a particular outcome.

Researchers studying the association of visual functions with falls and hip fractures have focused on the following visual characteristics: visual acuity, contrast sensitivity, depth perception and visual fields. While there may be other visual functions that play a role in falls, such as dark adaptation and glare sensitivity, few studies have investigated these with respect to falls or fractures.

Visual acuity

High-contrast distance visual acuity is a commonly investigated visual function in relation to falls. Data from accident and emergency departments have shown that about half of the older people presenting due to falls have reduced visual acuity,^{47,48} while reduced visual acuity has been reported to increase postural instability.³⁷⁻³⁹ Older people with reduced visual acuity walk significantly more slowly compared to those with normal visual acuity,⁴⁹ suggesting that an adaptive strategy is employed to maintain safe mobility in the presence of impaired visual information. Conversely, visual acuity is not a significant predictor of mobility performance.^{50,51}

Large cross-sectional population studies have consistently found that reduced visual acuity is significantly associated with falls. The Beaver Dam Eye Study found a 2.6 times higher risk of multiple falls, if habitual binocular visual acuity was 6/7.5 or worse.⁴⁹ Their follow-up study⁶ and the Blue Mountains Eye Study²⁶ both showed that multiple falls were approximately twice as likely, if habitual binocular visual acuity was worse than 6/9. In addition, both studies found that the poorer the visual acuity, the greater the risk of multiple falls, although this was not a linear association. While these studies are limited by the retrospective nature of the data, the use of such large samples provides convincing statistical evidence of the link between reduced visual acuity and falls.

A recent large scale prospective study by Coleman and colleagues⁵² found that women aged over 65 years, whose visual acuity had decreased by two or more lines in the previous four to six years, were 43 per cent more likely to have multiple falls

in the following year than women whose visual acuity had reduced by less than two lines over that same period. The risk of multiple falls was even greater (74 per cent more likely) when baseline acuity was worse than 6/12. Similarly, reduced distance visual acuity (worse than 6/20) was found to be a significant risk factor for injurious falls (falls resulting in an injury) in a two-year prospective study of dependent older people requiring assistance with daily living tasks (such as dressing, doing housework and bathing).⁹ Importantly, Koski and associates⁹ found that the relationship between the risk of injurious falls and visual acuity was not significant, when the same study design was applied to independently living adults. This finding suggests that once functional abilities decline, sensory factors such as visual acuity may become more significant as a risk factor.

Other prospective studies have failed to show any significant difference between visual acuity in groups of those who have fallen compared with those who have not.^{1,10,18,53-57} However, these studies tended to use smaller samples, which can reduce the level of significance of the risk factors after adjusting for the many confounding factors.

Studies that have used self-reported measures of visual acuity (such as the ability to recognise faces) have reported conflicting findings. Some have shown that reduced self-reported visual acuity increases the risk of falls,^{2,24,58} while others have failed to show an association.^{25,57} It is likely that these differences are due to the crude and variable nature of such self-reported measures of visual acuity.

Prospective hip fracture studies have provided much more consistent evidence to support the association between reduced visual acuity and fractures, which may be due to the more accurate reporting of hip fractures, which generally require medical attention. In the Framingham study,⁵⁹ the risk of hip fractures was 1.73 times more likely if visual acuity was worse than 6/9 in either eye, and the risk was 2.17 times more likely if both eyes had a visual acuity of 6/30 or worse. Similarly, in the French EPIDOS study,⁶⁰ reduced visual acuity was a significant risk factor for hip fractures, where

women who had habitual visual acuity of 6/15 or worse were nearly twice as likely to suffer a hip fracture than those with visual acuity better than 6/9. However, the large prospective hip fracture study by Cummings and co-workers⁶¹ found no association between visual acuity and fractures.

Many of the large population studies have confirmed the link between visual acuity and the occurrence of hip fractures. The Blue Mountains Eye Study⁶² found that the likelihood of a hip fracture was increased 8.4 times for those with visual acuity worse than 6/18, while the Beaver Dam Eye study⁶ found that the odds of a hip fracture within a five-year retrospective period increased by a factor of 1.75, if vision was 6/12 or worse. An earlier study by the Beaver Dam research group⁴⁹ showed that the risk of any fracture after the age of 40 increased 3.7 times, if vision was 6/7.5 or worse.

Self-reported indices of acuity are a significant risk factor in hip fractures. Reductions in face recognition ability can increase the likelihood of hip fracture by a factor of 3.1⁵⁷ or 4.8.⁶³ In a large case control study in Auckland, hip fracture risk increased up to 1.4 times for those who self-reported their vision as 'adequate' or 'minimal/blind' rather than 'good'.⁶⁴ In addition, the risk of hip fracture is increased significantly by a factor of 1.5, if vision (Snellen) is worse than 6/18, which is similar to the level of self-reported measures. It is unclear why the self-reported measures of vision are more consistently related to the rates of hip fractures but less to falls.

The evidence from the studies reviewed here indicates that reduced visual acuity can increase the likelihood of a fall by around 1.5 to 2.0 times. However, these studies do not provide a clear indication of what constitutes a clinically important decrease in visual acuity relating to the risk of falls, which would provide useful information for clinicians.

Contrast sensitivity

The visual environment contains a wide range of spatial frequencies and contrast levels. Therefore, tests of contrast sensitivity may provide a better measure of visual

performance for balance and mobility than visual acuity. Avoidance of trip hazards and negotiating stairs are likely to be reliant on adequate visual information across all spatial frequencies and measures of contrast sensitivity are more highly correlated with performance in mobility tasks than visual acuity.^{51,65} In addition, older individuals with reduced contrast sensitivity walk at significantly slower speeds than those with normal levels of contrast sensitivity.⁴⁹

With no standard measure, different tests have been used to measure contrast sensitivity at a variety of spatial frequencies. Some tests measure only narrow ranges of spatial frequencies. The Pelli-Robson measures contrast at around one cycle per degree (cpd),⁶⁶ while the Melbourne Edge Test (MET) measures low to mid-spatial frequencies.⁶⁷ Other chart tests, such as the Vistech or computer-generated tests, can measure contrast sensitivity across a range of spatial frequencies. Comparison of results of these studies is problematic because different contrast sensitivity tests have been used and this may explain why the evidence associating reduced contrast sensitivity with falls and fractures is inconclusive.

Anand and associates³⁸ suggested that postural stability depends more on lower spatial frequency information than high spatial frequencies. Similarly, Lord and Menz⁴⁰ found that the MET was an independent predictor of postural stability, whereas visual acuity was not. Therefore, reductions in contrast sensitivity at low and mid spatial frequencies may be an important risk factor for falls, given their role in postural stability.

The Blue Mountains Eye Study²⁶ found a slight increase in retrospective falls risk (1.2 times) with reductions in contrast sensitivity measured using the Contrast Sensitivity Grating Chart at a range of spatial frequencies, with the greatest risk occurring at six cycles per degree. The Beaver Dam Study Eye Group⁴⁹ found that the risk of a hip fracture increased by 1.8 times for those with a Pelli-Robson score of 1.50 or worse but there was no increase in risk of falls. In contrast, a follow-up study by the same researchers found that reduced Pelli-Robson contrast sensitivity was not associ-

ated with an increased risk of fracture but did elevate the risk of falls by a factor of 1.63.⁶ Possible reasons for these inconsistent results could be the use of a younger cohort in the follow-up study, along with differences in the falls outcome measures.

Prospective studies have confirmed that reduced contrast sensitivity can increase the risk of falls. A three-year study by de Boer and colleagues⁵⁷ showed that reductions in low-frequency contrast sensitivity, as measured using the Vistech chart, increased the likelihood of a second fall by a factor of 1.66, yet did not significantly increase the likelihood of a fracture. In a four-year study, Cummings and associates⁶¹ showed that women were 1.2 times more likely to have a hip fracture when their low-frequency contrast sensitivity was reduced on the Vistech chart. Wainwright and co-workers⁶⁸ confirmed that impairment in low frequency contrast sensitivity increases the risk of a hip fracture by a factor of 1.5 times in women (both with and without signs of osteoporosis). A small study by Lord, Clark and Webster⁵⁵ found that multiple fallers performed significantly worse on the MET than non-fallers, while that of Lord and Dayhew¹ reported that poor performance on the MET and a low-contrast (10 per cent) visual acuity test nearly doubled the risk of falling.

Conversely, a number of studies has failed to find any significant association between reduced contrast sensitivity and falls^{18,49,54} or hip fracture risk.^{6,60,62}

While the postural stability and mobility studies strongly suggest that low frequency contrast sensitivity information is important for good balance, the evidence to suggest that impaired contrast sensitivity increases the risk of falls or fractures is equivocal. This lack of a clear link between reduced contrast sensitivity and the risk of falls and/or hip fracture may be attributed to the use of a variety of contrast sensitivity tests, different population samples, as well as variations in the cut-off criteria used to define impaired and normal contrast sensitivity.

Depth perception

Impaired depth perception may increase the risk of falling due to the possibility of

inaccurate foot placement during activities such as stair negotiation or obstacle avoidance. The importance of the role of depth perception in balance is supported by findings that depth perception, as measured with the near Frisby stereotest, is an independent predictor of postural stability in older individuals.⁴⁰

Few studies have investigated depth perception as a risk factor for falls. Reduced stereoacuity, defined as 200 seconds of arc or worse as measured with the Randot test, doubles the risk of multiple falls.¹⁸ Similarly, Lord and Dayhew¹ found that fallers performed significantly worse on both distance (Howard-Dolman apparatus) and near (Frisby test) depth perception compared to a group of non-fallers. This study also found that poor depth perception performance on both tests doubled the risk of multiple falls. In contrast, other studies have failed to find an association between the risk of falls and depth perception, as assessed by the Randot Stereotest⁵⁴ or with asymmetry in visual acuity between the eyes.⁶

The fracture studies also show inconclusive findings. A case-control study by Ivers and associates⁶⁴ found that the risk of hip fracture was three times greater in those with near stereoacuity worse than 50 seconds of arc (Randot stereotest). A larger study by Wainwright and colleagues⁶⁸ showed that women with baseline osteoporosis had a 67 per cent increased risk of hip fracture, if distant depth perception (Howard-Dohlman) was reduced. Similarly, a large prospective study by Cummings and co-workers⁶¹ found that poor Howard-Dohlman depth perception increased the risk of fractures by 1.5 times. In contrast, the prospective EDIPOS study did not find an association between increased hip fracture risk and depth perception (Randot),⁶⁰ nor was asymmetry in visual acuity between eyes associated with a risk of hip fracture.⁵⁹

In summary, although a relationship between depth perception and increased risk of falls and hip fractures is likely, the evidence is inconclusive due to the limited number of studies, along with the use of different depth perception measures. In addition, monovision refractive correction

(using contact lenses or laser surgery) is known to impair stereopsis.⁶⁹ Monovision correction is becoming popular with presbyopes and reductions in depth perception may increase the risk of falls in this population as they age.

Visual fields

Impaired ability to detect and avoid peripherally located obstacles/hazards due to peripheral visual field loss is likely to increase the risk of falls. This is supported by studies showing that artificially restricted visual fields reduced postural stability in normally sighted subjects.^{29,70} Mobility studies with glaucoma subjects have also shown that a reduction in visual field sensitivity is associated with slower walking speed and poorer mobility performance.⁷¹ Impaired visual field performance is associated with reduced walking speed, along with a 22 per cent increase in collisions with obstacles.⁷² The association between reduced visual fields and increase in falls is inconclusive, as only a limited number of studies have been undertaken.

The Rotterdam prospective study investigated the prevalence and causes of visual field loss in the elderly and found that the likelihood of frequent falls was six times greater in those with unilateral and bilateral visual field losses.⁷³ While this study did not adjust for any confounding factors that can contribute to falls, it still supports the findings that visual field loss can increase the risk of falling in older people.

The Beaver Dam Eye Studies found that reduced visual field sensitivity, assessed on a Henson perimeter, almost doubled the risk of a fall or fracture,^{6,49} while the Blue Mountains Eye Study showed that more than five points missed on a Humphrey screening test increased the risk of falls by a factor of 1.5.²⁶ Ivers and colleagues⁶² showed that the risk of hip fracture increased 5.5 times, if more than five points were missed on a Humphrey screening test. Conversely, a retrospective study of 489 patients with glaucoma found that while losses of more than 40 per cent of the visual fields elevated the risk of falls, it did not reach significance. Another large prospective study conducted by Friedman and co-

workers⁵⁴ found no association between reduced visual fields using Humphrey screening tests and the risk of falls.

This lack of conclusive evidence may be due to the limited number of studies that have investigated visual fields and falls/fractures, along with variations in the types of visual field tests and criteria used to define abnormality. It is essential that appropriate, sensitive measures of visual fields are used in future studies so that the association between visual field loss and falls and fracture risk can be accurately determined.

There has been recent interest in the association between attentional visual fields, as measured by the useful field of view (UFOV) and indices of balance and mobility. The UFOV is a computerised test of a person's ability to simultaneously extract and process central and peripheral visual information, measured by processing speed during divided and selective attention tasks;⁷⁵ skills which may be important in avoiding falls. A study by Owsley and McGwin⁷⁶ showed that a reduction in the UFOV in older individuals is significantly associated with reduced mobility performance, although it was not associated with the number of retrospective falls. Reduced UFOV performance increases slightly (by five per cent) the likelihood of bumping while walking.⁷⁷ These studies suggest a weak association between attentional visual fields and decreased mobility performance but further research is required to fully investigate this relationship.

Spectacle correction

The use of various types of spectacle correction has been linked to increased risk of falls, particularly in individuals wearing multifocal lenses (bifocals, trifocals and progressive lenses). It has been suggested that the multifocal reading segment impairs visual acuity, contrast sensitivity and depth perception at ground level, which is required for walking, possibly leading to a fall due to incorrect foot placement, while descending stairs or on uneven terrain.⁷⁸

A prospective study of 156 community-dwelling older people found that the

multifocal spectacle wearers (76 bifocals and 11 trifocals/progressives) were more than twice as likely to fall than non-wearers, and suggested that nearly 35 per cent of falls could be prevented, if multifocal spectacles were not worn.⁷⁸ However, this study did not address the issue of whether spectacle wear of any kind may be a risk factor for falls. Davies and co-workers⁷⁹ provided further evidence that multifocals may be a significant risk factor for falls. They documented the risk of underfoot accidents in patients attending a hospital fracture clinic and found that wearing multifocals was a risk factor for 'missed edge of step' accidents (not necessarily resulting in a fall), whereas wearing single vision distance spectacles was not a significant risk factor. In contrast, bifocal use was not significantly associated with either hip fractures⁶⁴ or the number of falls.⁵²

Importantly, none of these studies distinguishes between the types of multifocal lens design worn. Future research is required to investigate the association between the risk of falls and hip fractures and the use of single vision distance spectacles compared to various multifocal designs (bifocals, trifocals, progressive lenses).

MAJOR CAUSES OF VISUAL IMPAIRMENT AND FALLS

The prevalence of visual impairment in Australia, as in other developed countries, rises with increasing age for individuals aged 65 years or older. For instance, the prevalence of bilateral visual impairment, classified as visual acuity worse than the driving standard of 6/12, increases from one per cent for those aged 60 to 69 years to 26 per cent for those aged 80 or more.⁴³ In 2000, the number of Australians aged over 60 with visual impairment was estimated to be about 300,000.⁸⁰

Under-corrected refractive error remains the major cause of visual impairment, followed by ocular disease, primarily from age-related macular degeneration (ARM), cataract, glaucoma and diabetic retinopathy. Importantly, these ocular conditions often lead to reductions in visual acuity, contrast sensitivity, visual fields and depth perception or a combination of these, all

of which have been associated with increased risk of falls. Therefore, it is likely that these ocular conditions are associated with a risk of falls and that prevention or treatment will reduce that risk.

The leading cause of visual impairment is under-corrected refractive error. More than 20 per cent of Australians aged 40 or older have under-corrected refractive error (defined as visual acuity 6/9 or worse), with almost half (45 per cent) amenable to improved vision by at least two lines (to 6/6 equivalent) by provision of appropriate spectacle corrections.⁸¹ As the falls research estimates that reduced visual acuity approximately doubles the risk of a fall, the use of appropriate refractive corrections for older individuals should reduce the incidence of falls, although this has yet to be demonstrated in large studies.

Cataract is a major cause of visual impairment, with Australian population studies estimating that more than 30 per cent of the older population have significant cataract in at least one eye.⁸² By 2021, it is projected that there will be 2.7 million older Australians with clinically significant cataract in at least one eye.⁸²

Studies that have conducted ophthalmic examinations to characterise the presence or absence of cataract have found that cataracts can increase the risk of falls. Posterior subcapsular cataract increases the risk of falls by 2.1 times, while no increase in risk was found for individuals with either nuclear or cortical cataract.²⁶ Similarly, posterior subcapsular cataract is the only type of cataract to increase the risk of hip fracture by a factor of five.⁶² Conversely, McCarty, Fu and Taylor⁸³ reported that the presence of nuclear cataract significantly increased (almost three-fold) the risk of a fall, while no other form of cataract had an effect. Only the Framingham study⁵⁹ failed to find any association between cataract (defined as late lens changes) and the incidence of hip fractures. While most of these studies suggest that the presence of some form of cataract can significantly increase the risks of falling or fractures, the specific types of cataract implicated vary among studies.

In contrast, a number of studies has failed to find an association between self-

reported cataract and hip fracture or falls in either prospective^{9,52} or case controlled studies.^{63,64} However, these studies are limited by the lack of accuracy of self-reported measures and the associated inability to grade the severity of the cataract.

Primary open angle glaucoma is the leading cause of visual field loss in the older population.⁷³ An estimated four per cent of older Australians have glaucoma, although around half of these are currently undiagnosed.^{82,84} While a number of studies has shown that glaucoma and the use of certain topical glaucoma medications are associated with the risk of falls and hip fracture, others have not.

A large-scale US study examined medical risk factors associated with hospitalisation for unintentional falls and found that glaucoma was a significant risk factor (1.1 times).⁸⁵ A retrospective study by Dolinis, Harrison and Andrews² showed that self-reported glaucoma is associated with an increased risk of falls (1.63 times), while a prospective hip fracture study by Ivers and colleagues⁶² reported that glaucoma (confirmed by ophthalmic examination) in those aged over 75 years was a significant risk factor (8.1 times). Other studies using self-reported glaucoma have failed to find any association with falls⁵² or hip fractures,^{63,64} while diagnosed glaucoma had no significant association with falls^{26,83} or hip fractures.⁵⁹

Interestingly, several studies have shown a link between the use of topical glaucoma medications and an increased likelihood of falls. Glynn and co-workers⁷⁴ retrospectively investigated 489 subjects with glaucoma and found that the risk of falls increased by a factor of five if non-miotic glaucoma medications were used (of which 90 per cent were β -blockers) and by a factor of three if a miotic was used. While there was an increased risk of falls with 40 per cent loss of the visual field, this was not significant in their multivariate model. Similarly, Ivers and associates²⁶ found that the use of non-miotic medications doubled the prevalence ratio of multiple falls, while the presence of the disease showed no increased risk of falls. These studies suggest that the side-effects of certain topical glaucoma medications,

particularly the non-selective beta-blockers known to affect cardiac and respiratory functions, may be the cause of increased falls in individuals with glaucoma. However, the use of prescribed oral beta-blockers to treat hypertension and angina has not been shown to increase the risk of falls in older people.⁸⁶

In summary, there is no clear evidence to support an association between glaucoma and an increased risk of falls, nor with the role of topical medications. Further investigation is required to determine whether glaucoma medication is a risk factor or whether it simply reflects some aspect of impaired visual function. The use of newer topical anti-glaucoma agents, such as prostaglandin analogues and alpha-antagonists, may also be associated with falls. While these newer drugs have less cardiac and respiratory side-effects, there is the potential for other side effects, such as sedation and dizziness,⁸⁷ which may increase the risk of falls.

Age-related macular degeneration (ARM) is the leading cause of irreversible visual impairment, affecting around one per cent of people aged between 70 and 79 years and rising sharply to more than 16 per cent in those aged over 90.⁸⁰ Age-related macular degeneration can result in reduced visual acuity, along with changes in other visual functions, such as contrast sensitivity, macular recovery, central field sensitivity and dark adaptation.^{88,89} Individuals with ARM rely less on their vision to maintain stable posture, especially during disruptions to their proprioceptive system.^{31,90} This would suggest that individuals with ARM are more likely to fall during times of somatosensory disruptions (such as on slippery surfaces).

While there is extensive research to support an association between reduced visual acuity and increased risk of falls, there is very little evidence to suggest that ARM is a specific risk factor. Three studies have failed to find ARM to be a significant risk factor for falls²⁶ or hip fractures.^{59,62} This could be due to the relatively small numbers of participants with ARM in these studies and varying degrees of disease severity.

Diabetic retinopathy can result in visual impairment and is estimated to occur in

less than one per cent of older Australians.⁸⁰ Changes in the visual and somatosensory systems, due to polyneuropathy, can compromise balance in people with diabetes. Diabetic polyneuropathy describes the distal sensory loss and pain that can occur due to nerve damage in the feet and legs and occurs in about 25 per cent of diabetic patients after 10 years and rises to about 70 per cent after 30 years.⁹¹ Visual function can be affected due to diabetic retinopathy and maculopathy and is present to some degree in almost all diabetic patients after 20 years.⁹² In addition, the treatment of diabetic eye disease can produce unwanted side-effects such as visual field loss, impaired colour vision, contrast sensitivity and dark adaptation and increased glare sensitivity.^{93,94}

The rate of falls among diabetic patients is 49 per cent and severe polyneuropathy is a significant risk factor in these falls.⁹⁵ Koski and associates⁹ found that the presence of polyneuropathy increases the odds of an injurious fall by a factor of 2.5 for individuals over 70 years of age, who are living independently.

Impaired vision by self-report is also associated with increased risk of hip fracture.⁹⁶ In fact, impaired vision in both men and women having type 2 diabetes of more than five years duration and aged over 75 doubles the risk of a hip fracture. The presence of diabetic retinopathy, diabetic disease duration of greater than 10 years and cortical cataract greater than 25 per cent are significant risk factors for hip fractures.⁹⁷ This same research group did not find diabetic retinopathy to be a significant risk factor in an earlier retrospective study of falls²⁶ or a five-year prospective study of hip fracture.⁶² Likewise, Felson and colleagues⁵⁹ found no association between hip fracture and diabetic retinopathy in their 10-year prospective study.

These studies provide only limited evidence that visual impairment from diabetic retinopathy can be a risk factor in falls. However, these visual risk factors may be important, if additional diabetic risk factors for falls, such as polyneuropathy, are also present.

VISION INTERVENTIONS TO PREVENT FALLS

The implication of the research evidence is that prevention, detection and treatment of visual impairment should reduce the risk of falls in older people, however, there is limited research to support the effectiveness of visual interventions. A number of multifactorial intervention programs have included visual screening to identify and modify known risk factors, while there have been only two studies which have investigated the effect of a specific visual intervention, namely cataract surgery, in reducing the rate of falls. Indeed, recent reviews support the need for intervention studies that focus specifically on vision.^{98,99}

Multifactorial programs

Falls patients presenting to an accident and emergency clinic and assigned to an intervention group received a detailed Medical and Occupational Therapy assessment and referral was made to appropriate services, if required.⁴⁸ This detailed examination included vision screening, however, the visual outcome provided for those considered visually impaired is not described. Importantly, the intervention group, when compared to the control group, demonstrated a significant reduction (approximately 60 per cent) in falls.

Clemson and colleagues¹⁰⁰ evaluated the effectiveness of a falls prevention program that consisted of educational sessions and a home visit. These sessions included discussions of the importance of vision and regular eye examinations in reducing the risk of falls. The intervention group receiving these sessions experienced a 31 per cent reduction in falls, highlighting the effectiveness of such programs. Similarly, Casteel and associates¹⁰¹ evaluated an intervention program that included identification and treatment of existing visual impairment. Nearly half of those participating in the intervention program received some form of visual intervention in the form of referral to other health services. The participants who completed the program had a 53 per cent reduction in the risk of a fall, while there was no sig-

nificant change in risk for those not participating in the program.

Day and co-workers¹⁰² evaluated the effect of three specific interventions (exercise, home hazard management and vision), as well as combinations of these, in 1,090 community-dwelling people aged 70 or older. The visual intervention strategy involved referral for further ophthalmic assessment, if vision was reduced, although the criterion was not specified. The strongest effect was observed for a combination of all three interventions, producing an estimated 14 per cent reduction in rate of falls, however, the visual intervention alone had no effect. This may be because the control group showed an improvement in visual acuity, while those receiving the visual intervention did not. In fact, less than five per cent of those in the visual intervention group received any change in prescription or surgery, while all participants were given a brochure on the importance of eye care.

In summary, these multifactorial studies highlight the possibility that strategies to improve visual function in older people, particularly in combination with other forms of intervention, can play an important role in falls prevention.

Specific visual intervention:

Cataract surgery

The postural stability of people with cataract improves significantly following cataract removal.¹⁰³ In a small study of 84 cataract patients by Brannan and associates,¹⁰⁴ 31 individuals (37 per cent) had experienced a fall in the six months leading up to their cataract surgery. Six months following surgery, only eight individuals (10 per cent) reported a fall (six of these were presurgery fallers), showing that the odds of an individual having a fall after having cataract surgery were reduced by 69 per cent.

In a study by Harwood and colleagues,¹⁰⁵ 154 of 306 women received expedited cataract surgery, while 152 were allocated to a control group, who were placed on the standard operation waiting list. Twenty-eight patients receiving expedited cataract operations fell twice or more, compared with 38 of the control patients, showing a 40 per cent risk reduction for multiple falls

| |
|---|
| <p>Increase awareness of visual factors for falls</p> <ul style="list-style-type: none"> Provide education for professional groups (such as GPs) Provide education to increase public awareness Promote regular eye examinations in older age groups Improve screening of high-risk populations (such as nursing home residents); <p>Refractive correction</p> <ul style="list-style-type: none"> Provide appropriate refractive error correction Consider single vision lenses in higher risk fallers; Provide careful instruction on the use of multifocal lenses Recommend frame choices that minimise frame impedance in the peripheral visual field Beware of monovision correction in older people with high falls risk; <p>Cataract</p> <ul style="list-style-type: none"> Provide referral for cataract surgery to improve visual function Refer for second eye surgery if there is impaired depth perception <p>Glaucoma</p> <ul style="list-style-type: none"> Provide early detection and treatment to minimise visual losses Increase awareness that certain glaucoma medications increase the risk of falls Provide education and advice on managing field loss <p>Diabetic retinopathy</p> <ul style="list-style-type: none"> Early treatment can reduce visual impairment; Screening for retinopathy for newly diagnosed diabetics Provide education on importance of good diabetes management <p>Age-related macular degeneration</p> <ul style="list-style-type: none"> Referral for early treatment for neovascular maculopathy to limit visual impairment Provide education and advice on managing visual loss <p>Permanent visual impairment</p> <ul style="list-style-type: none"> Discuss visual environment modification Referral to low vision rehabilitation Referral for home hazard management: Commonwealth and State funded programs within the National Aged Care Assessment Program (Aged and Community Care information line 1800 500 853); Department of Veterans Affairs 'HomeFront' program (1800 80 1945). |
|---|

Table 1. Recommendations for optometrists in falls prevention in older people

following the cataract operation. Similarly, four patients in the operated group had a fracture, compared with 12 in the control group, showing a 67 per cent risk reduction. Thus, cataract surgery reduced the overall rate of falling by 34 per cent. Both of these studies^{104,105} highlight the fact that cataract surgery can prevent falls.

The optometrist's role

Optometrists have an important role in falls prevention given their expertise in prescribing appropriate refractive corrections, recognising and diagnosing ocular disease, referring patients for appropriate

ophthalmic treatment and educating patients about ocular disease (Table 1).

The evidence that reduced visual acuity is associated with an increased risk of falls emphasises the importance of optometrists providing optimal correction for their patients with the most appropriate form of spectacle lenses, taking into account other factors affecting the risk of falls. For example, optometrists should promote the use of single vision lenses for walking in patients who are high-risk fallers due to other health conditions, such as those with Parkinson's disease or diabetes. Optometrists also need to educate their

patients on the importance of wearing their optimal spectacle correction when walking, especially under poor lighting conditions.

Optometrists also have an important role in falls prevention through their detection of eye disease at an early stage, given the link between ocular disease and the increased risk of falls. For example, as more than 50 per cent of individuals with glaucoma are unaware of their condition,⁸² effective screening and early detection of glaucoma are imperative. This further emphasises the need to use the most effective strategies, including the use of new technologies, such as frequency doubling technology, laser scanning polarimetry and ocular coherence technology, to detect and monitor ocular diseases.

The treatment of ocular disease is developing and improving disease outcomes, underscoring the need for early detection. For instance, photodynamic therapy is useful in reducing visual impairment resulting from neovascular ARM, while antioxidant supplementation is effective in preventing complications in some forms of ARM. Similarly, advances in anti-glaucoma medications are effective with the benefit of fewer ocular and systemic side-effects.

Patients need to be more aware of the importance of prevention and treatment of ocular disease and the need for regular eye examinations. Patients should be aware of modifiable risk factors such as smoking, and the non-modifiable risk factors, such as family ocular history. Patients should be informed of the importance of following treatment regimes carefully and how their visual conditions may increase their risk of falls. For instance, patients with diabetes need vision screening at the time of initial diagnosis and they should be aware that effective control of diabetes can reduce the risk of developing retinal complications.¹⁰⁶

Finally, optometrists need to play an active role in community health care. There is a need for improved eye-care services in nursing homes, a setting known to have high rates of visual impairment and falls. For the elderly fallers living in the community, the implementation of multidisciplinary fall care programs should also

involve optometrists to provide appropriate visual assessment and advice.

CONCLUSION

Recent literature on falls in older people indicates an association between visual function and falls. While there are many factors associated with falls in older people, good vision is essential for maintaining postural stability, effective mobility within the environment and avoiding falls and hip fractures. Impairment in visual functions, such as visual acuity, contrast sensitivity, visual fields and depth perception, are associated with an increased risk of falls as is visual impairment due to eye disease. Falls can be reduced using cataract surgery as a visual intervention. Optometrists have a major role to play in optimising the visual function in older people to prevent falls.

GRANTS AND FINANCIAL SUPPORT

We acknowledge support from the NHMRC Prevention of Injuries in Older People Partnership in Injury grant.

REFERENCES

1. Lord SR, Dayhew J. Visual risk factors for falls in older people. *J Am Geriatr Soc* 2001; 49: 508-515.
2. Dolinis J, Harrison JE, Andrews GR. Factors associated with falling in older Adelaide residents. *Aust N Z J Public Health* 1997; 21: 462-468.
3. Lord SR, Sambrook PN, Gilbert C, Kelly PJ, Nguyen T, Webster IW, Eisman JA. Postural stability, falls and fractures in the elderly: results from the Dubbo Osteoporosis Epidemiology Study. *Med J Aust* 1994; 160: 684-685, 688-691.
4. Lord SR, March LM, Cameron ID, Cumming RG, Schwarz J, Zochling J, Chen JS, Makaroff J, Sitoh YY, Lau TC, Brnabic A, Sambrook PN. Differing risk factors for falls in nursing home and intermediate-care residents who can and cannot stand unaided. *J Am Geriatr Soc* 2003; 51: 1645-1650.
5. Rubenstein LZ, Josephson KR, Robbins AS. Falls in the nursing home. *Ann Intern Med* 1994; 121: 442-451.
6. Klein BE, Moss SE, Klein R, Lee KE, Cruickshanks KJ. Associations of visual function with physical outcomes and limitations 5 years later in an older population: the Beaver Dam eye study. *Ophthalmology* 2003; 110: 644-650.

7. Australian Bureau of Statistics. Projections of the Populations of Australia, States and Territories 1999-2101. 2002: ABS Cat No 3222.0.
8. Dunn C, Sadkowsky K, Jelfs P. Trends in Death. *Australian Institute of Health and Welfare* 2002.
9. Koski K, Luukinen H, Laippala P, Kivela SL. Risk factors for major injurious falls among the home-dwelling elderly by functional abilities. A prospective population-based study. *Gerontology* 1998; 44: 232-238.
10. Tinetti ME, Speechley M, Ginter SF. Risk factors for falls among elderly persons living in the community. *N Engl J Med* 1988; 319: 1701-1707.
11. Davidson CW, Merrilees MJ, Wilkinson TJ, McKie JS, Gilchrist NL. Hip fracture mortality and morbidity—can we do better? *N Z Med J* 2001; 114: 329-332.
12. Rosell PA, Parker MJ. Functional outcome after hip fracture. A 1-year prospective outcome study of 275 patients. *Injury* 2003; 34: 529-532.
13. Alegre-Lopez J, Cordero-Guevara J, Alonso-Valdivielso JL, Fernandez-Melon J. Factors associated with mortality and functional disability after hip fracture: an inception cohort study. *Osteoporos Int* 2004: Epub.
14. Kreisfeld R, Newson R, Harrison J. Injury Deaths, Australia 2002. *Australian Institute of Health and Welfare* 2004.
15. Helps Y, Cripps R, Harrison J. Hospital separations due to injury and poisoning, Australia 1999-00. *Australian Institute of Health and Welfare* 2002.
16. Legters K. Fear of falling. *Phys Ther* 2002; 82: 264-272.
17. Cumming RG, Salkeld G, Thomas M, Szonyi G. Prospective study of the impact of fear of falling on activities of daily living, SF-36 scores, and nursing home admission. *J Gerontol A Biol Sci Med Sci* 2000; 55: M299-M305.
18. Nevitt MC, Cummings SR, Kidd S, Black D. Risk factors for recurrent nonsyncopal falls. A prospective study. *JAMA* 1989; 261: 2663-2668.
19. Tinetti ME, Mendes de Leon CF, Doucette JT, Baker DI. Fear of falling and fall-related efficacy in relationship to functioning among community-living elders. *J Gerontol* 1994; 49: M140-M147.
20. Tinetti ME, Williams CS. Falls, injuries due to falls, and the risk of admission to a nursing home. *N Engl J Med* 1997; 337: 1279-1284.
21. Hall SE, Hendrie DV. A prospective study of the costs of falls in older adults living in the community. *Aust N Z J Public Health* 2003; 27: 343-351.
22. Moller J. Projected costs of fall related injury to older persons due to demographic changes in Australia. *Commonwealth Depart-*

- ment of Health and Ageing 2003.
23. Close JC. Interdisciplinary practice in the prevention of falls—a review of working models of care. *Age Ageing* 2001; 30 Suppl 4: 8-12.
 24. Tromp AM, Pluijm SM, Smit JH, Deeg DJ, Bouter LM, Lips P. Fall-risk screening test: a prospective study on predictors for falls in community-dwelling elderly. *J Clin Epidemiol* 2001; 54: 837-844.
 25. Graafmans WC, Ooms ME, Hofstee HM, Bezemer PD, Bouter LM, Lips P. Falls in the elderly: a prospective study of risk factors and risk profiles. *Am J Epidemiol* 1996; 143: 1129-1136.
 26. Ivers RQ, Cumming RG, Mitchell P, Attebo K. Visual impairment and falls in older adults: the Blue Mountains Eye Study. *J Am Geriatr Soc* 1998; 46: 58-64.
 27. Lord S, Ward J, Williams P, Anstey K. An epidemiological study of falls in older community-dwelling women: the Randwick falls and fractures study. *Aust J Public Health* 1993; 17: 240-245.
 28. Tomany SC, Wang JJ, Van Leeuwen R, Klein R, Mitchell P, Vingerling JR, Klein BE, Smith W, de Jong PT. Risk factors for incident age-related macular degeneration: pooled findings from 3 continents. *Ophthalmology* 2004; 111: 1280-1287.
 29. Paulus WM, Straube A, Brandt T. Visual stabilization of posture. Physiological stimulus characteristics and clinical aspects. *Brain* 1984; 107: 1143-1163.
 30. Paulus W, Straube A, Brandt TH. Visual postural performance after loss of somatosensory and vestibular function. *J Neurol Neurosurg Psychiatry* 1987; 50: 1542-1545.
 31. Turano KA, Dagnelie G, Herdman SJ. Visual stabilization of posture in persons with central visual field loss. *Invest Ophthalmol Vis Sci* 1996; 37: 1483-1491.
 32. Pykko I, Jantti P, Aalto H. Postural control in elderly subjects. *Age Ageing* 1990; 19: 215-221.
 33. Park JJ, Tang Y, Lopez I, Ishiyama A. Age-related change in the number of neurons in the human vestibular ganglion. *J Comp Neurol* 2001; 431: 437-443.
 34. Skinner HB, Barrack RL, Cook SD. Age-related decline in proprioception. *Clin Orthop Relat Res* 1984; 184: 208-211.
 35. Choy NL, Brauer S, Nitz J. Changes in postural stability in women aged 20 to 80 years. *J Gerontol A Biol Sci Med Sci* 2003; 58: 525-530.
 36. Turano K, Rubin GS, Herdman SJ, Chee E, Fried LP. Visual stabilization of posture in the elderly: fallers vs. nonfallers. *Optom Vis Sci* 1994; 71: 761-769.
 37. Anand V, Buckley J, Scally A, Elliott DB. The effect of refractive blur on postural stability. *Ophthalmic Physiol Opt* 2002; 22: 528-534.
 38. Anand V, Buckley JG, Scally A, Elliott DB. Postural stability changes in the elderly with cataract simulation and refractive blur. *Invest Ophthalmol Vis Sci* 2003; 44: 4670-4675.
 39. Anand V, Buckley JG, Scally A, Elliott DB. Postural stability in the elderly during sensory perturbations and dual tasking: the influence of refractive blur. *Invest Ophthalmol Vis Sci* 2003; 44: 2885-2891.
 40. Lord SR, Menz HB. Visual contributions to postural stability in older adults. *Gerontology* 2000; 46: 306-310.
 41. Lee HK, Scudds RJ. Comparison of balance in older people with and without visual impairment. *Age Ageing* 2003; 32: 643-649.
 42. Liou HL, McCarty CA, Jin CL, Taylor HR. Prevalence and predictors of undercorrected refractive errors in the Victorian population. *Am J Ophthalmol* 1999; 127: 590-596.
 43. Wang JJ, Foran S, Mitchell P. Age-specific prevalence and causes of bilateral and unilateral visual impairment in older Australians: the Blue Mountains Eye Study. *Clin Exp Ophthalmol* 2000; 28: 268-273.
 44. Ivers RQ, Mitchell P, Cumming RG. Visual function tests, eye disease and symptoms of visual disability: a population-based assessment. *Clin Exp Ophthalmol* 2000; 28: 41-47.
 45. Marks R, Allegrante JP, Ronald MacKenzie C, Lane JM. Hip fractures among the elderly: causes, consequences and control. *Ageing Res Rev* 2003; 2: 57-93.
 46. Cummings SR, Nevitt MC, Kidd S. Forgetting falls. The limited accuracy of recall of falls in the elderly. *J Am Geriatr Soc* 1988; 36: 613-616.
 47. Jack CI, Smith T, Neoh C, Lye M, McGalliard JN. Prevalence of low vision in elderly patients admitted to an acute geriatric unit in Liverpool: elderly people who fall are more likely to have low vision. *Gerontology* 1995; 41: 280-285.
 48. Close J, Ellis M, Hooper R, Glucksman E, Jackson S, Swift C. Prevention of falls in the elderly trial (PROFET): a randomised controlled trial. *Lancet* 1999; 353: 93-97.
 49. Klein BE, Klein R, Lee KE, Cruickshanks KJ. Performance-based and self-assessed measures of visual function as related to history of falls, hip fractures, and measured gait time. The Beaver Dam Eye Study. *Ophthalmology* 1998; 105: 160-164.
 50. Kuyk T, Elliott JL. Visual factors and mobility in persons with age-related macular degeneration. *J Rehabil Res Dev* 1999; 36: 303-312.
 51. Geruschat DR, Turano KA, Stahl JW. Traditional measures of mobility performance and retinitis pigmentosa. *Optom Vis Sci* 1998; 75: 525-537.
 52. Coleman AL, Stone K, Ewing SK, Nevitt M, Cummings S, Cauley JA, Ensrud KE, Harris EL, Hochberg MC, Mangione CM. Higher risk of multiple falls among elderly women who lose visual acuity. *Ophthalmology* 2004; 111: 857-862.
 53. Stalenhoef PA, Diederiks JP, Knottnerus JA, Kester AD, Crebolder HF. A risk model for the prediction of recurrent falls in community-dwelling elderly: a prospective cohort study. *J Clin Epidemiol* 2002; 55: 1088-1094.
 54. Friedman SM, Munoz B, West SK, Rubin GS, Fried LP. Falls and fear of falling: which comes first? A longitudinal prediction model suggests strategies for primary and secondary prevention. *J Am Geriatr Soc* 2002; 50: 1329-1335.
 55. Lord SR, Clark RD, Webster IW. Visual acuity and contrast sensitivity in relation to falls in an elderly population. *Age Ageing* 1991; 20: 175-181.
 56. Campbell AJ, Borrie MJ, Spears GF. Risk factors for falls in a community-based prospective study of people 70 years and older. *J Gerontol* 1989; 44: M112-M117.
 57. de Boer MR, Pluijm SM, Lips P, Moll AC, Volker-Dieben HJ, Deeg DJ, Van Rens GH. Different aspects of visual impairment as risk factors for falls and fractures in older men and women. *J Bone Miner Res* 2004; 19: 1539-1547.
 58. Morris M, Osborne D, Hill K, Kendig H, Lundgren-Lindquist B, Browning C, Reid J. Predisposing factors for occasional and multiple falls in older Australians who live at home. *Aust J Physiother* 2004; 50: 153-159.
 59. Felson DT, Anderson JJ, Hannan MT, Milton RC, Wilson PW, Kiel DP. Impaired vision and hip fracture. The Framingham Study. *J Am Geriatr Soc* 1989; 37: 495-500.
 60. Dargent-Molina P, Favier F, Grandjean H, Baudoin C, Schott AM, Hausherr E, Meunier PJ, Breart G. Fall-related factors and risk of hip fracture: the EPIDOS prospective study. *Lancet* 1996; 348: 145-149.
 61. Cummings SR, Nevitt MC, Browner WS, Stone K, Fox KM, Ensrud KE, Cauley J, Black D, Vogt TM. Risk factors for hip fracture in white women. Study of Osteoporotic Fractures Research Group. *N Engl J Med* 1995; 332: 767-773.
 62. Ivers RQ, Cumming RG, Mitchell P, Simpson JM, Peduto AJ. Visual risk factors for hip fracture in older people. *J Am Geriatr Soc* 2003; 51: 356-363.
 63. Grisso JA, Kelsey JL, Strom BL, Chiu GY, Maislin G, O'Brien LA, Hoffman S, Kaplan F. Risk factors for falls as a cause of hip fracture in women. The Northeast Hip Fracture Study Group. *N Engl J Med* 1991; 324: 1326-1331.
 64. Ivers RQ, Norton R, Cumming RG, Butler M, Campbell AJ. Visual impairment and risk of hip fracture. *Am J Epidemiol* 2000; 152: 633-639.
 65. Marron JA, Bailey IL. Visual factors and orientation-mobility performance. *Am J Optom Physiol Opt* 1982; 59: 413-426.
 66. Woods R, Wood J. The role of contrast sen-

- sitivity charts and contrast letter charts in optometric practice. *Clin Exp Optom* 1995; 78: 43-57.
67. Verbaken JH, Johnston AW. Population norms for edge contrast sensitivity. *Am J Optom Physiol Opt* 1986; 63: 724-732.
 68. Wainwright SA, Marshall LM, Ensrud KE, Cauley JA, Black DM, Hillier TA, Hochberg MC, Vogt MT, Orwoll ES. Hip fracture in women without osteoporosis. *J Clin Endocrinol Metab* 2005; 90: 2787-2793.
 69. Johannsdottir KR, Stelmach LB. Monovision: a review of the scientific literature. *Optom Vis Sci* 2001; 78: 646-651.
 70. Turano K, Herdman SJ, Dagnelie G. Visual stabilization of posture in retinitis pigmentosa and in artificially restricted visual fields. *Invest Ophthalmol Vis Sci* 1993; 34: 3004-3010.
 71. Turano KA, Rubin GS, Quigley HA. Mobility performance in glaucoma. *Invest Ophthalmol Vis Sci* 1999; 40: 2803-2809.
 72. Turano KA, Broman AT, Bandeen-Roche K, Munoz B, Rubin GS, West S. Association of visual field loss and mobility performance in older adults: Salisbury Eye Evaluation Study. *Optom Vis Sci* 2004; 81: 298-307.
 73. Ramrattan RS, Wolfs RC, Panda-Jonas S, Jonas JB, Bakker D, Pols HA, Hofman A, de Jong PT. Prevalence and causes of visual field loss in the elderly and associations with impairment in daily functioning: the Rotterdam Study. *Arch Ophthalmol* 2001; 119: 1788-1794.
 74. Glynn RJ, Seddon JM, Krug JH Jr, Sahagian CR, Chiavelli ME, Champion EW. Falls in elderly patients with glaucoma. *Arch Ophthalmol* 1991; 109: 205-210.
 75. Owsley C, Ball K. Assessing visual function in the older driver. *Clin Geriatr Med* 1993; 9: 389-401.
 76. Owsley C, McGwin G Jr. Association between visual attention and mobility in older adults. *J Am Geriatr Soc* 2004; 52: 1901-1906.
 77. Broman AT, West SK, Munoz B, Bandeen-Roche K, Rubin GS, Turano KA. Divided visual attention as a predictor of bumping while walking: the Salisbury Eye Evaluation. *Invest Ophthalmol Vis Sci* 2004; 45: 2955-2960.
 78. Lord SR, Dayhew J, Howland A. Multifocal glasses impair edge-contrast sensitivity and depth perception and increase the risk of falls in older people. *J Am Geriatr Soc* 2002; 50: 1760-1766.
 79. Davies JC, Kemp GJ, Stevens G, Frostick SP, Manning DP. Bifocal/varifocal spectacles, lighting and missed-step accidents. *Safety Sci* 2001; 38: 211-226.
 80. Weih LM, VanNewkirk MR, McCarty CA, Taylor HR. Age-specific causes of bilateral visual impairment. *Arch Ophthalmol* 2000; 118: 264-269.
 81. Thiagalingam S, Cumming RG, Mitchell P. Factors associated with undercorrected refractive errors in an older population: the Blue Mountains Eye Study. *Br J Ophthalmol* 2002; 86: 1041-1045.
 82. Rochtchina E, Mukesh BN, Wang JJ, McCarty CA, Taylor HR, Mitchell P. Projected prevalence of age-related cataract and cataract surgery in Australia for the years 2001 and 2021: pooled data from two population-based surveys. *Clin Exp Ophthalmol* 2003; 31: 233-236.
 83. McCarty CA, Fu CL, Taylor HR. Predictors of falls in the Melbourne visual impairment project. *Aust N Z J Public Health* 2002; 26: 116-119.
 84. Weih LM, Nanjan M, McCarty CA, Taylor HR. Prevalence and predictors of open-angle glaucoma: results from the visual impairment project. *Ophthalmology* 2001; 108: 1966-1972.
 85. Guse CE, Porinsky R. Risk factors associated with hospitalization for unintentional falls: Wisconsin hospital discharge data for patients aged 65 and over. *Wis Med J* 2003; 102: 37-42.
 86. Leipzig RM, Cumming RG, Tinetti ME. Drugs and falls in older people: a systematic review and meta-analysis. II. Cardiac and analgesic drugs. *J Am Geriatr Soc* 1999; 47: 40-50.
 87. Novack GD, O'Donnell MJ, Molloy DW. New glaucoma medications in the geriatric population: efficacy and safety. *J Am Geriatr Soc* 2002; 50: 956-962.
 88. Midena E, Degli Angeli C, Blarzino MC, Valenti M, Segato T. Macular function impairment in eyes with early age-related macular degeneration. *Invest Ophthalmol Vis Sci* 1997; 38: 469-477.
 89. Brown B, Adams AJ, Coletta NJ, Haegerstrom-Portnoy G. Dark adaptation in age-related maculopathy. *Ophthalmic Physiol Opt* 1986; 6: 81-84.
 90. Elliott DB, Patla AE, Flanagan JG, Spaulding S, Rietdyk S, Strong G, Brown S. The Waterloo Vision and Mobility Study: postural control strategies in subjects with ARM. *Ophthalmic Physiol Opt* 1995; 15: 553-559.
 91. Simmons RW, Richardson C, Pozos R. Postural stability of diabetic patients with and without cutaneous sensory deficit in the foot. *Diabetes Res Clin Pract* 1997; 36: 153-160.
 92. Klein R, Klein BE, Moss SE, Davis MD, DeMets DL. The Wisconsin epidemiologic study of diabetic retinopathy. II. Prevalence and risk of diabetic retinopathy when age at diagnosis is less than 30 years. *Arch Ophthalmol* 1984; 102: 520-526.
 93. Mackie SW, Walsh G. Contrast and glare sensitivity in diabetic patients with and without pan-retinal photocoagulation. *Ophthalmic Physiol Opt* 1998; 18: 173-181.
 94. Buckley S, Jenkins L, Benjamin L. Field loss after pan retinal photocoagulation with diode and argon lasers. *Doc Ophthalmol* 1992; 82: 317-322.
 95. Richardson JK. Factors associated with falls in older patients with diffuse polyneuropathy. *J Am Geriatr Soc* 2002; 50: 1767-1773.
 96. Forsen L, Meyer HE, Midthjell K, Edna TH. Diabetes mellitus and the incidence of hip fracture: results from the Nord-Trøndelag Health Survey. *Diabetologia* 1999; 42: 920-925.
 97. Ivers RQ, Cumming RG, Mitchell P, Peduto AJ. Diabetes and risk of fracture: The Blue Mountains Eye Study. *Diabetes Care* 2001; 24: 1198-1203.
 98. Legood R, Scuffham P, Cryer C. Are we blind to injuries in the visually impaired? A review of the literature. *Inj Prev* 2002; 8: 155-160.
 99. Gillespie LD, Gillespie WJ, Robertson MC, Lamb SE, Cumming RG, Rowe BH. Interventions for preventing falls in elderly people. *Cochrane Database Syst Rev* 2003; CD000340.
 100. Clemson L, Cumming RG, Kendig H, Swann M, Heard R, Taylor K. The effectiveness of a community-based program for reducing the incidence of falls in the elderly: a randomized trial. *J Am Geriatr Soc* 2004; 52: 1487-1494.
 101. Casteel C, Peek-Asa C, Lacsamana C, Vazquez L, Kraus JF. Evaluation of a falls prevention program for independent elderly. *Am J Health Behav* 2004; 28 Suppl 1: S51-S60.
 102. Day L, Fildes B, Gordon I, Fitzharris M, Flamer H, Lord S. Randomised factorial trial of falls prevention among older people living in their own homes. *Br Med J* 2002; 325: 128.
 103. Schwartz S, Segal O, Barkana Y, Schwesig R, Avni I, Morad Y. The effect of cataract surgery on postural control. *Invest Ophthalmol Vis Sci* 2005; 46: 920-924.
 104. Brannan S, Dewar C, Sen J, Clarke D, Marshall T, Murray PI. A prospective study of the rate of falls before and after cataract surgery. *Br J Ophthalmol* 2003; 87: 560-562.
 105. Harwood RH, Foss AJ, Osborn F, Gregson RM, Zaman A, Masud T. Falls and health status in elderly women following first eye cataract surgery: a randomised controlled trial. *Br J Ophthalmol* 2005; 89: 53-59.
 106. Walker R. Diabetic retinopathy: protecting the vision of people with diabetes. *Br J Community Nurs* 2004; 9: 545-547.

Corresponding author:
Associate Professor J Wood
School of Optometry
Queensland University of Technology
Kelvin Grove QLD 4059
AUSTRALIA
j.wood@qut.edu.au