PROVISION OF SPECTACLE LENS CORRECTION TO ELDERLY PEOPLE AT RISK OF FALLS

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SUMMARY

Falls have a major impact on the quality of life of fallers and on the health and social economy of the nation.

An evidence base of predominantly laboratory studies exists, which suggests bifocal and progressive addition lens designs increase falls risk. Findings either lacked discrimination between bifocal and progressive addition lenses, were not powered to differentiate between them, or were based on the premise that gaze direction when walking or using stairs is through the lower, near powered zones. This has led to single vision lenses being recommended to those at falls risk.

The primary aim of the studies described in this thesis was, therefore, to investigate whether field trials in the form of a retrospective case control and a prospective cohort study of community-dwelling elderly persons supported previous recommendations.

A survey of GOC registered optometrists and dispensing opticians was undertaken before the main study. Single vision lenses were the lens design of choice for patients deemed at risk of falls.

The main study uniquely differentiated between single vision, bifocal and progressive addition lenses in a UK-based population study of well habituated wearers.

A measure of visual attention (Global Measure of Vision) was designed and evaluated specifically for the study. Established “Timed up and Go” and SF12v2® provided measures of participants’ balance, mobility, and physical and emotional wellbeing.

Logistic regression analysis showed no variable demonstrated statistically significant influence on falls risk in the retrospective study, including spectacle lens design. In the prospective study, previous fall history was the only significant predictor of falls (Odds Ratio: 2.71, $p = .01$), aligning with levels reported in a recent meta-analysis.

This study did not confirm that bifocal or progressive addition lens wear increases falls risk in well-habituated community-dwelling older people, and indicates that changing to single vision lenses may not be necessary.

Keywords: vision, single vision, bifocal, progressive addition lens, multifocal

DEDICATION

To my children, and the joys of the scenic route.

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Undertaking this thesis would not have been possible without the support of Thomas Pocklington Trust, to which I extend my gratitude.

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CONTENTS

LIST OF ABBREVIATIONS

AARP	American Association of Retired Persons
ABDO	Association of British Dispensing Opticians
Add	Addition
ADL	Activities of Daily Living
AGS	American Geriatrics Society
AG	Adaptive Gait
AIO	Association for Independent Optometrists and Dispensing Opticians
AL	Adaptive Locomotion
AMD	Age-related Macular Degeneration
ARCHA	Aston Research Centre for Healthy Ageing
AUC	Area Under the Curve
BGS	British Geriatrics Society
Bif	Bifocal
BOS	Bristol Online Surveys
BP	Bodily Pain
BS EN ISO	British Standard European Norm International Organization for Standardization
BVD	Back Vertex Distance
CG	Clinical Guidance
CHAID	Chi-squared Automatic Interaction Detection
CI	Confidence Interval
CoSt	Co-ordinated Stability
CRT	Classification and Regression Tree(s)
CS	Contrast Sensitivity
d	Distance of lens to eye
D	Dioptre

LIST OF ABBREVIATIONS (cont.)

df	Degrees of freedom
DGI	Dynamic Gait Index
DO	Dispensing Optician(s)
EPV	Events Per Variable
F	Falls
F'_v	Lens power: back vertex
F_1	Lens power: front surface
Fra	Fractures
GH	General Health
GMV	Global Measure of Vision
GOC	General Optical Council
GP	General Practitioner
HES	Hospital Episode Statistics
HFra	Hip Fractures
HNTB	Halstead-Reitan Neuropsychological Test Battery
IF	Injurious Falls
IQR	Inter-Quartile Range
LOCSU	Local Optical Committee Support Unit
LR	Logistic Regression
LVF	Lower Visual Field
MAIM	Merseyside Accident Information Model
MCS	Mental Component Score
ME	Mental Health
MECC	Make Every Contact Count
MMSE	Mini-Mental State Examination
MRC	Medical Research Council

LIST OF ABBREVIATIONS (cont.)

n	Refractive index
n/a	not applicable
n/k	not known
NDNS	National Diet and Nutrition Survey
NHS	National Health Service
NICE	National Institute for Health and Care Excellence
ONS	Office for National Statistics
Optom	Optometrist(s)
OR	Odds Ratio(s)
PAL	Progressive Addition Lens
PCS	Physical Component Score
PF[a]	Physical Function(ing)
PF[b]	Power Factor
POMA	Performance Oriented Mobility Assessment
PPL	Progressive Power Lens
ProFANE	Prevention of Falls Network Europe
PS	Postural Stability
QUEST	Quick Unbiased Efficient Statistical Tree(s)
RE	Role-Emotional
RF	Recurrent Falls
ROC	Receiver Operator Curves
RP	Role-Physical
SD[a]	Stereo-Deficiency
SD[b]	Standard Deviation
SF[a]	Shape Factor
SF[b]	Social Functioning

LIST OF ABBREVIATIONS (cont.)

SF-12v2®	Short Form – 12v2 Health Survey
SM	Spectacle lens Magnification
SV	Single Vision
t	lens thickness
TMT-A	Trail-Making Test A
TMT-B	Trail-Making Test B
Trif	Trifocal
TUG	Timed Up and Go
UFOV	Useful Field of View
UK	United Kingdom
VA	Visual Acuity
VF	Visual Fields
VI	Vision Impairment
VISIBLE	Visual Intervention Strategy Incorporating Bifocal and Long-distance Eyewear
VT	Vitality
WFra	Wrist Fractures
WS	Walking Speed
χ^2	Chi square

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Chapter 1. Thesis objectives and structure

1.1 Thesis objectives

The causes of falls in the elderly population are multifactorial, and their outcomes impact not only on the quality of life and mortality of those who sustain falls, but also on the health and social economy of the nation as a whole. This thesis provides an overview of generic falls risk factors, a literature review of visual falls risk factors, and a review of research pertaining to spectacle lens design features and falls risk.

Previous research has reported an increased falls risk when wearing bifocal or progressive addition lens designs. It has been recommended that switching to single vision lenses (SV) may be beneficial for everyday locomotion or for negotiating stairs if one is considered to be at high risk of falling, and for older people who take part in regular outdoor activities. Key limitations of this research are its predominance of laboratory-based investigations of gait adaptations, a majority of bifocal wearers in the earlier population-based studies, and - most importantly - insufficient discrimination between bifocal and progressive addition lens designs.

A survey of practising optical professionals was undertaken to determine whether and how falls research findings are interpreted in practice. The primary focus of the questionnaire was to ascertain chosen prescribing and dispensing practices for those deemed to be at risk of falls.

Traditional measures of vision, such as visual acuity (VA), contrast sensitivity (CS) and visual fields (VF), provide no information about visual attention, the impairment of which is associated with mobility problems. It was, therefore, considered fundamental that some measure of this aspect should be included in the study.

The Global Measure of Vision (GMV), an inexpensive paper and pencil test, was devised specifically for this purpose.

The primary aim of this study was, therefore, to investigate the influence on falls risk of spectacle lens designs worn by presbyopes, in a community dwelling UK population of persons aged 65 and older. Of specific interest was whether wearers of bifocal (Bif) or progressive addition lenses (PAL) performed differently with regard to sustained falls. To this end, field trials in the form of a retrospective case-control and a prospective cohort study of community-dwelling elderly persons were undertaken.

Visual attention was measured with the GMV, participant mobility was assessed with the Timed up and Go test, and the short form health questionnaire SF12v2® provided physical and emotional health measures. Logistic regression was employed to analyse the study outcomes. The number of falls over a 12 month retrospective and a 12 month prospective period, their circumstances and the severity of sustained injury were identified and analysed with regard to habitual lens wear (SV, Bif or PAL).

1.2 Thesis structure

Chapter 2 details the definitions of "fall" found in research papers, and the definition adopted in this study. The impact of falls on the quality of life of an individual, and the health and social economy of the nation are highlighted, especially with regard to the forecast changes in the UK population structure. A range of falls risk factors are presented as the backdrop to this study.

Vision impairment is a widely acknowledged falls risk factor and Chapter 3 reviews the literature pertaining to visual aspects of falls, such as stereopsis, depth perception, contrast sensitivity and visual acuity. Chapter 4 reviews the literature that directly investigated spectacle lens form (single vision, bifocal or progressive addition lens designs) and falls. Currently valid British, European and International Standard definitions of these lens forms are provided. As this research may be of interest to non-optical professionals, a brief introduction to presbyopia precedes the literature review.

The survey of prescribing and dispensing practices of optical professionals is described in Chapter 5.

Chapter 6 details the rationale for the development of the GMV, and the study evaluating its correlation with the computer-based Useful Field of View (UFOV) test, providing justification for its use in the main studies.

Both the retrospective and prospective studies are discussed in Chapter 7, which provides detailed information on the methodology and instruments used. Descriptive, thematic and logistic regression analyses are presented and discussed.

Chapter 8 summarises the thesis and provides suggestions as to future research areas.

Chapter 2. Risk factors and prevention strategies

2.1 Introduction

To understand the roles of vision and spectacle lenses in falls risk (see Chapter 3 and Chapter 4) it is helpful to have an appreciation of the multifactorial nature of falls. This chapter introduces definitions for the term "fall" and highlights the demographic and socio-economic drives for falls reduction strategies.

Although falls are generally thought to be "accidents", they are not in fact just "random events" [1]. This means that causative factors can be identified and either reduced or eliminated. A range of common falls risk factors are described, but this section should not be considered exhaustive.

This chapter also addresses the purpose and features of falls prevention strategies.

2.2 Definitions of a fall

One of the difficulties encountered when comparing studies is the use of different fall definitions, with some studies also restricting their findings to injurious falls only. A Cochrane review suggested that a simple consensus definition of a fall would aid comparison of falls studies[2].

The American Geriatrics Society (AGS) and the British Geriatrics Society (BGS) defined a fall as:

"..an event whereby an individual unexpectedly comes to rest on the ground or another lower level without known loss of consciousness[3]*".*

This is a more concise version of the definition used in 1987 by the Kellogg International Working Group of:

"*unintentionally coming to the ground or some lower level and other than as a consequence of sustaining a violent blow, loss of consciousness, sudden onset of paralysis as in a stroke or an epileptic seizure*[4]*".*

The Prevention of Falls Network Europe (ProFANE) Consensus group recommended a fall should be defined as:

"an unexpected event in which the participants come to rest on the ground, floor or lower level[5]*".*

The Cochrane review proposed this version should be adopted.

The main study in this thesis used the ProFANE fall definition in conjunction with a falls injury classification system, proposed by Schwenk et al.[6] (see Section 7.8.1.4).

2.3 Demographic and socio-economic factors of falls

The Office for National Statistics (ONS) predicts a change in the structure of the UK population, especially with regard to the number of older people. In 2014 there were almost equal numbers of pensioners (≥ 65years) and children under the age of sixteen (12.4million and 12.2million respectively). ONS projections for 2039, however, show the number of pensioners outstripping the number of children by 3.3million[7]. Long term predictions suggest there will be 28.6 million people aged 65 and over by 2114[8].

These demographic changes have a particular relevance to falls research, as the majority of falls occur in the over 60 age group and have a significant impact on NHS costs. Hip fracture statistics are often used to illustrate this burden on health and social care costs, as a substantial number (88%) occur as a result of falls. Incidence rates have been found to increase sevenfold between the 50 – 54 and 70 - 74 year age bands[9]. Hospital Episode Statistics (HES) 2014 – 2015 show a total of 203,784 people aged 80 or over were admitted to hospital in England as a result of a fall. This age group represented almost half (44.4%) of all fall-related admissions[10]. Figure 2.1 illustrates this steep increase in hospital admission episodes for older age groups.

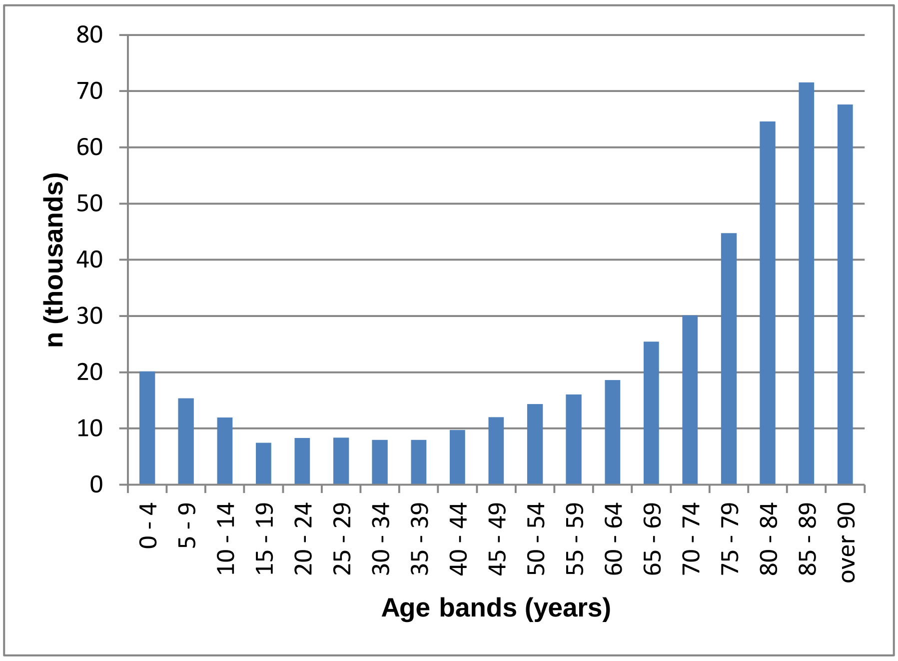


Figure 2.1 Hospital admission episodes for all falls (England 2014 – 2015)[10]

The costs to the NHS to treat hip fractures alone have been estimated to be £1.7billion per annum[11]. Further to in-patient treatment, subsequent social care is often required, increasing the cost to over £2billion per annum[12].

In addition to purely financial implications, the costs to the quality of life of individuals, particularly those who have suffered injurious falls, should not be forgotten. Loss of independence, fear of falling again, reduction in social activities and subsequent depression are reported[13]. Twenty-five percent of those living independently prior to their hip fracture remain in a nursing home for at least a year. One fifth of elderly people who suffer a hip fracture die within the year[9].

2.4 Falls risk factors

The range of identified falls risk factors is extensive, and is usually categorised into intrinsic and extrinsic factors.

Intrinsic factors pertain to the individual's specific characteristics, such as general health issues, physical or cognitive abilities. Extrinsic factors are external influences which impact on the individual, such as the home environment, footwear, and use of walking aids.

Lord[14] identified 5 key risk factors: dementia, depression, multiple medications, inappropriate footwear, and visual impairment, but a more recent review identified impaired balance and gait, polypharmacy and history of previous falls as the major risk factors[15]. The latter is widely acknowledged to increase risk of further falls[1,16,17]. It has also been demonstrated that fallers and non-fallers show different characteristics. A large study (n = 9592) employing logistic regression tree analysis identified the highest risk factor for non-fallers was cognitive impairment (OR 2.3), and for fallers was prescription drugs use (OR 3.6)[18].

2.4.1 Cognitive impairment and emotional wellbeing

A 2005 published study found the prevalence of cognitive impairment in the UK in the 75 years and older age group to be 18.3%[19]. In 1988 Tinetti reported an adjusted falls odds ratio of 5.0 for cognitive impairment[20]. A more recent 2013 study found a slightly lesser but still marked falls odds ratio of 2.3 for cognitively impaired persons aged 77 or above who had no limitation in activities of daily living (ADL)[18]. The mechanism of this increased falls risk is complex, but neuro-degenerative effects impact on physical and functional processes, such as slowed reaction times and gait impairments[21]. The risk of multiple falls has also been found to be greater[22].

Physical activity restrictions can also be self-imposed as a result of a previous fall, due to the fear of falling again. This fear of repeated falling is linked to depression[23], which can be both the cause and the result of falls. Its causative mechanisms can include attention deficits and slowed processing speeds, which may be exacerbated by anti-depressant usage[24]. A meta-analysis found the odds ratio for depression and falls to be 1.63 in community dwelling older people[25].

2.4.2 Dehydration and continence

Dehydration is known to increase confusion and disorientation in the elderly[26] and there have been accounts of fall reduction when increased water consumption was encouraged in a residential home setting[27]. Those who suffer from urge or stress incontinence may reduce fluid intake to help control symptoms, thereby increasing the risk of dehydration.

Poor urinary control increases falls risk, especially with regard to night visits to the toilet. A systematic review of urinary continence found a pooled odds ratio of 1.54 for the association of falls with urge incontinence (the sudden need to urinate) [28].

2.4.3 Footwear and foot care

Appropriate footwear can play an important role in falls prevention. Comfortable slippers or shoes may not provide enough support for stability. Menant[29] describes recommended shoe features as a slip-resistant sole, a supported heel collar, and a thin firm midsole, as shown in Figure 2.2.

Rheumatoid arthritis, bunions, claw toes and lack of toenail care can also lead to discomfort and instability when walking, having an adverse effect on balance.

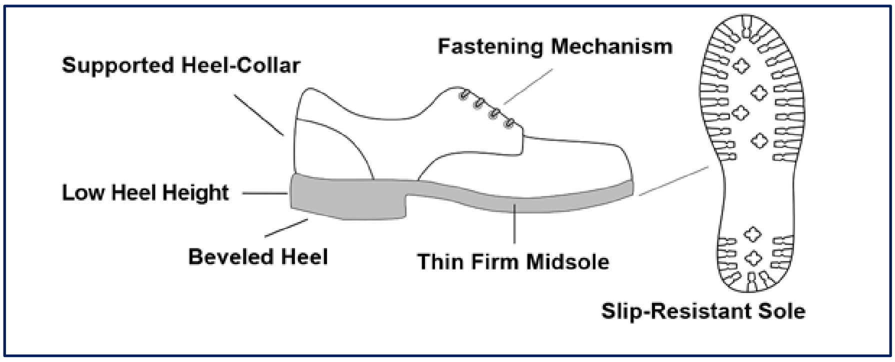


Figure 2.2 Recommended shoe features by Menant[30]

2.4.4 Balance

Balance is the term used to describe “the dynamics of body posture that prevent falling”, and is maintained by a combination of three sensory systems: visual, vestibular, and somatosensory[31].

The somatic senses are those of the skin, muscles, joints and viscera, and their proprioceptors give feedback about change in joint movements and muscular tension, contributing thereby to a sense of position and self-movement.

The vestibular system provides information about linear motion (moving forward or sideways), rotation, and sense of gravity (which way is up). The visual and vestibular systems are connected by the vestibulo-ocular reflex (VOR), the main purpose of which is to stabilise the retinal image during head movements. The visual contribution to postural stability is often referred to as visual stabilisation[32,33].

Disruption of one or more of these sensory mechanisms disturbs balance and can lead to falls.

Balance is affected by age-related difficulties in walking and mobility as well as certain pathologies, such as stroke or Parkinson’s disease. The inability to walk and talk simultaneously is also an indicator of a disturbance in balance mechanisms and is an increased falls risk factor[34].

In good lighting conditions, healthy individuals are considered to achieve postural stability by relying on somatosensory information to 70%, vision to 10% and vestibular information to 20%[35]. Those with a vision impairment depend more on their somatosensory and vestibular systems to maintain stability[36].

Vertigo and dizziness no doubt affect postural stability, however, the use of these terms has been inconsistent, both by professionals and lay persons[37]. International classifications are being developed, based on presenting symptoms, producing a complex matrix under four main headings (vertigo, dizziness, vestibulo-visual symptoms and postural symptoms)[38]. Briefly, vertigo can be considered the feeling that "things are spinning or moving around"; dizziness can be considered the feeling of being "lightheaded, swimmy or giddy"; and unsteadiness the sensation that one is "feeling unsteady, about to lose balance"[39].

Dizziness has been found to increase the risk of recurrent falls[40,41].

2.4.5 Medications

Polypharmacy – the taking of multiple medications – is implicated in falls risk. The greater the number of drugs taken, the greater the risk of falling[42]. It has been reported that there is no clear advice on which number of medications can be considered as a cut-off point for increased falls risk, although ≥ 4 is frequently quoted[42]. Benzodiazepines, antidepressants, antipsychotics, antiepileptics, anticholinergics, sedative hypnotics, muscle relaxants and cardiovascular medications are all frequently associated with falls[43].

Side effects of medications have a wide range of presentations, amongst which can be low blood pressure, possibly leading to dizziness, disturbances of balance, or fainting.

2.4.6 Osteoporosis

Medical and social care costs of falls are often illustrated using the example of hip fractures (See Section 2.3). The principal cause of hip fractures is an injurious fall in those with bone disease or osteoporosis. In the UK there are an estimated 3million people with osteoporosis[44], with three quarters of all hip fractures occurring in women[45]. 20% of men over the age of 50, however, also suffer fractures as a result of bone disease[46].

Mortality risks in the first year after a fracture are higher in men than in women, but it has been reported that a 50 year old woman has a 2.8% risk of death due to hip fracture during her remaining lifetime, equal to that of breast cancer[47].

2.4.7 Vision impairment

Vision impairment is quoted as approximately doubling falls risk, with the risk increasing as visual function deteriorates[48].

Chapter 3 discusses the impact of different types of vision impairment on falls risk, but is it possible to identify where vision impairment ranks with regard to other risk factors?

Masud and Morris[49] summarised 12 studies that identified the most likely cause of fall in 3684 cases, by ranking the mean percentage found across the studies. Excluding the categories “other specified causes” and “unknown”, vision disorders were ranked last but one (Table 2.1). Nonetheless, optical professionals – as primary healthcare providers - should be aware of any vision-related falls risk factors, (see Chapter 3), as they are in a position to address these either directly or by onward referral, thereby contributing to falls reduction strategies. Furthermore, it is important to remember that loss of vision combined with hearing or balance impairments potentiates falls risk[50].

	Mean (%)
Accident / environment related	31
Gait / balance disorders	17
Dizziness / vertigo	13
Drop attacks	9
Confusion	5
Postural hypotension	3
Visual disorder	2
Syncope	0.3
Other specified causes	15
Unknown	5

Table 2.1 Most likely cause of fall according to mean percentage ranking[49]

2.4.8 Location

The Health Education Authority reported in 2001 that for older people, accidents happen mainly in the home environment and contribute to 53% of injuries in the 65 – 74 age group, and 72% in those aged over 75[51].

The National Health Service (NHS) collects admission statistics on falls in twenty different categories, such as falls on same level from slipping, on and from ladders, and even from trees (Table 2.2).

Figure 2.3 highlights the top five categories in the total admission episodes for falls during 2014 – 2015.

Category	Description
W00	Fall on same level involving ice and snow
W01	Fall on same level from slipping, tripping and stumbling
W02	Fall involving ice-skates, skis, roller-skates or skateboards
W03	Other fall on same level due to collision with/pushing by another person
W04	Fall while being carried or supported by other persons
W05	Fall involving wheelchair
W06	Fall involving bed
W07	Fall involving chair
W08	Fall involving other furniture
W09	Fall involving playground equipment
W10	Fall on and from stairs and steps
W11	Fall on and from ladder
W12	Fall on and from scaffolding
W13	Fall from, out of or through building or structure
W14	Fall from tree
W15	Fall from cliff
W16	Diving or jumping into water causing injury other than drowning or submersion
W17	Other fall from one level to another
W18	Other fall on same level
W19	Unspecified fall

Table 2.2 National Health Service Fall Statistics Categories

A study by Bleijlevens *et al.*[52] identified fall locations according to the type of activity undertaken:

- Indoor falls related to lavatory visits
- Indoor falls during other activities of daily living
- Outdoor falls near the home during instrumental activities of daily living
- Outdoor falls away from home, occurring during walking, cycling and shopping for groceries

and concluded that there was a higher risk of injurious fall at either end of the activity spectrum: those who were most inactive sustained injuries indoors relating to lavatory visits, and those who were most active sustained injuries outdoors, away from home.

Whilst falls from stairs and steps have been implicated as the most common place for falls[53], the hospital admission statistics show only 9% for this location. There is, however, a very large percentage of unspecified falls (36% see Figure 2.3).

Falls on stairs are considered to be a cause of serious injuries and death. Templer[54] reported that the top and bottom three stairs are the main locations for falls accidents. The Health and Safety Laboratory[53] reported that in the UK deaths from accidents in the home are nearly as frequent as deaths from traffic accidents. In more than half of these home accidents, falls are the cause of death. Half of these falls occur on stairs. This is the driver for investigations into stair negotiation dynamics.

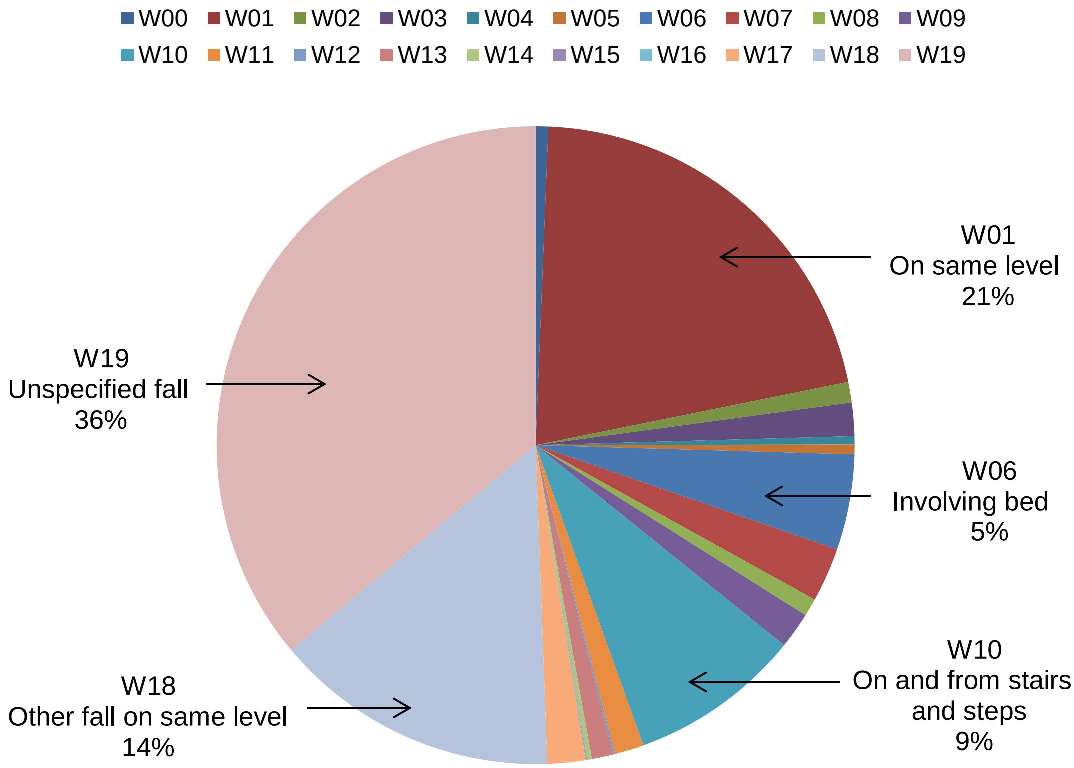


Figure 2.3 Hospital admission episodes by NHS fall category (England 2014 – 2015)

2.4.9 Environmental factors

Hazards in the home that contribute to tripping include wayward pets, trailing wires from extension cables, frayed carpets, loose rugs and clutter on the floor. These can often be easily identified and remedied.

An adequately heated home is vital for older people, and the concern over excessive heating costs may lead to restricted use of heating. A cold home can increase deaths from respiratory and cardiovascular diseases[55], with hyperventilation and hypotension (as well as a range of other cardiovascular abnormalities), leading to faints. Arthritis becomes worse in cold, damp environments and mobility is affected, leading to an increased falls risk[56].

Poor lighting or moving from a well-lit room to a dark hallway can also increase falls risk, as older adults require significantly more time to recover light sensitivity in the dark than younger adults[57] and have longer glare recovery times[58]. Stairways are often poorly lit and have unsuitable, highly patterned carpets that obscure step edges, which is especially dangerous when descending stairs (Figure 2.4).

All stairs should also have a bannister or stair rail for safety, and to aid stair negotiation.

With regard to stairways outside the home, strip edging is used to highlight the step edge, and if high friction material is used, to offer slip resistance. High contrast edge strips flush with the step edge have been found to improve safety on stairs[59]. Figure 2.5a is an image of a stairwell in a shopping centre with two anti-slip treads per step, with the outer strip not flush with the stair edge, giving rise to a misleading impression of the step edge position. Figure 2.5b shows the improvement in step edge visibility after re-painting.

Figure 2.4 Patterned carpets obscuring stair edges

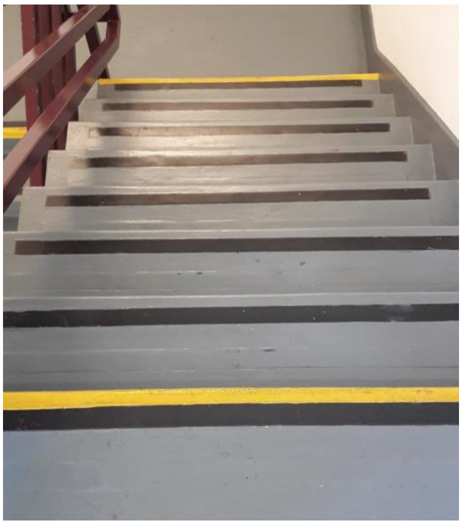
a  b 

Figure 2.5 Strip edge highlighter and anti-slip treads
a) misleading stair edge location b) improvement after re-painting

2.4.10 Behavioural aspects

Behavioural factors further contribute to falls risk. Alcohol and drug misuse may affect perception and reaction times, and overstretching to reach objects just out of reach can lead to loss of balance. Rushing to catch a bus or to get to the bathroom creates a less careful approach to obstacles, such as kerbs or uneven pavement slabs, and may also create situations where balance recovery is impaired. A review of fifteen studies found a pooled odds ratio of 5.3 for falling when undertaking a walking task in conjunction with an attention-demanding task, such as counting backwards or having a conversation[34]. This is referred to as “dual tasking”. Not having one’s hands free to break a fall makes carrying large or heavy objects (especially up and down stairs) inadvisable.

2.4.11 Previous fall history

Perhaps the most important fall risk factor is the history of having already sustained a fall. A systematic review and meta-analysis of risk factors for falls in community-dwelling older people found history of falls, gait problems, walking aids use, vertigo, Parkinson disease and anti-epileptic drug use to have the strongest associations[25]. 74 studies were analysed and for all fallers (ie single and recurrent fallers), history of falls had an OR of 2.8. It is noted that none of the studies were UK based.

2.5 Fall prevention strategies

Falls prevention strategies can be considered to have three goals: to decrease the number of first falls, to reduce the chances of falling again, and to minimise injury when people do fall[42].

2.5.1 Risk assessments

In order to decrease the number of first falls or to reduce the chances of falling again a falls risk assessment personalised to each individual's specific circumstances is recommended.

The National Institute for Health and Care Excellence Clinical Guideline 161 (NICE CG161)[60] states that a multifactorial risk assessment should be offered to those aged 65 or older presenting for medical attention because of a fall. The assessment should be tailored to the individual and carried out by an appropriately trained healthcare professional, and may contain the following:

- Falls history (causes and consequences)
- Assessment of gait, balance and mobility, and muscle weakness
- Assessment of osteoporosis risk
- Assessment of functional ability and fear of falling
- Assessment of cognitive impairment and neurological examination
- Assessment of urinary continence

- Assessment of home hazards
- Cardiovascular examination and medication review
- Assessment of visual impairment (added in 2013)

Assessment of appropriate footwear was highlighted with regard to hospital in-patients.

It was identified as a priority that older people in contact with healthcare professionals should be routinely asked whether, or how many times, they have fallen in the past year, and the circumstances of the falls. Optical professionals providing primary healthcare should, therefore, be incorporating falls history into their routine history and symptoms assessment.

2.5.2 Falls prevention

Falls risk factors have been shown to vary between non-fallers, fallers and recurrent fallers, indicating the need for differently structured falls risk prevention programmes according to falls history[18]. Individualised multifactorial risk assessments lead to individualised multifactorial interventions, common features of which are strength and balance training, home hazard reduction, treatment of vision impairments and medication review. The optical professional can refer at risk individuals to local falls prevention teams, many of which operate an open referral system.

2.5.3 Injury reduction

Injury reduction may be achieved by adapting the environment (to remove sharp edges or hard surfaces), maximising bone health by treating osteoporosis, and educating the faller how to act if unable to get up after a fall. The so-called "long lie" is a situation where the faller is unable to summon help for a considerable amount of time, and as a result may suffer dehydration or hypothermia. Advice is to remain calm, check for injuries, and attempt to get up from the floor if at all possible. Otherwise try to keep warm by covering with a blanket or any other item close to hand [61]. Having a personal alarm can aid swift assistance and, with this, better recovery times.

Hip protectors in the form of padded underwear (Figure 2.6) are sometimes used as a strategy to minimise injury when people fall. They do not, however, prevent all fractures and their use can lead to skin irritation. Most research has looked at their use in residential care situations[42].

Figure 2.6 SAFEHIP® hip protectors

2.6 Summary

This chapter has defined the term “fall” and discussed the impact of socio-demographic changes on both health and social care costs, and the quality of life costs to the individual.

The causes of falls are both varied and specific to each individual, and differ between fallers and non-fallers, creating the need for appropriately tailored falls risk assessments and falls prevention programmes.

It is important to recognise that falls do not always have one single identifiable cause. In fact, in most cases, falls are a result of a combination of one or more intrinsic and extrinsic factors, a range of which have been identified.

Falls risk increases with the number of risk factors present, ranging from 8% with no risk factors, to 78% with four or more risk factors[20]. The falls risk attributed to vision impairment is potentiated when compounded by hearing or balance impairments (dual sensory loss)[50].

Optometrists have a duty, as primary health care providers, to identify individuals at falls risk, and to signpost appropriately.

Chapter 3 addresses falls risk factors attributed to vision.

Chapter 3. Visual falls risk factors

3.1 Introduction

Vision impairment is a widely acknowledged falls risk factor, with its traditional definitions based on visual acuity and visual field defects. This chapter describes current UK definitions of vision impairment, and investigates the prevalence and causes of vision impairment in the UK that have been associated with increased falls risk. In addition to reduced visual acuity and restricted visual fields, levels of contrast sensitivity and stereopsis or binocular vision have also been found to be falls risk factors.

3.2 Vision impairment definitions

In the UK, registration as "sight impaired" (formerly partially-sighted) and "severely sight impaired" (formerly blind) is based on a combination of visual acuity and visual

Sight impaired (partially sighted)	**Severely sight impaired** (blind)
3/60 – 6/60 Snellen with full field	**< 3/60** Snellen
Up to 6/24 Snellen with moderate contraction of the field, opacities in the media or aphakia	**3/60 – <6/60** Snellen with a very contracted field of vision
6/18 Snellen or better if there is a gross defect for example hemianopia, or if there is a marked contraction of the visual field	**6/60 Snellen or better** with a contracted field of vision, especially in the lower part of the field.

Table 3.1 UK criteria for vision impairment registration[62]

field defects as detailed in Table 3.1.

In clinical practice however, vision impairment is generally acknowledged when the level of vision an individual has, no longer allows them to fulfil their activities of daily living without supplementary devices, daily living aids or specialist training.

3.3 Vision-related falls risk factors

Reduced visual acuity is a recognised descriptor of vision impairment. However, other aspects of vision impairment have also been implicated as falls risk factors, predominantly reductions in stereo-acuity, contrast sensitivity and visual fields.

Table 3.2 analyses 33 studies that attributed aspects of vision to falls risk. It is evident that there is no agreement on the role of any one visual factor. Furthermore, the studies vary according to the investigated outcome, with some studies investigating all falls, and others investigating specific types of fracture or injury. Adaptive locomotion and postural stability have also been employed as surrogate markers of falls risk.

3.3.1 Visual Acuity: Prevalence of low vision and falls-related risk

Direct comparisons of studies investigating prevalence of low vision in the UK are difficult because of differences in the adopted definitions of vision impairment and variances in age categories.

The North London Eye Study[63] found the prevalence of bilateral visual impairment (defined as <6/12 Snellen) in a random sample of 1547 over 65s to be 30%. Of note is that nearly three quarters of these had an impairment that was deemed potentially remediable.

In a random postcode selection of areas in mainland Britain, the prevalence of low vision (defined as <6/18 Snellen) was investigated as part of the National Diet and Nutrition Survey (NDNS)[64]. Overall prevalence in the over 65s was found to be 14.3%, with prevalence increasing with age (65 – 74 years: 3.1%; 75 – 84 years: 11.6%; over 85: 35.5%).

A 2002 Medical Research Council (MRC) trial[65] found the prevalence of vision impairment (VI) defined as <6/18 Snellen in those aged 75 years and above to be 12.4% overall, but rising to 36.9% in those age 90 and above.

Using the prevalences found in the latter two studies in conjunction with 2001 population census data, a 2007 paper estimated there would be over 600,000 people in the UK aged over 75 with a vision impairment[66].

Assuming a prevalence of 14% in the over 65s and applying this to the ONS 2014 UK population of 12.4million in this age group would give an estimate of over 1.7million vision impaired people. Applying this same prevalence to the projected mid-2035 population of 16.9million, this figure increases to almost 2.4million.

Given the size of the affected population, the question is raised whether screening for vision impairment would be appropriate. A Cochrane review of community screening for vision impairment in older people reported, however, that no evidence existed to show that screening resulted in an improvement of asymptomatic older patients' vision[67].

Twenty-two of the 33 studies detailed in Table 3.2 - which is by no means exhaustive - identified reduced visual acuity as a falls risk factor. Ten studies found this to be the only contributory visual factor[50,68–76]. Other studies found poor depth perception[77,78], or visual field defects[79–83] alone to be causative. Reduced contrast sensitivity was only implicated in combination with other factors.

Author	Year	SD[a]	VA	CS	VF	Outcomes	Comments
Källstrand[84]	2016	✓	✓	x	x	F	SD[a] associated with recurrent falls; VA better eye
Black[85]	2016	-	✓	-	✓	AL	Optical blur and gaze position
Pineles[78]	2015	✓	-	-	-	F, IF, Fra, HFra	Disorders of binocular vision except amblyopia
Black[86]	2014	-	✓	✓	-	AL	Optical blur and low contrast
Yip[68]	2014	-	✓	-	-	F	VA and Self-reported VA
Wood[87]	2011	-	✓	✓	x	F, IF, Fra	Central 24° visual field loss not significantly associated
Black[79]	2011	-	x	x	✓	F, IF	Inferior field loss
Patino[88]	2010	-	✓	-	✓	F, IF	Binocular VA
Graci[80]	2010	-	-	-	✓	AL	Toe clearance and foot placement in obstacle avoidance
Rossat[69]	2010	-	✓	-	-	F, RF	Distance binocular acuity
Lamoureux[89]	2010	x	x	x	x	F	Significance found for non-participation in physical activity
Knudtson[90]	2009	✓	✓	✓	-	F, RF	Any of these factors
Kulmala[50]	2009	-	✓	-	-	F	Especially with other sensory and balance impairments
Marigold[81]	2008	-	-	-	✓	FP	Inferior visual field for navigation
Freeman[91]	2007	x	x	x	✓	F	Especially peripheral fields
Cumming[92]	2007	-	x	-	-	F, Fra	Improvement of vision may increase risk of falls
Coleman[82]	2007	-	x	x	✓	RF	Binocular visual field loss

SD[a] = Stereo-deficiency, VA = Visual Acuity, CS = Contrast Sensitivity, VF = Visual Fields
✓ = found to be falls risk factor, x = found not to be falls risk factor, - = not investigated
F = Falls, IF = Injurious Falls, Fra = Fractures, HFra / WFra = Hip / Wrist Fractures, AL = Adaptive Locomotion, RF = Recurrent falls, PS = Postural Stability

Table 3.2 Comparison of studies of visual aspects attributed to falls

Author	Year	SD[a]	VA	CS	VF	Outcomes	Comments
Harwood[93]	2005	-	✓	✓	-	F	First eye cataract surgery reduces the rate of falling
Buckley[70,71]	2005	-	✓	-	-	AL	Effect of foot placement on stepping dynamics
Coleman[72]	2004	-	✓	-	-	RF	Declining visual acuity
Heasley[94]	2004	-	✓	✓	-	AL	Vertical stepping up toe clearance and foot placement
Brannan[73]	2003	-	✓	-	-	F	Cataract-related visual impairment
Anand[95]	2003	-	✓	✓	-	PS	CS implied by cataract simulation
Anand[74]	2003	-	✓	-	-	PS	Refractive blur and dual tasking in elderly subjects
Anand[75]	2002	-	✓	x	-	PS	Refractive blur: young subjects
Patla[77]	2002	✓	-	-	-	AL	When approaching and negotiating an obstacle
Lord[96]	2001	✓	✓	✓	-	F	Only weak association found with visual field loss
Ramrattan[83]	2001	-	-	-	✓	F, HFra, WFra	Falls recorded as a measure of disability in daily activities
Ivers[97]	2000	✓	✓	-	-	HFra	Also not wearing glasses and time since last eye exam
Ivers[98]	1998	-	✓	✓	✓	RF	Also cataracts
Dargent-Molina[76]	1996	-	✓	-	-	HFra	VA strongly associated with CS and depth perception
Cummings[16]	1995	✓	x	✓	-	HFra	VA not an independent risk factor
Felson[99]	1989	✓	✓	-	-	HFra	VA in women only

SD[a] = Stereo-deficiency, VA = Visual Acuity, CS = Contrast Sensitivity, VF = Visual Fields
✓ = found to be falls risk factor, x = found not to be falls risk factor, - = not investigated
F = Falls, IF = Injurious Falls, Fra = Fractures, HFra / WFra = Hip / Wrist Fractures, AL = Adaptive Locomotion, RF = Recurrent falls, PS = Postural Stability

Table 3.2. (cont.) Comparison of studies of visual aspects attributed to falls

One study found no significant influence of any of the four studied visual aspects, concluding that only physical inactivity was independently associated with falls[89].

Age-related macular degeneration (AMD) is the most common cause of sight loss in the UK, with a UK prevalence of late stage AMD estimated to be 4.7% in those aged ≥ 65 years, rising to 12.2% in those ≥ 80 years[100]. Wood[87] investigated 76 community dwelling adults with AMD and found both visual acuity and contrast sensitivity to be significant predictors of falls. Indeed, many studies find that not just one component of vision impairment increases falls risk, and this is to be expected, as eye conditions, such as AMD or cataracts for example, impact on more than one aspect of vision.

Buckley *et al.*[70,71], however, reported on the effects of blurred vision as a stand-alone factor, with regard to stair negotiation, which is particularly important as falls on stairs cause significant injuries, and even death. When stepping up, toe clearance increased both vertically and horizontally as a compensation strategy for the reduced acuity. Blurred vision and simulated cataracts increased step execution time and affected physical attributes such as knee flexion, with participants tending to "feel" their way to the next step down[70,94]. Accurate visual feedback plays an important role in the stability of medio-lateral balance dynamics when stepping up or down, and improving visual acuity was proposed as an intervention to improve stair negotiation[71].

3.3.2 Cataract: Prevalence and falls-related risk

The presence of cataracts is another common cause of reduced visual acuity. In a random sample of 1547 people aged 65 and over, the 1998 North London Eye Study[63] found the prevalence of vision impairment (defined as VA <6/12 Snellen) caused by cataracts to be 30%. An add-on study to the MRC trial looked at the causes of vision impairment in 49 GP practices and found a similar prevalence: vision impairment (defined as VA < 6/18) attributed to cataracts was 36%, with its prevalence increasing with age (Figure 3.1)[101].

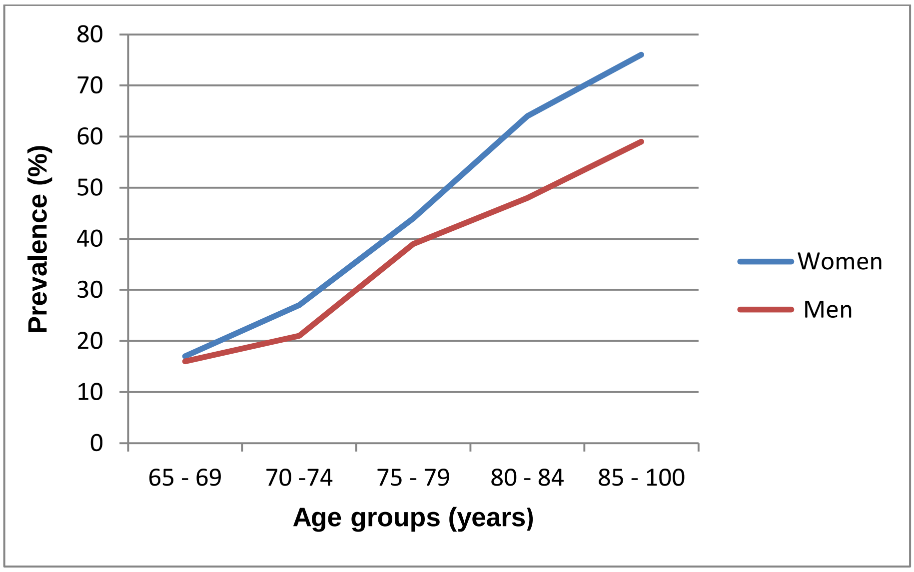


Figure 3.1 Cataract prevalence (%) with age[101]

It is vital, therefore, that we understand the specific impact of cataract on falls risk. Cataracts affect both contrast sensitivity and visual acuity. Five studies were found that identified a combination of these two factors alone as increasing falls risk[86,87,93–95].

There are, however, conflicting research findings with regard to cataract surgery. A longitudinal study of participants with and without cataract surgery found no difference in falls risk ratio between the two groups, and concluded that in independently living adults, there was no association with cataract surgery and the rate of falls[102].

A 2012 study, however, found an increase in falls in the first year after unilateral cataract surgery, compared with the falls rate in the year prior to surgery[103].

Conversely, a prospective study of the rate of falls before and after cataract surgery found it to be an effective intervention[73].

A randomised controlled trial published in 2006[104] noted that although second eye cataract surgery improved "visual disability", the effect on falls remained uncertain. In contrast, Tseng *et al.*[105] reported in 2012 that, in a cohort of over 1.1million patients with cataract in the United States between 2002 and 2009, those who had undergone surgical intervention had lower hip fracture odds within one year after surgery, than those who had no surgical intervention.

As mentioned above, the presence of cataracts influences both visual acuity and contrast sensitivity. Harwood[48] highlights the close correlation between these two factors and depth perception (r ~ 0.6) and compares odds ratios (OR) for falls risk for each of these factors (Table 3.3).

	Odds Ratio min – max	**Odds Ratio (adjusted)** min – max
Visual Acuity	1.1[26] – 5.1[39]	1.2[40] – 4.8[39]
Depth Perception	1.2[40] – 2.1[26]	1.9[26] – 2.1[41]
Contrast Sensitivity	1.2[42] – 1.8[43]	1.2[26]

Table 3.3 Comparison of Odds Ratios for falls risk[48]

Cataract surgery has also been found to improve postural control[106], reduce dizziness[107], and aid mobility by improving obstacle avoidance[108].

One particular issue of concern is anisometropia after unilateral surgery, and its effect on depth perception, which is critical in determining accurate information about the environment and obstacles within it. Spectacle lens magnification changes are addressed in Section 4.4.

3.3.3 Depth perception

Depth perception is the ability to appreciate differences in distances to objects remote from an observer. Whilst other cues, such as shadow or motion parallax also enable depth perception with monocular vision, stereoscopic vision is considered to increase its precision. Stereopsis occurs in binocular vision as a result of slight disparities between the retinal images of the two eyes[109]. In an investigation into the effects of binocular disorders on falls risk, amblyopia was found to have the weakest association, which was considered a reasonable finding, given that it is a longstanding condition, to which patients would have adapted during their lifetime[78].

As part of the Auckland Hip Fracture Study[97], it was found that both reduced binocular visual acuity and reduced stereopsis were risk factors for hip fracture. The Framingham Eye Study took place between 1973 and 1975, and the Framingham Study[99] investigated hip fracture rates in this group of 2,633 participants over the subsequent ten years. Findings indicated that those with moderately reduced vision in one eye only, had a higher risk of fracture than those with a comparable degree of reduced vision in both eyes, suggesting that good stereoscopic vision is a falls prevention factor. Recurrent falls have been found to be more frequent in those with a lack of stereopsis[84].

Patla *et al.*[77] reported on the results of three experiments undertaken to investigate the role of binocular vision with regard to locomotion, specifically how it influences head movement, fine-tuning of movement, and pre-planning of obstacle negotiation. The results showed that binocular vision was not critical in determining distance to the object, but was necessary in providing accurate information about the environment and obstacles within it. Head movements were found to be important for reorientation of the visual field when binocular vision was suddenly compromised. No additional head movements, however, were required under monocular vision conditions, as the retinal motion created by normal head movements provided sufficient information.

Whilst all three experiments were conducted on young participants (22.1±3.3yrs, 20.8±1.6yrs, 22.2 ±2.6yrs respectively) with binocular vision reported as "in the normal range", situations do occur in the elderly population that also create sudden changes in stereopsis, such as monocular vascular incidents, wet age-related macular degeneration, or post-operative outcomes.

A retrospective population-based study found an association with increased hospital admissions from fall injuries in the year following first eye cataract surgery, and proposed further research was necessary to identify causes[103]. It is reasonable to assume a post-operative change in the refractive error of the operated eye. Depending on the magnitude of this change, a disturbance of stereo-efficiency is feasible. In clinical practice, emmetropia often seems to be the target post-operative outcome. In former ametropes, this may well lead to anisometropia until second eye surgery is performed.

Further investigations into stepping precision regarding the accuracy of foot placement and toe clearance when negotiating stairs have been undertaken by Johnson and colleagues[110–112], specifically with reference to spectacle lens design, which is discussed in Chapter 4.

3.3.4 Visual fields

The Rotterdam Study[113] found the incidence of visual field loss to increase 5-fold between the ages of 55 and 80 or above (Figure 3.2) with glaucoma being the most common cause in those aged ≤ 75 years, followed by stroke, AMD , then retinal vascular occlusive disease. These pathologies have very different patterns of field loss, and studies have investigated both peripheral and central field loss.

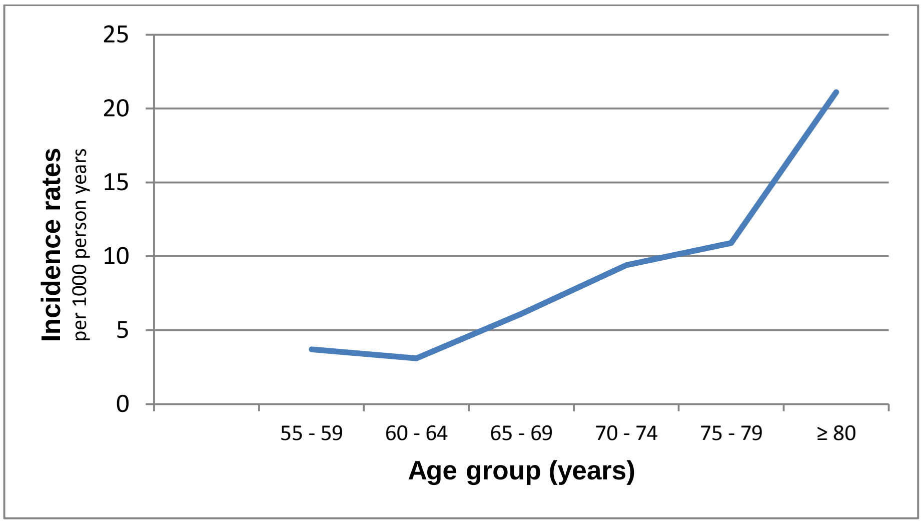


Figure 3.2 Visual Field Loss incidence rates[113]

Ramrattan *et al.*[83] carried out a population-based cohort study, to determine the prevalence of visual field loss in 6250 community dwelling elderly residents. An increase in prevalence with advancing age - comparable to the previously noted age-related increases in cataracts and visual impairment - was reported, specifically 3.0% in those aged 55-64 years, rising to 17% in those aged 85 and older.

Although it would initially seem that visual field loss could be considered independently to the correlated factors of contrast sensitivity, visual acuity and depth perception, the findings of Ramrattan *et al.*[83] indicate a difference between unilateral and bilateral visual field loss, and therefore a possible link to stereo-deficiency.

It is conceivable for unilateral visual field loss to create problems with stereopsis, and it is interesting to note that this study reported more frequent falls and wrist fractures in these subjects, than in those with no field loss.

Although bilateral field loss was found to increase falls frequency 6-fold, these falls did not result in an increase in wrist and hip fractures when compared with subjects with no field loss.

AMD particularly links central visual field loss with reduced visual acuity and contrast sensitivity, and - in its unilateral presentation - with reduced stereopsis. Studies pertaining to AMD and postural stability or gait have found binocular central scotoma size[114] to be the most significant predictor of mobility performance, and contrast sensitivity[115] to be the strongest correlate with postural stability. A further study of AMD patients by Wood *et al.*[87] found central 24º field measures in this sample were not predictive of falls, whilst there was a significant association with reduced contrast sensitivity and increased rates of falls and other injuries. Reduced visual acuity was only associated with increased fall rate, not injuries.

Glaucomatous visual field loss effects postural sway[116]. An investigation into the effects of central visual field loss in AMD patients on postural sway found that, when compared to subjects with normal vision, those with central visual field loss had a lesser contribution of vision to postural stabilisation[33]. When investigating the effects of different types of field loss on postural sway, it was found that when comparing equal sized (30º) areas of central or peripheral field, it is the central visual field that dominates postural control[32].

When looking at visual stabilisation in patients with peripheral field loss as a result of retinitis pigmentosa (RP), it has been found that increased field loss decreased visual stabilisation[117]. However, when comparing the results with individuals with matched artificially restricted fields, they indicated other causative factors may be involved, such as anomalous processing of visual information.

Investigations by Freeman *et al.*[91] into the effects of contrast sensitivity, visual acuity, stereopsis, and visual field loss, found that only binocular visual field loss was associated with falls. Central, lower and upper peripheral fields were all found to be associated with an increased risk of falls. In a multiple regression model analysis of central and peripheral visual field loss, only peripheral field loss remained significant.

The lower visual field has been found to be important when negotiating multi-surface terrain[81]. Loss or reduction of binocular inferior visual fields were implicated in increasing the rate of falls in a study looking at glaucomatous field loss[79].

Coleman *et al.*[82] studied a large cohort of 4071 community dwelling women aged 70 or above and found severe binocular field loss in 10% (n=409). In a third of these, frequent falls were attributed to the field loss. When looking at results adjusted for age, race, study site and cognitive function, a later study estimated the risk of hip and non-spine, non-hip fractures to be 66% greater in women with severe binocular visual field loss, than in those with no visual field loss[118].

3.4 Summary

The reviewed literature illustrates the complexities in attributing specific falls risk- or odds ratios to stand-alone visual factors. Studies vary not only in the type of visual impairment investigated, but also according to outcome data. Some studies report on falls, injurious falls, or specific falls-related injury such as hip fracture, and others on adaptive locomotion factors, such as postural stability, obstacle avoidance or foot and toe placement.

Falls are generally accepted as the outcome of a combination of contributory factors, with vision impairment widely recognised as one such. Although the role of reduced visual acuity is widely understood and reported on, both in academic research papers and public information leaflets, it is important to recognise that - along with acuity - contrast sensitivity, visual fields and depth perception all play important intertwined roles. A 2012 systematic review of nineteen studies concluded that the evidence regarding poor depth perception and poor low contrast visual acuity as falls risk factors was convincing, with other factors being more controversial[119].

The impact of blur on the lower visual field is one of the falls risk factors implicated when wearing bifocal or progressive addition lenses (PAL). Research findings regarding spectacle lens design and falls risk are investigated in the following chapter.

Chapter 4. Spectacle lens design and falls risk

4.1 Introduction

This chapter examines spectacle lens correction modes for the ageing eye and their possible influence on falls risk. The literature review is approached with regard to four main critical issues:

1. Confusing use of the term “multifocal” and poor differentiation of lens designs in study outcomes
2. An assumption that, when walking or undertaking stepping tasks, wearers of bifocal or progressive addition lenses habitually look through the near area of the lens
3. Misconceptions about perceived distortion and other peripheral aberrations by comparing step edge appearances when looking through progressive addition lenses held at arm’s length
4. Whether or how any allowances for habitual wear were incorporated.

In addition, blur and spectacle lens magnification are discussed, particularly in respect to their influence on stepping strategy and gait adaptations.

As falls research is of interest to a range of non-optical professions such as occupational therapists, nurses, rehabilitation workers, or physiotherapists, this review is preceded by a brief introduction to the ageing process of the eye, in order to understand the need for spectacle lenses that incorporate two or more different powers. A description of bifocal (Bif) trifocal (Trif) and progressive addition lenses (PAL) and their salient features is also provided, along with their currently valid British and International Standard definitions.

4.2 Presbyopia

The ability of the eye to focus at different distances is termed accommodation, and its range is referred to as its amplitude. The eye's amplitude of accommodation reduces with increasing age, causing an individual's near point to recede. This is referred to as presbyopia. Its age of noticeable onset varies with the individual and their specific visual demands, but can be from as early as 40 years.

The outcome of this reduction in accommodation is that no one lens power can provide a clear range of vision from distance to near. Different, task-specific spectacle lens powers are required in order to provide the wearer with a range of vision comparable to that in their youth. The difference between the lens power required at distance and the more positive lens power at near is referred to as the addition, traditionally abbreviated to "Add". Lens powers are measured in dioptres (D), with typical Add values ranging from +0.75D to +2.75D.

Many studies have investigated the rate of progression of presbyopia. The early studies of Donders and Duane[120,121] in the late 19th and early 20th century respectively describe a reduction in mean amplitude of accommodation from the age of 10 to 60. Duane[120] compared his findings of a reduction from 14.00D to 1.20D, with the reduction from 18.00D to 1.50D found by Donders. Whilst the overall trend was comparable, Duane found the loss of accommodation was not a steady process, with periods of stability being followed by periods of more rapid deterioration. The present study is investigating falls risk in those aged 65 and above, so it important to understand how much residual accommodation is present in this age group. Figure 4.1 depicts the data from Duane's 1922 study[121].

Although in later research it has been argued that the non-linear decline in amplitude of accommodation could be a manifestation of false high readings for the oldest age groups, there is nonetheless agreement that there is little change in accommodative ability after about 50 years of age[122].

Binocular measures of amplitude of accommodation have consistently been found to be greater than monocular measurements, and are considered the result of increased accommodative ability driven by the coupled mechanism of convergence and accommodation. In those aged over 53, binocular accommodation was found to be 0.30D greater than monocular values.

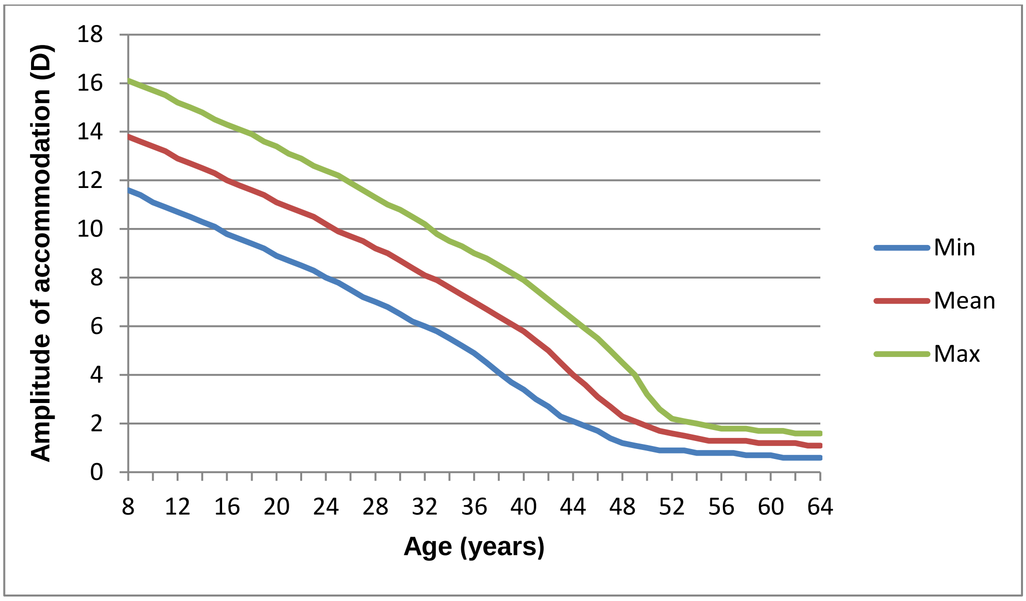


Figure 4.1 Monocular amplitude of accommodation (Data from Duane[121])

Whereas Duane ruled out the argument that depth of focus accounted for the 1.00D residual accommodation in older age groups, a more recent study concluded otherwise[123].

It has also been postulated that after the early 50s, the need for increased reading addition for near tasks, is a result of an age-dependent reduction in visual acuity[122].

Whilst the exact mechanism of presbyopia has been the subject of much academic research and debate, the fact remains that its correction modalities, in the form of spectacle lenses that incorporate two or more powers, are a feature of everyday prescribing and dispensing practices.

4.2.1 Spectacle lenses for presbyopia: definitions and design features

An understanding of the basics of presbyopic lens forms and their correct nomenclature is fundamental to the analysis of published research. It is useful at this stage, therefore, to introduce the currently valid definitions as found in the British, European and International standards document BS EN ISO 13666:2012[124] (Table 4.1) as well as simulated depictions of their appearance when worn (Figure 4.3).

Lens form	Definition
multifocal	lens designed to provide two or more visibly divided portions of different focal powers
bifocal	multifocal lens having two portions, usually for distance and near vision
trifocal	multifocal lens having three portions, usually for distance, intermediate and near vision
progressive power (PPL) progressive addition (PAL)	lens with at least one progressive surface, that provides increasing (positive) addition power as the wearer looks down
progressive surface	surface which is non-rotationally symmetrical, with a continuous change of curvature over part or all of the surface

Table 4.1 BS EN ISO 13666:2012 Spectacle lens nomenclature

Inaccurate usage of the term “multifocal” has led to it also being used to describe progressive addition lenses (PAL), which are also frequently termed “varifocal” lenses. This confusion may be one of the reasons why advice issued to the public, such as found on the Directgov website[125], misleadingly referred to “vari-focal” (PAL) lenses alone (Figure 4.2). This was subsequently amended to “inappropriate spectacles”. (This website has now been replaced by www.gov.uk).

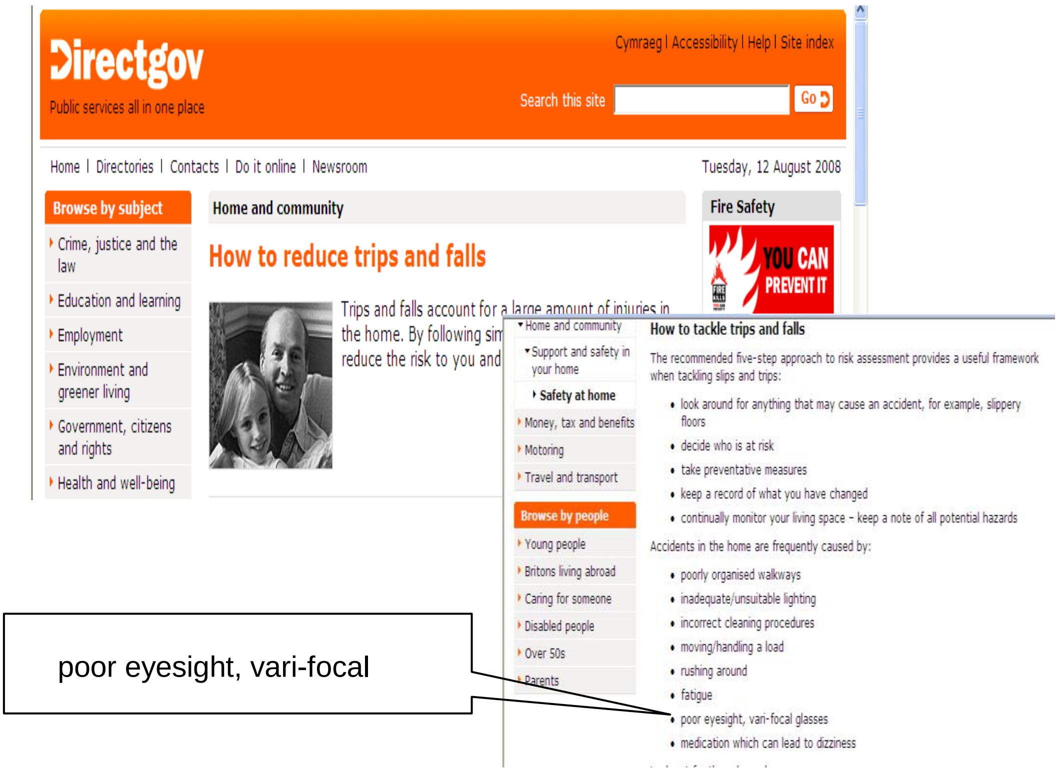


Figure 4.2 Screenshot of Directgov webpage

There are many variations in construction designs for each of the lens categories. This means that comparisons of bifocal wearers or progressive addition lens wearers (PAL or alternatively progressive power lens PPL) are most likely not comparing identical products, yet there will be common salient features, such as image jump in bifocal and trifocal lenses, and unwanted peripheral astigmatism in PALs.

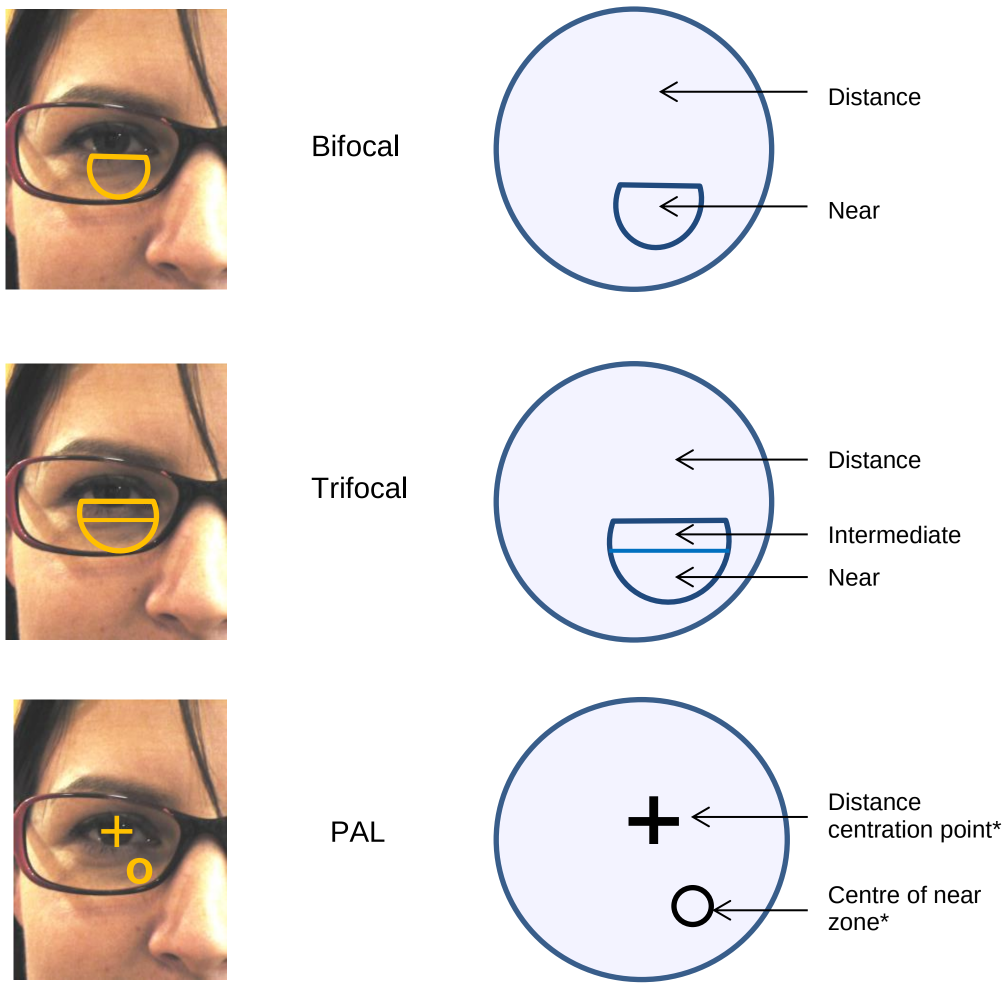


Figure 4.3 Schematic representation of lens designs for presbyopia

* The reference points in PAL lenses are invisible.

4.2.1.1 Bifocal lens design

With regard to bifocal lens design, image jump on transition from the distance portion to the near segment is often quoted as contributing to increased falls risk[111,112,126–131]. Image jump occurs as a result of the change in prismatic effect at the segment dividing line, which is a factor of the distance of the near geometric centre from the segment dividing line (x), and the power of the reading addition (Equation 4.1 and Figure 4.4)

Equation 4.1 Image jump (prism dioptres) = x (cm) · Add (D)

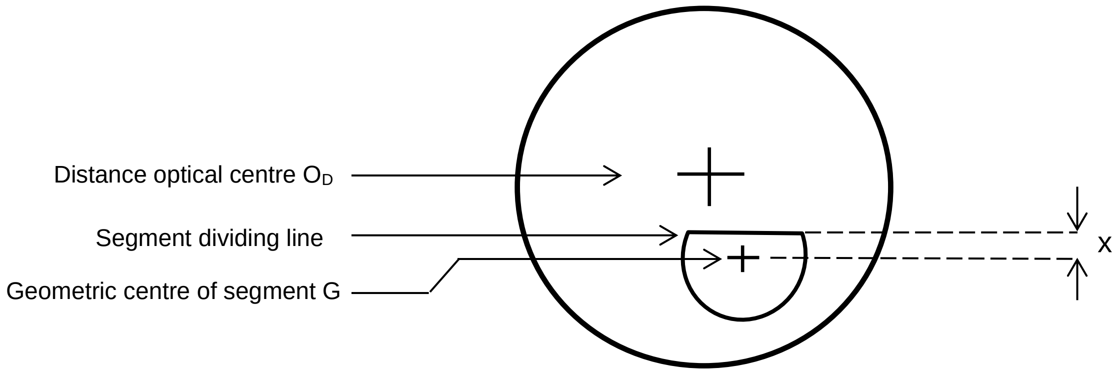


Figure 4.4 Bifocal lens dimensions for image jump calculation

Two commonly encountered bifocal lens designs in the UK are referred to as C and D segments, a simple descriptor of their shapes. (A “D” segment is depicted in Figure 4.3 and Figure 4.4. A “C” segment has a curved dividing line.) The notation D28 refers to a D segment 28mm across at its widest point. In these designs, the segment geometric centre is below its dividing line, which gives rise to a base down prism. The image will therefore seem to move upwards, when the eyes move from the distance to the near portion.

Trifocal lenses have an additional intermediate segment, which usually has half the full Add power. Image jump in trifocals is, therefore, less when transitioning the top of the trifocal segment, than that of a bifocal lens with equal distance and near prescriptions. There is, however, an additional image jump when transitioning from intermediate to near zone, but - because of the proximity of the geometric near centre to the top of the near segment - this is considered negligible.

Walsh[132] proposed that the concept of jump may be flawed, as it assumes a sudden transition from distance to near segment, and does not take into account the size of the pupil, whereby images from both distance and near may be perceived simultaneously. This would give rise to monocular diplopia, and if the near segments were not correctly positioned, then a binocular perception of four images could occur. Although investigations were carried out on young subjects (n=20) aged between 17 and 30, it was concluded that diplopia may be “at least as likely as jump” to cause problems when using bifocal lenses.

4.2.1.2 PAL lens design

PAL lenses do not display image jump. The power of the lens increases gradually from an area allocated for distance vision, through a corridor of increasing positive power for intermediate distances, reaching a near zone in the inferior portion of the lens. However, peripheral astigmatism occurs in the areas both temporal and nasal to the progression corridor, and can induce peripheral image blur and distortion. The amount and direction of this astigmatism can also create a changed room perspective.

An iso-cylinder plot of a currently available PAL is shown in Figure 4.5, courtesy of Dr.C.W.Fowler, Aston University. The areas with little or no surface astigmatism (<0. 50D) are depicted white.

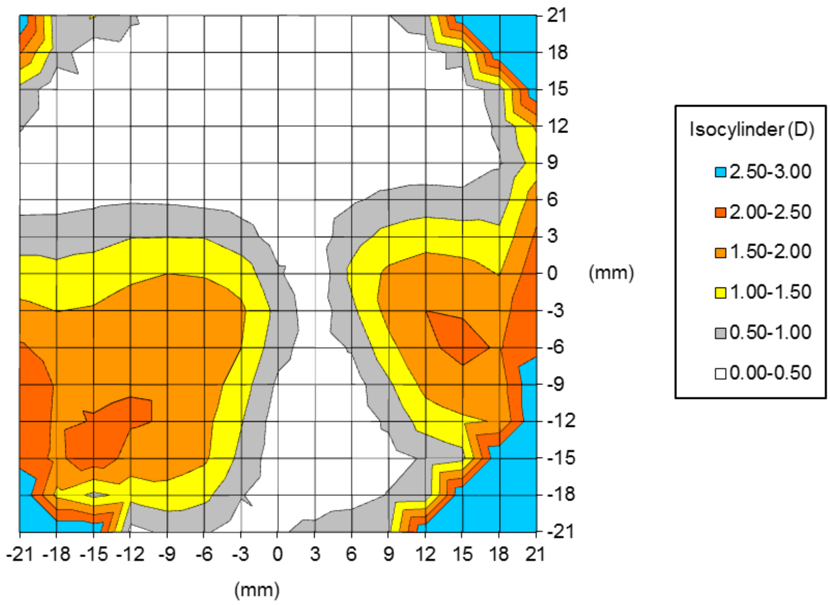


Figure 4.5 Isocylinder plot of a right PAL (Distance plano, Add 2.00D)

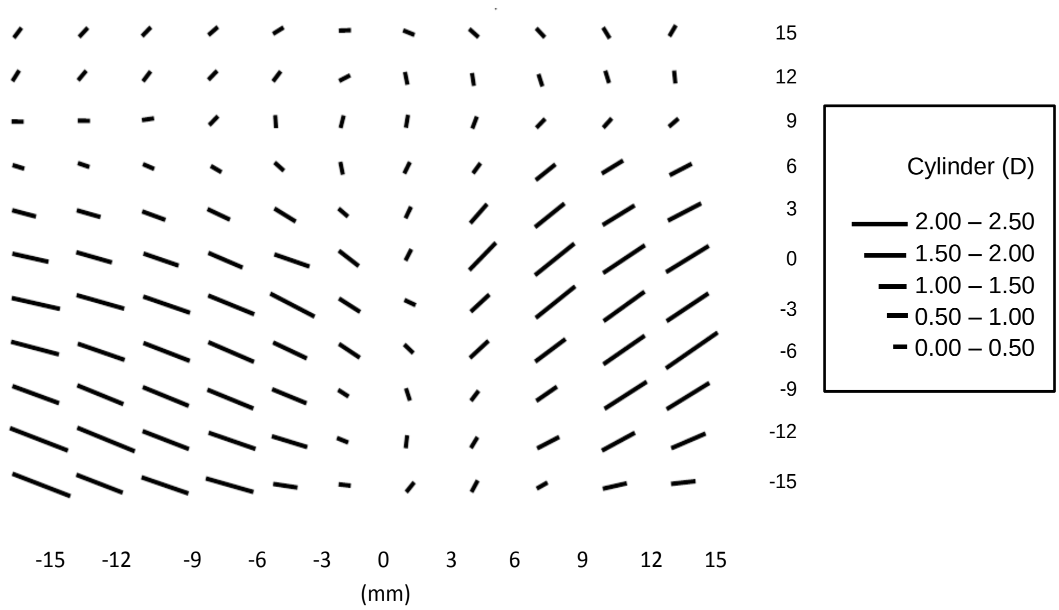


Figure 4.6 Power and axis vectors of oblique astigmatism of lens shown in Figure 4.5

The direction of the peripheral astigmatism is not consistent, as can be seen in a vector diagram created by the author with data from the same lens as in Figure 4.5 (Figure 4.6). The centre of the plot is the prism reference point, which is situated just below the distance centration point (fixation cross). Peripheral astigmatism, together with peripheral prismatic effects, cause in some wearers a perceived movement of the environment, often referred to as “swim”[133,134].

4.3 Literature Review

A literature search into spectacle lens forms and falls risk was performed in August 2012 using the Web of Science and Medline databases and the following search terms for all years: fall, elderly (older, aged, ageing, aging, over 65s, over 75s), single vision, bifocal, multifocal, varifocal and progressive addition lenses. Weekly search alerts were programmed and secondary searches were also performed.

An updated search was carried out in December 2016, with 21 papers identified that either directly investigated spectacle lens form and falls, or inferred increased falls risk as a result of lens-related properties, such as optical blur or spectacle lens magnification. One conference abstract was also included as it uniquely investigated the effects of two different PAL designs.

4.3.1 Differentiation of lens design

The search results were analysed to examine the definitions used for lens design, the number of wearers in each lens groups, and whether the lens design was differentiated in the study outcomes in nineteen of the identified studies (Table 4.2). This is vital in order to be able to attribute falls risk to a specific lens design, ie bifocal or PAL.

This analysis was not applicable in two studies which investigated the effect of spectacle lens magnification[135] and the effect of combined spectacle lens magnification and blur[136] when stepping up, as these were laboratory studies undertaken with single vision lenses. It was also not applicable in a study investigating walking behaviour with occlusion of the lower visual field[81].

No studies referred to the above-mentioned BS EN ISO13666:2012 standard or any of its earlier versions. 10 studies defined multifocal lenses as bifocal and PAL; 4 studies included trifocal lenses in the definition, and a further five did not provide any definition. Only six studies differentiated between bifocal and PAL lenses in their results: a narrow evidence base for lens design recommendations regarding falls risk. In the earlier studies a predominance of bifocal wearers is apparent.

Differentiation is of particular importance when interpreting study outcomes, especially those disseminated to optical professionals in falls prevention literature, such as the College of Optometrists' publication "The Importance of Vision in Preventing Falls"[137]. As an example, one of the references in this document, supporting the statement that the incidence of falls has been linked with "bifocal and varifocal wear" was a laboratory-based study that investigated stepping behaviour when wearing single vision lenses, bifocals or PALs[111]. The study was underpowered to detect any difference between bifocal and PAL lens design and gave no information as to how the habitual lens wear of the participants (12 bifocal, 7 PAL) may have influenced the outcomes.

Another example of the need to exercise caution is a reference in a paper by Gassmann[41]. Lord's 2002[126] findings are misquoted as *"Varifocal glasses impair depth perception and edge contrast sensitivity at critical distances for detecting obstacles in the environment*". The original statement referred to "multifocal", not varifocal.

Author	Year	Definition of multifocal	Regular wearers of lens designs (n)						Lens differentiation in results
			Bifs	Trifs	PALs	Bifs or PALs	PALs or Trifs	Subjects TOTAL	
Black[85]	2016	Bifs and PALs	5		5			19	No
Supuk[107]	2016	Bifs and PALs				115*		287	No
Källstrand-Eriksson[84]	2016	Bifs and PALs	50		101			212	Yes
Elliott[138]	2016	Bifs and PALs			14			14	Yes
Ellison[139]	2014	Bifs, Trifs and PALs			31			31	n/a
Black[86]	2014	Bifs and PALs	1		3			10	No
Beschorner[140]	2013	No definition	0	0	0			22	n/a
Brayton-Chung[141]	2013	Bifs, Trifs and PALs	1	4	28			46	No
Timmis[112]	2010	Bifs and PALs	11		9			20	Yes
Haran[127]	2010	Bifs, Trifs and PALs	192 (173)**	26 (33)**	66 (79)**			305 (301)**	No
Gassmann[41]	2009	No definition			277			622	No
Menant[128]	2009	Bifs and PALs	18		12			30	No
Johnson[130]	2009	Bifs and PALs	9		9			18	Yes
Johnson[110]	2008	Bifs and PALs	n/k		n/k			19	Yes
Johnson[111]	2007	Bifs and PALs	12		7			19	No
Hill[142]	2007	No definition	136***					300	No
Lakkis[143]	2005	No definition	17					17	Yes
Lord[126]	2002	Bifs, Trifs and PALs	76				11	156	No
Davies[144]****	2001	No definition				80		1250	No

* pre-operatively; ** Intervention (Cohort); *** includes non-specified spectacles and 82 bifocals; **** Details referring to 1996 study on leisure and domestic injuries

Table 4.2 Lens definitions and differentiation

Although Lord defined multifocal as bifocal, trifocal or progressive lenses, that study comprised 76 bifocal wearers and 11 participants who wore either trifocal or PAL lenses and was not powered to examine differences between these lens designs.

It is important to examine the sources of recommendations about lens design and falls risk and to understand their limitations in order to ensure best possible prescribing and dispensing advice is given to our elderly patients.

4.3.2 Overview of core publications

Table 4.3 lists the 22 publications that were identified as core to this review, and details the studied variables. These cover five main categories: visual aspects, head and eye movements, indicators of balance, physical health, and falls.

Visual aspects included visual acuity, low contrast visual acuity, stereopsis, contrast sensitivity and visual fields. The implications of these factors for falls risk were addressed in Chapter 3.

Investigations of head and eye movement parameters have included gaze direction and head pitch, particularly when walking and under conditions of obstacle avoidance[81,85,86,128]. It is widely accepted that, when walking, an individual fixates an average of about 2 steps ahead of their current position[145]. In the core studies, it has not, however, been determined through which part of a bifocal or PAL lens the wearer is looking when walking or negotiating steps, although there is a common assumption they are looking through the lower near segment[81,85,86,110–112,126,130,141]. This has formed the basis of many theories about increased falls risk with bifocal and PAL use. Indicators of balance included adaptive gait measures (such as obstacle avoidance[81,85,128,141] and step negotiation[111,112,135,136,138,140],) postural stability [107,110,126,130,143,144], co-ordinated stability [143], proprioception[126], stepping accuracy[86]

Author	Year	Variables													Comments
		Visual					**Eye/Head**		**Balance and Mobility**				**Health**	**Falls**	
		VA	VA (LC)	SA	CS	VF	Track	Pitch	AG / DGI	PS	CoSt	WS	PF[a]	F	
Black[85]	2016	✓			✓	✓	✓		✓						blur on foot placement and precision stepping
Supuk[107]	2016	✓								✓			✓	✓	cataract surgery, dizziness and falls
Källstrand-Eriksson[84]	2016	✓		✓	✓	✓								✓	vision, lens type and falls
Elliott[138]	2016	✓							✓						intermediate Add PALs
Ellison[139]	2014						✓								prismatic effect on reaction time and accuracy
Black[86]	2014	✓			✓	✓	✓		✓			✓			blur and CS on foot placement and precision stepping
Beschorner[140]	2013								✓						stepping up and down in novice PAL wearers
Brayton-Chung[141]	2013			✓	✓				✓			✓		✓	falls in middle-aged when wearing Bifs, Trifs or PALs
Chapman[135]	2011	✓		✓					✓						SM when stepping up
Elliott[136]	2010	✓		✓	✓				✓						SM and blur when stepping up
Timmis[112]	2010	✓	✓	✓	✓				✓						when stepping down with SV, Bifs and PALs

VA = visual acuity, VA(LC) = low contrast visual acuity, SA = stereoacuity, CS = constrast sensitivity, VF = visual fields Track= Head / Eye tracking, Pitch = head pitch
PS = postural stability/dizziness, CoSt= co-ordinated stability, WS = walking speed, PF[a] = physical function, AG = adaptive gait, DGI = Dynamic Gait Index
SV = single vision, Bif(s) = bifocal(s),Trif(s) = trifocal(s) PALs = Progressive addition lenses, SM = spectacle lens magnification

Table 4.3 Comparison of core study variables

Author	Year	Variables													Comments
		Visual					**Eye/Head**		**Balance and Mobility**				**Health**	**Falls**	
		VA	VA (LC)	SA	CS	VF	Track	Pitch	AG / DGI	PS	CoSt	WS	PF[a]	F	
Haran[127]	2010	✓		✓	✓								✓	✓	falls when comparing SV use with Bifs, Trifs, and PALs
Gassmann[41]	2009									✓			✓	✓	falls in community dwelling older people
Menant[128]	2009	✓					✓	✓	✓			✓			obstacle avoidance when wearing Bifs and PALs
Johnson[130]	2009	✓	✓	✓	✓					✓					balance control when wearing SV cf Bifs and PALs
Johnson[110]	2008	n/k	n/k	n/k	n/k				✓						stepping up to raised surface with SV, Bifs and PALs
Marigold[81]	2008	✓			✓	✓		✓	✓						VF when walking across multi-surface terrain
Johnson[111]	2007	✓	✓	✓	✓				✓						stepping up to raised surface with SV, Bifs and PALs
Hill[142]	2007	✓											✓	✓	sleep disturbances; Bifs identified as falls risk factor
Lakkis[143]	2005	✓								✓	✓	✓			comparing 2 different PALs and a bifocal
Lord[126]	2002	✓		✓	✓					✓			✓	✓	risk of falls when wearing Bifs, Trifs or PALs
Davies[144]	2001									✓				✓	influence of bifs / PALs on falls risk

VA = visual acuity, VA(LC) = low contrast visual acuity, SA = stereoacuity, CS = constrast sensitivity, VF = visual fields Track= Head / Eye tracking, Pitch = head pitch
PS = postural stability/dizziness, CoSt= co-ordinated stability, WS = walking speed, PF[a] = physical function, ,AG = adaptive gait, DGI = Dynamic Gait Index
SV = single vision, Bif(s) = bifocal(s),Trif(s) = trifocal(s) PALs = Progressive addition lenses, SM = spectacle lens magnification

Table 4.3 (cont.) Comparison of core study variables

and walking speed[86,128,141,143,146]. Co-ordinated stability is the ability to maintain balance by adjusting body position, when the feet are stationary. No study the writer is aware of has included an analysis of all three balance components, namely visual, vestibular, and somatosensory. It is, therefore, not possible to say whether those who have a predominantly visual balance deficit are more likely to experience falls with any one particular lens design.

Health factors recorded have included a wide range of known risk factors: dizziness [41,107], reduced cognitive ability as assessed by the mini-mental state examination (MMSE)[127,128,142], limitations in physical ability, as determined by the timed get-up-and-go test (TUG)[127,112], reaction time[126], pain scores[142], and physical activity levels or reductions in activities of daily living (ADL)[41,111,112,126,127,130]. Medication use and health issues such as Parkinson's disease, diabetes mellitus, heart disease, or orthostatic hypotension have also received attention[41,126,127112,142].

Whilst a range of the above factors were either examined as predictors of falls, or used to categorise subjects, only eight studies had falls as an outcome measure, and no studies investigated variables across all five main categories.

4.4 Spectacle Lens magnification (SM)

Spectacle lens magnification (SM) applies to all lens designs, including single vision lenses. An awareness of SM allows a greater understanding of studies investigating gait adaptations and step negotiation, particularly those of Chapman[135] and Elliott[136]. The latter paper investigated the relationship between SM and blur, and is addressed in Section 4.7 (Dioptric blur).

Convex (positive) lenses enlarge the retinal image size of an object, when compared with the image size in the uncorrected eye; conversely concave (negative) lenses reduce the retinal image size. This is referred to as spectacle lens magnification, and is a product of the power factor of the lens (PF^b) and its shape factor (SF^a).

The power factor takes into account the back vertex power of the lens (F'_v) and distance of the lens to the eye (d), otherwise known as the back vertex distance (BVD) (Equation 4.2).

Equation 4.2 $$PF^b = 1 / [1-(d \cdot F'_v)]$$

The lens thickness (t), its refractive index (n) and the front surface power (F_1) are used to calculate the shape factor (Equation 4.3).

Equation 4.3 $$SF^a = 1/ [1-(t/n) \cdot F_1]$$

The power factor is greater with increased back vertex distance, whilst steeper curvature of the front surface of the lens increases the shape factor. Modern lens designs, especially with lenses of higher refractive indices and flatter front surface curves – particularly in concave lenses – demonstrate a reduced shape factor.

Chapman[135] investigated the effect of spectacle lens magnification (±1%, ±2%,±3% and ±5%) on adaptive gait changes in 10 young subjects (mean age 22.3 ± 4.6 years) and ten older subjects (mean age 74.2 ± 4.3 years), when approaching and stepping up to a raised surface at 152mm. Building regulations stipulate a maximum rise of 220mm, a minimum going of 220mm and a 42º maximum pitch for stairs in private properties[147]. (See Figure 4.7 for a diagrammatic explanation of the terminology and Table 4.4 for minimum and maximum data.)

It is well known that positive lenses make objects seem larger and closer than they are in reality, and negative lenses reduce image size and make objects appear further away, which suggests SM may influence safe step negotiation.

The height of the raised surface in Chapman's investigation is just above the minimum rise height for domestic properties and expected increases in foot clearance when positive (size magnifying) lenses were worn, and reduced clearance when negative (size minifying) lenses were worn were confirmed. Mean trail vertical toe clearance was found to be 20.3mm (SD[b] 10.1) in older adults, and 22.3mm (SD[b] 12.2) in younger adults. With a positive SM of 5% this increased to 22.5mm (SD[b] 5.8) in older adults and 22.9mm (SD[b] 8.3) in younger adults.

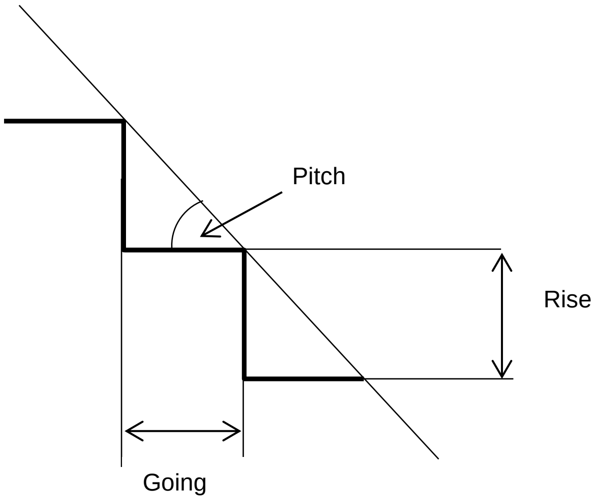


Figure 4.7 Stair terminology[53]

	Minimum	Maximum
Rise (mm)	150	220
Going (mm)	220	300
Pitch	-	42º

Table 4.4 Minimum and maximum dimensions for domestic staircase treads[147]

Of more concern would be reduction in clearance when the image seemed further away, with a negative 5% SM. In this case the reduction was 2.8mm (SD^b 8.2) in older adults (from 20.3mm SD^b 10.1 to 17.5mm SD^b 8.2) with no difference found in younger participants (22.4mm SD^b 9.9 compared with 22.3mm SD^b 9.9). This would suggest that, even with a 5% image size reduction, sufficient toe clearance for safe stair negotiation is present.

The effects of long-term adaptation to altered room perception were not investigated, but short-term adaptation was found not to take place. Information about the length of time it takes to adapt to different image size and room perception would be invaluable for the practitioner. Although large prescription changes, in both the sphere (to correct myopia or hypermetropia) and cylinder (to correct astigmatism), and large cylinder axis changes are usually avoided by the seasoned practitioner, there are some cases where these are unavoidable, such as in post-operative cataract outcomes.

The effect of changes in lens power on image size difference can be calculated with Equation 4.2 and Equation 4.3. Table 4.5 shows a range of values calculated from -6.00D to +6.00D in 2.00D steps, using front surface power (F_1) and lens thickness (t) data kindly provided by Frank Norville, The Norville Group, for two refractive indices.

To achieve a ± 5% image size change, a variation in prescription of more than ± 2.00D would be necessary, which is not commonly encountered in routine prescription updates, but is entirely feasible as a post-cataract surgery outcome.

This should prompt us to consider which post-operative refractive outcome is least likely to increase falls risk. In light of this study, emmetropia – in the case of previous ametropes – may not be the optimum post-operative outcome, especially after unilateral cataract surgery.

Back vertex power	F'_v (D)	-6.00	-4.00	-2.00	0.00	+2.00	+4.00	+6.00
Back vertex distance	d (m)	0.012	0.012	0.012	0.012	0.012	0.012	0.012
PF^b 1/(1-dF'v)		**0.93**	**0.95**	**0.98**	**1.00**	**1.02**	**1.05**	**1.08**
				For refractive index n = 1.50				
Refractive index	n	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Front surface Power	F_1 (D)	1.95	1.95	4.00	5.00	5.80	7.68	7.68
Lens thickness	t (m)	0.0020	0.0020	0.0020	0.0022	0.0032	0.0054	0.0073
SF^a $1/[1-(t/n)F_1]$		**1.00**	**1.00**	**1.01**	**1.01**	**1.01**	**1.03**	**1.04**
SM								
$SM = PF^b \cdot SF^a$		0.94	0.96	0.98	1.01	1.04	1.08	1.12
$SM(\%) = 100\,[(PF^b \cdot SF^a)-1]$		**-6.47**	**-4.33**	**-1.82**	**0.74**	**3.74**	**8.03**	**11.94**
				For refractive index n = 1.60				
Refractive index	n	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Front surface Power	F_1 (D)	2.17	2.17	2.17	4.86	6.29	7.43	8.57
Lens thickness	t (m)	0.00191	0.00191	0.00191	0.00220	0.00280	0.00460	0.00630
SF^a $1/[1-(t/n)F_1]$		**1.00**	**1.00**	**1.00**	**1.01**	**1.01**	**1.02**	**1.03**
SM								
$SM = PF^b \cdot SF^a$		0.94	0.96	0.98	1.01	1.04	1.07	1.12
$SM(\%) = 100\,[(PF^b \cdot SF^a)-1]$		**-6.47**	**-4.33**	**-2.09**	**0.67**	**3.60**	**7.34**	**11.52**

D = Dioptre, m = metre, PF^b = Power factor, SF^a = Shape factor, SM = Spectacle lens magnification

Table 4.5 Spectacle lens magnification calculations

Whichever presbyopic lens design is investigated, spectacle lens magnification issues hold true in all cases. With the advent of freeform technology, it is becoming increasingly more common for progressive surfaces to be worked on the back surface of the lens, so the SF[a] in such a lens is comparable with that found in single vision lenses.

4.5 Stair negotiation

Four other studies in the core publications reviewed also addressed the issue of stair negotiation and “multifocal” lens use[110–112,140].

Beschorner[140] investigated the influence of multifocal lens use (in this case PALs only) in a group of 15 young and 7 middle-aged adults who had never worn PALs previously, when undertaking step up and step down tasks. It is asserted that PALs distort step edge perception, as demonstrated by an image taken through a lens held at arm’s length (Figure 4.8a). This, however, is misleading as it does not replicate the optics and the visual perception when a lens is worn at the correct back vertex distance (BVD).

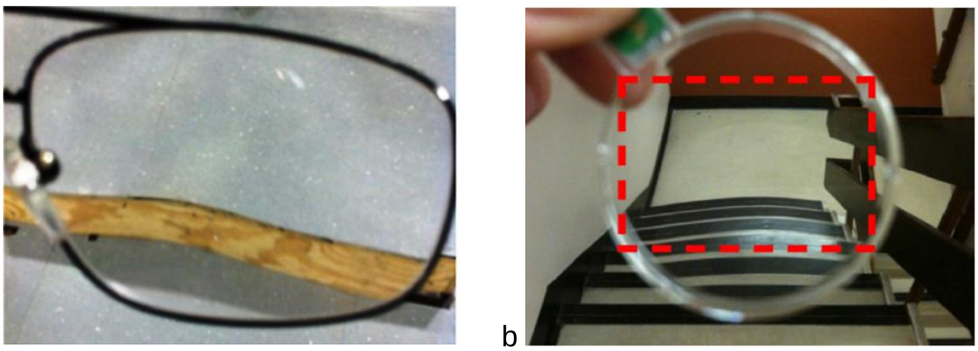
a b


Figure 4.8 Images through PAL lens at arm’s length a) Beschorner b) Ellison

The same assumption is found in a paper investigating prismatic displacement effects of PALs[139] (Figure 4.8b).

Beschorner reiterates that multifocal lenses reduce contrast sensitivity and “distort” depth perception needed for locating steps. This finding was, as previously reported, based on the assumption that wearers look through the lower portions of their lenses when walking or stepping.

This paper aimed to inform about the effects of PALs on novice wearers, but used lenses with a 2.75D Add, which does not reflect the norm in clinical practice for new wearers. No adaptation time was allowed. No difference was found between the age groups, with both demonstrating increased toe clearance and increased time taken and less controlled landing when stepping down. A similar investigation using Add powers commonly found in new PAL wearers – in the region of 1.00 D - would be helpful to highlight if similar issues presented. Adaptation to lens change is a highly individual trait, dependent on factors such as change in prescription, change in lens design or material, size and fit, particularly pantoscopic tilt and BVD.

Johnson[111] investigated the effect of multifocal lens use (defined as bifocals and PALs) compared with single vision lens use, when stepping up to three different levels. The previously mentioned studies used a height of 152mm. Johnson’s study used heights of 75mm, 150mm, and 220mm, representing kerb heights, stair risers and bus entry steps respectively.

Nineteen elderly subjects (mean age 71.4 years) were issued with 3 different pairs of spectacles to wear when carrying out the stepping tasks: single vision, D28 bifocal, and a Norville NCF5 PAL design. Twelve subjects were regular bifocal wearers, and seven regular PAL wearers. It was stated that the subjects were not informed which lens design they were wearing during the trials, but it is doubtful this was not easily perceived.

The tasks involved stepping up to the new height from a standing position that was half a foot length away from the front of the step. The influence of bifocal and PAL lenses on the minimum horizontal and vertical lead limb toe clearance were measured, as were centre of mass dynamics. It was stated that a one-step situation was chosen to reflect the transition from level walking to stair ascent, yet the subjects did not have a walking approach in the trials.

All measurements of visual function were taken at a distance of 1.4m when wearing distance, intermediate and near prescriptions in trial frames. Understandably, the results were worse when looking through near powers. This situation cannot be directly compared with that of wearing a spectacle frame fitted with bifocal or PAL lenses, as no analysis of the actual gaze direction and subsequently accessed area of lens power was undertaken.

The results showed no influence of lens design (including single vision) on centre of mass dynamics, and also no difference in the mean vertical toe clearance. It was proposed that the greater within-subject variability found in bifocal or PAL wearers would give rise to more tripping incidents. How or whether habitual use of a particular lens design was factored in, was not indicated, so it is not possible to say whether habituated bifocal lens wearers performed worse when wearing PAL lenses or vice-versa.

Johnson also reported on a similar study of nineteen participants (mean age 72.5 years) where a walking approach was used from a distance of 3m, and the step was a platform of 15 x 100 x 300 cm[110]. In this case performance was assessed when habitual bifocal and PAL wearers used D28 bifocals, NCF5 PALs and single vision lenses. Mean vertical toe clearance of the platform edge decreased with single vision, as opposed to bifocal or PAL lenses. Less within-subject variability was also found with single vision lenses, when measuring the lead toe–to-platform, and trail toe-to-platform distances. Here it is proposed that not toe clearance, but control of foot placement is the critical factor when considering collision with the front of the platform. It was concluded that changing habitual bifocal and PAL wearers to single vision lenses – in those at high risk of falling – may be a useful risk reduction strategy.

Changing elderly habituated lens wearers to a different lens design is generally avoided in practice. Having to cope with two separate pairs of spectacles brings its own set of challenges; confusion about which pair of spectacles to wear for which task arises, and the correct pair is not always to hand. Walking in single vision reading lenses would give rise to the same amount of blur attributed to looking through near zones of bifocal or PAL lenses. If toe clearance can be ruled out as a contributing factor, then it may be necessary to look again at the influence of SM. A comparison of SM across a range of SV, bifocal and PAL lenses may be advantageous.

4.5.1 Step descent

Step descent is more dangerous than step ascent, as the trip or fall will not be broken by the facing vertical rise of the flight of stairs. A study by Timmis *et al*[112] found that the accuracy and manner of foot placement when stepping down (landing control) was improved when wearing single vision lenses. In common with previous studies[110,111], visual factors of high and low contrast visual acuity, contrast sensitivity and depth perception were measured at 1.4m, in this case to simulate the distance from the subject's eyes to the ground when standing on a 15cm high block. The assumption that viewing would take place through the lower near portion of the lenses was also repeated.

20 long term multifocal (bifocal and PAL) wearers, mean age 71.9 ± 4.2 years were each issued with three different lens designs (single vision, D28 bifocal, and NCF5 PAL) using a prescription taken from their current spectacles by focimetry.

This would ensure that no adaption to a new prescription was necessary, but could also give rise to measuring errors. A copy of the latest issued prescription would have ensured an exact power match. Using the same step-down heights as were used in the step-up experiment by Johnson[111], a step-down task was initiated from a standing position onto a force platform. Timmis suggested a walking approach should be the subject of further studies.

Pre-landing kinematics (ankle and knee angle, medio-lateral and vertical centre of mass velocity) and the mechanics of landing (angular velocity of knee and ankle, vertical centre of mass velocity and peak force during landing) were investigated with each of the lens designs. Again, no information was provided how habitual bifocal lens wearers performed with the PAL lenses, or vice versa.

Whereas other studies have highlighted the variability of within-subject data, this study found no variability across all lens designs. It did, however, draw attention to some differences between the mean results of bifocal and PAL lenses, whereby the pre-landing kinematic of knee angle was reduced with both single vision and PAL lenses, but not with bifocals.

With regard to landing mechanics, ankle angular velocity and vertical centre of mass velocity decreased with both single vision and PAL lenses, but not with bifocal lenses. In the context of falls risk, this means that single vision and PAL wearers were more certain about the lower step position, and stepped down in a more controlled manner. This suggests that the optical differences in the two lens designs may come into play here. Should the wearer be looking through the lower segment of bifocal lenses, this would lead to blurred vision. Buckley[70] found blur led to a change in foot and ankle angles, as the subject “felt” for the position of the lower step, rather than lowering the limb onto it.

4.5.2 Missed edge accidents

Although elderly people may use staircases step by step, it would be interesting to see whether gait is modified in the same way when negotiating a flight of several steps. Templer[54] reported that the top three and bottom three steps on staircases were the main locations for falls accidents.

A paper by Davies *et al*[144] reported on two studies that investigated accidents looking at use of bifocal and PAL lenses, lighting, and missed step accidents. One study reported on accidents in paid employment, and the other in domestic and leisure settings. This review investigates the results reported for the domestic and leisure settings, on the assumption that the subjects of interest to this report are aged 65 and above and no longer in full-time employment.

A retrospective analysis of 1250 underfoot accidents, using patient interviews obtained with the Merseyside Accident Information Model (MAIM), looked at two hypotheses: a) the use of any type of spectacle (as a result of visual field losses caused by frame) and b) the wearing bifocal or varifocal (PAL) lenses, as risk factors.

The 1250 patients had all suffered injurious accidents and were attending fracture clinics. 745 had experienced “underfoot accidents”. Although data was recorded about whether spectacles were worn at the time of the accident, and if so, which lens design, no differentiation was applied between bifocal and PAL lenses.

618 participants reported they did not need spectacles. 378 participants reported not wearing their spectacles at the time of their accident: in the over 60 age group, this included 11 bifocal and varifocal (PAL) wearers who should have been wearing their spectacles.

Of the 243 who reported wearing the correct spectacles, 45 in the over 60 age group were wearing either bifocal or PALs, and one was wearing reading glasses. In this latter case, it is not feasible that these were the correct spectacles.

The odds ratio for missed edge of step (as an underfoot first event) with bifocal or varifocal (PAL) spectacles compared with all other underfoot first events (trips, slips, turned ankle, loss of balance, or unintended step) was found to be 3.7 ($p = .005$) with a 95% confidence interval of 1.5 – 9.1. When investigating movements such as turning a corner, moving down, and stepping down when wearing bifocals or varifocals (PALs), stepping down was found to have the greatest odds ratio for missed edge of step of 27.9 ($p = .003$) with a 95% confidence interval of 4.6 – 168.6.

Visual field limitations caused by the spectacle frame itself were not found to increase underfoot accidents.

There was no information regarding the visual acuities of the participants, nor the time elapsed since their last eye examination. It was assumed that those wearing bifocal or varifocal (PAL) lenses would be looking through the near lens portion when walking about.

Age was also found to be a predictor of underfoot accidents. Although there was an association between underfoot accidents and wearing spectacles, this does not necessarily indicate causality.

4.6 Gaze direction

Gaze behaviour can influence safe obstacle and stair negotiation, by providing timely information about the environment to enable adaptive gait changes. Aligning the head with the direction of travel gives the central nervous system a frame of reference to the environment, that helps control body movement[148]. When initiating a change of direction, the head turns before the rest of the body.

On average, the gaze position is two steps ahead, and is interspersed with obstacle fixation or landing target fixation. A stepping point is fixated approximately a second beforehand[145] and is fixated during the approach phase, and not during its actual negotiation[149].

With regard to stair negotiation, Templer[54] suggested that a conceptual scan initially takes place, to assess the stair's shape and condition, then the first step is fixated to accurately locate its position. This is often preceded by a noticeable hesitation. Thereafter the staircase is scanned about every seven steps, with a final scan to locate the last step and the transition to a level surface.

Zietz and Hollands found central visual information necessary to identify upcoming stepping locations, with both older and younger adults primarily fixating on these (approximately 90% of the time during stair descent, and between 75% and 90% during stair ascent)[150]. On average, a position three stairs ahead was fixated on ascent. On descent, older participants fixated more frequently (two stairs ahead) than younger participants (four stairs ahead).

Conversely, den Otter[151] found that foveal information was not imperative for safe stair negotiation, as a substantial amount of treads that were stepped on were never fixated (28% - 34%).

When investigating the influence of bifocal lenses or PALs on safe stair negotiation, not only the direction of gaze is relevant, but also the amount of head pitch adopted, as this will influence the accessed lens area.

Marigold [81] looked at walking adaptations when negotiating a walkway with many different surface structures: solid, rocky, slippery, compliant, tilted and irregular. Walking trials were undertaken with ten young (mean age 26.1 ± 5.2 years) and ten older (74.1 ±7.2 years) adults, both with and without spectacles that completely blocked the lower visual field.

It was demonstrated that head pitch was increased and walking speed was reduced when the lower visual field (LVF) was occluded, in both cases to a greater extent in the older than in the younger subjects. In all settings, the older subjects took shorter steps, and this was used to explain their increased head pitch.

It was proposed that, when the LVF is occluded, one of two situations can occur. Firstly, the subject may shift the direction of the eye, in conjunction with increased head pitch, in order to view the ground closer to them. Secondly, the subject may maintain a gaze at 2 steps ahead, but the increased head tilt allows information about the terrain to be perceived using peripheral vision. It is also feasible that a combination of these two responses takes place.

The increase in head pitch observed with occlusion of the LVF was compared with adaptations that multifocal lens users (bifocal, trifocal, and PALs) may make in order to view through the upper lens areas. In a previous study by Marigold[152], however, peripheral vision was found to be “sufficient for obstacle avoidance”, which would negate the need for increased head pitch.

Wearing bifocal or PAL lenses does not occlude the LVF, and - when looking through the near vision areas at distant objects - causes blur, not distortion as suggested by Marigold. It is possible to assess the amount of blur encountered.

Let us assume the subject in question has a depth of focus of 1.00D and is wearing a +2.50D Add. The range of clear focus when looking through the distance portion of a bifocal lens would be from infinity to 1m. When looking through the near portion, it would be from 40cms to approximately 29cms. At a viewing distance of 1.4m, the target would be in focus using the distance portion. If looking through the near portion, the target would be 1m beyond the range of focus, and would require a lens power of +0.71 D (1/1.4m) to bring it into focus. As the subject is wearing a 2.50 D Add, the resultant blur would be 2.50 D – 0.71 D = 1.79 D. Each spherical dioptre of blur reduces visual acuity by a frequently quoted average of four lines

(Snellen). Given the non-linear construction design of the Snellen chart, this can only give us a guideline, but we can estimate the visual acuity through a conventional +1.75D value to be about 6/60, given a starting acuity of 6/6. I would suggest, even at this relatively low level of visual acuity, there is a large amount of useful visual information provided to the subject, than when compared with total occlusion of the lower visual field.

Black[85] investigated stepping accuracy with optical blur and gaze direction either on target, 30cm ahead or 60cm ahead. Again the assumption is made that the lower visual field is blurred in “multifocal” lens wear and the trials were undertaken with participants wearing single vision lenses with +2.50D in addition to their best distance correction, mounted in Halberg trial clips, to represent “the blur resulting from commonly prescribed multifocal lens additions”.

Disregarding the blur condition, results showed that stepping accuracy was reduced when gaze was directed further away from the target. In the blur condition, significant understepping errors were attributed to SM, which in trial lenses is unlikely to be of the same magnitude as in full aperture lenses.

In addition, it was found that some participants transferred their gaze away from the target, before they had completed the stepping task, and that this also impaired stepping accuracy. The recommendation was to maintain gaze on the stepping position until heel contact had occurred.

The finding that older people at high risk of falls might benefit from single vision lenses to improve stepping accuracy can be called into question, as the trial situation does not replicate real-life situations, where head pitch and eye movement may mean that bifocal and PAL wearers are not looking through the near lens segments.

4.6.1 Postural stability when looking down

Postural stability can be affected by head flexion, and it has been found that flexing the head downwards, presumably in order to maintain a visual axis through the distance portion of the lens, can increase instability. However a study by Johnson[130] found that no multifocal design (in this case bifocals and PALs) affected standing postural stability, and that a “head flexed gaze down” approach had less impact on postural stability than “head neutral gaze down”, when looking at a target on the ground, with either bifocal, PAL or single vision lenses.

Each participating subject was issued with 3 different pairs of spectacles to wear when carrying out the postural stability tasks, with single vision, D28 bifocal, and Norville NCF5 PAL lenses. Of the eighteen participants, nine were regular bifocal wearers, and nine regular PAL wearers. It was stated that the subjects were not informed which lens design they were wearing during the trials, but it is doubtful this was not easily perceived.

Postural stability was least affected in the “head neutral gaze forward” position. It is notable that postural stability deteriorated when viewing in the “head flexed gaze down” position even with single vision lenses. This could lead us to assume that lens design per se has no influence on postural stability. Interestingly, a study investigating postural stability and gait characteristics in patients with age-related macular degeneration (AMD) found no difference in outcome measures in a group of 32% bifocal , 23% PAL, 4% trifocal and 5% single vision wearers[115].

4.7 Dioptric Blur

When considering the effects of blur, the study by Elliott and Chapman[136] is informative. The effects of dioptric blur on adaptive gait changes were investigated in a group of 10 older adults (mean age 77.1 ± 4.3 years). These subjects approached a step of 152mm in height from a distance of 2 walking paces, in this case 1.79 ± 0.9m, and stepped up onto the raised surface. Using a trial frame, the subjects wore their optimal refractive correction for this distance, as well as additional blur lenses of ± 1.00D and ± 2.00D. If blur had been the driver for gait adaptation, then leading vertical toe clearance would be expected to be the same for positive or negative 1.00D blur situations, and likewise for positive or negative 2.00D blur.

Although trial frame lenses were used, where shape factor is negligible due to the shallow front surface curve and reduced lens thickness, power factor still contributes to image size. As vertical toe clearance was found to be greater with positive blur lenses, and smaller with negative blur lenses, it was concluded that not blur, but spectacle magnification was the cause of these adaptations. This was subsequently confirmed by the later paper by Chapman[135], as detailed in Section 4.4.

Black[86] investigated blur with regard to stepping accuracy. The task was to walk up and down a corridor stepping as closely as possible onto the middle of each stepping target and to walk around or over the other non-stepping carpet rectangles. Halberg trial clips were fitted into eye tracker goggles and the task was repeated with best subjective refraction, +2.00 blur and +3.00D blur.

The conclusion that older adults at high risk of falls might benefit from SV glasses to improve stepping accuracy does not take into account that the wearing of SV Halberg clips does not provide a real-life simulation of bifocal or PAL lenses and that wearers may indeed be using the distance portion of the lenses when walking. Blur was found to have a significant effect on stepping accuracy, (understepping) but only with the +3.00D blur lens. There was no significant difference between the +2.00 D blur condition and no blur condition. Step accuracy also decreased when stepping onto the low contrast target compared with the high contrast target, and this was combined with a longer fixation time on the low contrast target, which would have implications for executive function and future planning.

Studies of this nature replicate more the situation where SV reading spectacles are used for walking, which is not comparable with the use of bifocals or PALs.

To investigate whether reduced blur levels improved stepping accuracy was the aim of a study that compared intermediate and full Add bifocals and PALs[138]. Fourteen well habituated PAL wearers undertook step ascent and descent trials when wearing their own PALs, intermediate and full Add PALs, intermediate and full Add bifocals, and single vision lenses. Gait parameters with the participants' own spectacles were similar to the results found using the trial intermediate PALs and single vision lenses. This would suggest that habituation is a critical factor in step negotiation safety.

4.8 Multifocal lenses and dual tasking

Dual tasking, specifically stopping walking when talking, is a recognised risk factor for falls[34,153]. The study by Menant[128] looked at how older, habituated mutifocal (bifocal and PAL) wearers fared when a) negotiating a walkway with obstacles, and b) negotiating the same walkway and simultaneously carrying out two additional visual tasks. Of the thirty participants (mean age 77 ± 6.5 years), 18 were bifocal wearers, and 12 wore PALs. The walkway was 14.5m long and contained obstacles in the form of foam blocks at different heights and cardboard strips, which were to be stepped over.

Measurements of the mean head angle and the mean pitch to pitch movements of the head and eye were taken. Eye movements were recorded with an eye-tracker. However, this was not able to identify through which part of the lens the participants were looking.

The additional visual tasks were demanding. The participant had to identify a sequence of three letters presented at eye level, over a total of 1.5 seconds, followed by a 2 second break, and then a further presentation block. Although not specifically stated, it seems that this task continued for the length of the walking task. In addition, at one position to the right hand side of the walkway, and one to the left, the suit of a playing card, positioned at eye level, had to be identified. This effectively constitutes triple-tasking. It was found that multifocal wearers, when carrying out the additional visual tasks, did not increase head pitch, in order to utilise the distance areas of the lens to view the walkway. As a result of this, more obstacle contacts occurred. The reduced head pitch could indeed drive the subjects to look through the near area of the lenses, increasing dioptric blur at ground level, but the position of the eye relative to the lens was not identified. It may have been the case that the predominant visual gaze direction, in order to read the letters presented at eye level, was straight ahead. In this scenario, the obstacle negotiating task would not be performed in line with the usual “two steps ahead” gaze direction when walking.

4.9 A comparison of two PAL designs with a bifocal

An abstract was presented at the American Academy of Optometry Conference in 2005, entitled “The Effects of Multifocals on Balance and Mobility in Older Persons[143]. Unfortunately, it was never published as a full paper (personal communication with SA Haymes).

In spite of this it deserves attention, because it forms a starting point in investigating the optical differences, not only between bifocal and PAL lenses, but also between two different PAL designs. The study focussed on balance and mobility performance in a group of 17 experienced bifocal wearers (65 years or older).

In a random masked crossover trial, two PAL designs were worn for three weeks each. At baseline (with bifocals), with PAL at time of supply, and after 1 and 3 weeks' wear, the following variables were measured: distance visual acuity, postural sway, co-ordinated stability, and walking speed using an indoor obstacle course and step negotiation.

The PAL designs were both found to be better than the bifocal with regard to co-ordinated stability ($p = <.05$). No significant differences were found between any of the lens designs with regard to walking speed and step negotiation with both high and low illumination, or different step widths. Dynamic postural stability was significantly better with one of the PAL designs, when compared to the bifocal, and fell just short of statistical significance with the other design.

Even though the subjects were aged 65 or older, and change in lens design would normally be approached with caution, all of the subjects in this trial continued to wear the PALs after the study had finished. No indication was given for the subjects' motives for remaining with the PALs.

Here we see, for the first time, a study concluding that PAL design may in fact be superior to bifocal lenses with regard to balance and mobility.

4.10 Population-based studies

Six population-based studies investigated a range of physical, medical and visual aspects on falls risk[41,84,126,127,142,144], with Lord's 2002 study on edge contrast sensitivity and depth perception providing an impetus for many of the previously discussed laboratory–based studies.

4.10.1 Edge contrast sensitivity and depth perception

Lord's paper "Multifocal Glasses Impair Edge-Contrast Sensitivity and Depth Perception and Increase the Risk of Falls in Older People"[126] is widely cited in the core papers[81,85,110–112,127,128,130], and also in the College of Optometrists' document "The Importance of Vision in Preventing Falls"[137], and therefore deserves particular attention.

Lord's paper reported on a one year prospective cohort study in Australia, of 156 community dwelling elderly people between the ages of 63 and 90. The study did not differentiate between the different optical properties of bifocal, trifocal and PAL lenses. Indeed, of the 87 subjects who were regular wearers of any of these lens designs, 76 were bifocal wearers and 11 were wearers of either trifocal or PAL lenses. How many were PAL wearers was not identified. Edge-contrast sensitivity and depth perception were measured on all participants, but wearers of multifocal lenses (defined in this study as bifocal, trifocal or PAL) carried out the tests twice: once looking through the near area of the lens, and a second time looking through the part of the lens for distance vision.

The edge-contrast sensitivity measurements were conducted with the test chart at ground level, at a distance to the subject of 135cm. This distance was chosen to represent the "two steps ahead" distance.

Edge contrast sensitivity has been found to be sensitive to blur[154]. Each 1.00D of blur reduces contrast sensitivity by half. If we assume the mean height of male participants to be 175cms, and of female participants to be 162cms, this would give a viewing distance of 221cms and 211cms respectively. Given that the depth of focus in these elderly subjects is around +1.00D, this would give a clear range of focus up to 1m, when looking through the distance part of the lens.

It is, therefore, no surprise that Lord's results showed reduced edge contrast sensitivity measurements when looking through the near portion of bifocal, trifocal or PAL lenses. Assuming an Add of 2.50D, the furthest distance of clear vision through the near portions of the above lenses would be around 40cms, which would give rise to approximately 1.75D of blur for the edge contrast testing distance. This would reduce contrast sensitivity to an estimated quarter of its distance value.

It still remains to be ascertained whether users of bifocal, trifocal or PAL lenses do in fact look through the lower portions of the lenses when walking or navigating steps, and whether there is a difference in use between bifocal and PAL lenses, given their different design characteristics.

Although Lord measured proprioception, sway, strength and reaction time in his subjects, this was not investigated as a dependent variable of “multifocal” lenses, but to identify whether “multifocal” lens use was an independent falls risk factor. In the one year follow-up on falls in this cohort, it was found that regular “multifocal” lens wearers were – possibly unsurprisingly - wearing their glasses at the time of their falls. No non-regular wearers fell when wearing “multifocals”. “Multifocal” wearers were found to be more likely to trip, fall when walking up or down stairs, or fall when outdoors.

It could be argued that non-regular wearers are more cautious when wearing lenses they are not completely familiarised with. Inferences about the impact of spectacle lens magnification or blur are not possible, as there is no information about lens powers worn.

It is worth recalling that the number of PAL wearers was not identified in this study, and that the PAL and trifocal wearers, grouped together, accounted for 7.05% of the cohort, and bifocal wearers for 48.7%. We should therefore be cautious in assuming that the findings of this study apply to PAL wearers.

Depth perception in the same study was measured using the Howard-Dohlman equipment, where the subject has to align the position of two vertical rods, from a distance of 3m. This test was also performed twice: firstly through the distance portion of the lens, and secondly through the near portion. The argument about whether looking through the near portion is a valid representation of habitual bifocal or PAL lens use also applies here. With increased blur - caused by looking through the near segments - it was found that regular multifocal (bifocal, trifocal and PAL) wearers performed significantly worse than when looking through the distance lens area.

Reconciling these findings with those of Elliott[136], it could be argued that the poorer performance was not indeed a consequence of blur, but of spectacle lens magnification.

4.10.2 The VISIBLE trial

The Visual Intervention Strategy Incorporating Bifocal and Long-distance Eyewear (VISIBLE) randomised controlled trial[127] investigated the effect of providing an additional pair of single vision distance spectacles to multifocal wearers, with instructions to wear them when walking up and down stairs outside the home, walking in the street and in shopping centres, walking or standing in other peoples' homes or in unfamiliar buildings, negotiating rough or uneven ground, and when alighting public transport.

In this trial, the number of bifocal, trifocal and PAL wearers was stated, but the analysis of outcome measures of falls and injurious falls did not differentiate between these lens designs. The majority of participants were bifocal lens wearers, which were stated to be the most common type of "multifocal" lenses. (Intervention group: 63% Bifocal, 22% PAL, 9% Trifocal; Control group: 57% Bifocal, 26% PAL, 11% Trifocal).

This is not comparable with the UK market, where in 2010 bifocal lenses accounted for only 12% and PALs for 22% of all lenses dispensed[155].

Whilst care was taken to ensure prescriptions were updated, and that the prescription in the single vision lenses matched the distance prescription in the "multifocal" lenses, the outcomes are confounded by the fact that the single vision lenses were either photochromic (Transitions) or had some sort of fixed or graduated tint. There is no data whether, or how many, spectacles with "multifocal" lenses incorporated any tint. The assumption is we are comparing tinted single vision lenses with untinted "multifocals".

Whereas in other core studies those with falls risk factors were excluded, in this case relatively high risk of falls was an inclusion criterion. High falls risk was defined as either being aged 80 or over, being 65 or over and having either had a fall in the previous twelve months or a timed up and go (TUG) score of at least 15 seconds.

The intervention group were advised by the optometrist how "multifocal" glasses impaired visual abilities for judging depth and obstacle avoidance, and were also shown images of street scenes with and without the lower field subject to simulated blur. As the control group did not receive this information, it could be argued that the intervention group then used their multifocal lenses with an increased perception of risk, or even a greater fear of falls. This in itself is a falls risk factor[40,156].

The figure that detailed the reasons for withdrawals from the trial (28 from the intervention group, and 19 from the control group) was missing from the paper, but the completion rate was high at 90% and 94% respectively.

It was found that falls rates did not differ significantly between groups, but a subanalysis highlighted that more active participants in the intervention group had fewer overall falls, fewer falls outside the home, and fewer injurious falls. The less active participants in the intervention group had a significant increase in falls outside the home.

The subsequent recommendation that single vision lenses should be provided for outdoor use when the first pair of multifocal lenses is prescribed, does not necessarily follow from this intervention. This cohort of early presbyopes would not have an increased falls risk factor due to age, and would generally have a level of fitness that would not increase TUG scores. The low Add required at this age would also not give rise to an intermediate area of optical blur if wearing bifocals.

Other recommendations were that multifocal lens use should be avoided in those with a minimal (not defined) distance prescription. It is, however, conceivable that PAL use could enhance intermediate vision specifically for those with a low level of uncorrected hypermetropia.

The study was not able to shed light on any variations in falls outcome measures related to lens design in the control group. Given that the majority of participants were bifocal lens wearers, the study's findings that more active "multifocal" wearers should have a supplementary single vision distance pair for outdoor use, and less active "multifocal" wearers should use multifocals rather than different pairs of glasses, may not be applicable to PAL wearers.

4.10.3 Falls and sleep disturbances

An investigation into sleep disturbances in a group of hostel participants and a group of internet questionnaire respondents used bifocal lens wear, the use of any spectacles, and Snellen chart score as a descriptor of poor vision[142]. The assumption of poor vision purely by spectacle or bifocal lens wear cannot be made. In the internet respondents, only self-reported visual impairment was possible. Nonetheless, bifocal use was found to have a statistically significant association with falls in people reporting sleep disturbances. The questionnaire was not available, so it was not possible to determine whether participants had been asked about PAL or single vision wear. Given that this paper was published in 2006, and the majority of respondents came from Australia, it is likely that PAL wearers would have been included in the study. In-depth analysis of what type of influence bifocal lens wear may have had, did not take place.

4.10.4 Merseyside Accident Information Model (MAIM) reports

Interviews of patients attending a hospital clinic in Liverpool were investigated using the MAIM software system of analysing accidents according to their causative factors and injury outcomes, as well as personal and activity-related factors. There were two parts to this study: accidents that occurred during paid employment, and accidents that occurred during domestic or leisure activities. The outcomes of the latter part were discussed in Section 4.5.2 (Missed edge accidents).

4.10.5 PALs and falls in an older community-dwelling German population

A trial of 622 community-dwelling people aged 65 years or older in Germany investigated a range of demographic, medical and functional data with regard to falls. Varifocals (PALs) wear was found to be a predictor for any falls, (OR 1.76; CI 0.99 – 3.13, p = .05), yet the findings were not statistically significant when comparing non-fallers and single fallers (OR 1.59; CI 0.81 – 3.12) and when comparing recurrent fallers and non-fallers (OR 2.19; CI 0.79 – 6.00). There was no information as to whether any other lens designs were taken into consideration or worn by the trial group. This may simply reflect a predominance of PAL wear in Germany. The strongest predictor was a history of recurrent falls, with an OR of 31.99 (CI 12.99 – 78.71).

4.10.6 Spectacle lens design and falls in an older community-dwelling population in Sweden

A 2016 Swedish study examined purely visual aspects (the influence of monocular and binocular visual acuity, contrast sensitivity, stereoscopic vision and visual fields as well as the type of habitual lens wear) on retrospective falls data. 298 independently living people aged between 70 and 80 years were assessed, of whom 50 were habitual bifocal wearers, and 101 habitual PAL wearers. The only statistically significant risk factor for falls was best monocular VA (OR 2.26, $p = .013$). For recurrent falls, statistical significance was found only for stereoscopic vision (OR 3.23, $p = .002$). No significant association was found for worn lens design and single falls ($p = .078$) or worn lens design and recurrent falls ($p = .15$).

4.11 Summary

This chapter has described presbyopia and its correction modalities in the form of bifocal, trifocal and progressive addition lenses, and investigated a range of studies that have looked at lens design features and falls risk.

Advice based on current research to those at risk of falls, or those who have already fallen, is to wear single vision lenses as opposed to “multifocal” lenses[110–112,126,127].

The literature review highlighted that the definition of multifocal is not consistent across the studies, with poor discrimination between the optical characteristics of bifocal, trifocal and progressive addition lenses. The inherent differences in the optical design features of these lenses should drive us to consider them as separate entities.

To the author’s knowledge, no data of head and eye movements, which identifies the lens area typically looked through when walking or using stairs, is available. The assumption that gaze direction is through the near portion remains to be confirmed.

Gaze direction through the near portion at a point two steps ahead would create a level of blur, dependent on the individual's depth of focus and near addition. It has however been proposed that not blur, but spectacle lens magnification with its inherent alteration of perceived object location, is the causative factor for changes in foot and toe placement.

The amount of head pitch adopted, and the subsequent influence on postural stability, may vary between bifocal and PAL designs. This could be an important factor in stair descent, which accounts for 75% of all falls on stairs[49]. The recommendation to substitute single vision lenses for "multifocal" lenses in active elderly subjects did not discriminate between bifocal and PAL wearers. Whether a deficit in the visual component of our balance system has a different effect on performance with bifocals or PALs has not been established.

Both bifocal and PAL lenses are unable to provide the wearer with a perfect substitution for pre-presbyopic vision. Image jump and diplopia challenge the bifocal wearer, as do peripheral astigmatism and prismatic effects for the PAL wearer. Perceived distortion is not as simulated when looking through a lens at arm's length.

The next chapter describes a survey undertaken to explore current attitudes to dispensing and prescribing for elderly patients or customers at risk of falls.

Chapter 5. Survey of professional attitudes

5.1 Introduction

The Prescribing and Dispensing Survey was undertaken as a precursor to further studies directed at investigating the effects of different spectacle lens designs on falls risk, in order to gain an understanding of current dispensing and prescribing practices of GOC registered optometrists and dispensing opticians, when dealing with elderly patients or customers at risk of falls.

5.1.1 Study goal and objectives

The primary aim of the study (Objective A) was to identify the professional's level of agreement with the statement:

"It is advisable to switch elderly (65 and over) long-term varifocal and bifocal wearers, who are at a high risk of falling, to single vision lenses."

This statement was chosen based on the following research findings:

- …."this study provides preliminary evidence that switching long-term multifocal wearers to single-distance-vision eyeglasses may be a useful strategy in elderly multifocal wearers at high risk of falling"[110].
- …."use of single vision distance lenses in everyday locomotion may be advantageous for elderly multifocal wearers who have a high risk of falling"[112]
- "With appropriate counselling, provision of single lens glasses for older wearers of multifocal glasses who take part in regular outdoor activities is an effective falls prevention strategy"[127]
- "Older people may benefit from wearing nonmultifocal glasses when negotiating stairs and in unfamiliar settings outside the home"[126].

Further objectives were:

B: identifying how confident the professional feels with regard to assessing a patient's risk of falls

C: identifying how the professional who feels confident in the above task, undertakes this assessment

D: investigating prescribing and dispensing practices when the patient / customer is assessed either "at risk of falls" or "may be at risk of falls"

E: investigating prescribing and dispensing practices when the patient / customer is either "not assessed" or "assessed and found not to be at risk of falls"

F: investigating variations or consistencies in practice

G: investigating the level of interest in specific practice support documentation and/or a dedicated falls assessment tool for use in practice

5.2 Methods

Ethics approval was granted by Aston University Life and Health Sciences Research Ethics Committee (Appendix 1).

5.2.1 Sample size

Sample size was calculated using a freely available online calculation tool[157]. A population figure of 23,000 was applied, based on General Optical Council (GOC) Annual Report 2010 registration figures of 23,110 registered individuals, including student members. 378 respondents are required to obtain results at a 95% confidence level with a confidence interval (margin of error) of 5%.

5.2.2 Questionnaire design and structure

The questionnaire was designed using Bristol Online Surveys (BOS), which was created by the University of Bristol and is reported to be used by approximately 130 universities as well as other public bodies and companies. An online survey was chosen as an inexpensive, environmentally friendly, and widely accessible format.

The questionnaire was reviewed by the Head of Market Research at Aston University, and the project supervisor, and subsequently piloted by 12 optical professionals. Minor amendments, mainly regarding routing of the questions, were made in line with the feedback.

	Objectives	**Question(s)**	**(n)**
A	Level of agreement with primary aim statement	7	(1)
B	Level of confidence in assessing falls risk in elderly patients	8/9	(2)
C/D/E	Method of risk assessment; Preferred lens designs, coatings and tints for elderly patients at risk/ at possible risk / not at risk or not assessed	10/11/12/13/14	(5)
F	Respondent profile (age, gender, qualifications and work environment)	1/2/16/17/18/19/20/21	(8)
F	Usual patient profile (age, visual acuity)	3/4	(2)
F	Lifestyle questions routinely asked	5/6	(2)
G	Level of interest in practice support documentation	15	(1)

Table 5.1 Questionnaire content structure

The final questionnaire (Appendix 2) comprised 21 questions linked to the objectives listed in Section 5.1.1 (see Table 5.1).

Freeform boxes were included either for additional information or for answers that did not conform to the chosen categories.

5.2.3 Recruitment

The questionnaire was launched on 26.02.2013, with an expected time span of 8 weeks to obtain sufficient responses from the identified population.

It was widely publicised in the optical press (Optician 01.03.13, Optometry Today 08.03.13), in online e-newsletters (General Optical Council (GOC) e-bulletins Spring 2013 and July 2013, Association of British Dispensing Opticians (ABDO) e-newsletter March 2013, Optometry Today e-newsletter 07.03.13), and in the newsletters of the Association for Independent Optometrists and Dispensing Opticians (AIO) Spring 2013, and the Local Optical Committee Support Unit (LOCSU) April 2013, and printed cards with details of the survey were handed out to attendees of Optrafair 2013. As the response rate was lower than expected, the time span was extended and the survey closed on 26.08.2013 with a total of 209 respondents.

5.3 Results reporting structure

The findings of the survey are reported on in categories: survey respondent characteristics according to gender, age and profession; supplementary qualifications, working environment and years in practice; response to core statement; level of confidence in risk assessment; falls risk assessment modalities; lifestyle questions; lens design choices, lens tints and coatings according to confidence level.

Decision tree analyses then examine which factors influenced the response to the core statement and the level of confidence identified by the practitioners themselves.

5.3.1 Gender, age and profession of respondents

The survey was open to all professionals registered with the General Optical Council (GOC), including pre-registration optometrists and trainee or pre-registration dispensing opticians. As, however, only 3 responses from trainee/pre-registration dispensing opticians and one sole pre-registration optometrist completed the survey, these categories were excluded from the evaluation.

205 respondents completed the survey, which was lower than required. Nonetheless, this still represented a confidence interval of 6.81% with a 95% confidence level. This was based on the population of registered dispensing opticians and optometrists (n = 19,798) excluding student members, according to figures released in the GOC Annual Report 2012 - 2013.

The Chi square (χ^2) frequency distribution of dispensing opticians and optometrists in the survey and on the GOC register showed no statistically significant difference (χ^2 = 3.81, df = 1, p = .051).

When considering fully qualified dispensing opticians and optometrists, the 2012 - 2013 ratio of female to male General Optical Council (GOC) registrants was 1.30 : 1. The response ratio for all female to male questionnaire respondents was greater than this, at 1.73 : 1, but this difference was not statistically significant (χ^2 = 3.83, df = 1, p = .050), albeit at a marginal level.

A G*Power 3[158] analysis showed that the number of respondents sufficient to yield a power of 0.80 when investigating gender distribution according to professional category was satisfied (n= 44 per group). The difference between the gender response ratios for optometrists and dispensing opticians was not statistically significant for either group (Table 5.2).

Most (99.5%) respondents submitted age data, which was collected in 5-year age bands, and analysed according to gender (Figure 5.1) and profession (Figure 5.2).

	Optometrists (%)		**Dispensing Opticians (%)**	
	Survey	GOC	Survey	GOC
Female	61.0	55.3	70.6	59.5
Male	38.9	44.7	29.4	40.5
Ratio F:M	1.57:1	1.24:1	2.40:1	1.47:1
Chi square	2.02		2.60	
p-value	0.16		0.11	

Table 5.2 Gender breakdown of respondents and GOC registrants

Chi square tests for independence showed a statistically significant gender difference across the age bands (χ^2 = 33.03, df = 9, p = <.001). Figure 5.1 indicates that females outnumbered males below the 46 - 50 year age band, but that the distribution became more equal after that. There was no statistically significant difference in the proportion of optometrists and dispensing opticians across the age bands (χ^2 = 4.79, df = 9, p = .85); responses from optometrists consistently outnumbered those from dispensing opticians.

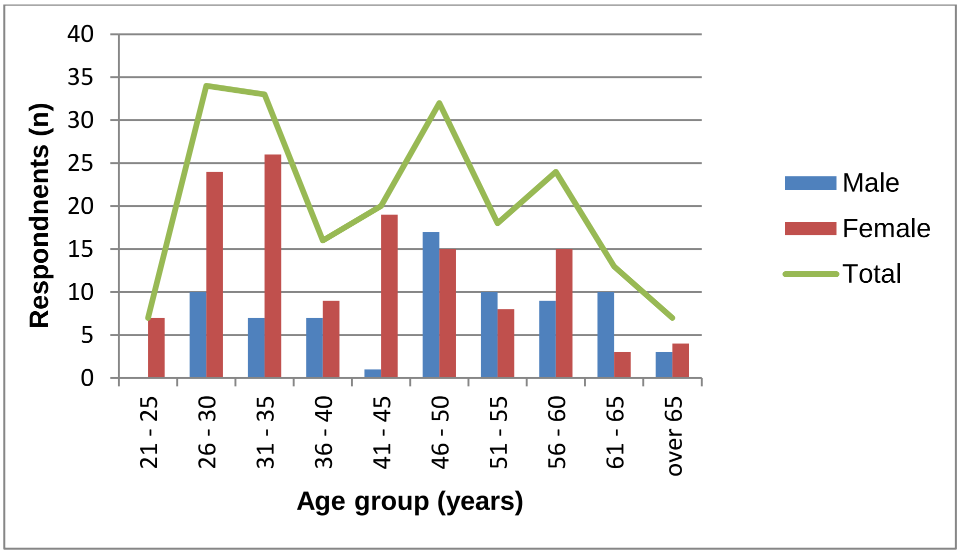


Figure 5.1 Age and gender of respondents

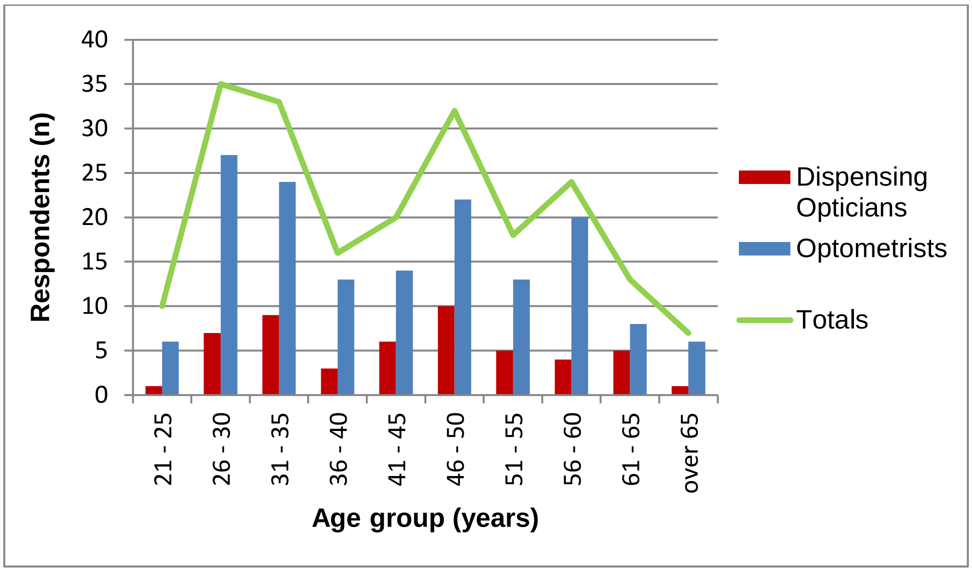


Figure 5.2 Age and profession of respondents

5.3.2 Supplementary qualifications

Forty seven respondents (22.93%) indicated that they had additional qualifications. The majority of the additional qualifications (n=39) were directly related to the practice of optics (postgraduate diplomas and certificates in contact lenses, glaucoma, ocular conditions, diabetes, low vision, spectacle lens design, Eye Health Examination Wales accreditation, membership of the British Association of Behavioural Optometrists, fellowship of the College of Syntonic Optometry, and fellowship by examination of the College of Optometrists).

Not directly related were qualifications in dementia, kinesiology, counselling and fitness instruction. Academic qualifications (n=13) included 7 doctorates and 6 masters degrees.

5.3.3 Working environment and years in practice

The greatest amount of respondents came from the independent sector (44.9%), followed by those from large multiple chains (32.2%) (Figure 5.3). The modal group for the amount of years in practice was 6 – 10 for those working in a large multiple chain, and 26 - 30 for those in independent practice. Surprisingly, this did not contribute to a statistically significant difference regarding the working environment and practice years ($\chi^2 = 49.25$, df = 40, p = .15) (Figure 5.4).

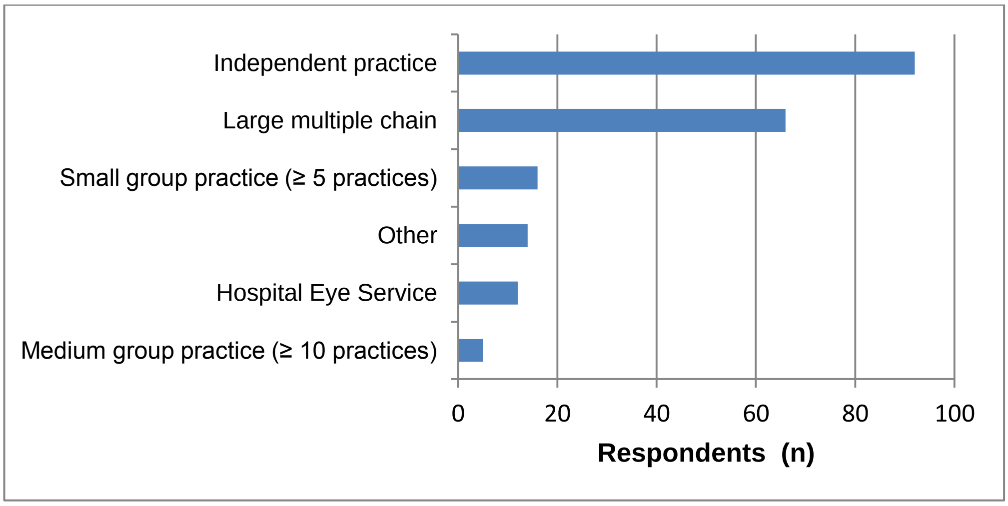


Figure 5.3 Working environment of respondents

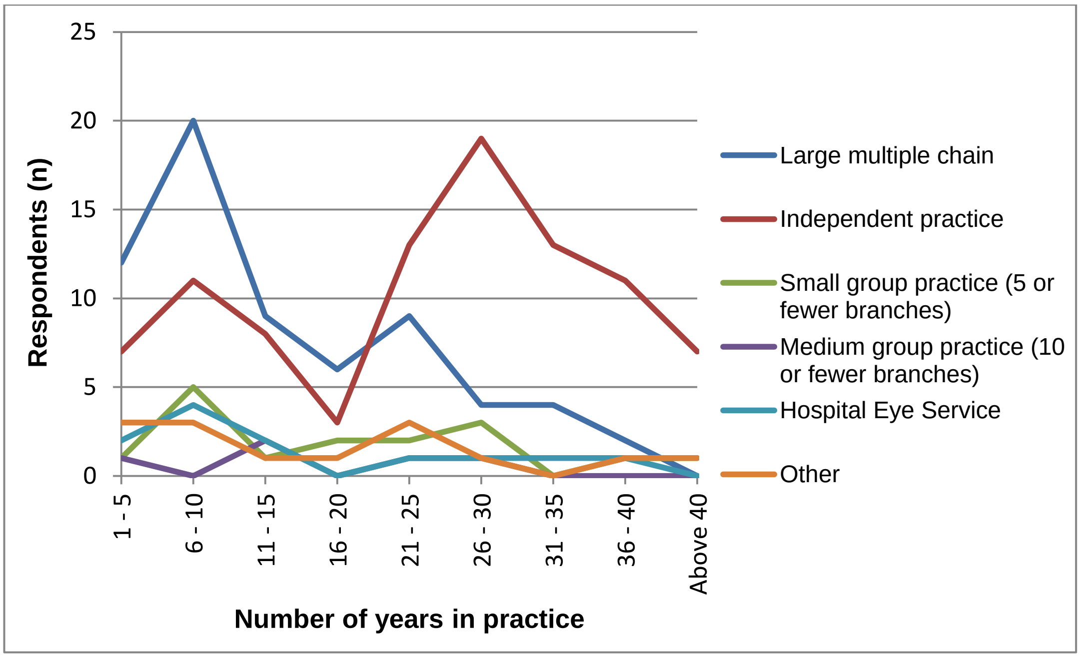


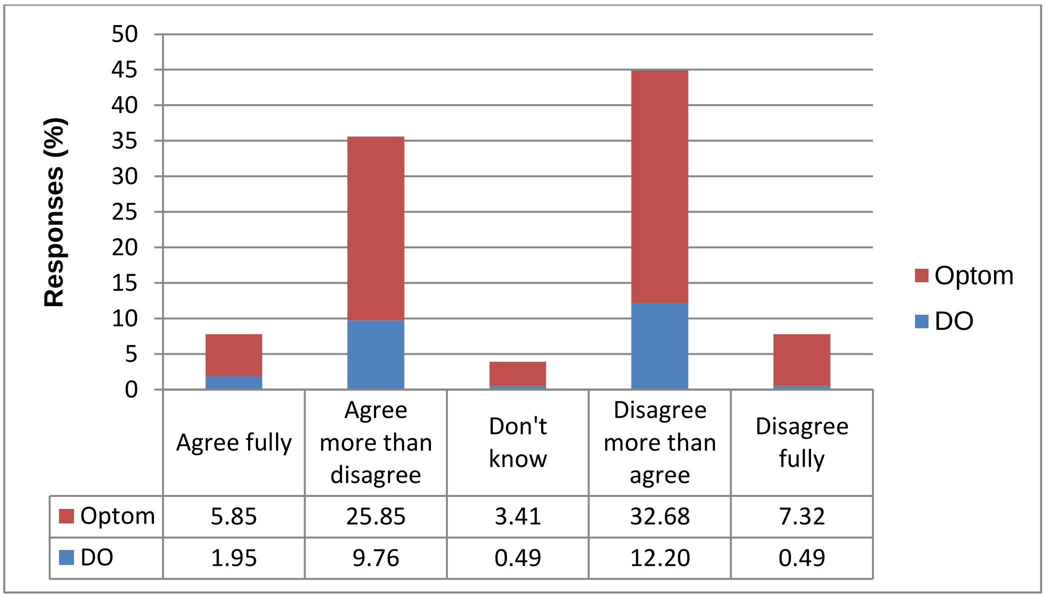
Figure 5.4 Working environment and practice years

5.3.4 Response to statement

To address the main objective of the survey (Objective A, Section 5.1.1) respondents were asked to rate, on a five-point Likert scale, their level of agreement with the statement:

"It is advisable to switch elderly (65 and over) long-term varifocal and bifocal wearers, who are at a high risk of falling, to single vision lenses."

As seen in Figure 5.5 only 3.9% of total respondents had no opinion on the statement, 44.9% disagreed more than agreed, and 35.6% agreed more than disagreed. The categories "agree fully" and "disagree fully" were equally represented at 7.8%. This demonstrates both a polarity of opinion, and a level of ambivalence across the profession.



Optom = Optometrists, DO = Dispensing Opticians

Figure 5.5 Statement agreement according to profession

5.3.5 Level of confidence in assessment of falls risk

Contributing to Objective B, survey participants were asked to rate their level of confidence in being able to assess falls risk on a Likert scale ranging from 1 = not at all confident to 10 = totally confident, with the additional option of choosing a “do not assess” category. The percentage distribution is shown in Figure 5.6 according to professional status.

Nearly a fifth of all respondents (19.5%) indicated that they do not assess falls risk, with slightly greater percentage of dispensing opticians (25.5%) than optometrists (17.5%) choosing this category. The remaining distribution showed a confidence level of 7 as the mode for both professions.

The participants were then asked to allocate themselves to a broader category with only 3 options: confident to assess falls risk, not confident to assess falls risk, do not assess falls risk. It was anticipated that the category “do not assess falls risk” would

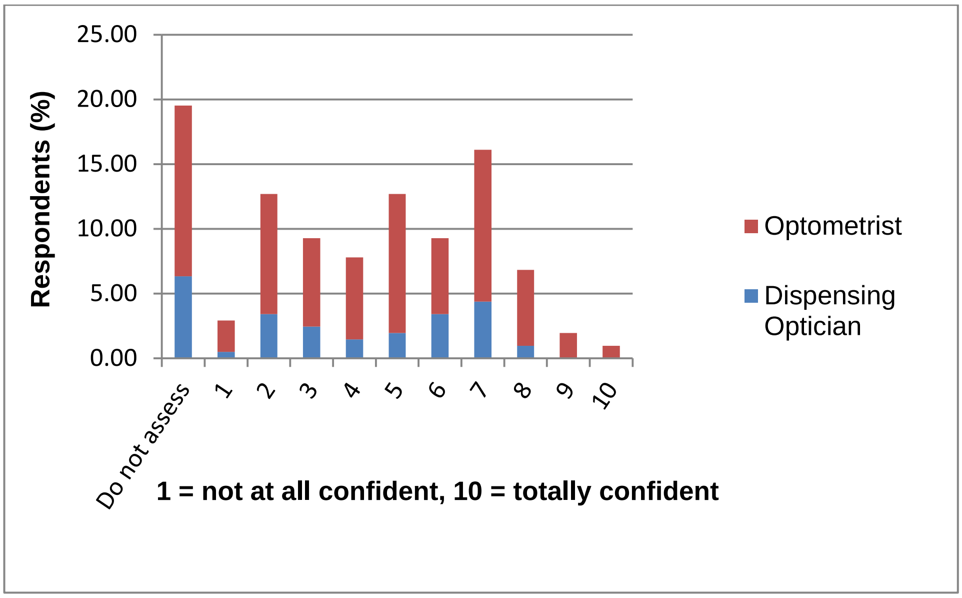


Figure 5.6 Level of confidence in assessing falls risk

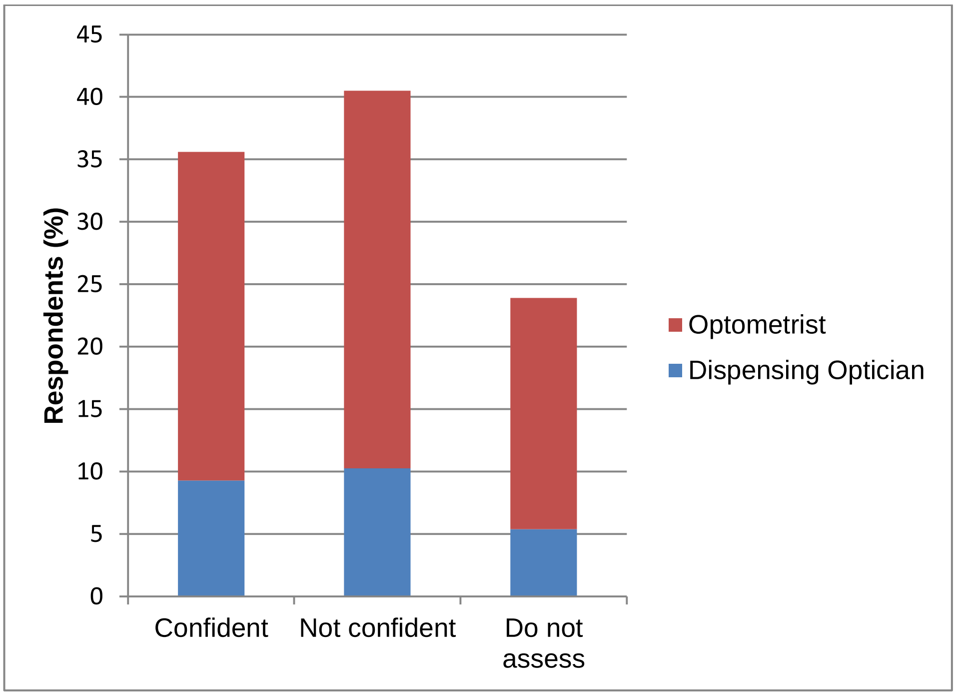


Figure 5.7 Forced choice confidence categories

relate directly to the count in the previous question, (n = 13 for dispensing opticians, n = 27 for optometrists) but this reduced in the dispensing category to 11, and increased in the optometrist category to 38. It is not clear why this should have been the case, as the wording of the question did not prove problematical in the piloting of the survey. The fact that respondents had to click through to the forced choice category question, meant that the original question was no longer visible on the screen, which may have been a contributing factor. In total nearly a quarter of all respondents (23.9%) did not assess falls risk. The greatest percentage of respondents chose the “not confident to assess” category (40.5%). There was no statistically significant difference in overall category choice between optometrists and dispensing opticians ($\chi^2 = .233$, df = 2, p = .89).

5.3.6 Falls risk assessment modalities

Respondents who had identified themselves as confident (n = 73) were asked how they assessed falls risk (Objective B). Ten themes (Figure 5.8) were identified from the responses:

- asking about patient’s level of confidence
- living circumstances: living alone, lighting at home, level of activity
- types of spectacles worn
- vision: all aspects of visual assessment
- problems with steps or stairs
- general health: including medications, balance, hearing, history and symptoms
- observation of mobility and gait in practice
- asking about history of falls
- discussion with patient, family members or carers
- identifying use of mobility aids

Figure 5.8 indicates that falls risk assessment was undertaken primarily based on observation of patient mobility and discussion with the patient and their family or carers.

With only one practitioner reporting use of a specific falls risk assessment tool, the absence of a structured approach was apparent.

In addition to the above categories, one practitioner referred to a senior member of staff for advice, and a further respondent used the experience gained from having a family member at risk of falls.

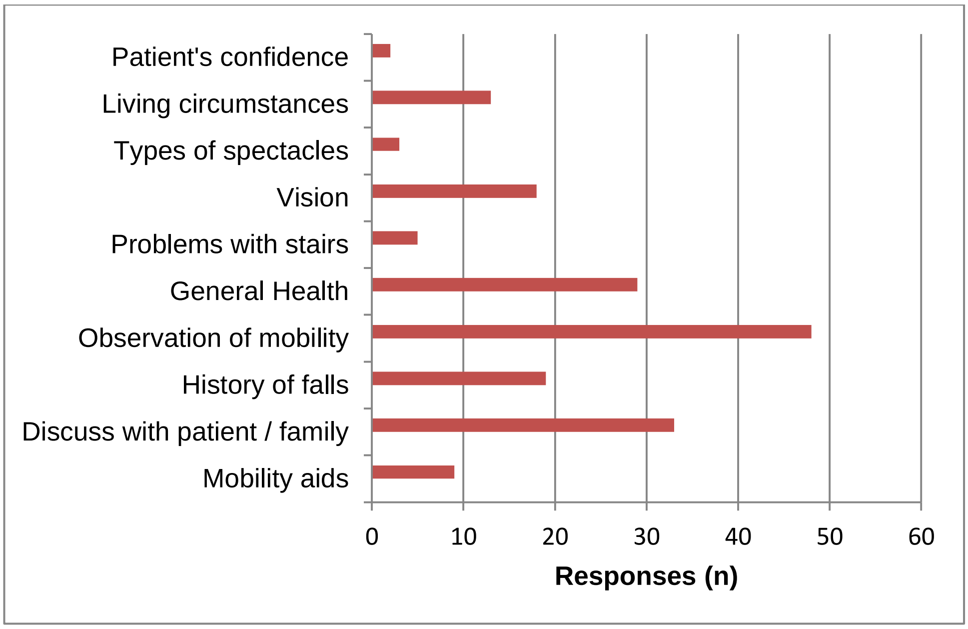


Figure 5.8 Thematic analysis of falls risk assessment modalities

The type of spectacles worn was specifically mentioned only by two practitioners, with one other identifying if the spectacles were broken in the course of a fall.

5.3.7 Lifestyle questions

This topic was directed at investigating whether lifestyle questions asked of patients aged 65 and above differed from those asked of younger patients, specifically with regard to eliciting information about falls risk (Objective F). Respondents were first asked what lifestyle issues they routinely asked of those aged 65 and over. Along with hobbies, television, computer use, mobility and driving, the option to choose an "other" category was provided (Figure 5.9). A freeform box enabled respondents to enter their own lifestyle questions.

The latter option was completed by 36 respondents, providing 9 topics. A thematic analysis of these responses identified four main areas: daily living skills; reading and visual problems; outdoor activities, sports and mobility; current or previous profession (Table 5.3).

A history of previous falls was only mentioned by one respondent.

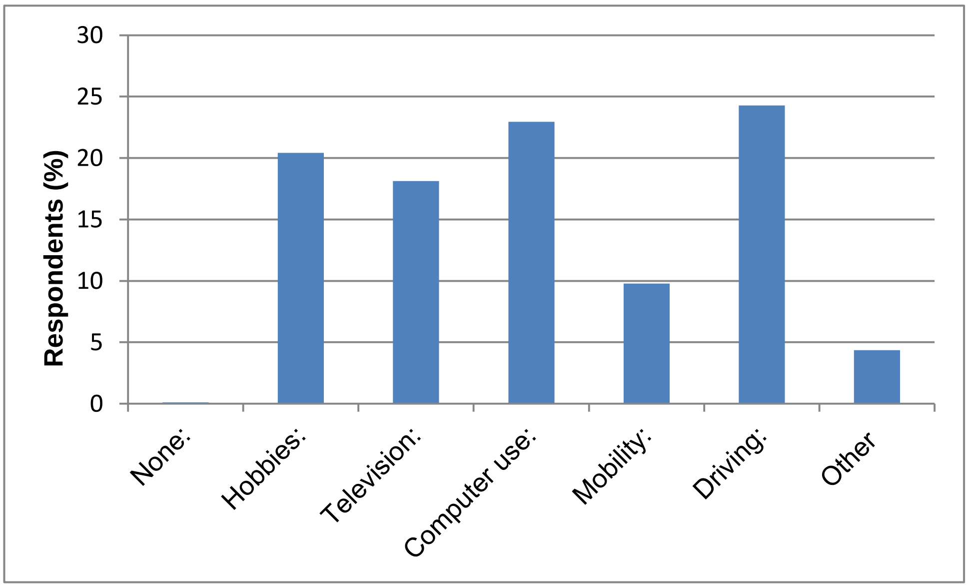


Figure 5.9 Lifestyle questions asked of patients aged 65 years and older

Response theme	(n)
Daily living skills	10
Reading and visual problems	9
Outdoor activities, sports, mobility	9
Profession	7
Smoking	3
Crafts	2
Living circumstances	2
Piano	1
Falls, balance	1

Table 5.3 Analysis of responses in “other” category

Only 40 respondents (19.5%) indicated the lifestyle questions they asked their patients or customers aged 65 years and older differed from those asked of the under 65s (Table 5.4). This suggests there is an unmet requirement for a tailored approach, which may provide an insight into a patient’s falls risk profile.

The main difference was with regard to questions about mobility (n=18), with 7 respondents saying they do not ask under 65s about this. Living circumstances were not asked of the younger group by 3 participants. Stereotypically, driving and crafts or hobbies were asked more of the older age group, whereas computer use, occupation and sport were targeted at the younger age group.

	< 65 years		≥65 years	
	Ask (n)	Do not ask (n)	Ask (n)	Do not ask (n)
Mobility	-	7	11	-
Crafts/Hobbies	-	-	2	-
Computer	5	-	-	1
Lighting	-	-	1	-
Driving	1	-	3	-
Living circumstances	-	3	1	-
TV	-	1	-	-
Contact lenses	1	-	-	-
Occupation	2	-	1	-
Posture and balance	-	-	1	-
Sport	2	-	-	-

Table 5.4 Breakdown of differences in lifestyle questions

5.3.8 Lens design preferences

Lens design preferences were investigated according to the chosen level of confidence of the survey respondents.

For those assessed at risk of falls, whether confidently or not confidently, the amount of bifocal and trifocal lens designs chosen was negligible. Separate single vision distance and near lenses were chosen by 80.6% of those who were confident in assessing falls risk. A slightly greater percentage of those who were not confident (84.7%) also chose separate single vision distance and near lenses, and were comparatively less likely to choose a progressive lens design (Figure 5.10).

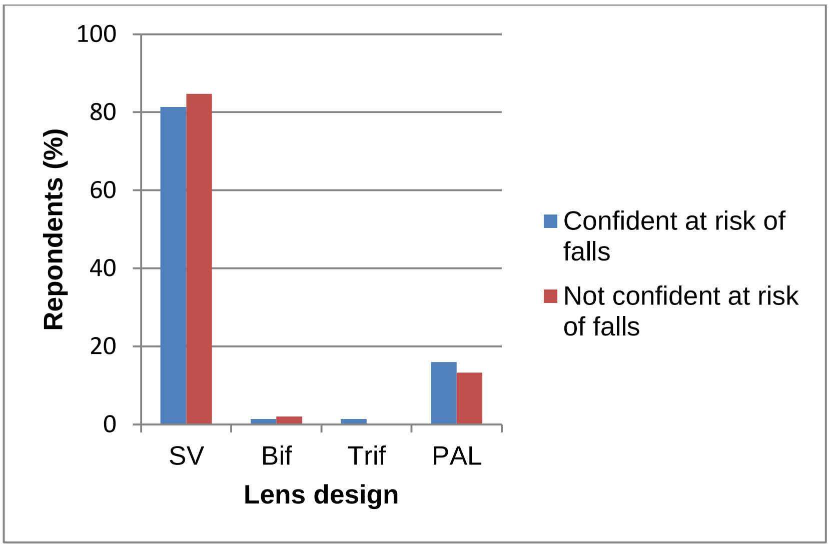


Figure 5.10 Lens design of choice for those assessed at risk of falls

For those practitioners who did not assess falls risk, as well as for those who assessed (whether confidently or not) and found their patients to be not at falls risk, progressive addition lenses were found to be the most popular lens choice (Figure 5.11).

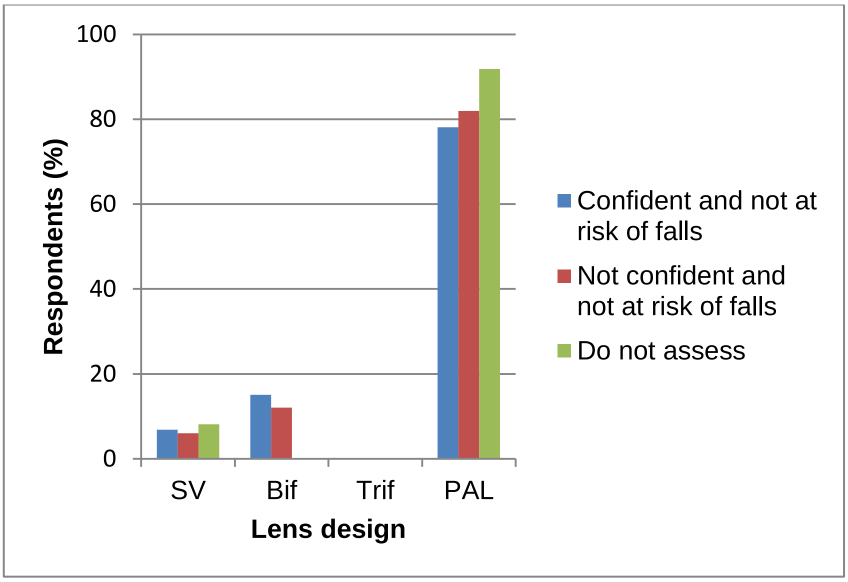


Figure 5.11 Lens design of choice for those not at falls risk, or not assessed.

5.3.9 Lens tints and coatings

The great majority of respondents indicated they would not prescribe specific tints to their patients at falls risk.

The responses in the "other" category (n = 23) indicated that their recommendations would depend on clinical requirements, co-morbidity and whether the patient was symptomatic (n= 13). One respondent highlighted that inappropriate tints could contribute to falls risk.

From Figure 5.12 and Figure 5.13 it is apparent that tints are more frequently prescribed for those either not assessed, or assessed and found not to be at risk of falls. The difference was found to be statistically significant ($\chi^2 = 73.46$, df = 7, p = <.001).

There was no statistically significant difference in the type of coatings chosen for those assessed (either confidently or not confidently) at falls risk, and those either not assessed, or assessed and found to be not at falls risk ($\chi^2 = 7.49$, df = 6, p = .28).

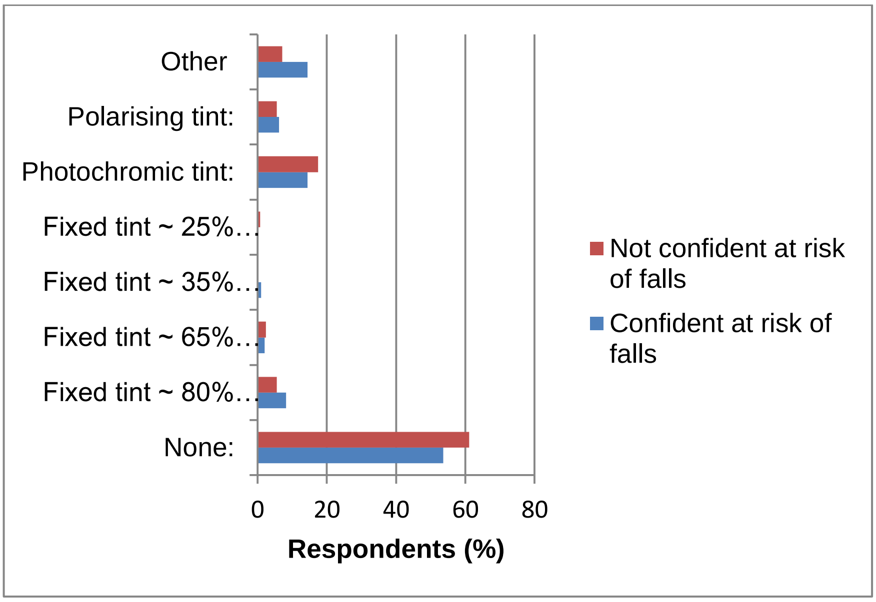


Figure 5.12 Lens tints of choice for those assessed at risk of falls (confidently or not confidently)

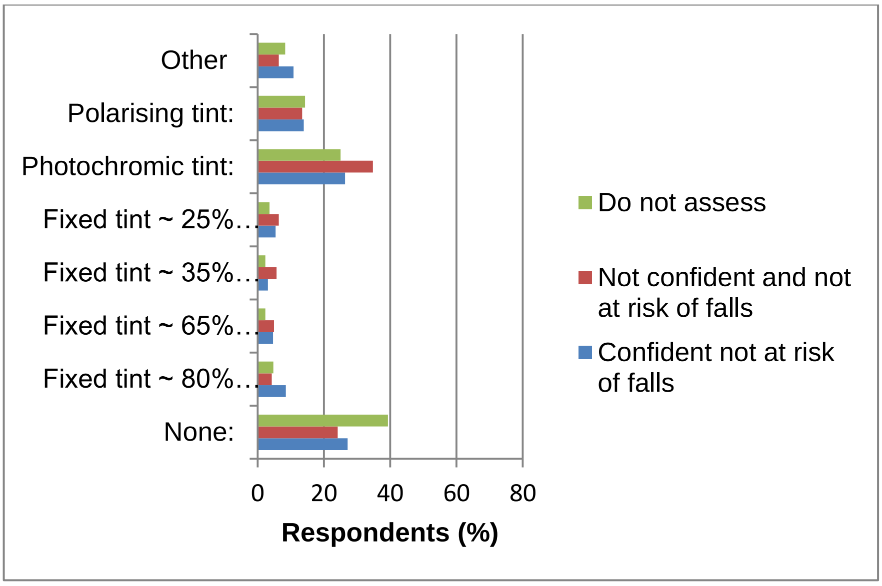


Figure 5.13 Lens tints of choice for those assessed not at falls risk (confidently or not confidently), or not assessed

5.4 Decision Tree Analysis

Chi-squared Automatic Interaction Detection (CHAID) is a Decision Tree Analysis model created in 1980 by Gordon v. Kass[159]. At each split of its tree, CHAID identifies which of the independent variables has the strongest interaction on the dependent variable[160]. It has the advantage of being able to merge categories and provide multi-way splitting, in contrast to the binary splits found in Classification and Regression Trees (CRT) and Quick, Unbiased, Efficient Statistical Trees (QUEST). CHAID analysis was chosen for its chi-square analysis base, and its ease of interpretation in diagrammatic form. The analyses were performed using IBM SPSS for Windows, Version 21.0[185].

CHAID works best with large sample sizes, but parameters can be adjusted to account for smaller samples. As the recommended preferred method for small samples, the Likelihood Ratio method was chosen in preference to the Pearson method[160].

Further adjustments were made to the parent and child node size. The parent node size determines whether the node is acceptable for sub-analysis. Personal communication from Frank Wyman (Vice President, Advanced Analytics, MARC Research) recommended that, as a rule of thumb, the smallest node should be no smaller than 5% of the total sample. This would be n = 10 for the current study. Bonferroni adjustment was also removed in accordance with his recommendations.

5.4.1 Level of agreement with core statement

CHAID analysis was undertaken to see which of the variables listed below influenced the level of agreement with the core statement:

- Gender
- Years in practice
- Practice environment
- Profession
- Supplementary qualifications
- Number of >65s seen in an average week
- Number of >65s with a VA of 6/12 Snellen or less in an average week
- Age in years
- Employment status
- Chosen confidence category

The independent variable that had the greatest influence on the level of agreement with the core statement was the number of years in practice (χ^2 = 25.74, df = 8, .001).

Those with 1-5, 11-15, or 16-20 years of practice agreed more than disagreed with the statement. The next level of influence on this group was employment status (χ^2 = 13.49, df = 4, p = .009), with the majority of practice owners, self-employed locums or those in the “other” category, agreeing more than disagreeing with the statement (Figure 5.14).

Those with 31 and more years of practice disagreed more than agreed. This node (Node 3) is a terminal node: no other factors had a significant influence on this group.

Of those with either 6-10 or 21-30 years of practice, the majority disagreed with the core statement. This node was further influenced by practice environment, whereby those in independent practice, large multiple chains, and medium group practices predominantly disagreed more than agreed more with the statement (χ^2 14.86, df = 4, p = .005).

None of the other independent variables had a statistically significant influence on the level of agreement with the core statement.

Whilst this analysis would appear robust, given the levels of statistical significance calculated for the nodes, it is important to take the risk estimate into consideration, which in this case was calculated to be 0.502. This means that the risk of misclassifying, if using as a predictive model, is 50.2%.

However, for those who disagreed more than agreed with the statement, the model was correct in 94.6% of cases, whereas for those who agreed more than disagreed, the model was weak, being correct in only 20.5% of cases.

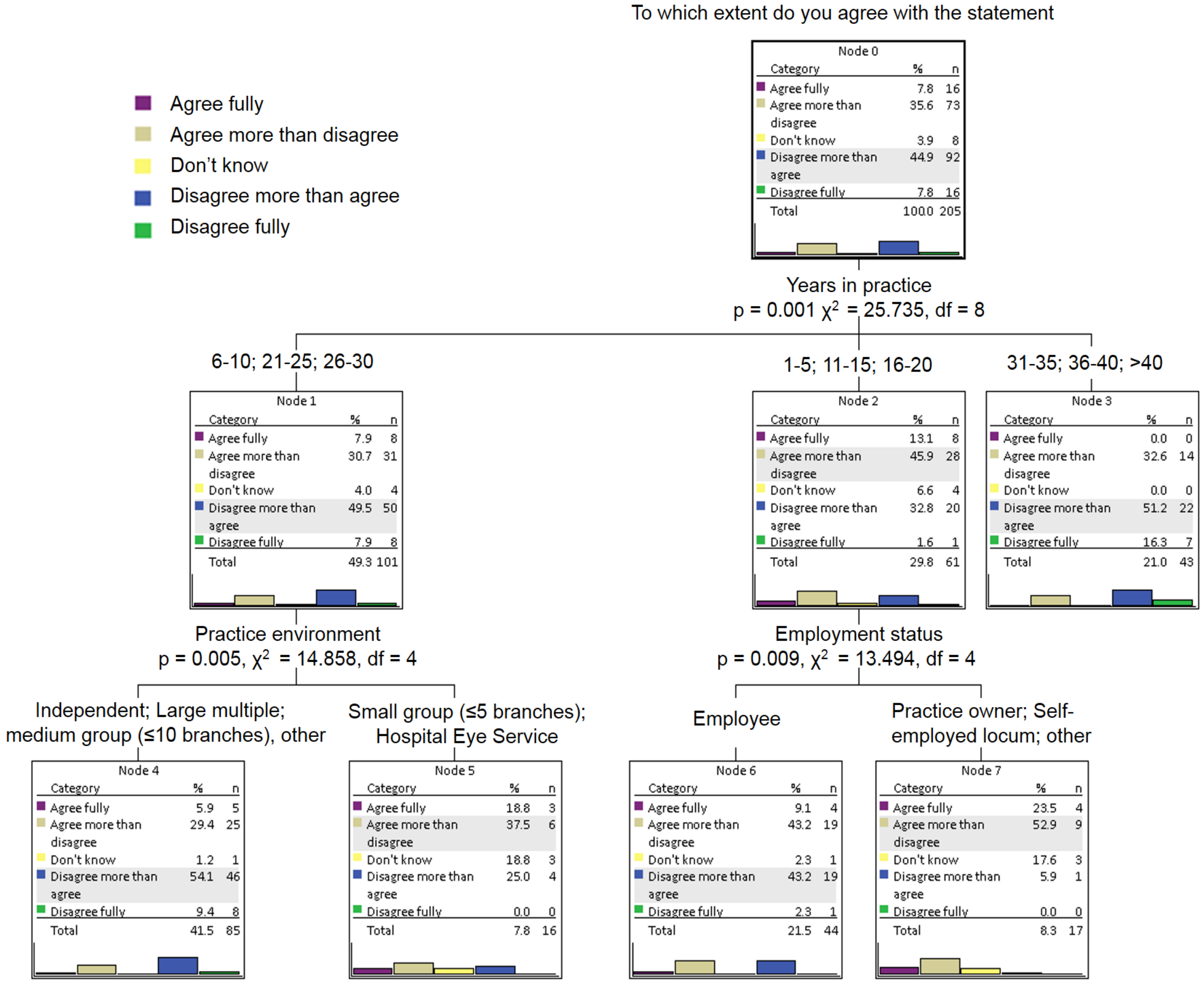


Figure 5.14 CHAID decision tree analysis of variables influencing the level of agreement with the core statement

5.4.2 Chosen confidence category

A further CHAID decision tree analysis was undertaken to see which factors influenced the forced choice category of confidence to assess falls risk (Figure 5.15)

The independent variables were the same as those used for the previous analysis (Section 5.4.1).

The main predictor of confidence was the number of patients seen in a week aged 65 and over with a visual acuity of 6/12 Snellen or less ($\chi^2 = 10.11$, df = 2, p = .006).

The majority of those who saw more than 10 such patients per week chose the "confident to assess" category (55.8%). The majority of those who saw fewer than 10 such patients per week chose the "not confident to assess" category (43.8%).

For both Nodes 1 and 2 the next defining variable was age. No other variables had a statistically significant influence on the chosen confidence level.

The risk estimate was again 0.502. In this case, however, the model correctly identified "not confident to assess" in 72.6% of cases. "Confident to assess" and "do not assess risk of falls" would be correctly identified in 33.3% and 34.7% of cases respectively.

5.4.3 Falls information

The majority of respondents indicated that they would benefit from further information about falls generally (75.9%), further information about the visual aspects of falls (87.9%), practice leaflets about falls generally (65.7%) and practice leaflets about the visual aspects of falls (79.7%). This indicates that there is a large interest base in additional knowledge regarding falls and their visual aspects.
85% of practitioners would welcome a quick and easy falls risk assessment tool to support them in practice.

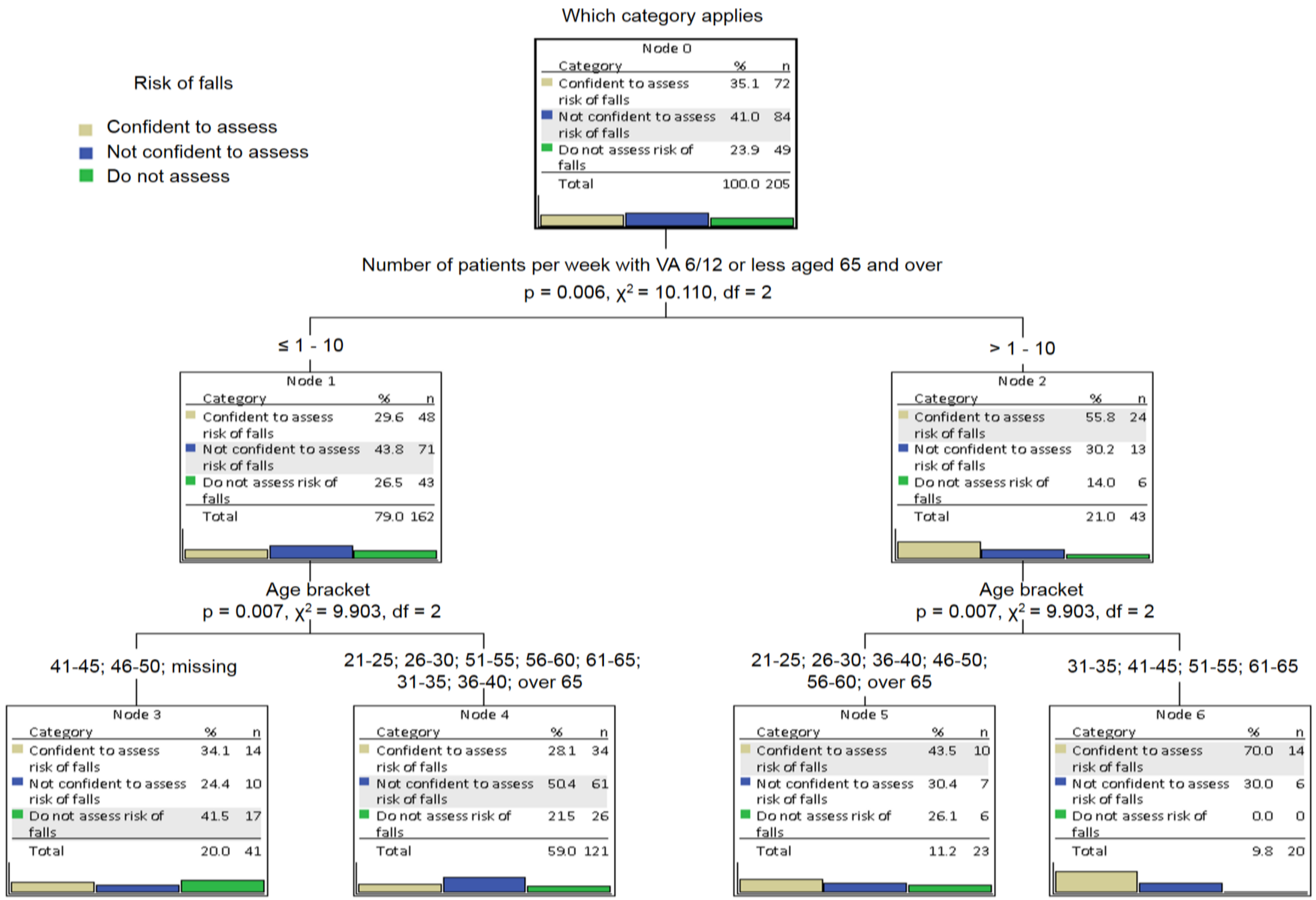


Figure 5.15 CHAID decision tree analysis of chosen level of confidence

5.5 Summary

The survey outcomes provided an insight into current UK prescribing and dispensing practices for elderly patients at risk of falls.

It could be argued that the survey results were subject to self-selection bias, by respondents with a particular interest in falls research, or a pre-defined opinion about best prescribing practices. This would appear to be borne out by the fact that only 3.9% of respondents chose the "*don't know*" category for the level of agreement with the core statement, and 80.5% fell into two categories ("agree more than disagree", "disagree more than agree").

The lower level of response to the survey than expected, in spite of a wide range of publicity both in paper journals and electronic media, could be indicative of a lack of interest in the topic of falls among optical professionals.

CHAID decision tree analysis proved to be a useful tool for investigating the hierarchical influence of a range of variables. The level of agreement with the core statement was seen to be primarily influenced by the respondents' number of years in practice, with the CHAID model accurately predicting the category "disagree more than agree" in 94.6% of cases. The statistical differences in respondents' other demographics (gender, profession, age) did not therefore impact on this analysis.

Confidence grows - not unexpectedly - with familiarity with the target population group. It was an interesting finding, therefore, that the level of confidence did not alter the choice of lens design for those at risk of falls (separate single vision distance and near lenses). Progressive addition lenses were the design of choice for those not assessed, or assessed and found not to be at falls risk. On reflection, the survey would have benefitted from identifying the underlying rationale for these choices.

No significant difference between groups was found with regard to recommended lens coatings, but the prescribing and dispensing of tints was found to vary at a significant level.

Although the topic of falls has received increased attention in recent years, practitioner awareness of falls risk could still be improved with continued publication of falls information relevant to optical professionals. Identification or development of a suitable dedicated fall risk assessment tool could contribute to reducing the currently lacking structured approach to falls risk assessment in optical practice.

The recent drive to include primary care practitioners in programmes such as “Make Every Contact Count” (MECC)[161], where health professionals utilise their patient interaction to deliver health protection messages (for example smoking cessation), could be expanded to include falls risk identification and appropriate signposting to falls prevention teams.

Chapter 6. Global Measure of Vision

6.1 Introduction

Many studies of visual aspects of falls have investigated traditional visual function measures such as low or high contrast visual acuity, contrast sensitivity, or visual fields (see Chapter 3). These, however, provide no information about visual attention aspects such as visual search or attention switching, otherwise known as divided attention. Impairment of visual attention and slowed visual processing speed are associated with mobility problems[162–165]. Divided attention has a significant association with the Performance Oriented Mobility Assessment (POMA) which assesses balance and gait in community dwelling populations[162], and with bumping into objects when walking[163].

It was, therefore, considered fundamental that some measure of visual attention should be included in the present study, given its potential to predict mobility better than standard visual measures. A paper and pencil test was devised for this purpose, and - to differentiate it from other visual attention tests - was named the Global Measure of Vision (GMV).

This chapter describes the purpose and design of the Global Measure of Vision test (GMV), and the study investigating its correlation with the computer-based measure of visual attention, the Useful Field of View test (UFOV).

6.2 The Useful Field of View Test

The Useful Field of View Test (UFOV) was designed as a screening instrument, and is a computer-based test of functional vision and visual attention[166]. A meta-analysis of eight studies confirmed its validity and reliability as an indicator of driving performance[167].

The UFOV comprises three subtests that investigate processing speed, divided attention, and selective attention.

Scores are given in milliseconds for each subtest, with cut-off points classifying normal or reduced response times. Combined subtest results provide an overall crash-involvement risk category ranging from 1(very low risk) to 5 (high risk).

Subtest 1 (processing speed) presents a central object, either a car or a truck, and the participant has to identify which object was presented. The presentation time is shortened after two correct responses, and increased if the response was incorrect. If the score for this subtest exceeds 500ms, then Subtest 2 is not presented, and the test is complete.

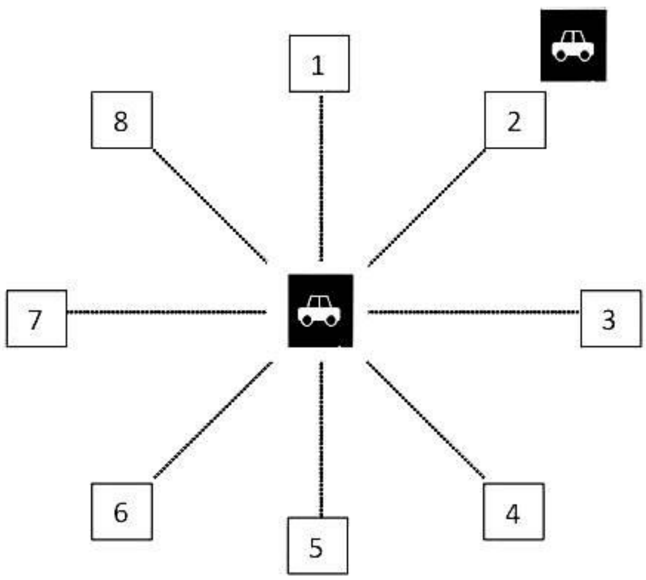


Figure 6.1 Schematic diagram of UFOV divided attention subtest showing the eight possible radial orientations, with example in position 2.

Subtest 2 (divided attention) also presents a central object, but at the same time a target is presented in one of eight peripheral locations (Figure 6.1)

The task is to simultaneously identify the central object, again either a car or a truck, and the location of the peripheral target, which is always a car. Presentation times are adjusted according to correct or incorrect responses. As with Subtest 1, if the score for this section exceeds 500ms, then the test is complete and Subtest 3 is not presented.

Subtest 3 (selective attention) is the same as Subtest 2, but the peripheral target is embedded in a field of 47 triangles, which act as distractors (Figure 6.2)

Figure 6.2 Screenshot of UFOV selective attention subtest, showing central lorry target, peripheral car target, and field of distractors

6.3 Global Measure of Vision design

The design brief was that the GMV should be a quick and easy measure of visual attention, able to be used in high street practice without recourse to expensive equipment or software. Its design was based on i) the Trail-Making Test A (TMT-A)[168], ii) the American Association of Retired Persons' (AARP) driver skill assessment resource[169] and iii) the Auto-Trails II test[170].

6.3.1 Trail Making Test A (TMT-A)

The Trail Making Test (TMT) is one of the most commonly used neuro-psychological tests in clinical practice[171] and forms part of the Halstead-Reitan Neuropsychological Test Battery (HNTB)[172]. The TMT comprises two sections: TMT-A and TMT-B.

TMT-A consists of 25 circles containing the numbers 1 to 25 displayed randomly on a page (Figure 6.3). The participant has to draw lines connecting the numbers in consecutive ascending order, as quickly as possible, without lifting the pencil from the paper. TMT-B is a more complex task and consists of circles containing both numbers 1 to 13 and letters from A to L. In this case, the participant has to draw lines connecting alternate consecutive numbers and letters in alphabetical order (1:A:2:B:3:C:4:D etc.).

The TMT-A is primarily a test of visual attention skills[173] and a general measure of visuospatial scanning ability[174]. TMT-A specifically measures visual search and motor speed[175]. In a study investigating brain injury, visual attention and the UFOV, TMT-A had a significant correlation with the divided attention subset of the UFOV ($r = .594$, $p = .02$)[176].

Poorer performance on TMT-A and TMT-B has a significant association with fall rates (Incident Rate Ratio 1.30, $p = .009$ and 1.33, $p = .009$ respectively)[21]. TMT-A and TMT-B have been found to be equal regarding visual search demands, with TMT-B having a higher cognitive burden[177]. GMV, therefore, used the TMT-A type of simple number sequence.

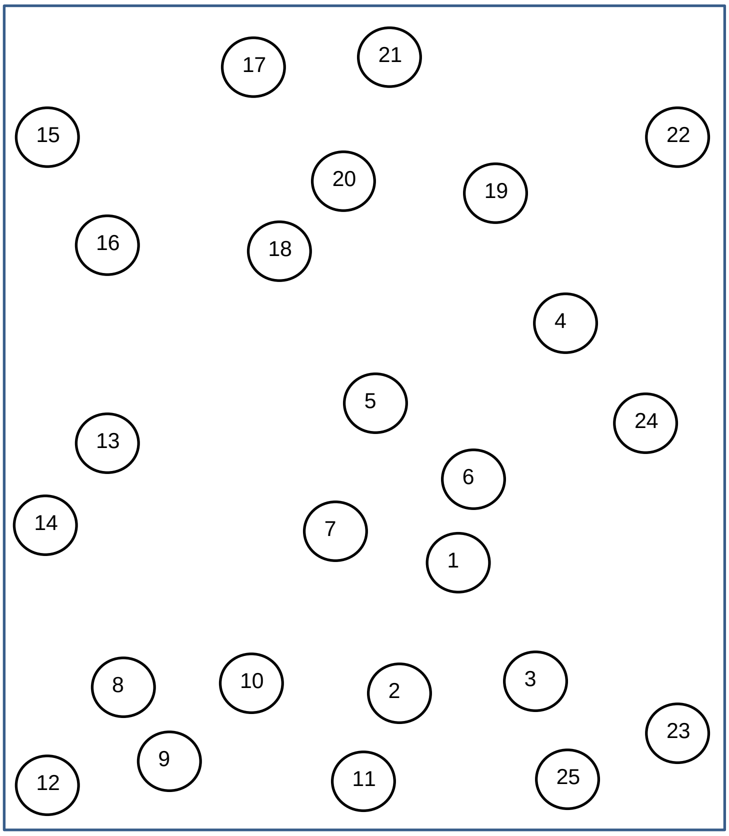


Figure 6.3 Schematic representation of Trail Making Test A

6.3.2 The AARP reaction time test

The AARP reaction time test was reported on in the US Department of Transportation Safe Mobility for Older People 1999 notebook, along with the AutoTrails II test[178], and was developed in conjunction with the ITT Hartford Insurance Group .

Similar to the TMT-A, the AARP test showed a series of numbers. In this case they ranged from 1 to 14 and were superimposed on a driving scene, which acted as a background distractor. The object of the test was to touch the numbers in ascending order within a ten second timeframe. The last number touched represented the achieved score. Scoring was later modified to the total time taken to touch all numbers. A significant reduction in performance with increasing age was reported[179].

A scanned copy of the 1992 test version was kindly provided by Frank Carroll, Curriculum Development, AARP (Figure 6.4). This test has been superseded by more comprehensive driving courses and interactive tools.

Aston University

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Figure 6.4 AARP Reaction Time Test

6.3.3 Autotrails II

The AARP test evolved into a postcard-sized unit containing a chip that sounded an alarm when the test time had expired. This was called AutoTrails. Professor Frank Schieber, University of South Dakota, USA, developed a computer-based version of the Auto Trails test (AutoTrails II) that ran on a touch-screen principle[170].   Again, numbers from 1 to 14 were superimposed on a driving scene (Figure 6.5). In this case the outcome measure was the total time taken to complete the trail.

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Figure 6.5 AutoTrails II Screenshot

6.4 GMV construction principles

The GMV is a simple paper and pencil test. Like the AutoTrails II and the AARP reaction time test, the GMV shows a series of numbers from 1-14, superimposed on a distracting background scene. As the GMV was used to investigate falls risk in the present study, a pedestrian scene was employed instead of a road image (Figure 6.6). A black and white design was adopted to ease reproducibility.

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Figure 6.6 Global Measure of Vision (not to scale)

The actual image used measured 17 x 10.6 cm, with a total trail length of 115.5 cm. The white numbers followed a spatial distribution similar to that of the AARP reaction time test and had a height of 3mm (approximately equivalent to Sloan 2M or N16) enclosed in a black oval (14mm horizontal x 9mm vertical) (Appendix 3).

The UFOV software is designed for use on a 17inch (43.2 cm) monitor with a recommended viewing distance of 18 – 24 inches (45.7 – 61.0 cm). The visible horizontal screen dimension of 32.6 cm equates to an angular field of view of 39.2° and 30.0° respectively. In order to match this field of view, the GMV would have to be carried out at distances between 23.8 and 31.8 cm. As most of the elderly participants in the present study required an increased near addition for these distances, participants were allowed to carry out the GMV at a comfortable reading distance of their own choice, using their own spectacles.

For the TMT-A, a completion time of 5 minutes is allowed[177], and this was also used as the maximum allowed time for the GMV.

6.5 UFOV and GMV Comparison Study

6.5.1 Study goal and objectives

A link between driving difficulties and risk factors for falling has been reported[180–182] and the visual factors measured by the UFOV have also been found to be associated with mobility in older adults[162,163]. The rationale behind the study described in this chapter was that if performance on the GMV was related to performance on the UFOV test, then poor GMV performance may also indicate elevated risk of mobility problems. The advantage of the GMV over the UFOV would be, however, that it could be suitable for use in high street practice without recourse to expensive equipment or software. The purpose of this study was to investigate, therefore, whether a correlation existed between the computerised UFOV and the paper-based GMV.

6.5.2 Methods

This study was approved by Aston University Life and Health Sciences Research Ethics Committee (Appendix 4). An a priori power analysis was carried out using G*Power 3.1[158]. This indicated that 29 study participants were required to detect a large effect size effect[183] at the 5% level of statistical significance and with 80% power when using a bivariate normal model of correlation. A large effect size provided a realistic number of participants to justify the intervention, and statistically significant findings would be more likely to be of clinical value. Participants were recruited from volunteer members of the Aston Research Centre for Healthy Ageing (ARCHA) and personal contacts.

Thirty participants (13 male, 17 female) with a median age of 71 years (IQR 67.75 – 76.75 years) completed both the GMV and the UFOV, alternating which test was undertaken first.

The UFOV test was administered as directed in the UFOV User's Guide Version 6.1.4[184]. Participants were seated comfortably at a desk with a monitor and mouse. Instructions on how to use the mouse were given if required. Participants were informed that the test consists of three parts and would take about 15 minutes to complete. They were also advised that the length of time screen images are presented becomes ever shorter. Practice tests preceded the actual assessments for each subtest. The recommended viewing distance of 18 – 24inches (45.7 – 61.0 cm) was observed, with a median participants' viewing distance of 56.8 cm (IQR 52.5 – 60.0 cm). Participants wore the spectacles they normally used for computer tasks. The testing room was quiet and void of distractions, with dim ambient lighting to ensure absence of screen glare. Time (ms) taken to complete each subtest and the overall risk category were noted.

The GMV was administered with the participant seated at a comfortable distance of their choice at a desk. The median viewing distance was 45.0 cm (IQR 41.75 – 48.25 cm and the field of view achieved ranged from 16.1° minimum to 25.2° maximum. A demonstration of the test procedure was given using a TMT-A sample sheet, which has no background distractors (Figure 6.7). This was chosen as a practical solution to reduce printing costs.

The participants were advised that the actual test was similar, but had numbers ranging from 1 to 14, superimposed onto a black and white image (Figure 6.6). They were informed they had to join the numbers in rising sequence as quickly as possible, without taking their pencil off the page. They were also advised that if they made an error, it would be pointed out to them and they would have to resume from the place before the error happened. The participant started the assessment with a pencil positioned on number 1 and the remainder of the image covered with a blank sheet. The masking sheet was removed after a countdown (3 -2 -1- go) and the total completion time was measured using a timer on a tablet device.

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Figure 6.7 Trail Making Test Part A – Sample

(derived from University of Iowa example sheets[185])

6.5.3 Results

Results were analysed with IBM SPSS Version 21.0[186].

Normality of distribution was investigated with Shapiro Wilk's W. No variables demonstrated normal distribution [S1 (W = .377, p = <.001); S2 (W = .739, p = <.001); S3 (W = .788, p = <.001); UFOV risk category (W= .483, p = <.001); GMV time (W = .686, p = <.001)]. Correlations (Spearman's rho) between the speed of GMV test completion versus the three UFOV subscores, as well as the UFOV overall risk category are shown in Table 6.1.

Statistically significant correlations were found between GMV and S2 (divided attention), GMV and S3 (selective attention), and GMV and UFOV overall risk category. All three correlations demonstrated a medium effect size according to Cohen's guidelines (0.1 - <0.3 = small effect size; 0.3 - <0.5 = medium effect size; ≥0.5 – large effect size)[183]. No statistically significant correlation was found between GMV and UFOV processing speed (p = .156).

		1	2	3	4	5
1	UFOV - S1					
2	UFOV - S2	.683**				
3	UFOV - S3	.530**	.647**			
4	UFOV - risk category	.761**	.831**	.540**		
5	GMV time	.266	.438*	.391*	.462*	

* = correlation is significant at the 0.05 level (2-tailed)
** = correlation is significant at the 0.01 level (2-tailed)

UFOV = Useful field of view, S1 = processing speed, S2 = divided attention, S3 = selective attention, GMV = Global Measure of Vision.

Table 6.1 UFOV / GMV Spearman's rho correlation matrix

6.6 Summary

Impaired visual attention, especially impaired divided attention, predicts mobility difficulties in the elderly. It was, therefore, considered essential that a measure of visual attention should be included in the present study, given its potential to predict mobility better than standard visual measures.

The UFOV is a computer-based test of functional vision and visual attention. A paper and pencil test of visual attention, the GMV, was devised specifically for the present study. Its design principles and features were described.

A comparison study of the GMV with the UFOV was undertaken, the rationale being that if performance on the GMV was related to performance on the UFOV test, then poor GMV performance may also indicate elevated risk of mobility problems

Statistically significant correlations between the GMV and all but one UFOV score indicated that the GMV test could be used for this purpose.

Together with the Timed-Up-and Go (TUG)(Section 7.8.1.2) and the SF-12v2®(Section 7.8.1.3), the GMV forms part of the assessment of health, mobility and visual awareness of participants in the study described in the following chapter, which investigates the influence of spectacle lens design on falls risk in elderly, community-dwelling individuals. If found to be predictive of falls, the GMV could constitute a simple practice-based assessment of falls risk in high street practice.

Chapter 7. Retrospective and Prospective studies

7.1 Study goal and objectives

The primary study objective was to investigate the influence on falls risk of spectacle lens designs worn by presbyopes (either SV, Bif or PAL lenses) in a community dwelling UK population of persons aged 65 and older. The secondary objective was to analyse the nature and severity of any sustained falls. It is hoped the results will contribute to the evidence base accessed by optical professionals when dispensing to older adults at risk of falls.

7.2 Study design

The explanatory observational study comprised two parts: a retrospective case control study and a prospective cohort study. The outcome measures for the study were counts of all falls that had occurred in the previous twelve months (retrospective study) and the twelve months during the trial (prospective study), along with an evaluation of the severity of the sustained injury. Data was also collected on the location and nature of the fall, and whether the participant was wearing spectacles at the time of the incident. In addition, visual acuity data on presentation, when commencing and completing the study was obtained from Aston University Clinic records, which were also used to confirm the reported worn lens design.

7.3 Internal validity

The study addressed four of the five key areas identified in the 22 core studies of vision, head pitch and eye tracking, balance indicators, physical health, and falls (see Chapter 4). The instrument chosen for each category is detailed in Table 7.1. This study was unable to investigate which part of the lens was used when walking or negotiating steps, as commercially available equipment, such as ISCAN's video-based eye tracking system (ISCAN Inc, Woburn, Massachusetts, USA) was prohibitively expensive.

The rationale for choosing the instruments is detailed in Section 7.8 (Methodology).

Key area	**Instrument**
Visual aspects	Global Measure of Vision Visual acuities (decimal)
Balance and mobility	Timed up and Go
Physical and Emotional Wellbeing	SF-12v2 health questionnaire
Falls - level of sustained injury	ProFANE definition Schwenk et al. definition
Head pitch / Eye tracking	not assessed

Table 7.1 Instruments used in key areas

7.4 Ethics

Ethics approval was granted by Aston University Life and Health Sciences Ethics Committee (Appendix 5).

7.4.1 Consent

All participants received a Research Participant Information Sheet, which detailed the purpose of the study, who was eligible, and what would happen when taking part. Participants were also made aware that they may withdraw from the study at any time without any explanation. Contact details for queries and complaints were included. Signed consent was obtained at the initial assessment appointment.

7.4.2 Risk assessment

The designated University risk assessment spreadsheet identified no medium or high risk interventions and was considered to have low potential risk in accordance with the University Regulation REG/11/203(2).

7.4.3 Data Management

All individual patient data was stored in an encoded format. The key to the coding was stored in a separate password protected database, accessible only by the author.

7.5 Participants

Study participants were patients who attended the Aston University Eye Clinic for their routine eye examinations, and fulfilled the required inclusion criteria.

7.5.1 Inclusion and exclusion criteria

The inclusion criteria were as follows:

- Aged 65 or over
- Community dwelling individuals

- Habitual wearers of either single vision, bifocal or progressive addition lenses
- Independently mobile, including use of mobility aids (walking sticks etc.)
- Sufficient command of the English language to understand test instructions
- Basic numeracy to be able to complete the Global Measure of Vision test

No exclusion criteria were applied.

7.5.2 Sample size

The primary investigated outcome was whether there was a statistically significant difference in number of falls experienced during the twelve months prior to the initial assessment (retrospective study) or in the subsequent twelve months (prospective study), according to worn lens design (SV, Bif or PAL).

A logistic regression (LR) method was chosen to analyse this dichotomous, mutually exclusive outcome (fall(s) versus no fall(s). LR is suitable for both categorical and continuous independent variables, and is not constrained by the need for normal distribution[187]. In particular, it describes the effect of any one independent variable, whilst controlling for all others. In addition, using LR enabled more meaningful comparisons with a seminal paper in this field[126].

In LR the limiting sample size is determined by the least frequent event of the dichotomous outcome rather than the total sample size[188,189]. For example, if the most frequent outcome were that the participants experienced a fall, then the number of non-fall events would be used to estimate the sample size. In falls research, however, falls rates between 30% and 40% have been reported in independent living people aged 65 and older[129,190,191]. It is, therefore, expected that fallers represent the least frequent outcome event.

In a computer simulation study of proportional regression analysis, Peduzzi et al[192] found a ratio of 10 or fewer events per variable (EPV) made resulting coefficient values less accurate and precise. In a later study, Vittinghoff and McCulloch[193] found there was no clear dividing line for an acceptable level of EPVs. Identifying levels of false positive errors > 7%, confidence interval <93% and relative bias >15% as problematical, they discovered these levels were uncommon with EPV ratios of 5 – 9, but were not completely absent in greater EPV ratios of10 – 16. The authors concluded that discounting statistically significant results of studies with EPVs from 5 – 9 did not seem justified. Sample size for the study was, therefore, calculated for a range of EPVs from 5 – 10.

Sample size N is calculated as:

$$N = EPV * k / p$$

where k is the number of independent variables in the regression, and p is the expected proportion of events. Seven variables were planned regressors: Age, Gender, GMV, TUG, SF-12v2-P, SF-12v2-M and Lens design. Using EPVs ranging from 5 to 10, and an expected fall rate of 35%, the number of participants to be recruited would be between 100 (min) and 200 (max). This would increase to 120 (min) and 240 (max) when accounting for 20% attrition.

7.6 Originality of study

To the author’s knowledge, this was the first UK-based observational study of falls rates in a community-dwelling older population, which differentiates between three types of worn lens design (SV, Bif and PAL).

7.7 Recruitment

Potential participants were identified by reviewing records of patients booked into the clinic. They were contacted by telephone prior to their appointment, to invite them to take part in the study. No immediate response was required. Flyers and posters were also displayed in the clinic waiting area to increase awareness and capture any possible participants who had not been contactable by telephone.

From October 2014 to April 2015 inclusive, 132 community dwelling individuals aged 65 and over were recruited to take part in the retrospective case-control study, with 130 participants going on to complete the subsequent prospective cohort study. Final assessments took place from October 2015 to April 2016.

7.8 Methodology

At the initial assessment, the research information sheet and consent form were issued and signed. The participant then completed the Short Form SF-12v2® health questionnaire. The type of worn lens design (SV, Bifocal or PAL) was confirmed, and the participant gave an estimation of how long they had been wearing that specific design. Any falls that had occurred in the previous twelve months were recorded, along with their location (eg indoors/outdoors), activity being undertaken, time of day and associated lighting levels (e.g. daylight/dusk), whether the participant was wearing spectacles at the time of the fall, and what level of injury they sustained according to the guidelines proposed by Schwenk[6] (see Section 7.8.1.4). The Global Measure of Vision test (GMV) was then undertaken, and, lastly, the Timed Up and Go Test (TUG). Visual acuity data was obtained from clinic records.

Falls diaries (Appendix 6) were issued to all participants for the twelve month prospective study. Rather than using the formal definition of a fall (See Section 2.2), wording more appropriate to the lay community, as suggested by the Prevention of Falls Network Europe (ProFANE)[5], was used in the diary. The instructions for completion, therefore, stated:

“If you experience any fall, including a slip or trip in which you lost your balance and landed on the floor, ground or lower level, please record this in your diary. It is important also to note any slips or trips where you did not hurt yourself.”

Participants were asked to record the same information as was collected for the retrospective study. This was facilitated by the diary’s column headings and the guidelines on the reverse of the diary.

A range of prospective falls studies, which are considered the gold standard in falls research[191], have used monthly falls diaries[87,194–196]. In order to reduce the administrative burden and eliminate associated postage costs, participants were asked if they were happy to be contacted by email (n =95) or phone (n=37). An anonymised email group was created to provide general updates (n = 9) to keep participants engaged in the project. Time burdens resulted in less frequent update phone calls (n = 4). Participants were encouraged to email or phone the study to report falls as and when they occurred, as well as noting them in their diary. In this way it was possible to record falls throughout the trial duration, thereby reducing the risk of data loss through misplaced diaries. Fridge magnets were also issued to all participants, to act as a constant reminder.

After the 12 month follow-up period, participants were invited to a de-brief appointment, where the falls diaries were reviewed and the SF-12v2®, GMV and TUG were repeated. Visual acuity data at the end of the study was again obtained from clinic records (see Study Flowchart Figure 7.1). Participants unable to attend were interviewed by telephone.

All data was entered into an Excel 2010 (Microsoft Corporation) spreadsheet and was analysed using IBM SPSS Version 21.0[185].

7.8.1 Instruments

The instruments used in the study were the Global Measure of Vision (GMV), the Timed Up and Go Test (TUG), the Short Form-12v2® Health Survey (SF-12v2®), and the Fall Injury Classification System proposed by Schwenk[6].

7.8.1.1 Global Measure of Vision (GMV)

The rationale and development of the GMV was addressed in Chapter 6.

7.8.1.2 The Timed Up and Go Test (TUG)

Five reviews on fall screening assessments informed the choice of the Timed up and Go test from the wide range of possible instruments to evaluate the participants' balance and mobility[197–201]. It is one of the most commonly used screening tests in community settings[3,202] and gives a "global indication of postural stability"[203].

Developed by Podsiadlo and Richardson in 1991[204], it is a timed version of the Get up and Go Test, which used a 5 point evaluation scale ranging from normal to severely abnormal[205]. Five of the studies investigated in Chapter 4[111,112,127,130,142] also reported TUG findings.

Furthermore, the TUG requires little additional training and minimal equipment, is quick and easy to complete, and poses minimal risk to the participant. The participant is required to stand up from a chair, walk a 3m long course, turn, walk back to the chair and sit down.

In one study it was found to be a sensitive (87%) and specific (87%) measure for identifying those prone to falls in a community dwelling elderly population[206]; in another it discriminated between fallers and non-fallers, correctly classifying 72% of all subjects[207].

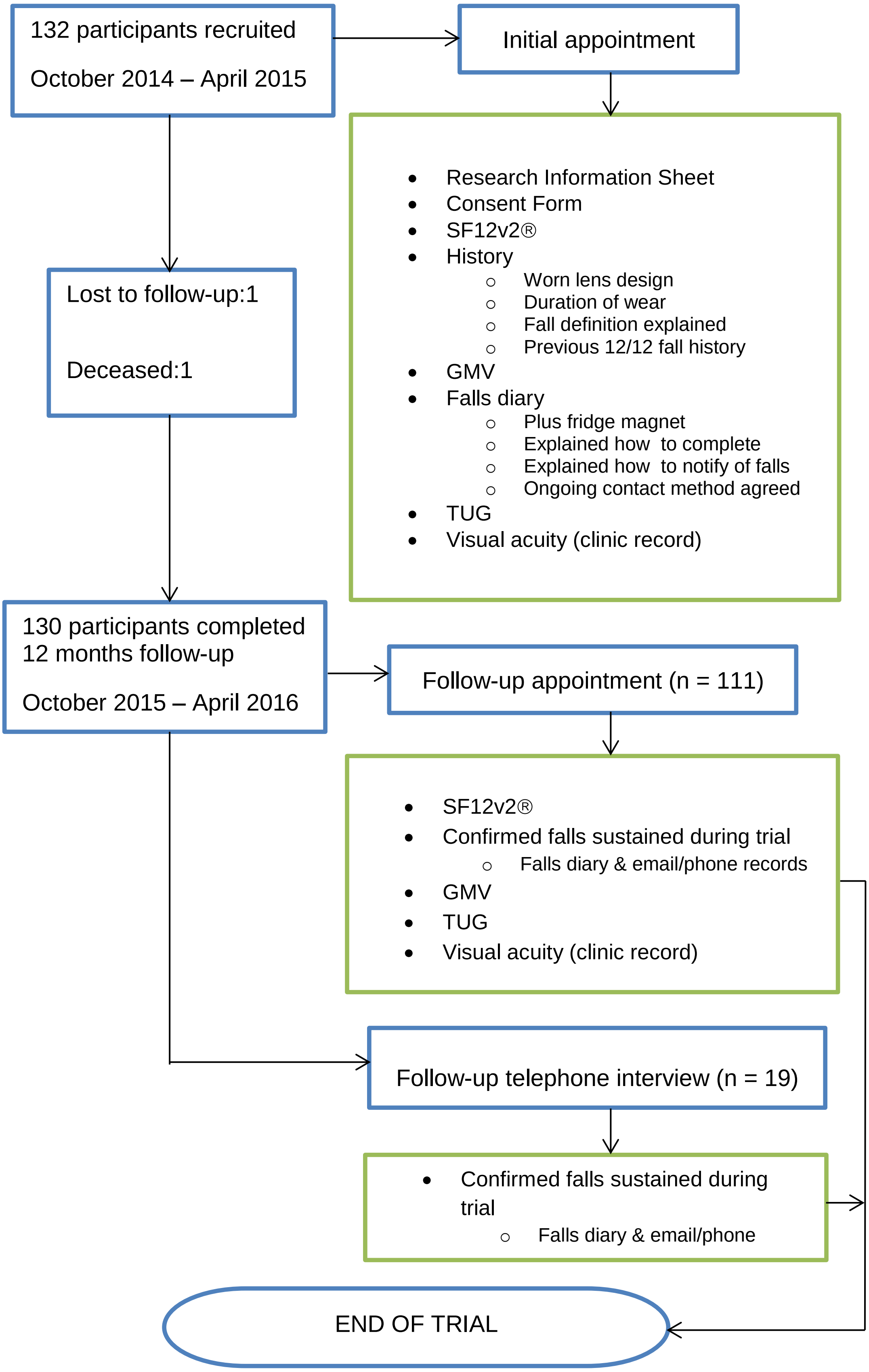


Figure 7.1 Study flowchart

Whilst it is acknowledged that there is a debate about the predictive ability of the test[198,199], the TUG has been found to have the largest area under the curve (AUC) for predicting the occurrence of falling, when compared with the One-Leg Stand, Functional Reach and Tinetti Balance tests[208].

Different cut-off points have been suggested for evaluation of the test results. This may be a result of documented variances in the test procedure, such as advised walking pace (usual pace, as fast as possible, a comfortable and safe pace) or chair design (with or without armrests)[198,209].

Results were, therefore, not categorised as low / medium / high risk of falls, but as time taken (in seconds) to complete the course. Should the TUG results be predictive of falls, receiver operator curves (ROC) can be further investigated to identify cut-off scores for this population. The chair and walkway used in this study are shown in Figure 7.2.

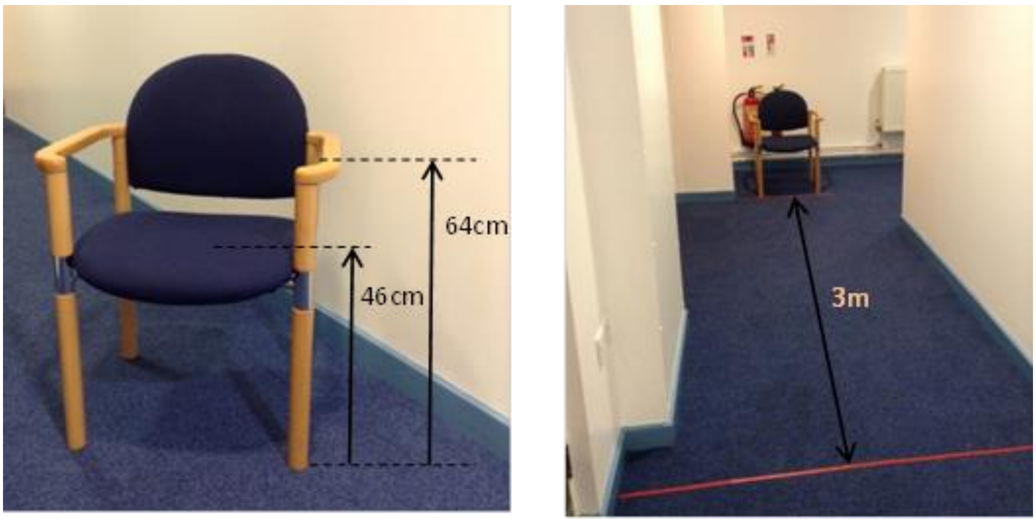


Figure 7.2 Chair and walkway dimensions for Timed Up and Go Test

Equipment

Arm chair:	seat height approximately 46 cm arm height approximately 65 cm
Stopwatch / Timer	
Level Walkway:	3m long, measured from front of chair legs

Protocol

Ensure the chair is stable so it will not move when the participant stands or sits

Use of the arm rests during the sit-to-stand and stand-to-sit movements is allowed

The participant should wear their regular footwear

The participant may use any walking aids they normally use

The participant may not be assisted by another person

Start timing on the word go

Stop timing when the participant's buttocks come into contact with the chair seat

There is no time limit and the participant may stop and rest if needed

A practice trial that is not timed should be performed first

Participant instructions

Sit with your hips all the way back onto the chair seat, with your back touching the chair back.

Your arms should be resting on the armrests and your walking aid, if needed, at hand.

When I say “go”, I would like you to stand up and walk to the line, cross over it and turn round, then walk back to the chair and sit down again. I will count you down “3,2,1,go”.

Walk at a comfortable and safe pace.

Table 7.2 Timed up and Go procedure

Table 7.2 shows the required equipment, the protocol (based on the original Podsiadlo and Richardson design, as reported in Tate[210]) and participant instructions.

7.8.1.3 Short Form-12v2® Health Survey

The Short Form-12v2® Health Survey (SF-12v2®) was chosen to evaluate the participants' perceived physical and emotional health status. It is one of the recommended generic health-related quality of life measures proposed by ProFANE in their common outcome data set for fall injury prevention trials[5].

The SF-12v2® belongs to a family of short form health surveys that are available in formats with 36, 12, or 8 questions. The SF-36 contains 36 questions from a range of eight domains [Physical Functioning (PF[a]), Role-Physical (RP), Bodily Pain (BP), General Health (GH), Vitality (VT), Social Functioning (SF[b]), Role-Emotional (RE) and Mental Health (ME)]. The SF-12v2® is a more concise version of the SF-36, containing 12 of the SF-36 questions taken from each of the eight domains, and - in the same fashion as the SF-36 - provides two summary measures of physical and mental health [Physical Component Score (PCS) and Mental Component Score (MCS)]. Whilst PF[a], RP, BP and GH are attributed mainly to the PCS (Table 7.3), it is important to note that they also contribute to MCS. Similarly, VT, SF[b], RE and ME contribute to PCS.

In the United States (US) the PCS-36/PCS-12 and MCS-36/MCS-12 are reported to be closely correlated (0.95 and 0.97 respectively). An international study found some subtle country-specific variations as to which twelve questions most closely matched the US results. However, the US SF-12 questions and scoring algorithms were recommended to enable comparison of study results[211]. The SF-12v2®

offered a compromise solution providing an acceptable level of precision and a minimal time burden for the participant.

Domain		Question
		Physical Health Measures
Physical Function	2a	Moderate activities such as moving a table, pushing a vacuum cleaner, bowling, or playing golf
	2b	Climbing several flights of stairs
Role-Physical	3a	As a result of your physical health, how often have you accomplished less than you would like
	3b	Were limited in the kind of work or activities
Bodily Pain	5	How much did pain interfere with your normal work (including both work outside the home and housework?
General Health	1	In general, would you say your health is: excellent,very good, good,fair or poor?
		Mental Health Meaures
Mental Health	6a	Have you felt calm and peaceful?
	6c	Have you felt downhearted and low?
Social Functioning	7	How much of the time has your physical health or emotional problems interfered with your social activities (like visiting with friends, relatives, etc.)?
Role Emotional	4a	As a result of feeling depressed or anxious, how often have you accomplished less than you would like
	4b	Did work or other activities less carefully than ususal
Vitality	6b	Did you have a lot of energy?

Table 7.3 SF-12v2® questions and domains

The PCS and MCS scores range from 0 to 100, where 50 represents the norm with a standard deviation of 10. Standard and acute forms of the questionnaire are available, whereby the standard form is recommended for single application, or for re-use after a period of at least four weeks.

The SF-12v2® standard form was completed by the study participant in a self-administered paper and pencil based form and in accordance with the recommendations in the administration guide, specifically before any other health questions were posed, and in a quiet environment [212]. Five point (10 questions) or three point (2 questions) Likert scale responses were evaluated using Quality Metric Health Outcomes™ Scoring Software 4.0.

7.8.1.4 Fall injury classification system

Chapter 3 highlighted the difficulty in comparing falls studies because of variation in outcome measures and lack of standardisation, especially when recording falls where injuries have been sustained. A review paper by Schwenk et al.[6] evaluated 41 randomised controlled trials and proposed fall injury classification guidelines which were adopted in this study (Table 7.4).

	Category	**Definition**
a	serious injury	medically recorded fracture, head or internal injury requiring accident and emergency or inpatient treatment
b	moderate injury	wounds, bruises, sprains, acuts requiring a medical / healthcare professional examination such as physical examination, x-ray, suture
c	minor injury	minor bruises or abrasions not requiring health professional assistance; reduction in physical function (eg due to pain, fear of falling) for at least three days
d	no injury	no physical injury detected

Table 7.4 Falls injury classification system (Schwenk et al.[6])

These guidelines were based on the most frequent type of definition used in the examined studies, a system initially adopted by Campbell et al.[213]. Fall severity is recorded according to type of injury (ranging from abrasions to fractures) and level of medical intervention.

7.9 Results

The study results are presented for both the retrospective and the prospective study in three sections: descriptive data, thematic analysis, and logistic regression.

7.9.1 Descriptives

Participant data for the retrospective study are detailed in Table 7.5. These variables also provided baseline data for the prospective study. The median length of trial participation was 366 days (IQR 365 – 376).

A chi square test for independence indicated no statistically significant association between gender and worn lens design [χ^2 (2, n = 132) = 1.52, p = .47].

Shapiro Wilk's W was used to investigate normality of distribution. In the study population as a whole, no variables demonstrated normal distribution [Age (W = .971, p = .006); GMV (W = .626, p = <.001); TUG (W = .661, p = <.001); SF-12v2-P (W = .968, p = .004); SF-12v2-M (W = .937, p = <.001); Duration of wear (W = .944, p = <.001)].

A Kruskal-Wallis test revealed a statistically significant difference in duration of wear across the three lens designs [χ^2 (2, n = 132) = 8.87, p = .012]. The median length of wear was statistically significantly longer in bifocal than PAL wearers (Mann-Whitney U = 712.5, z = -2.876, p = .004, r = .29).

	SV		Bif		PAL		Total	
	n (%)							
Lens design	31 (23.5)		32 (24.2)		69 (52.3)		132 (100)	
Gender (Female)	13 (41.9)		17 (53.1)		38 (55.1)		68 (51.5)	
	median (IQR)							
Age (yrs)	76.0	(71.0 - 80.0)	75.5	(71.5 - 80.5)	74.0	(71.0 - 80.0)	76.0	(71.0 - 80.0)
GMV (s)	48.3	(35.6 - 59.4)	45.8	(42.8 - 71.8)	45.9	(35.6 -53.6)	46.0	(36.8 - 57.3)
TUG (s)	11.2	(9.9 - 13.3)	12.7	(10.9 - 14.1)	11.1	(9.9 - 12.4)	11.4	(10.2 - 13.3)
SF12v2® - P score	50.8	(39.9 - 56.7)	47.1	(40.4 - 53.7)	48.2	(41.6 - 56.9)	48.8	(40.7 - 55.9)
SF12v2® - M score	55.3	(49.0 - 59.2)	56.2	(50.0 - 59.9)	56.0	(48.0 - 59.2)	55.9	(48.9 - 59.3)
Time worn (yrs)	20.0	(12.5 - 32.5)	25.0	(20.0 - 30.0)	20.0	(10.0 - 25.0)	20.0	(10.5 - 28.0)

Table 7.5 Participant data: retrospective study

	SV		Bif		PAL		Total	
	n (%)							
Lens design	31 (23.8)		32 (24.6)		67 (51.5)		130 (100)	
Gender (Female)	13 (41.9)		17 (53.1)		38 (56.7)		68 (52.3)	
	median (IQR)							
Age (yrs)	76.0	(71.0 - 80.0)	75.5	(71.5 - 80.5)	74.0	(71.0 - 80.0)	76.0	(71.0 - 80.0)
GMV (s)	48.3	(35.6 - 59.4)	45.8	(42.8 - 71.8)	45.9	(35.0 - 53.9)	46.0	(36.7 - 57.5)
TUG (s)	11.2	(9.9 - 13.3)	12.7	(10.9 - 14.1)	11.1	(9.9 - 12.4)	11.4	(10.2 - 13.3)
SF12v2® - P score	50.8	(39.9 - 56.7)	47.1	(40.4 - 53.7)	48.2	(42.0 - 56.9)	48.8	(40.8 - 56.0)
SF12v2® - M score	55.3	(49.0 - 59.2)	56.2	(50.0 - 59.9)	56.2	(48.2 - 59.2)	56.0	(49.0 - 59.3)
Time worn (yrs)	20.0	(12.5 - 32.5)	25.0	(20.0 - 30.0)	20.0	(10.0 - 25.0)	20.0	(11.0 - 28.0)

Table 7.6 Participant data: prospective study

All other variables displayed no statistically significant difference across lens design [χ^2 (2, n = 132) Age = .679, p = .712; GMV = 3.158, p = .206; TUG = 5.607, p = .061; SF-12v2-P = 2.265, p = .322; SF-12v2-M = .478, p = .787].

The attrition rate for the study was 1.5%. One participant was lost to follow-up, and one participant was deceased. They were both male, PAL wearers. Participant data for the prospective study was therefore as in Table 7.6.

Wilcoxon Signed Rank tests for the 111 participants who attended a follow-up appointment showed no significant difference in GMV, SF12v2-P and SF12v2-M measures at begin and end of the prospective trial across all three lens types [GMV (SV) z = -1.105, p = .269, (Bif) z = -.267, p = .790, (PAL) z = -.736, p = .462; SF12v2-P (SV) z = -1.626, p = .104, (Bif) z = -1.841, p = .066, (PAL) z = -1.719, p = .086; SF12v2-M (SV) z = -.165, p = .869, (Bif) z = -1.206, p = .228, (PAL) z = -.422, p = .673]. TUG scores showed no significant difference in SV and Bif wearers [(SV) z = -1.842, p = .066, (Bif) z = -.750, p = .453)] but a significant difference in PAL wearers (z = -2.472 p = .013) was found with a small to medium effect size of .23 according to Cohen's classification[183].

In compliance with ProFANE's recommended data outcome set[5], the number of falls, fallers and repeat fallers for both retrospective and prospective studies is shown in Table 7.7. This equates to a fall rate per person year (ppy) of 0.6 for the retrospective study, and 0.5 for the prospective study.

	Retrospective study				Prospective study			
	SV	Bif	PAL	TOTAL	SV	Bif	PAL	TOTAL
Participants	31	32	69	132	31	32	67	130
Falls								
n	22	22	36	80	17	14	33	64
fall rate ppy	**0.7**	**0.7**	**0.5**	**0.6**	**0.5**	**0.4**	**0.5**	**0.5**
Fallers								
n	13	13	28	54	11	10	24	45
%	**41.9**	**40.6**	**40.6**	**40.9**	**35.3**	**31.3**	**35.8**	**34.6**
Repeat fallers								
n	5	6	6	17	4	3	8	15
%	**16.1**	**18.8**	**8.7**	**12.9**	**12.9**	**9.4**	**11.9**	**11.5**

Table 7.7 Retrospective and Prospective study falls data

7.9.2 Thematic analysis

The retrospective and prospective studies were further analysed according to the following themes:

- Spectacle wear at time of fall by worn lens design
- Level of sustained injury by worn lens design
- NHS Fall categories
- Indoor / outdoor falls and level of sustained injury
- Lighting levels at time of fall
- Low Vision fallers

7.9.2.1 Spectacle wear at time of fall

Table 7.8 shows whether study participants were wearing their spectacles at the time of their sustained falls.

		Retrospective study				Prospective study			
		SV	Bif	PAL	TOTAL	SV	Bif	PAL	TOTAL
Total falls		22	22	36	80	17	14	33	64
Falls with spectacles									
	n	9	20	30	59	10	11	22	43
	%	**40.9**	**90.9**	**83.3**	**73.8**	**58.8**	**78.6**	**66.7**	**67.2**
Falls without spectacles									
	n	13	2	6	21	7	3	11	21
	%	**59.1**	**9.1**	**16.7**	**26.25**	**41.2**	**21.4**	**33.3**	**32.8**

Table 7.8 Spectacle wear at time of fall

In the retrospective study, two participants were wearing their reading spectacles at the time of their fall, and this was deemed to be comparable with not wearing spectacles. It was apparent in both retrospective and the prospective studies that bifocal and PAL wearers were more likely to be wearing their spectacles at the time of their fall than single vision wearers. Single vision wearers were more likely to fall - compared with bifocal or PAL wearers - when walking unaided or with their reading spectacles, in both studies.

7.9.2.2 Level of sustained injury

The level of sustained injury was analysed according to the system described in Section 7.8.1.4 (Table 7.9).

	Retrospective study				Prospective study			
	SV	Bif	PAL	TOTAL	SV	Bif	PAL	TOTAL
Total falls	22	22	36	80	17	14	33	64
Level of injury (n)								
a	0	2	3	5	1	2	2	5
b	1	3	2	6	3	1	4	8
c	8	8	14	30	6	5	15	26
d	13	9	17	39	7	6	12	25
Level of injury (%)								
a	0.0	9.1	8.3	6.3	5.9	14.3	6.1	7.8
b	4.5	13.6	5.6	7.5	17.6	7.1	12.1	12.5
c	36.4	36.4	38.9	37.5	35.3	35.7	45.5	40.6
d	59.1	40.9	47.2	48.8	41.2	42.9	36.4	39.1

a = serious injury, b = moderate injury, c = minor injury, d = no injury (see Table 7.4)

Table 7.9 Level of sustained injury

Injury classifications a and b are those that require some form of medical attention. This applied in 11 falls (13.75%) in the retrospective study, which included three fractures (2 x wrist, 1 x thumb; 0.02 fractures ppy), and 13 falls (20.3%) in the prospective study, which included 6 fractures (3 x wrist, 2 x thumb, 1 x vertebrae; 0.05 fractures ppy) . Figure 7.3 demonstrates the cumulative distribution (%) of sustained injuries, and shows that in the majority of cases for all lens types either no injury, or minor injuries were sustained.

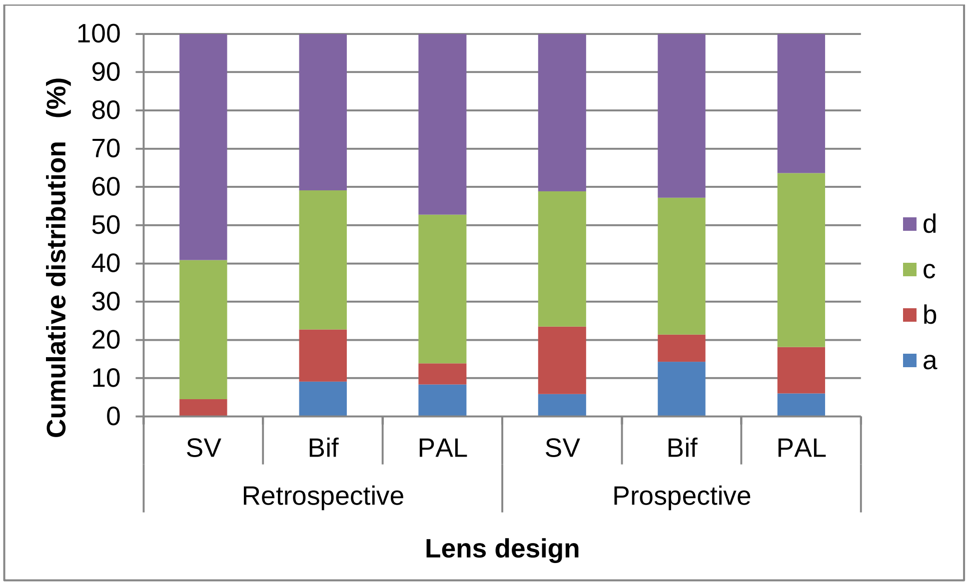


Figure 7.3 Comparison of sustained injury levels

7.9.2.3 HES Falls category comparison

Of the twenty HES fall categories (see Table 2.2), nine applied in the retrospective, and eight in the prospective study (Table 7.10)

The Hospital Episode Statistics (HES) for England 2014 – 2015 (Figure 2.3) showed the greatest number of falls recorded as unspecified (W19). However, the circumstances of all falls in both retrospective and prospective studies were recorded, rendering the category redundant in this analysis.

A comparison between the percentage of falls sustained during the trials and their respective frequency in HES 2014 – 2015 is shown in Figure 7.4.

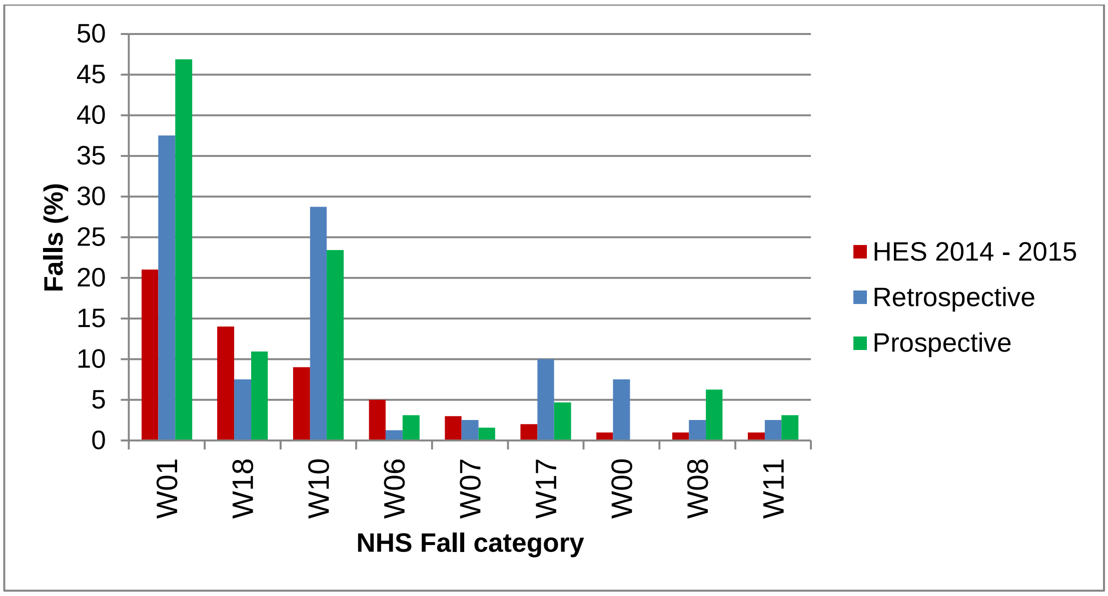
Category	Retrospective		Prospective	
	n	(%)	n	(%)
W00 Ice and snow	6	(7.5)	0	(0.0)
W01 Same level	30	(37.5)	30	(46.9)
W06 Involving bed	1	(1.3)	2	(3.1)
W07 Involving chair	2	(2.5)	1	(1.6)
W08 Other furniture	2	(2.5)	4	(6.3)
W10 Stairs and steps	23	(28.8)	15	(23.4)
W11 Ladder	2	(2.5)	2	(3.1)
W17 Other different level	8	(10.0)	3	(4.7)
W18 Other same level	6	(7.5)	7	(10.9)
Total	80	(100.0)	64	(100.0)

Table 7.10 Falls according to HES Fall category

Excluding the HES unspecified fall category, there is agreement that the greatest number of falls were sustained in category W01 (fall on same level, from slipping, tripping and stumbling).

Falls on and from stairs and steps (W10) ranked second in the retrospective and prospective study, whereas in HES 2014 – 2015 other falls from same level (W18) ranked second.

Falls on the same level (W01 and W18 combined) and falls on stairs and steps (W10) were, therefore, the most frequent fall locations in all cases.



HES = Hospital Episode Statistics

Figure 7.4 Comparison of Hospital Episode Statistics, Retrospective and Prospective studies according to NHS Fall category

7.9.2.4 Indoor / Outdoor falls

Lord[126] found that regular multifocal (Bif, Trif, PAL) wearers were more likely to fall outside the home than non-wearers (39.8% vs 24.6%). Both retrospective and prospective studies identified indoor and outdoor falls, and falls that occurred when transitioning from indoors to outdoors or vice-versa.

The majority of falls for all categories together occurred outdoors (59%) in the retrospective study, and indoors (50%) in the prospective study. In the retrospective study, SV and bifocal wearers showed a greater difference between outdoor vs indoor falls (31.8% and 45.5% respectively) than PAL wearers (13.9%), suggesting that PAL wearers perform differently. This variation was not as marked in the prospective study, where only bifocal wearers fell more outdoors, with a modest 7.1% difference.

		Retrospective study				Prospective study			
		SV	Bif	PAL	TOTAL	SV	Bif	PAL	TOTAL
Total falls		22	22	36	80	17	14	33	64
Indoor									
	n	5	5	15	25	9	6	17	32
	%	**22.7**	**22.7**	**41.7**	**31**	**52.9**	**42.9**	**51.5**	**50.0**
Outdoor									
	n	12	15	20	47	8	7	13	28
	%	**54.5**	**68.2**	**55.6**	**59**	**47.1**	**50.0**	**39.4**	**43.8**
Indoor / Outdoor Change									
	n	5	2	1	8	0	1	3	4
	%	**22.7**	**9.1**	**2.8**	**10.0**	**0.0**	**7.1**	**9.1**	**6.3**

Table 7.11 Indoor / Outdoor Fall location

7.9.2.5 Lighting levels at time of fall

As inappropriate lighting conditions have been identified as fall risk factors (Section 2.4.9), the studies were analysed according to five different descriptors derived from the participants' own accounts of ambient lighting conditions at the time of fall.

In both studies most falls were reported as having occurred in good lighting conditions (retrospective 81%, prospective 76.6%), with the prospective study also showing dim or overcast situations reported in 17.2% of falls. There were only infrequent reports of falls occurring in glare conditions, or when adapting to a change in lighting conditions.

		Retrospective study				Prospective study			
		SV	Bif	PAL	TOTAL	SV	Bif	PAL	TOTAL
Total falls		22	22	36	80	17	14	33	64
Daylight / good indoor lighting									
	n	17	19	29	65	13	10	26	49
	%	**77.3**	**86.4**	**80.6**	**81**	**76.5**	**71.4**	**78.8**	**76.6**
Dim / Overcast									
	n	0	0	4	4	4	3	4	11
	%	**0.0**	**0.0**	**11.1**	**5**	**23.5**	**21.4**	**12.1**	**17.2**
Glare									
	n	0	2	0	2	0	0	1	1
	%	**0.0**	**9.1**	**0.0**	**2.5**	**0.0**	**0.0**	**3.0**	**1.6**
Dark									
	n	2	1	3	6	0	1	1	2
	%	**3.0**	**0.0**	**0.0**	**3.0**	**0.0**	**7.1**	**3.0**	**3.1**
Change in lighting levels									
	n	3	0	0	3	0	0	1	1
	%	**13.6**	**0.0**	**0.0**	**3.8**	**0.0**	**7.1**	**3.0**	**3.1**

Table 7.12 Lighting levels at time of fall

7.9.2.6 Low Vision Fallers

For the retrospective study, visual acuity data was recorded as presenting VA at the time of the participant's eye examination at study begin. Prospective VA was recorded as best VA after this eye examination. All data was obtained from clinical records and transposed to decimal acuity, to facilitate analysis.

To align with the recommendations in the College of Optometrists' falls document[137] participants with a best monocular VA of 0.5 decimal (6/12 Snellen) or less were considered to have low vision. Table 7.13 shows falls data for low vision participants.

	Retrospective study				Prospective study			
	SV	Bif	PAL	TOTAL	SV	Bif	PAL	TOTAL
Participants	31	32	69	132	31	32	67	130
Low Vision	7	3	9	19	5	2	4	11
Falls								
n	7	3	6	16	5	3	5	13
fall rate ppy	**1.0**	**1.0**	**0.7**	**0.8**	**1.0**	**1.5**	**1.3**	**1.2**
Fallers								
n	3	2	4	9	3	1	3	7
%	**42.9**	**66.7**	**44.4**	**47.4**	**60.0**	**50.0**	**75.0**	**63.6**
Repeat fallers								
n	1	1	1	3	1	1	1	3
%	**14.3**	**33.3**	**11.1**	**15.8**	**20.0**	**50.0**	**25.0**	**27.3**

Table 7.13 Retrospective and Prospective study falls data for low vision participants

Low vision participants represented 14.4% (retrospective) and 8.5% (prospective) of the study participants. The fall rate per person year overall was 0.8 and 1.2 respectively, and is higher in both studies for all lens designs than for persons with VA > 0.5 decimal (6/12 Snellen) (Figure 7.5). In the retrospective study those with low vision fell 1.33 times more frequently (falls rate ppy 0.8 vs 0.6), but this difference rose to 3 times in the prospective study (falls rate ppy 1.2 vs 0.4).

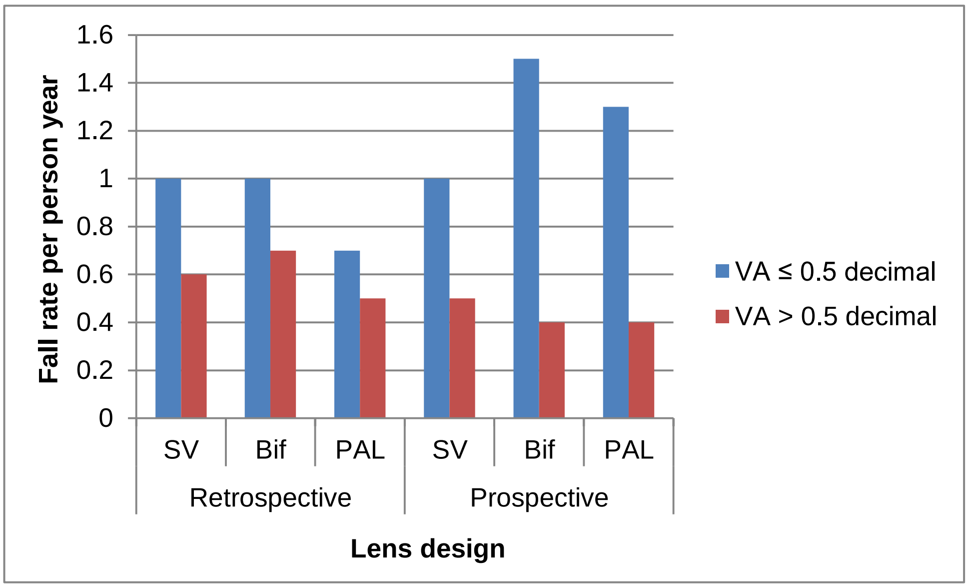


Figure 7.5 Fall rate per person year

7.9.3 Logistic Regression

For the retrospective study, a logistic regression was carried out to assess the influence of worn lens design (SV, Bif, PAL) on falls risk, adjusting for age, gender, GMV, TUG, SF-12v2-P and SF-12v2-M.

This represented a total of eight variables for calculation of the EPV, as the lens design option was not binary, and therefore has to be counted as two variables. For the retrospective study this equated to an EPV of 6.75, reducing to 5.6 in the prospective study.

Model 1 contained all the variables except lens design; Model 2 included lens design in the model.

The Model 1 Hosmer and Lemeshow Goodness of Fit test indicated support for the model (χ^2 = 10.77, df = 8, p = .215) and is the most reliable test of model fit[214,215]. The omnibus test of model coefficients, however, showed that the model did not perform better than the baseline (Block 0) assessment ($\chi^2 = 3.53$, df = 6, p =.741). None of the independent variables made a significant contribution to the model, with correctly predicted percentages only increasing from 59.1% to 59.8%.

For Model 2, with the inclusion of worn lens design, the Hosmer and Lemeshow test again indicated a good model fit ($\chi^2 = 12.44$, df = 8, p = .133), and the omnibus test of model coefficients again showed no improvement over baseline ($\chi^2 = 3.57$, df = 8, p = .89). Correctly predicted percentages remained at 59.1%. Lens design - both per lens type and as an overarching category - was not found to have a statistically significant influence on the odds ratio of falls (Table 7.14).

The prospective study was analysed in the same fashion, but previous falls (as found in the retrospective study) were entered as an additional independent variable (Table 7.15).

The Hosmer and Lemeshow Goodness of Fit tests indicated good fit for models with and without worn lens design [Model 1 ($\chi^2 = 6.48$, df = 8, p = .59); Model 2 ($\chi^2 = 7.12$, df = 8, p = .52)]. Only previous history of falls was a significant predictor of falls in both cases, with an odds ratio of 2.71. Including lens design in the model did not improve its predictive ability, and indeed reduced it slightly from 65.4% to 64.6%.

	Model 1								Model 2							
	B	SE	Wald	*df*	*p*	Odds Ratio	95% CI for Odds Ratio		*B*	SE	Wald	*df*	*p*	Odds Ratio	95% CI for Odds Ratio	
							Lower	Upper							Lower	Upper
Constant	-0.80	3.33	0.06	1	0.81	0.45	-	-	-0.74	3.37	0.05	1	0.83	0.48	-	-
Age	0.02	0.03	0.38	1	0.54	1.02	0.96	1.09	0.02	0.03	0.35	1	0.55	1.02	0.96	1.09
Gender (Female)	0.37	0.38	0.95	1	0.33	1.44	0.69	3.01	0.37	0.38	0.97	1	0.32	1.45	0.69	3.04
GMV	0.00	0.01	0.39	1	0.53	1.00	0.99	1.01	0.00	0.01	0.38	1	0.54	1.00	0.99	1.01
TUG	-0.01	0.06	0.01	1	0.91	0.99	0.89	1.11	0.00	0.06	0.00	1	0.95	1.00	0.89	1.12
SF12v2 - P	-0.01	0.02	0.23	1	0.63	0.99	0.94	1.04	-0.01	0.02	0.23	1	0.63	0.99	0.94	1.04
SF12v2 - M	-0.02	0.02	0.50	1	0.48	0.98	0.94	1.03	-0.02	0.02	0.47	1	0.49	0.98	0.94	1.03
Lens design											0.05	2	0.98			
Lens design (Bif)									-0.12	0.54	0.05	1	0.83	0.89	0.31	2.56
Lens design (PAL)									-0.06	0.45	0.02	1	0.89	0.94	0.39	2.28
Nagelkerke pseudo r^2	4.0%								4.0%							
Classification accuracy	59.8%								59.1%							

B = regression coefficient, SE = standard error, Wald = Wald statistic (B^2/SE^2), *df* = degrees of freedom, p = p-value, CI = confidence interval. The coefficient for Gender contrasts with Male. The coefficients for Lens design contrast with SV.

Table 7.14 Retrospective study: logistic regression results

	Model 1								Model 2							
	B	SE	Wald	*d*f	*p*	Odds Ratio	95% CI for Odds Ratio		*B*	SE	Wald	*d*f	*p*	Odds Ratio	95% CI for Odds Ratio	
							Lower	Upper							Lower	Upper
Constant	-5.01	3.67	1.86	1	0.17	0.01			-5.26	3.72	2	1	0.16	0.01		
Age	0.02	0.04	0.24	1	0.62	1.02	0.95	1.09	0.02	0.04	0.23	1	0.63	1.02	0.95	1.09
Gender (Female)	0.02	0.41	0.00	1	0.96	1.02	0.46	2.28	0.00	0.41	0.00	1	0.99	1.00	0.45	2.26
GMV	0.01	0.01	2.79	1	0.09	1.01	1.00	1.02	0.01	0.01	3.00	1	0.08	1.01	1.00	1.02
TUG	-0.05	0.08	0.48	1	0.49	0.95	0.81	1.10	-0.05	0.08	0.36	1	0.55	0.95	0.82	1.11
SF12v2 - P	0.02	0.03	0.75	1	0.39	1.02	0.97	1.08	0.02	0.03	0.78	1	0.38	1.02	0.97	1.08
SF12v2 - M	0.03	0.03	1.26	1	0.26	1.03	0.98	1.08	0.03	0.03	1.32	1	0.25	1.03	0.98	1.09
Previous falls	**1.00**	**0.40**	**6.28**	**1**	**0.01**	**2.71**	**1.24**	**5.90**	**1.00**	**0.40**	**6.29**	**1**	**0.01**	**2.71**	**1.24**	**5.92**
Lens design											0.38	2	0.83			
Lens design (Bif)									-0.05	0.58	0.01	1	0.94	0.95	0.30	3.00
Lens design (PAL)									0.22	0.49	0.21	1	0.65	1.25	0.48	3.26
Nagelkerke pseudo r^2				12.7%									13.0%			
Classification accuracy				65.4%									64.6%			

B = regression coefficient, SE = standard error, Wald = Wald statistic (B^2/SE^2), *df* = degrees of freedom, p = p-value, CI = confidence interval. The coefficient for Gender contrasts with Male. The coefficients for Lens design contrast with SV.

Table 7.15 Prospective study: logistic regression results

7.10 Discussion

7.10.1 Evaluation of results

The logistic regression analysis for both the retrospective and prospective studies did not find an influence of lens design on falls risk. This corroborates the findings of the recent Swedish study referred to in Section 4.10.6. The only statistically significant variable was history of previous falls, with an OR of 2.71. This aligns with the findings of an OR of 2.8 in the previously reported review of risk factors in community-dwelling older people[25].

Although GMV, TUG, SF12v2®, age and gender were not found to be statistically significant variables, their measures confirmed homogeneity of visual status and physical and mental health across all three lens types.

Whereas Lord[126] found that regular "multifocal" wearers were wearing their glasses at the time of most of their falls, this study demonstrated that falls in single vision wearers occurred with almost equal frequency when walking with or without spectacles in both retrospective (40.9% vs 59.1%) and prospective (58.8% vs 41.2%) studies. When compared with bifocal or PAL wearers they fell more frequently when walking unaided or with their reading spectacles.

13.75% (retrospective) and 20.3% (prospective) of falls required medical attention, with three and six fractures reported respectively. No hip fractures were recorded. As the majority of falls did not require medical attention, it is possible that early intervention opportunities are being missed, that may avert subsequent falls with more severe injurious consequences.

This study did not confirm findings that "multifocal" wearers were more likely to fall outside the home. Whilst the majority of falls in the retrospective study did occur outdoors, this was found for all lens wear types, including single vision. The results varied for the prospective study, which showed an increase in outdoor falls only in bifocal lens wearers. When aligned with the HES falls categories, falls on the same level (from slipping, tripping and stumbling) and falls on stairs and steps were the most frequent locations.

That most falls occurred in good lighting conditions was not an expected outcome, given that poor lighting, glare and changes in lighting levels have all been implicated in increasing falls risk.

In the retrospective study, the percentage of low vision participants (14.4%) accurately reflected the 14% prevalence indicated in Section 3.3.1, but this reduced to 8.5% in the prospective study. Nonetheless, a higher falls rate was found in those with a best monocular VA of ≤ 0.5 decimal (6/12 Snellen). This was more pronounced in the prospective study (3x) than in the retrospective study (1.3x).

7.10.2 Strengths and limitations

A key limitation of the study was the lack of investigation into which part of the lens was used when walking or negotiating steps. Commercially available equipment was prohibitively expensive.

The decision to recruit solely through the Aston University Eye Clinic provided a source of trial participants who regularly attended the university for their eye examinations, and this no doubt contributed to the low attrition rate of 1.5%. It also provided access to clinical records for confirmation of worn lens designs and visual acuities. There may have been discrepancies in the recording of VA data, as it was taken by final year optometry students with a range of clinical supervisors.

The retrospective study is also likely to have suffered from recall bias, with events either being forgotten or mistakenly attributed to having happened within the 12 month timeframe in question.

Where other studies have struggled to find PAL wearers, the challenge here was to find sufficient SV or Bif wearers. The studies had a PAL to SV and PAL to Bif ratio in the region of 2:1, which reflected current UK sales figures. Adopting logistic regression analysis negated the need for equal group sizes. Although the sample sizes are within reasonable limits, the studies would have benefitted from a greater number of trial participants, which would have made the results more robust and possibly able to detect smaller effect sizes.

The main strength of the studies is that they follow many of the recommendations laid out in the ProFANE consensus document for a common outcome data set for fall injury prevention trials[5]. Specifically, the studies adhered to the ProFANE definition of fall, and the falls diaries employed the wording recommended for lay persons. The minimum monthly reporting system was not adhered to because of the associated administrative burden, but this was offset to some degree by email and telephone updates to maintain ongoing contact with participants. Telephone and face to face interviews were conducted in accordance with these recommendations to rectify missing data and obtain further details.

Falls data was also collected as recommended regarding number of falls, number of fallers / non-fallers / frequent fallers, and fall rate per person year. The requirement for a 12 months follow-up period was achieved with a mean completion time of 366 days.

The recommendations that injuries should be classified according to the International Classification of Diseases classification system was not complied with, as it was felt that this was not an appropriate system for lay persons. The injury classification system used in the studies has the advantage of being easy to understand and has been publicised on the ProFANE community network.

The psychological impact of falls was not specifically investigated, although the SF12v2® did provide a measure of emotional wellbeing, which was included in the logistic regression analysis and was one of the recommended health-related Quality of Life measures.

The consensus document deemed further research was required before a specific recommendation for physical activity measures could be made. Nonetheless, it was felt that a measure of physical ability should be incorporated into the study, and the TUG was chosen as detailed in Section 7.8.1.2. TUG did not prove to be predictive of falls in both studies, and this may reflect the fact that the participants were generally fit and active, with a maximum time completion score of 14.1s. Whilst it is acknowledged that, as a result of differences in test methodology there is a wide variation in recommended cut-off scores to categorise at risk participants, scores of less than 15s have been found to rule out a high fall risk in residential care facilities[216]. The study would have benefited from a greater number of participants with a more diverse range of physical abilities.

7.11 Summary

This chapter described the retrospective case control and prospective cohort studies that were carried out to investigate the influence of spectacle lens design on falls risk in community dwelling elderly persons. The studies' objectives and methodology were specified, with results presented according to descriptive, thematic and logistic regression analyses. The main outcomes of both studies were summarised, and their strengths and limitations were discussed.

Chapter 8 provides an overview of the whole thesis and suggestions for future work.

Chapter 8. Thesis summary and future work

8.1 Thesis summary

The primary aim of the study was to investigate the influence of spectacle lens designs on falls risk, in a community-dwelling UK population of persons aged 65 or older, in order to contribute to the body of evidence-based research on which currently recommended prescribing and dispensing practices are founded.

Background information about the multifactorial nature of falls (Chapter 2) provided an introduction to a review of falls risk factors related to vision impairment (Chapter 3).
A critical review of previous research into spectacle lens correction modes for presbyopes (SV, Bif and PAL) highlighted variations in the usage of the term "multifocal" and poor levels of differentiation between bifocal and PAL designs in study outcomes (Chapter 4). Furthermore, previous research has asserted that wearers of these lens designs looked through the lower or near lens area when walking on the level or using steps and stairs.

Whereas gaze direction studies have provided information about target gaze location, no studies have yet identified which lens area is accessed during locomotion. This brings into question the rationale for recommending single vision distance lenses as a preferred option for certain tasks, as there is no research base that confirms a gaze direction through these near portions, with their incumbent levels of blur or reduced contrast sensitivity. It is conceivable that a combination of head tilt and eye rotation is undertaken that provides a gaze direction through the distance area of bifocal lenses, or an intermediate area in PALs.

Furthermore, images of step edges through a PAL held at arm's length have shown distortion and peripheral aberrations that do not represent real-life situations when the lens is worn correctly fitted with an appropriate back vertex distance and pantoscopic tilt.

Other studies did not report whether or how allowances were made for previous habitual wear of trial participants, which may have influenced performance if switching from PAL to Bif or vice-versa in the trial setting. The importance of habituation was demonstrated in a study comparing intermediate and full Add lenses, where performance with the participant's own spectacles was comparable to results using trial PAL lenses with an intermediate Add and SV lenses. Habituation may also counterbalance any spectacle lens magnification issues.

A survey of optical professionals was undertaken to investigate how confident practitioners felt about identifying those at risk of falls, and what lens designs they recommended in such cases (Chapter 5). When asked to rate their level of agreement with a core statement (*"It is advisable to switch elderly (65 and over) long-term varifocal and bifocal wearers, who are at a high risk of falling, to single vision lenses")* the results showed an almost even distribution between "agree more than disagree" (35.6%) and "disagree more than agree" (44.9%), with very few participants agreeing or disagreeing fully, or not knowing.

The lens design of choice for those assessed at risk of falls, was overwhelmingly single vision, irrespective of confidence level. If not assessed, or assessed and found to be not at risk of falls, PALs were by far the lens of choice, again irrespective of confidence level. The survey did not identify the underlying rationale for these decisions, but it would seem a reasonable assumption that they were based on previously published research findings and their attendant recommendations.

Most respondents indicated they would benefit from further information about falls, and would welcome a quick and easy risk assessment tool for use in practice. During the course of this study, the College of Optometrists has contributed to practitioner awareness of falls with its 2014 publication “Focus on falls” and continuing education material.

The requirement for an inexpensive measure of visual attention for the retrospective and prospective studies, led to the development of the Global Measure of Vision (Chapter 6). This is a paper and pencil test based on the Trail Making Test, the AARP reaction time test, and AutoTrails II.

A link between driving difficulties and falls risk has been reported, and visual factors measured by the UFOV are also associated with mobility in older adults. The GMV had significant correlations with UFOV divided attention, selective attention and its overall risk category, and was, therefore, chosen as the measure of visual attention for the retrospective and prospective studies (Chapter 7).

132 participants took part in the retrospective case-control study, of which 130 completed the12 month prospective study. Both studies investigated the number and severity of sustained falls, the location and nature of the falls, the duration and nature of habitual spectacle lens wear (SV, Bif or PAL), and whether spectacles were worn at the time of the incident. Visual acuity data was obtained from Aston University clinic records, and GMV, TUG and SF12v2® data was taken at study onset and for 111 participants who were able to attend follow-up appointments.

Logistic regression analyses showed no influence of spectacle lens design on falls risk in both the retrospective and prospective studies. This corroborates findings of a recent Swedish community-based study and demands further investigations.

The prospective study identified a previous fall history as the only statistically significant risk factor. This highlights how important it is in practice to identify patients who have previously fallen. Indeed, the NICE guideline CG161 states that practitioners, as health care professionals, should routinely ask whether patients have fallen. Onward referral or signposting to appropriate agencies can then be undertaken for appropriate multifactorial risk assessments.

The difficulty faced, not only by optical professionals, is how to identify those who have not yet fallen, but may be at imminent risk.

8.2 Future research

8.2.1 Gaze direction

Studies investigating eye-lens position in conjunction with gaze direction when walking or negotiating stairs are necessary in order to provide a true evaluation of accessed lens powers and any associated levels of blur. This would dispense with the assumption that gaze direction is through the near portion of the lens. The main requirement would be that the equipment is sufficiently light and unobtrusive so as not to impair customary head and eye positions. Such studies should differentiate between bifocal and PAL designs, in order to assess whether adopted gaze positions are lens- or user-specific. Investigations should include wearers with a range of Adds, as it is feasible that gait adaptations may vary with the power of the Add. Use of the participant’s own lenses and frames, in addition to standardised lenses and frames for trial purposes, would provide information about how habituation contributes to safe locomotion.

8.2.2 Balance and postural stability

It has not yet been established whether the type of balance deficit (visual, vestibular or somatosensory) influences performance differently according to worn lens design.

Are those with a predominantly visual balance deficit more likely to experience falls with any one particular design? Does this vary with type and severity of vision impairment? There is a requirement for laboratory studies identifying the type of balance deficit to be coupled with prospective observational falls studies differentiating between habitually worn lens designs.

It may be possible to stratify further and identify a difference within the lens design: a variation in postural stability with two different PAL designs has already been found in one study[143], and further studies are required to build on this evidence base.

8.2.3 Safe stair negotiation

Most laboratory studies of gait adaptations on stairs have been carried out on either a single step or a flight of three steps. Whilst Templer[54] reported the top three and bottom three steps on staircases were the main locations for falls accidents, investigations into stair negotiation when covering a whole flight of stairs are lacking. These would preferably be undertaken with the participant's own spectacles, to ensure habituation is accounted for, in addition to standardised lenses and frames for trial purposes. Staircases should correspond to current building regulation stipulations. Together with information from gaze direction studies that also identified eye-lens position, a complete picture of stair negotiation dynamics could be obtained.

8.2.4 Community studies

Further studies of community-dwelling older people would enrich the evidence base regarding the influence of spectacle lens design on falls risk in real-life scenarios.

These studies should be large enough to incorporate groups with complex needs that have been identified as being at greater risk of falling, such as those with cognitive or vision impairment. Adherence to the recommendations in the ProFANE consensus document would enable inter-study comparisons. As no agreement has yet been reached on a recommended measure of physical activity, further research is necessary to identify an appropriate metric.

In summary, a range of research across several areas is still required, before definitive statements about lens design and falls can be made that are pertinent to community-dwelling older people.

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APPENDICES

Appendix 1 Ethics Committee Approval Letter Project #513

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Memo

Life and Health Sciences Research Ethics Committee's Decision Letter

To: Dr Mark Dunne

Cc: Rachel Giles, administrator to the Life and Health Sciences Research Ethics Committee

From: Dr Robert Morse

Chair of the Life and Health Sciences Research Ethics Committee

Date: 25/2/2013

Subject: Project: #513 Provision of optical correction to elderly people at risk of falls

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The documentation and additional information for the above proposal has been considered by the Chair of the LHS Research Ethics Committee.
Please see below for details of the decision and the approved documents:

Reviewer's recommendation: Approved.

Reviewer's comments:

Reviewer #1.
Some elderly patients may have problems with on line format. Other than that good to proceed.
Reviewer #2.
This is a clearly written proposal and I can find no items that require attention.

Please see the tabled list below of approved documents:

Documentation	Version/s	Date	Approved
Consent Form	N/A		
Participant Information Sheet (PIS)	N/A		
Protocol	Version 1.0	31/1/2013	✓
Risk Assessment	N/A		
Questionnaires	1.0	29/1/2013	
Other (please detail)			

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Appendix 2 Prescribing and dispensing survey questions

Q1	Please indicate your professional status	Registered Dispensing Optician Registered Trainee / Pre-registration Dispensing Optician Registered Optometrist Registered Pre-registration Optometrist
Q2	Where do you mainly practise?	Hospital Eye Service Independent practice Small group practice (5 or fewer branches) Medium group practice (10 or fewer branches) Large multiple chain Other (please specify)
Q3	How many patients /customers do you see who are 65 years and over in an average week?	1-10; 51-60; 11-20; 61-70; 21-30; 71-80; 31-40; 81-90 41-50; >100
Q4	How many patients /customers do you see who are 65 years and over in an average week who have a binocular acuity of 6/12 Snellen or less?	1-10; 51-60; 11-20; 61-70; 21-30; 71-80; 31-40; 81-90 41-50; >100
Q5	What lifestyle issues do you routinely ask about for patients / customers aged 65 and over?	None Hobbies Television Computer use Mobility Driving Other (please specify)
Q6	Does this differ from the questions you ask under 65s?	Yes No If yes, please say how?
Q7	Please indicate to which extent you agree with the following statement: *It is advisable to switch elderly (65 and over) long-term varifocal and bifocal* *wearers, who are at a high risk of falling, to single vision distance lenses*.	Agree fully Agree more than disagree Don't know Disagree more than agree Disagree fully

Appendix 2 (cont.) Prescribing and dispensing survey questions

Q8	How confident do you feel in your ability to assess an elderly person's risk of falls?	Please indicate on a scale from Do not assess, 1 - 10, where 1 is not at all confident, and 10 = totally confident
Q9	If you had to summarise which category you feel applies to you overall, which would you choose?	Confident to assess risk of falls Not confident to assess risk of falls Do not assess risk of falls
Q10	Q10 applies to you if you chose confident to assess as your answer to Q9. Otherwise skip to the next question.	
	a) What is your lens design of choice for your patients / customers aged 65 or ove**r who are at risk of falls**	Separate single vision distance and near Bifocals Trifocals Varifocals
	b) Which coatings do you regularly recommend for your patients / customers aged 65 or over **who are at risk of falls?**	None Hard coat Basic AR coat Multiple AR coat Hydrophobic coat Combined MAR, hard and hydrophobic coat Other (please specify)
	c) Which tints do you regularly recommend to those aged 65 and over **who are at risk of falls?** (select all that apply)	None Fixed tint ~80% transmission Fixed tint ~65% transmission Fixed tint ~35% transmission Fixed tint ~25% transmission Photochromic tint Polarising tint Other (please specify)
	d) How do you assess the patient's fall risk?	Freeform answer box
Q11	Q11 applies to you if you chose not confident to assess in Q9 Otherwise skip to the next question	
	a) What is your lens design of choice for your patients / customers aged 65 or over, who you feel **may be at risk of falls?**	Separate single vision distance and near Bifocals Trifocals Varifocals

Appendix 2 (cont.) Prescribing and dispensing survey questions

	b) Which coatings do you regularly recommend for your patients / customers aged 65 or over who you feel **may be at risk of falls?**	None Hard coat Basic AR coat Multiple AR coat Hydrophobic coat Combined MAR, hard and hydrophobic coat Other (please specify)
	c) Which tints do you regularly recommend to those aged 65 and over who you feel **may be at risk of falls?** (select all that apply)	None Fixed tint ~80% transmission Fixed tint ~65% transmission Fixed tint ~35% transmission Fixed tint ~25% transmission Photochromic tint Polarising tint Other (please specify)
Q12	Q12 applies to everyone and is asking about dispensing and prescribing for those aged 65 and over who are a) **not assessed** or b) (confidently or not confidently) **assessed and found not to be at risk of falls.**	
	What is your lens design of choice for those aged 65 or over who are **not assessed** or **not at risk of falls?**	Separate single vision distance and near Bifocals Trifocals Varifocals
Q13	Which coatings do you routinely recommend to those aged 65 and over who are **not assessed** or **not at risk of falls**? (select all that apply)	None Hard coat Basic AR coat Multiple AR coat Hydrophobic coat Combined MAR, hard and hydrophobic coat Other (please specify)
Q14	Which tints do you routinely recommend to those aged 65 and over who are **not assessed** or **not at risk of falls**? (select all that apply)	None Fixed tint ~80% transmission Fixed tint ~65% transmission Fixed tint ~35% transmission Fixed tint ~25% transmission Photochromic tint Polarising tint Other (please specify)

Appendix 2 (cont.) Prescribing and dispensing survey questions

Q15 Would you benefit from any of the following:

	a) Further information about falls generally	Yes / No / Don't know
	b) Further information about visual aspects of falls	Yes / No / Don't know
	c) Practice leaflets about falls generally	Yes / No / Don't know
	d) Practice leaflets about visual aspects of falls	Yes / No / Don't know
	e) A quick and easy falls risk assessment tool for use in practice	Yes / No / Don't know

Q16	You are	Male Female		
Q17	Do you have any supplementary qualifications?	Yes No If so, then which?		
Q18	Which age bracket are you?	Under 20; 21 – 25; 26 – 30; 31 – 35; 36 – 40;	41 – 45; 46 – 50; 51 – 55; 56 – 60; 61 – 65;	over 65.
Q19	If fully qualified, how many years have you been in practice?	1 – 5; 6 – 10; 11 – 15; 16 – 20; 21 – 25;	26 – 30; 31 – 35; 36 – 40; above 40.	
Q20	Are you	Practice owner Employee Self-employed locum Other (please specify)		
Q21	How many days per week do you practise on average? Please use a daily testing time of 7 hours.	Less than 1; 1; 2; 3;	4; 5; 6; 7.	

Appendix 3 Global Measure of Vision (to scale)

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Appendix 4 Ethics Committee Approval Letter Project #694

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Memo

Life and Health Sciences Research Ethics Committee's Decision Letter

To: **Dr Mark Dunne**

Cc: Rachel Giles, administrator to the Life and Health Sciences Research Ethics Committee

From: Dr Corinne M. Spickett

Chair of the Life and Health Sciences Research Ethics Committee

Date: 22/7/2014

Subject: **Project #694: Investigation to examine possible correlations between Useful Field of View test (UFOV) and Attentional Field of View (AFOV)**

Thank you for your submission. The information for the above proposal has been considered by 2 reviewers and the Chair of the LHS Ethics Committee. Please see below for details of the decision and the approved documents.

Reviewer's recommendation: Approved

Please see the tabled list below of approved documents:

Documentation	Version/s	Date	Approved
Participant information sheet and Consent form	ufov_research_participant_information_and_consent_v1	21/7/2014	✓
Protocol	protocol_ufov_afov_v1	21/7/2014	✓
Test material	aarp_reaction_time_scan_v1	21/7/2014	✓
Test material	attentional_field_of_view_test_v1	21/7/2014	✓
Test material	trail_making_test_a_and_b_v1	21/7/2014	✓

NOTE: When printing the consent form, please ensure it is double-sided so that the participant and researcher signatures are on the same sheet.

After starting your research please notify the LHS Research Ethics Committee of any of the following:

> **Substantial amendments.** Any amendment should be sent as a Word document, with the amendment highlighted. The amendment request must be accompanied by all amended documents, e.g. protocols, participant information sheets, consent forms etc. Please include a version number and amended date to the file name of any amended documentation (e.g. "Ethics Application #100 Protocol v2 amended 17/02/12.doc").

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Appendix 5 Ethics Committee Approval Letter Project #680

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Memo

Life and Health Sciences Research Ethics Committee's Decision Letter

To: **Dr Mark Dunne**

Cc: Rachel Giles, administrator to the Life and Health Sciences Research Ethics Committee

From: Dr Corinne M. Spickett

Chair of the Life and Health Sciences Research Ethics Committee

Date: 22/7/2014

Subject: **Project #680*:* Comparison of falls in elderly people with three modes of spectacle lens wear**

Thank you for your resubmission. The additional information for the above proposal has been considered by the Chair of the LHS Ethics Committee.

Please see below for details of the decision and the approved documents.

Reviewer's recommendation: Approved

Please see the tabled list below of approved documents:

Documentation	Version/s	Date	Approved
Participant information sheet and Consent form	ethics_application_680_consent_form_v2_amended_18.07.14	21/7/2014	✓
Clinical protocol	ethics_application_680_clinical_protocol_v2_amended_18.07.14_0	21/7/2014	✓
Risk Assessment	ethics_application_680_risk_assessment_v2_amended_18.06.14	21/7/2014	✓
Amended application	ethics_application_680_word_version_online_application_v2_amended_18.06.14_0	21/7/2014	✓
Test material	attentional_field_of_view_test	21/7/2014	✓
Test material	timed_up_and_go_test	21/7/2014	✓
Questionnaire	sf-12v2_interview_script_standard	21/7/2014	✓
Supporting information	excerpt_linking_aarp_upon_which_the_afov_is_based_to_safe_mobility	21/7/2014	✓
Supporting information	grid_linking_the_tug_sf12_to_falls	21/7/2014	✓

After starting your research please notify the LHS Research Ethics Committee of any of the following:

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Illustration removed for copyright restrictions

Appendix 6 Falls diary

Please record the following information in the diary:

- The date of the fall, slip or trip
- The approximate time (morning, day, night)
- Whether you were indoors, outdoors, or doing a specific activity eg going up or down stairs, on the way to bathroom in the night, shopping etc.
- Whether you were wearing your spectacles at the time of the incident
- To what extent you hurt yourself according to the following categories:

a	serious injury	medically recorded fracture, head or internal injury requiring A&E or inpatient treatment
b	moderate injury	wounds, bruises, sprains, or cuts requiring a medical health professional examination such as physical examination, X-ray, or stitches
c	minor injury	minor bruises or abrasions not requiring health professional assistance, reduction in physical function (eg due to pain, fear of falling) for at least three days
d	no injury	no physical injury detected

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Life & Health Sciences

Falls diary

Name………………………………………

How to complete the diary

If you experience any fall, including a slip or trip in which you lost your balance and landed on the floor, ground or lower level, please record this in your diary. It is important also to note any slips or trips where you did not hurt yourself.

The back page of this booklet explains what to record, and how to categorise any injuries you may have had as a result of your fall.

Date	Time of day	Activity	Wearing specs Yes/No	Level of injury	Any other comments

Appendix 7 List of posters, presentations, other activities and publications

Posters

11.09.2015 **Can an inexpensive paper-based test serve as a surrogate measure of visual factors relating to mobility in community-based studies of elderly populations?**
British Geriatrics Society 16th Falls and Postural Stability Meeting 2015, London.

08.03.2015 **Can an inexpensive paper-based test serve as a surrogate measure of visual factors relating to mobility in community-based studies of elderly populations?**
Optometry Tomorrow 2015 Annual Conference, Brighton.

09.09.2013 **Spectacle lenses and falls: where do we look?**
British Geriatrics Society 14th International Falls and Postural Stability Conference, Bristol.

07.09.2012 **Spectacle lenses and Falls**
Falls and Balance Conference, Wales School for Primary Care Research & Wales Association of Chartered Physiotherapists in Neurology, Cardiff.

Presentations

24.03.2016 **An introduction to Logistic Regression**
Ophthalmic Research Group, Aston University (Appendix 8).

08.09.2016 **The impact of spectacles for presbyopes on mobility and falls**
Essilor University and College Symposium, Tring.

28.04.2015 **Considering vision in falls prevention**
Joint presenter with Suzy England, Occupational Therapist,Thomas Pocklington Trust,College of Occupational Therapists' CET Conference, Naidex, Birmingham.

24.01.2014 **Falls: the background story**
Ophthalmic Research Group, Aston University.

21.10.2013 **Spectacle lenses and Falls**
Royal National Institute of Blind People Research Day 2013, London.

26.06.2013 **Provision of optical correction to elderly people at risk of falls**
Life and Health Sciences Postgraduate Research Day, Aston University.
Awarded First Prize in Research Talk Category.

Appendix 7 (cont.)

25.04.2013 **Spectacle lenses and Falls**
Ageing Research Forum (Joint Aston Research Centre for Healthy Ageing & Keele University Ageing Initiative), Aston University.

30.09.2012 **Avoiding slips and trips in our elderly patients**
Association of British Dispensing Opticians' 2012 CET Conference and Exhibition, Stratford.

Other activities

14.06.2015 **Think sight with falls and older people**
Invited review of College of Occupational Therapists' e-module and supporting facilitation notes.

12.09.2013 **Falls and Varifocals – an open discussion**
Invited Chair, Essilor University and College Symposium, Stratford.

Publications

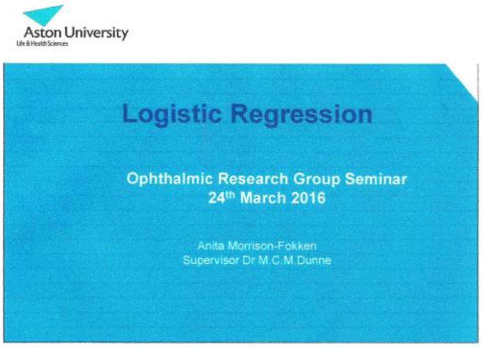
June 2016 **Falls information for the domiciliary practitioner**
Online CET article commissioned by Clearview Training for The Outside Clinic (Appendix 9).

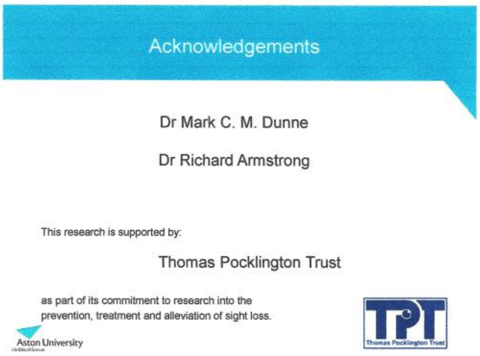
June 2014 **Fall risk assessment in optometric practice: an introduction to non-visual and visual risk factors**
Optometry in Practice, Vol15, Issue 2, 39-48 (Appendix 10).

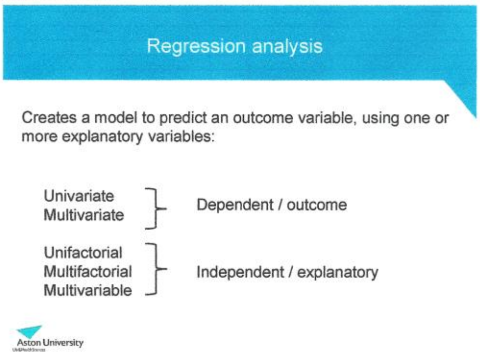
July 2012 **Avoiding slips and trips in our elderly patients**
Additional Learning Material with MCQs as supplement to 2012 ABDO Conference Presentation (Appendix 11).

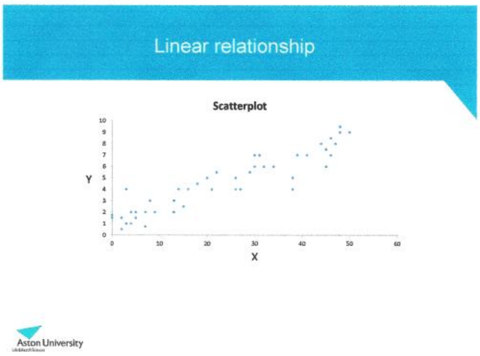
Appendix 8 An introduction to Logistic Regression

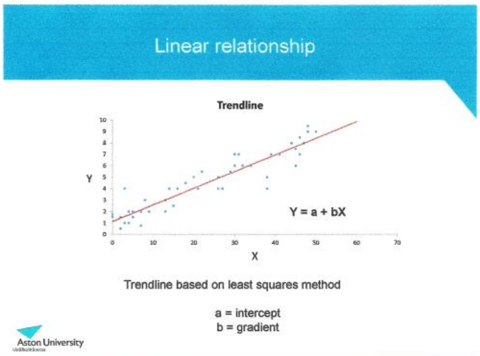
Presentation to Ophthalmic Research Group, Aston University, March 2016.

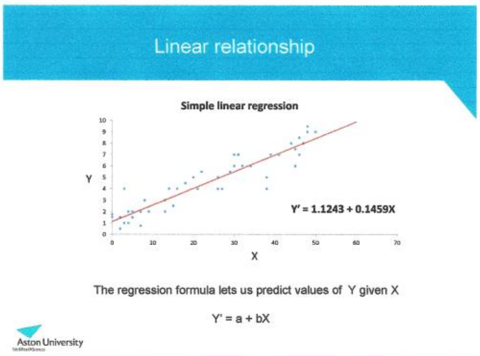


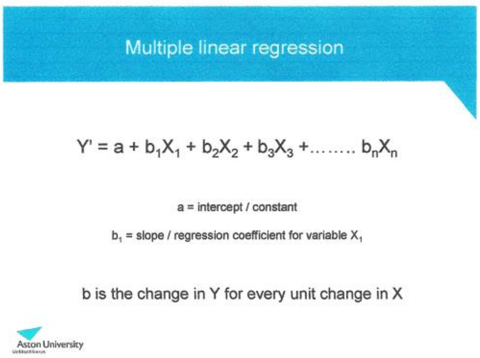


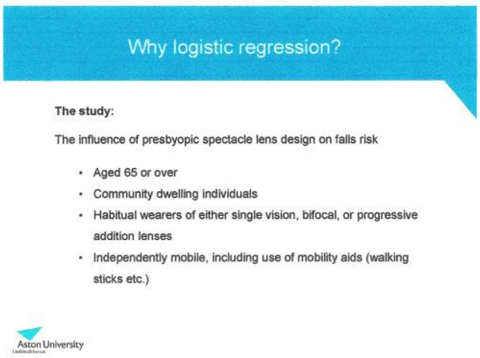












Appendix 8 (cont.)

Why logistic regression ?

Independent variables

- Age
- Gender
- SF12 (physical and mental health questionnaire)
- Global measure of vision (GMV)
- Timed Up and Go (TUG)
- Worn lens design

Dependent variable

- Falls v No Falls

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Logistic regression

A regression model for a dichotomous or binary outcome, where the two outcomes are **mutually exclusive**.

Y can only have one of two values:

0 = non-event (No fall)

1 = event (Fall)

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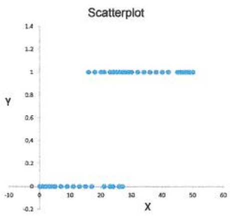
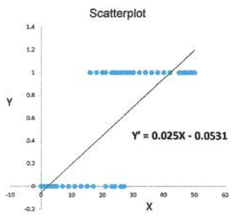
Logistic regression



Aston University

Logistic regression



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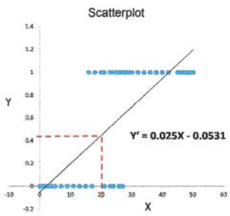
Logistic regression



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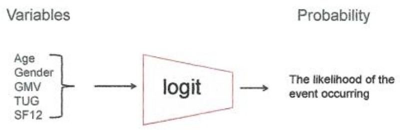
The logit



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Probability and Odds

$$\text{Probability (a)} = \frac{\text{odds}}{1 + \text{odds}} \qquad \frac{\text{number of outcomes corresponding to event (a)}}{\text{total number of outcomes}}$$

$$\text{Odds (a)} = \frac{p}{1 - p} \qquad \frac{\text{number of ways event (a) can occur}}{\text{number of ways event (a) fails to occur}}$$

Logit = ln (odds)

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Probability, Odds and Logit

Probability p	**Odds** p / (1-p)	**Logit** ln (odds)
0.01	0.01	-4.60
0.05	0.05	-2.94
0.1	0.11	-2.20
0.2	0.25	-1.39
0.3	0.43	-0.85
0.4	0.67	-0.41
0.5	1.00	0.00
0.6	1.50	0.41
0.7	2.33	0.85
0.8	4.00	1.39
0.9	9.00	2.20
0.95	19.00	2.94
0.99	99.00	4.60

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Appendix 8 (cont.)

Why logistic regression ?

Independent variables

- Age
- Gender
- SF12 (physical and mental health questionnaire)
- Global measure of vision (GMV)
- Timed Up and Go (TUG)
- Worn lens design

Dependent variable

- Falls v No Falls

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Logistic regression

A regression model for a dichotomous or binary outcome, where the two outcomes are **mutually exclusive**.

Y can only have one of two values:

0 = non-event (No fall)

1 = event (Fall)

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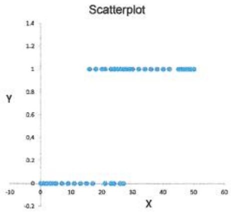
Logistic regression

Scatterplot



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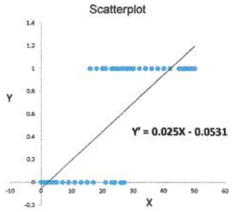
Logistic regression

Scatterplot



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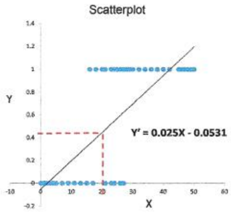
Logistic regression

Scatterplot



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The logit

Variables — Probability

Age, Gender, GMV, TUG, SF12 → logit → The likelihood of the event occurring

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Probability and Odds

$$\text{Probability (a)} = \frac{\text{odds}}{1 + \text{odds}} \qquad \frac{\text{number of outcomes corresponding to event (a)}}{\text{total number of outcomes}}$$

$$\text{Odds (a)} = \frac{p}{1 - p} \qquad \frac{\text{number of ways event (a) can occur}}{\text{number of ways event (a) fails to occur}}$$

$$\text{Logit} = \ln(\text{odds})$$

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Probability, Odds and Logit

Probability p	Odds p / (1-p)	Logit ln (odds)
0.01	0.01	-4.60
0.05	0.05	-2.94
0.1	0.11	-2.20
0.2	0.25	-1.39
0.3	0.43	-0.85
0.4	0.67	-0.41
0.5	1.00	0.00
0.6	1.50	0.41
0.7	2.33	0.85
0.8	4.00	1.39
0.9	9.00	2.20
0.95	19.00	2.94
0.99	99.00	4.60

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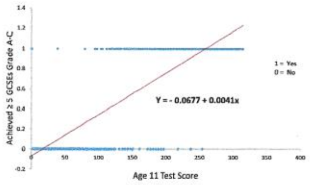
Appendix 8 (cont.)

Dichotomous outcome scatterplot

Relationship between Age 11 Test score and achieving ≥ 5 GCSEs Grade A-C



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Standardised form

Transformation of the IV and DV to standardised variables:

Mean = 0; SD = 1

$$z'_y = \beta_1 z_x$$

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Calculating proportion of students achieving ≥ 5 GCSEs Grade A-C

Standardised Age 11 score	5 or more GCSE A*-C incl. English & maths		Total	Proportion (Probability)
	0 no	1 yes		Yes / Total
-2.4	208	1	209	0.0048
-2.2	11	0	11	0.0000
-2.1	58	0	58	0.0000
-2	76	1	77	0.0130
-1.9	91	0	91	0.0000
-1.8	105	0	105	0.0000
-1.7	135	1	136	0.0074
-1.6	155	0	155	0.0000
-1.5	158	2	160	0.0125
-1.4	209	3	212	0.0142
-1.3	227	6	233	0.0258

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Calculating proportion of pupils achieving ≥ 5 GCSEs Grade A-C

Standardised Age 11 score	5 or more GCSE A*-C incl. English & maths		Total	Proportion (Probability)
	0 no	1 yes		Yes / Total
-2.4	208	1	209	0.0048
-2.2	11	0	11	0.0000
-2.1	58	0	58	0.0000
-2	76	1	77	0.0130
-1.9	91	0	91	0.0000
-1.8	105	0	105	0.0000
-1.7	135	1	136	0.0074
-1.6	155	0	155	0.0000
-1.5	158	2	160	0.0125
-1.4	209	3	212	0.0142
-1.3	227	6	233	0.0258

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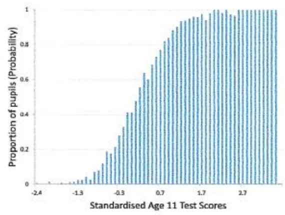
Proportion (Probability) of pupils achieving ≥ 5 GCSEs Grade A-C



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Calculating log odds of pupils achieving ≥ 5 GCSEs Grad A-C

Standardised Age 11 score	5 or more GCSE A*-C incl. English & maths		Total	Proportion (Probability)
	0 no	1 yes		Yes / Total
-2.4	208	1	209	0.0048
-2.2	11	0	11	0.0000
-2.1	58	0	58	0.0000
-2	76	1	77	0.0130
-1.9	91	0	91	0.0000
-1.8	105	0	105	0.0000
-1.7	135	1	136	0.0074
-1.6	155	0	155	0.0000
-1.5	158	2	160	0.0125
-1.4	209	3	212	0.0142
-1.3	227	6	233	0.0258

$$\text{Logit} = \ln(\text{odds}) = \ln\left(\frac{p}{1-p}\right) = \ln\left(\frac{0.0130}{1-0.0130}\right) = -4.33$$

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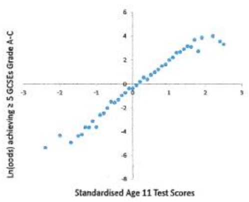
Ln transformation of Y axis

Ln (odds) pupils achieving ≥ 5 GCSEs Grade A-C



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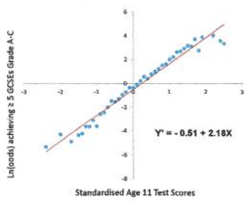
Regression equation

Ln (odds) pupils achieving ≥ 5 GCSEs Grade A-C



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Appendix 8 (cont.)

Logit equation

$$\text{Logit}(Y) = a + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots\ldots\ \beta_n X_n$$

a = intercept / constant

β_1 = slope / regression coefficient for variable X_1

β is the change in ln(odds) for each unit change in X

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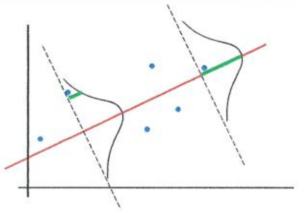
Maximum Likelihood Estimation



MLE maximises the log likelihood of getting the observed results given the fitted regression coefficients

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The logit equation

$$\text{Logit}(Y) = a + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots\ldots\ \beta_n X_n$$

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Equation interpretation

Logit $= a + \beta X$

Ln (odds) $= a + \beta X$

odds $= e^{a + \beta X}$

p/(1-p) $= e^{a + \beta X}$

Logistic regression equation: p $= e^{a + \beta X} / 1 + e^{a + \beta X}$

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Equation interpretation

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	age	.040	.030	1.870	1	.171	1.041
	gender(1)	.473	.364	1.688	1	.194	1.604
	Constant	-3.696	2.302	2.578	1	.108	.025

a. Variable(s) entered on step 1: age, gender.

$$\text{Logit} = \ln(\text{odds}) = a + \beta_1 X_1 + \beta_2 X_2$$
$$= -3.696 + 0.040\text{age} + 0.473\text{gender}$$

A one unit increase in age has a .040 increase in the ln(odds) of a fall

A one unit increase in age increases the odds of a fall by a factor of 1.041

A one unit increase in age increases the odds of a fall by 4.1%

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Classification table

Classification Table[a,b]

Observed			Predicted Faller N	Predicted Faller Y	Percentage Correct
Step 0	Faller	N	78	0	100.0
		Y	54	0	.0
	Overall Percentage				59.1

a. Constant is included in the model.

b. The cut value is .500

How good is the model without any regressors?

Baseline model with no IVs would predict correctly in 59.1% of cases.

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Have we improved the model?

Classification Table[a]

Observed			Predicted Faller N	Predicted Faller Y	Percentage Correct
Step 1	Faller	N	69	9	88.5
		Y	42	12	22.2
	Overall Percentage				61.4

a. The cut value is .500

Percentage correct after using age and gender as regressors is now 61.4%

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Omnibus Tests of Model Coefficients

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	3.164	2	.206
	Block	3.164	2	.206
	Model	3.164	2	.206

How well does the model perform over and above Block 0?

Not significant as > 0.05

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Appendix 8 (cont.)

-2LL Deviance statistic

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	175.402[a]	.024	.032

a. Estimation terminated at iteration number 3 because parameter estimates changed by less than .001.

-2LL = unexplained variance

Pseudo R^2 = ~ explained variance

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Hosmer and Lemeshow

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	7.392	8	.495

Is the model an adequate fit to the data?

Poor fit if $p < .05$

Good fit if $p > .05$

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Assumptions and violations

Non-logistic	Logistic (binary)
Continuous DV	Dichotomous DV (mutually exclusive)
Normal distribution	(Normal distribution desirable)
Linear relationship between each IV and DV	Linear relationship between IVs and DV ln(odds)
Independent errors	Independent errors
Homoscedasticity required	Homoscedasticity not required
No multicollinearity	No multicollinearity
No significant outliers	Not applicable
Normally distributed residuals	Normally distributed residuals not required

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Comparisons

	Non-logistic	Logistic (binary)
Regression coefficients (b)	Increase in Y for one unit increase in X	Increase in Y log odds for one unit increase in X
Deviation from the regression	Residual sum of squares	-2LL statistic
Correlation coefficient	R	(Point Biserial Correlation)
Coefficient of determination	R^2	Pseudo R^2 Nagelkerke's R^2
Importance of explanatory variable	t-test	Wald statistic
Goodness of fit	ANOVA	-2LL reduction

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Recap

- Regression
  - Modelling, prediction, hypothesis testing
- Logistic Regression (Binary)
  - Dichotomous outcome variable
- Independent variables
  - Continuous and/or categorical
- Uses ln(odds) transformation
- Predicts odds of DV occurring

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Resources

- Research Methods Module Dunne & Armstrong
- The use of data analysis methods Armstrong & Eperjesi OT 2000 – 2010
- National Centre for Research Methods www.restore.ac.uk
- Statistics 101 Brandon Foltz www.youtube.com/watch?v=zAULhNrnuL4
- Khan Academy www.khanacademy.org/math/probability/regression

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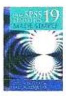
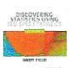
Resources

SPSS Survival Manual
Julie Pallant



IBM SPSS 19 Statistics made simple
Colin D. Gray & Paul R. Kinnear



Discovering Statistics using IBM SPSS Statistics
Andy P. Field

Using Multivariate Statistics
Barbara G. Tabachnick & Linda S. Fidell

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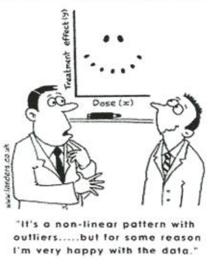
Thank you



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Appendix 9 Falls information for the domiciliary practitioner

Online CET article commissioned by Clearview Training for The Outside Clinic, June 2016.

Continuing Education & Training — C xxxxx (O/D) 1 CET point (General)

Falls information for the domiciliary practitioner

Anita Morrison-Fokken

TheOutsideClinic
Home Optician & Hearing Specialist

Anita Morrison-Fokken's research at Aston University is supported by Thomas Pocklington Trust as part of its commitment to research into the prevention, treatment and alleviation of sight loss.

Introduction

Maintenance of independence is of major concern to many of our frailer, community-dwelling elderly population. The ability to continue living in one's own home can be jeopardised by age-related physical and cognitive changes, which also increase the risk of sustaining an injurious fall. The results of falls can have a significant impact on both quality of life for the individual, and the health economy of the nation.

Primary eye care providers, particularly those offering domiciliary services, are uniquely placed to identify those who have fallen, or who may be at risk of falling. This article provides an overview of environmental and health-related causes of falls, discusses visual and spectacle lens aspects of falls risk, and directs the practitioner to helpful sites both for themselves, and for their patients.

What is a fall?

There are many different definitions of a fall being used in the literature, which can lead to some confusion when interpreting study results. Some articles only focus on injurious falls, or indeed specific types of falls injury, such as hip fractures. The American Geriatrics Society and the British Geriatrics Society define a fall as "an event whereby an individual unexpectedly comes to rest on the ground or another lower level without known loss of consciousness"[1]. This is a more concise version of the definition used in 1987 by the Kellogg International Working Group of "unintentionally coming to the ground or some lower level and other than as a consequence of sustaining a violent blow, loss of consciousness, sudden onset of paralysis as in a stroke or an epileptic seizure"[2].

The Prevention of Falls Network Europe (ProFaNE) Consensus group found some patients were reluctant to admit to falls, with phrases such as "slips" or "trips" often being used instead. This could be driven by the concern that the admission of having had a fall may threaten their independent living status. ProFaNE suggests that health professionals should ask *"Have you had any fall including a slip or trip in which you lost your balance and landed on the floor or ground or lower level?"* [3]. The National Institute for Health and Care Excellence (NICE) recommends that older people in contact with health professionals should be asked routinely whether they have fallen in the past year[4]. Judicious use of open and closed questions, coupled with awareness of verbal and non-verbal cues, will aid a comprehensive history-taking.

A standardised system for defining fall-related injuries has also been suggested by Schwenk et al., which optometrists may find useful[5] (Table 1).

Environmental falls risk factors

Falls are generally considered to be multifactorial, with a wide range of environmental (extrinsic) and individual (intrinsic) risk factors (Tables 2a,2b). Furthermore, certain behaviours such as multi-tasking, drinking alcohol, rushing, carrying large objects or overstretching can all contribute to falls risk. The fear of falling itself is considered a risk factor as it may lead to a reduction or modification of activity

Appendix 9 (cont.)

Category	Definition
a – serious injury	Medically recorded fracture, head or internal injury requiring accident and emergency or inpatient treatment
b – moderate injury	Wounds, bruises, sprains, cuts requiring a medical/health professional examination such as physical examination, x-ray, suture
c – minor injury	Minor bruises or abrasions not requiring health professional assistance, reduction in physical function (eg due to pain, fear of falling) for at least three days
d – no injury	No physical injury detected

Table 1: Standardised system for categorising and defining fall-related injuries (Schwenk et al).

levels, which can result in deconditioning of muscle tone, increased social isolation and depression[6].

A home hazard assessment can identify extrinsic risk factors, such as loose rugs or trailing wires, and propose appropriate amendments. Most local authorities have falls prevention teams staffed by occupational therapists, physiotherapists, nurse assessors or rehabilitation workers. Often there is an open referral system, so the concerned optometrist can refer directly to the team. Optometrists should make themselves aware of their local falls prevention teams and their specific referral criteria. A quick online search will identify community falls teams. For hospital-based services, NHS choices (www.nhs.uk) provides a "find falls services" search function according to location.

The Health Design and Technology Institute (HDTI) at Coventry University has developed a Fallcheck App that works on all mobile devices and via the web. The app guides you through locations in the house where falls risk factors may be present, and provides information on appropriate solutions. A checklist of "to do" items can be created. Your patients or their carers may find this a valuable resource. It can be downloaded free of charge from: https://cale.coventry.ac.uk/fallcheck/.

Lighting

Appropriate lighting is a particular example of an environmental factor that the visiting optometrist should be able to advise on. Only about one third of the light that reaches the retina of a 20 year old falls on the retina of a 60 year old[7]. In addition, older adults require significantly more time to recover light sensitivity in the dark than younger adults[8]. Suitable task lighting enhances reading ability, but we should also be aware that changes in lighting levels - from one room to the hallway, for example - can be a falls risk factor and should be avoided whenever possible. Stairways are often poorly lit and have unsuitable, highly patterned carpets that obscure step edges, which is especially dangerous when descending stairs (Image 1).

Older design energy saving compact fluorescent lightbulbs (CFLs) presented problems with slow onset to full brightness, but newer designs are available that have a

Table 2a: Examples of extrinsic falls risk factors

Extrinsic Falls Risk Factors
Poor lighting / change in lighting levels from room to room
Loose or frayed rugs and carpets
Patterned carpets obscuring stair edges
Trailing wires or bedcovers
Wet or slippery surfaces
Pets underfoot
Cold environment
Footwear (Unsuitable or lacking)

Table 2b: Examples of intrinsic falls risk factors

Intrinsic Falls Risk Factors
Cognitive impairment / dementia
Continence problems
Balance / gait disorders
Dual sensory loss
Polypharmacy
Orthostatic hypotension
Visual impairment
Depression
Parkinson's disease
Stroke
Diabetes
Arthritis
Osteoporosis

2

Appendix 9 (cont.)

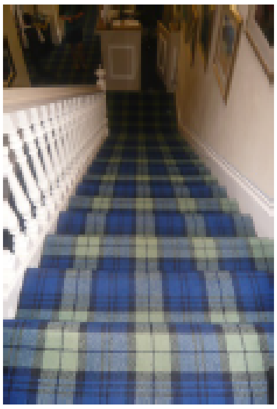

Image 1: Patterned carpet obscuring stair edges

"quick start" function. The Research Institute for Consumer Affairs (rica) and the RNIB in conjunction with the Thomas Pocklington Trust have helpful guides to the different types of bulbs available, and how to improve lighting within the home. These are available to download from:

- www.rica.org.uk/content/energy-saving-light-bulbs
- http://pocklington-trust.org.uk/wp-content/uploads/2016/04/Improve-the-lighting-in-your-home.pdf

Glare recovery time is also prolonged with increasing age [9]. This is important not only for the design of lighting, ensuring the bulb is sufficiently covered, but thought should also be given to the placement of ophthalmoscopy within the full eye examination.

Intrinsic falls risk factors

Intrinsic falls risk factors can be considered those related to general health conditions. Whilst balance or gait disorders as a result of a stroke, Parkinson's disease, diabetic-related peripheral neuropathy, or arthritis are readily identifiable, there is a wide range of more subtle factors.

It is beyond the scope of this article to discuss all intrinsic factors in detail, but the visiting optometrist should be aware of the implications of cognitive decline and multiple medication usage, which have both been recognised as key risk factors[10]. Falls odds ratio has been found to be 2.5 times greater in those with a cognitive impairment. This in turn compounds physiological impairments, thereby increasing the risk of multiple falls[11,12].

Medications can have unwanted side-effects which may also increase falls risk. The greater the number of drugs taken, the greater the risk of falling. There is no clear advice on which number of medications can be considered as a cut-off point for increased falls risk, although ≥ 4 is frequently quoted[13]. Benzodiazepines, antidepressants, antipsychotics, antiepileptics, anticholinergics, sedative hypnotics, muscle relaxants and cardiovascular medications are all frequently associated with falls[14]. If you identify that your patient is taking four or more different medications, it is wise to check that they are having a regular medication review with their GP.

Vision and Balance

Maintaining balance is a complex process, achieved using sensory information from three mechanisms: visual, vestibular, and somatosensory. The somatosensory system includes sensations of touch and pressure, the sense of body position (proprioception) and body movement, coordinated by the cerebellum. The balance organs in the vestibular system activate the vestibulo-ocular reflex (VOR), which utilises compensatory eye movements to stabilise the image on the retina during head movements. Reduced visual input may reduce this reflex [15], and those with a visual impairment are reported to rely more heavily on senses of touch and pressure, as well as vestibular senses, to enable them to detect body position and maintain stability[16]. Vision and hearing loss combined (dual sensory impairment) further increase falls risk.

Vision and Falls

Improving vision as a stand-alone falls reduction strategy has not been found to be effective[17], but should form part of a multifactorial intervention programme[4]. A systematic review and meta-analysis of falls risk factors in community-dwelling older adults found the six strongest associations for falls were: a previous falls history, gait problems, walking aid use, vertigo, Parkinson disease and anti-epileptic drug use. "Vision problems" accounted for a 1.6 increase in risk in recurrent fallers[18].

Elsewhere, visual impairment is reported to approximately double falls risk, with the level of risk increasing as visual function deteriorates[19]. The specific types of visual impairment contributing to falls risk have been found to include reduced visual acuity, reduced contrast sensitivity, visual field defects (both central and peripheral) and binocularity. It is difficult to assign falls risk to any one stand-alone visual factor, as an intertwined role of attributes is commonplace: cataracts reduce both visual acuity and contrast sensitivity; age-related macular degeneration reduces central fields, central visual acuity and contrast sensitivity; binocularity can be affected by unilateral eye disease, or unilateral interventions that affect refractive outcome, such as cataract surgery.

Cataract surgery

There are conflicting research findings with regard to falls risk reduction and surgical intervention for cataracts. A recent study found a reduction in dizziness, but not falls[20]. A longitudinal study of participants found no difference in falls risk ratio between those who had surgery, and those who did not[21], whereas another study found it to be an effective intervention[22]. Yet another found an association with increased hospital admissions from fall injuries in the year following first eye cataract surgery[23].

A particular issue of concern is anisometropia after unilateral surgery, and its effects on depth perception, which is critical in determining accurate information about the environment and obstacles within it[24]. If the patient is unable to tolerate spectacle correction of the surgical outcome, the optometrist is faced with a challenging scenario. Contact lenses may not be a practical solution, and prescribing a balance lens for the non-operated eye may also cause disorientation.

It has been recommended to partially prescribe large refractive changes, using a maximum change of 0.75D, and to warn patients of spectacle lens magnification (SLM) changes, which can affect safe negotiation of stairs[25,26]. SLM changes are a combination of power and shape factors (Equations 1 and 2), so consideration should also be given to changes in refractive index, especially when dispensing high power lenses.

Power factor $= PF = \frac{1}{1-(dF_v)}$ Equation 1

Shape factor $= SF = \frac{1}{1-\left(\frac{t}{n}\right)F_1}$ Equation 2

The best scenario here is prevention, rather than cure. A good rapport with your local eye clinic should inform you about their usual practices, and whether emmetropia is the target outcome. Not all myopic patients, who have been accustomed to reading unaided, may appreciate having to adapt to being post-operatively emmetropic at distance (with its associated SLM changes), and to now be in need of reading spectacles. Should you have a frail, significantly ametropic patient who may not be able to proceed to second eye surgery within a short timeframe, it would be prudent to discuss possible refractive outcomes of the surgery, so they can make informed choices.

Prescribing for the at-risk patient

The North London Eye Study found that nearly three quarters of its study population had a visual impairment that was potentially remediable, either through surgery or spectacles[27]. However, updating spectacles to improve visual acuity might not be the instant solution one would expect, with a 2007 study by Cumming finding contradicting evidence[17]. Furthermore, bifocal and Progressive Addition lenses (PALs) have been implicated in increasing falls risk in a range of studies, particularly those looking at safe stair negotiation. We could be forgiven for being confused as to the best way forward.

So what issues have been highlighted with regard to bifocals and PALs and falls? Whilst the current BS EN ISO 13666:2012[28] differentiates between multifocal (bifocal and trifocal) and PALs (Table 3), the term "multifocal" has often been used in research reports to include PALs, which are, of course, optically very different. Caution is, therefore, urged when interpreting research findings.

It is generally accepted that, when walking, an individual fixates about 2 walking steps ahead of their current position[29]. Many studies assume that the patient is looking through the near portion of the lens when walking, giving rise to a level of blur in the lower visual field, but to the author's knowledge no study has been carried out that investigates whether this is in fact the case. Whilst blur affects postural stability[30], it is spectacle lens magnification that drives step negotiation changes[26,31]. Reported reduction in edge contrast sensitivity also relates to using lenses in the above manner, i.e. looking through the near portion whilst fixating about 2 steps ahead[32].

Limitations in mobility are commonplace in the domiciliary patient. Gait adaptations as a result of physical changes such as kyphosis (commonly referred to as "dowager's hump") or use of walking aids may mean that the target viewing distance and the level of adopted head pitch may differ from that in a more mobile population. Furthermore, head extension, i.e. tipping the head backwards in relation to the torso, particularly when leaning forward, impairs postural control more than flexing the head forward[33]. Particular care should, therefore, be given to the fitting heights of bifocal and Progressive Addition lenses.

Changing elderly habituated lens wearers to a different lens design is generally avoided in practice. Having to cope with two separate pairs of spectacles brings its own set of challenges; confusion about which pair of spectacles to wear for which task arises, and the correct pair is not always to hand. Walking in single vision reading lenses would give rise to the same amount of blur attributed to looking through near zones of bifocal or PAL lenses.

Interestingly, a study investigating postural stability and gait characteristics in patients with age-related macular degeneration (AMD) found no difference in outcome measures according to lens design (32% bifocal, 25% PAL, 4%

Appendix 9 (cont.)

Lens type	Definition
multifocal lens	lens designed to provide two or more visibly divided portions of different focal powers
bifocal lens	multifocal lens having two portions, usually for distance and near vision
trifocal lens	multifocal lens having three portions, usually for distance, intermediate and near vision
progressive power lens	lens with at least one progressive surface that provides increasing (positive) addition power as the wearer looks down
progressive surface	surface, which is non-rotationally symmetrical, with a continuous change of curvature over part or all of the surface, generally intended to provide increasing addition or degression power

Table 3: Spectacle lens nomenclature (adapted from BS-EN ISO 13666:2012)

trifocal and 5% single vision wearers)[34].

One study that provided participants with a separate pair of single vision spectacles for outdoor use warrants our particular attention[35]. It was found that those who were less active had a significant increase in outdoor falls with this intervention. They recommended older, habitual "multifocal" wearers who undertake little outdoor activity should continue with their "multifocal" lenses for most activities. For the domiciliary service provider this would lend support to not changing well-adapted bifocal or PAL domiciliary patients into single vision lenses. Insufficient evidence was found whether bifocals or PALs were preferable.

Conclusion

Domiciliary optometrists can play an important role in falls prevention by identifying patients who may benefit from a falls risk assessment. The practitioner needs be aware that falls have many causes, and that improving vision should form part of a multifactorial falls prevention approach. Being aware of the locally available falls teams and their referral criteria will enable effective signposting to other agencies. Whilst it is beyond the remit of visiting optometrists to carry out comprehensive home hazard assessments, they should be able to advise on appropriate lighting and visual aspects of falls. Any unilateral or bilateral vision loss can contribute to an increased falls risk, yet surgical solutions may give rise to problems as a result of large changes in refractive error. In habitual bifocal or PAL wearers with low levels of outdoor activity, change of lens design was not recommended. For the practitioner, therefore, there is no "one size fits all" solution and measured clinical judgment should be applied with conservative prescribing practices.

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Appendix 9 (cont.)

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Appendix 9 (cont.)

To Access the Test Online:

- Follow the links online to the test page.
- You will be prompted to enter your current GOC registration number (in the format 01-12345 or D-1234) to access the test.

When taking the test:

- There is no time limit to complete each test
- You may save the test at any point to return to later
- You may only take the test up to two times.
- If more than one practitioner accesses the test on the same computer please ensure cookies are disabled
- The answers to each question will appear in *random order*, so if you have prepared the answers in advance then please check that you are entering your responses correctly.
- Once you complete the test, you will be able to see your score, the questions you got wrong and the correct answers.
- Your CET points will be uploaded to your account at the end of each quarter.

Your Feedback

We hope that you enjoy the CET we have produced for you and would welcome any feedback

Troubleshooting

If you are unable to login, or have any other questions regarding the CET then please contact us.

Multiple Choice Questions

1. **Which of the following are *not* considered to be intrinsic falls risk factors?**

   A. Poor fitting slippers
   B. A history of anxiety
   C. Reduced acuity in one eye only
   D. Low blood pressure when standing up from a sitting position

2. **Which of the following lighting advice is *appropriate* in an elderly person's home?**

   A. Avoid direct lighting for a near task in a darkened room
   B. Return to old-style incandescent light bulbs which are easier to control with dimmer switches
   C. When moving from hallway to bathroom a slow onset CFL bulb is advisable to avoid glare
   D. An elderly person needs a central living room light three times brighter than a 20-year-old person.

3. **What has been found to be an effective falls risk reduction strategy?**

   A. Prescribing for best possible visual acuity, especially if large changes in refractive error are found
   B. A home hazard assessment as part of a multifactorial intervention programme
   C. Not referring for unilateral cataract surgery
   D. Issuing advice leaflets

4. **Which of the following is *not* considered a visual risk factor for falls?**

   A. Anisometropia
   B. Visual field loss
   C. Recent cataract surgery
   D. Kyphosis

5. **When prescribing spectacles for a patient who has an increased risk of falls due to visual impairment, which of the following should *normally* be avoided:**

   A. Changing the prescription by +/- 0.50D sphere
   B. Changing a housebound patient who has habitually worn PAL's to two separate pairs of spectacles
   C. Prescribing single-vision reading prescription for a bed-bound patient
   D. All of the above should be avoided.

6. **Which of the following statements is *true*?**

   A. Geometric pattered carpets obscure stair edges more than dark coloured carpets.
   B. Optometrists must refer patients through the patient's GP to a local falls team when indicated.
   C. Spectacle lens magnification changes after cataract surgery can affect safe negotiation of stairs.
   D. Studies have shown that many elderly patients look through the near portion of their bifocal when walking.

Appendix 10 Fall risk assessment in optometric practice: an introduction to non-visual and visual risk factors

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Falls risk assessment in optometric practice: an introduction to non-visual and visual risk factors

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EV-20120 C-36683

1 CET point for UK optometrists

Introduction

To understand the roles of vision and spectacle lens design in falls risk, it is helpful to have an appreciation of the multifactorial nature of falls. This review defines a fall, highlights the demographic and socioeconomic drives for falls reduction strategies and identifies a range of visual and non-visual falls risk factors. The role of spectacle lens design (single-vision, bifocal or progressive addition lenses) is complex and is outside the remit of this review.

Optical professionals provide a front-line contact with the elderly and are well placed to offer timely advice with regard to falls risk, particularly by identifying those with a change or reduction in vision.

Lord et al. (2007) emphasise that, although falls are generally thought to be accidents, they are not 'random events'. This means that causative factors – often classified as intrinsic or extrinsic – can be identified and either reduced or eliminated. In terms of vision, a disease process leading to a visual impairment is an intrinsic factor, whereas spectacle lenses to correct a refractive error are extrinsic. Because extrinsic factors are easier to amend or adapt, it is vital that the optical correction choices offered to our elderly patients at risk of fall are based on sound findings. This is becoming ever more important with the changing demographic of the UK population, specifically the change in the ratio of old to young. The Office for National Statistics (ONS) reports that, whereas in 2010 there were 0.6 million more people of pensionable age than children aged under 16, this figure is projected to reach over 2.6 million by 2035 (ONS 2012).

Falls have a significant impact not only on the initial cost of medical care, but also on enduring social care costs. NHS care for hip fractures – the main cause of which is falls in the elderly – costs about £1.7 billion per year. When considering the additional cost of subsequent social care, a figure of £2.3 billion per year is quoted (National Osteoporosis Society (NOS) 2014). It is important to remember that there are not only financial cost implications. The quality of life of fallers can also be severely affected by loss of independence and fear of falling again. This in turn can lead to reduction of activity levels with associated social isolation and resultant depression (Peel 2011). The number of admission episodes for falls increases in the 60–79-year age group, and peaks in the over-80s, with females accounting for more admissions than males.

Fall definitions

The American Geriatrics Society (AGS) and the British Geriatric Society (BGS) define a fall as 'an event whereby an individual unexpectedly comes to rest on the ground or another lower level without known loss of consciousness' (AGS/BGS 2011). This is a more concise version of the definition used in 1987 by the Kellogg International Working Group.

The Prevention of Falls Network Europe (PROFANE) Consensus group recommended that a fall should be defined as 'an unexpected event in which the participants come to rest on the ground, floor or lower level' (Lamb et al. 2005).

One of the difficulties when comparing studies is the application of different fall definitions. Some studies also restrict their finding to injurious falls only.

Non-visual falls risk factors

Lord et al. (2007) identified four non-visual key risk factors: dementia, depression, multiple medications and inappropriate footwear. The National Institute for Health and Care Excellence (NICE) Clinical Guideline 161 (NICE 2013) states that a multifactorial risk assessment should be carried out for all inpatients at risk of falling, and should include:

- falls history (causes and consequences)
- cognitive impairment
- continence problems
- footwear (unsuitable or missing)
- health problems
- postural instability, mobility problems and/or balance problems
- medication
- syncope syndrome (fainting)

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(Visual impairment was added to these recommendations in 2013, and is addressed in the section on visual aspects of falls, below.)

Falls history, cognitive impairment and continence problems

Previous falls history increases risk of further falls (Cummings et al. 1995; Lord et al. 2007; Pluijm et al. 2006). A recent study of 9592 subjects used a tree-based logistical regression method to identify predictors of falls. The results showed that risk factors for falls varied between non-fallers and those who had already experienced a fall, indicating the need for differently structured falls risk prevention programmes according to falls history (Yamashita et al. 2012).

The same study also identified that those with a cognitive impairment had a falls odds ratio 2.3 times that of those with no impairment. A greater risk of multiple falls was also found, as cognitive impairment compounds physiological impairments (Martin et al. 2013).

Poor urinary control has been reported to increase falls risk, especially with regard to night visits to the toilet. Consolidated data from a systematic review of urinary continence found urge incontinence (the sudden need to urinate) was associated with a falls odds ratio of 1.54 (Chiarelli et al. 2009).

Those who suffer from urge or stress incontinence may reduce fluid intake to help control symptoms. Dehydration, however, is known to increase confusion and disorientation in the elderly (Begum and Johnson 2010) and there have been accounts of fall reduction when increased drinking of water was encouraged in a residential home setting (Cawley 2008).

Footwear and foot care

Appropriate footwear can play an important role in falls prevention. Comfortable slippers or shoes may not provide enough support for stability. Menant and colleagues (2008) describe recommended shoe features as a slip-resistant sole, a supported heel collar and a thin firm midsole.

Rheumatoid arthritis, bunions, claw toes and lack of toenail care can also lead to discomfort and instability when walking.

Health problems

Any general health issues that affect mobility or balance can impact on falls risk. The conditions implicated are extensive, and include Parkinson's disease, dementia, stroke, dual sensory loss, arthritis, diabetes and visual impairment. Medications used to treat disease processes can also disturb patients' stability and cognitive awareness. Osteoporosis or poor bone health can exacerbate the injurious effects of a fall.

Balance

An intact balance system is key to stability and reduced falls risk. Balance is driven by three sensory mechanisms: visual, vestibular and somatosensory. The somatosensory system includes sensations of touch and pressure, the sense of body position (proprioception) and body movement. Disruption of one or more of these sensory mechanisms disrupts balance and can lead to falls.

Balance can be affected by age-related difficulties in walking and mobility as well as certain pathologies, such as stroke or Parkinson's disease. The inability to walk and talk simultaneously has been identified as an indicator of a disturbance in balance mechanisms and an increased falls risk factor (Beauchet et al. 2009). Those with a visual impairment depend more on their somatosensory and vestibular systems to maintain stability (Horvat et al. 2003).

Medications

Polypharmacy – the taking of multiple medications – is implicated in falls risk. The greater the number of drugs taken, the greater the risk of falling (Easterbrook et al. 2001). It has been reported that there is no clear advice on which number of medications can be considered as a cut-off point for increased falls risk, although four or more has been quoted (Al-Aama 2011; Close et al. 2003; Easterbrook et al. 2001; Lee et al. 2013). Benzodiazepines, antidepressants, antipsychotics, antiepileptics, anticholinergics and cardiovascular medications are all frequently associated with falls (Moylan and Binder 2007).

Side-effects of medications have a wide range of presentations, amongst which can be low blood pressure, possibly leading to dizziness, disturbances of balance or fainting.

Osteoporosis

The principal cause of hip fractures is a fall in those with bone disease or osteoporosis. In the UK there are an estimated three million people with osteoporosis (NOS 2014). Loss of bone density occurs faster in women than in men, with three-quarters of all hip fractures occurring in women (Banks et al. 2009). Twenty per cent of men over the age of 50, however, also suffer fractures, mainly as a result of bone disease (NOS 2014).

Mortality risks in the first year after a fracture are higher in men than in women, but the NOS also reports that a 50-year-old woman has a 2.8% risk of death due to hip fracture during her remaining lifetime, equal to that of breast cancer.

Falls locations

Health Promotion England reported that, for older people, accidents happen mainly in the home environment and contribute to 53% of injuries in the 65–74 age group and 72% in those aged over 75 (Department of Trade and Industry 2001).

The NHS collects admission statistics on falls in 19 different categories, such as falls on the same level from slipping, on and from ladders, and even from trees. NHS admission episode statistics from March 2010 to February 2011 identify 5% falls from a bed, 19% on the same level and only 8% on stairs and steps, which elsewhere have been implicated as the most common place for falls (Scott 2005). Unspecified falls account for 40% of the admission episodes.

A study by Bleijlevens et al.(2010) identified four different fall locations:

1. indoor falls related to lavatory visits
2. indoor falls during other activities of daily living
3. outdoor falls near the home during instrumental activities of daily living
4. outdoor falls away from home, occurring during walking, cycling and shopping for groceries

and concluded that there was a higher risk of injurious fall at either end of the activity spectrum: those who were most inactive sustained injuries indoors relating to lavatory visits, and those who were most active sustained injuries outdoors, away from home.

Home environment

Hazards in the home that contribute to tripping include trailing wires from extension cables, frayed carpets, loose rugs and clutter on the floor. These can often be easily remedied. Other trip hazards include pets that get under your feet, or are poorly discernible.

Currently, there is much debate about the cost of heating and fuel poverty. Arthritis, for example, becomes worse in cold, damp environments and mobility is affected, leading to an increased falls risk (Marmot Review Team 2011).

Poor lighting or moving from a well-lit room to a dark hallway can increase falls risk, as elderly people need more light to see clearly and have slower dark adaptation (Jackson et al. 1999). Patterned stair carpets often obscure stair edges and, combined with clutter on stairs and poor stair lighting, create an unsafe environment (Figure 1).

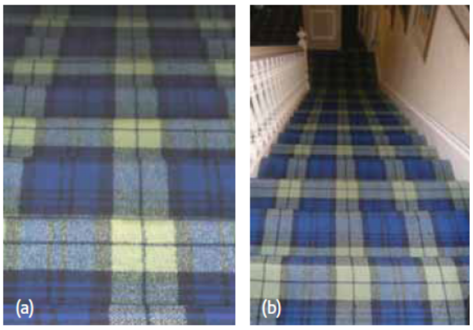

Figure 1. (a, b) Patterned carpet obscuring stair edges.

All stairs should also have a bannister or stair rail for safety and to aid stair negotiation.

Behavioural aspects

Certain behavioural aspects also contribute to falls risk, for example:

- overstretching to reach an object can lead to loss of balance
- carrying large or heavy objects, especially up and down stairs
- rushing to the bathroom
- not turning lights on
- drinking alcohol
- multitasking

Hip protectors in the form of padded underwear are sometimes used to minimise injury when people fall. They do not, however, prevent all fractures and their use can lead to skin irritation. Most research has looked at their use in residential care situations (Easterbrook et al. 2001).

Non-visual falls risk factors are many and varied. The above discussion should by no means be considered exhaustive.

Visual aspects of falls

Masud and Morris (2001) summarised 12 studies that identified the most likely cause of falls by ranking the mean percentage found across these studies (Table 1).

Table 1. Ranking of most likely cause of fall (Masud and Morris 2001)

Most likely cause of fall	Mean (%)	Range
Accident/environment-related	31	1–53
Gait/balance disorders or weakness	17	4–39
Dizziness/vertigo	13	0–30
Drop attacks	9	0–52
Confusion	5	0–14
Postural hypotension	3	0–24
Visual disorder	2	0–5
Syncope	0.3	0–3
Other specified causes	15	2–39
Unknown	5	0–21

Excluding the categories 'other specified causes' and 'unknown', visual disorders were ranked last but one. However, it is important to understand that falls do not always have one single identifiable cause. In fact, in most cases, falls are a result of a combination of one or more visual or non-visual factors. Having multiple factors can potentiate the falls risk, as in the case of visual loss combined with hearing or balance impairments (Kulmala et al. 2009).

Visual impairment is quoted as approximately doubling falls risk, with the risk increasing as visual function deteriorates (Harwood 2001).

In the UK, registration as 'sight-impaired' (formerly partially sighted) and 'severely sight-impaired' (formerly blind) is based on a combination of visual acuity and visual field data, as detailed in Table 2.

Table 2. UK criteria for registration as sight-impaired and severely sight-impaired (Department of Health 2007)

Sight-impaired (partially sighted)	Severely sight-impaired (blind)
3/60–6/60 Snellen with full field	<3/60 Snellen
Up to 6/24 Snellen with moderate contraction of the field, opacities in the media or aphakia	3/60–<6/60 Snellen with a very contracted field of vision
6/18 Snellen or better if there is a gross defect (e.g. hemianopia) or if there is a marked contraction of the visual field (e.g. in retinitis pigmentosa or glaucoma)	6/60 Snellen or better with a contracted field of vision, especially in the lower part of the field

In clinical practice, however, visual impairment is generally recognised when the level of vision of an individual no longer allows that person to fulfil activities of daily living without supplementary devices, daily living aids or specialist training.

Vision-related falls risk factors

Reduced visual acuity is a recognised descriptor of visual impairment. There are, however, studies that report that poor visual acuity does not increase the risk of falls or hip fracture, and that other visual factors such as poor depth perception (Patla et al. 2002), reduced contrast sensitivity (Cummings et al. 1995) or visual fields (Black et al. 2011; Coleman et al. 2007; Graci et al. 2010) are causative.

Visual acuity: prevalence of low vision and falls-related risk

In a random postcode selection of areas in mainland Britain, the prevalence of low vision, defined using the World Health Organization criteria, was investigated as part of the National Diet and Nutrition Survey (van der Pols et al. 2000). In all, 14.3% of participants aged 65 and older were found to have low vision, with prevalence – as expected – increasing with age. Three age groups were categorised: 65–74 years, 75–84 years and over 85, with a prevalence of 3.1%, 11.6% and 35.5% respectively.

The North London Eye Study (Reidy et al. 1998) found the prevalence of bilateral visual impairment (defined as <6/12 Snellen) in a random sample of 1547 over-65s to be 30%. Of note is that nearly three-quarters of these had an impairment that was deemed potentially remediable. Their results are compared with other UK studies of visual impairment prevalence in Table 3.

Despite the high prevalence, especially in the older groups, a Cochrane review of community screening for visual impairment in older people reported that no evidence existed that screening resulted in an improvement of asymptomatic older patients' vision (Smeeth and Iliffe 2001).

Table 3. Comparisons of visual impairment prevalence in UK studies according to age group

Study	Definition of visual impairment	Age group prevalence (%)		
		65–74 years	75–84 years	85 years and above
Van der Pols et al. (2000)	<6/18	3.1	11.6	35.5
RNIB (2006)	≤6/12	5.6	8.5	26.8
MRC trial (Evans et al. 2002)	<6/18		12.4	23.5
North London Study (Reidy et al. 1998)	<6/12	30		

MRC, Medical Research Council

Falls risk can be a combination of two or more non-visual factors, or a combination of visual and non-visual risk factors. Many studies find that more than one visual component contributes to falls risk. Buckley et al. (2005a, b) reported on the effects of blurred vision as a stand-alone factor. This was investigated with regard to stair negotiation, which is particularly important, as falls on stairs are a cause of serious injuries and death. Templer (1992) reported that the top and bottom three stairs are the main locations for falls accidents. A report prepared by the Health and Safety Laboratory highlighted that in the UK deaths from accidents in the home are nearly as frequent as deaths from traffic accidents. In more than half of these home accidents death is due to falls (Scott 2005).

Age-related macular degeneration (AMD) is the most common cause of sight loss in the UK, with a UK prevalence of late-stage AMD estimated to be 4.7% in those aged ≥65 years, rising to 12.2% in those ≥80 years (Owen et al. 2012). Wood et al. (2011) investigated 76 community-dwelling adults with AMD and found both visual acuity and contrast sensitivity to be significant predictors of falls. The loss or impairment of central visual fields is discussed later.

Cataract: prevalence and falls-related risk

The presence of cataracts is another common cause of reduced visual acuity. In a random sample of 1547 people aged 65 and over, the 1998 North London Eye Study (Reidy et al. 1998) found the prevalence of visual impairment (defined as visual acuity <6/12 Snellen) caused by cataracts to be 30%. Evans et al. (2002) examined Medical Research Council trial data for 14 600 over-75-year-olds from 106 general practices in the UK, and found a similar prevalence. In this study, cataract was later identified as the causative factor of visual impairment (defined as visual acuity <6/18) in 36% (Evans et al. 2004).

It is vital, therefore, that we understand the specific impact of cataract on falls risk. Cataracts can cause reduction in contrast sensitivity as well as reduced visual acuity. The authors identified five studies where a combination of these two factors was implicated (Anand et al. 2002; Anand 2003; Harwood et al. 2005; Heasley et al. 2004; Wood et al. 2011). Contrast sensitivity was not recognised to be a stand-alone contributory factor.

There are, however, conflicting research findings concerning cataract surgery. A longitudinal study of participants with and without cataract surgery found no association with cataract surgery and the rate of falls in independently living adults (McGwin et al. 2006). Conversely, a prospective study of the rate of falls before and after cataract surgery found this to be an effective intervention (Brannan et al. 2003).

A randomised controlled trial (Foss et al. 2006) noted that, although second-eye cataract surgery improves 'visual disability', the effect on falls remains uncertain. In contrast, Tseng et al. (2012) reported that, in a US cohort of over 1.1 million patients with cataract, those who had undergone surgical intervention had lower hip fracture odds within 1 year of surgery than those who had no surgical intervention.

As mentioned above, the presence of cataracts influences both visual acuity and contrast sensitivity. Harwood (2001) highlights the close correlation between these two factors and depth perception ($r \sim 0.6$) and compares odds ratios from a range of studies for each of these factors (Table 4).

Table 4. Comparison of odds ratios (OR) for falls

	OR min – max
Visual acuity	1.1 – 5.1 Cummings et al. (1995) – Grisso et al. (1991)
Depth perception	1.1 – 2.1 Kelsey et al. (1992) – Cummings et al. (1995)
Contrast sensitivity	1.2 – 1.8 Ivers et al. (1998) – Klein et al. (1998)

Derived from Harwood (2001).

Depth perception

As part of the Auckland Hip Fracture Study (Ivers et al. 2000), it was found that reduced binocular visual acuity and reduced stereopsis were independent risk factors for hip fracture. The Framingham Study (Felson et al. 1989) investigated hip fracture rates in a group of 2633 participants over a period of 10 years. Findings indicated that those with moderately reduced vision in one eye only had a higher risk of fracture than those with a comparable degree of reduced vision in both eyes, suggesting that good stereoscopic vision is a falls prevention factor.

Patla et al. (2002) reported on the results of three experiments undertaken to investigate the role of binocular vision in locomotion. The results showed that binocular vision was not critical in determining distance to an object, but was necessary in providing accurate information about the environment and obstacles within it. Head movements were found to be important for reorientation of the visual field when binocular vision was suddenly compromised.

While all three experiments were conducted on young participants (22.1 ± 3.3 years, 20.8 ± 1.6 years and 22.2 ± 2.6 years, respectively) with binocular vision reported as 'in the normal range', situations do occur in the elderly population that also create sudden changes in stereopsis, such as monocular vascular incidents or postoperative results.

A retrospective population-based study found an association with increased hospital admissions from fall injuries in the year following first-eye cataract surgery, and proposed that further research was necessary to determine causation (Meuleners et al. 2012). It is reasonable to assume a postoperative change in the refractive error of the operated eye. Depending on the magnitude of this change, a disturbance of stereo-efficiency is feasible. In clinical practice, emmetropia often seems to be the target postoperative outcome. In former ametropes, this may well lead to anisometropia until second-eye surgery is performed.

Visual fields

The Rotterdam Study (Skenduli-Bala et al. 2005) found the incidence of visual field loss to increase fivefold between the ages of 55 and 80 or above. Glaucoma is the most common cause in those aged ≤75 years, followed by stroke, AMD, then retinal vascular occlusive disease. These pathologies have very different patterns of field loss and studies have investigated both peripheral and central field loss.

Ramrattan et al. (2001) carried out a population-based cohort study to determine the prevalence of visual field loss in 6250 community-dwelling elderly residents. An increase in prevalence with advancing age was reported, specifically 3.0% in those aged 55–64 years, rising to 17% in those aged 85 and older.

Although it would initially seem that visual field loss could be considered independently from the correlated factors of contrast sensitivity, visual acuity and depth perception, the findings of Ramrattan et al. indicate a difference between unilateral and bilateral visual field loss, and therefore a possible link to stereo-deficiency. Although bilateral field loss was found to increase the frequency of falls sixfold, these falls did not result in an increase in wrist and hip fractures when compared with subjects with no field loss.

It is, however, conceivable that unilateral visual field loss may create problems with stereopsis and it is interesting to note that the above study reported more frequent falls and wrist fractures in these subjects than in those with no field loss.

AMD particularly links central visual field loss with reduced visual acuity and contrast sensitivity. In its unilateral presentation it is also linked with reduced stereopsis. Studies pertaining to AMD and postural stability or gait have found binocular central scotoma size (Hassan et al. 2002) to be the most significant predictor of mobility performance. Contrast sensitivity (Wood et al. 2009) was found to correlate best with postural stability. A further study of AMD patients by Wood et al. (2011) found central 24° field measures in this sample were not predictive of falls, whilst there was a significant association with reduced contrast sensitivity and increased rates of falls and other injuries. Reduced visual acuity was only associated with increased fall rate, not injuries.

Visual field loss is reported to have an effect on postural sway. Balance is the term used to describe the dynamics of body posture that prevent falling and is maintained by a combination of three sensory systems: visual, vestibular and somatosensory (Winter 1995). The somatic senses are those of the skin, muscles, joints and viscera, and their proprioceptors give feedback about change in joint movements and muscular tension, contributing thereby to a sense of position and self-movement. The visual contribution to postural stability is often referred to as visual stabilisation.

An investigation into the effects of central visual field loss in AMD patients on postural sway found that, when compared to subjects with normal vision, those with central visual field loss had a lesser contribution of vision to postural stabilisation (Turano et al. 1996). When investigating the effects of different types of field loss on postural sway, it was found that, when comparing equal-sized (30°) areas of central or peripheral field, it is the central visual field that dominates postural control (Straube 1984).

Investigations by Freeman et al. (2007) into the effects of contrast sensitivity, visual acuity, stereopsis and visual field loss found that only binocular visual field loss was associated with falls. Central, lower and upper peripheral fields were all found to be associated with an increased risk of falls. In a multiple regression model analysis of central and peripheral visual field loss, only peripheral field loss remained significant.

The lower visual field has been found to be important when negotiating multi-surface terrain (Marigold and Patla 2008). Loss or reduction of binocular inferior visual fields was implicated in increasing the rate of falls in a study looking at glaucomatous field loss (Black et al. 2011).

Coleman et al. (2007) studied a large cohort of 4071 community-dwelling women aged 70 or above and found severe binocular field loss in 10% ($n = 409$). In a third of these, frequent falls were attributed to the field loss. When looking at results adjusted for age, race, study site and cognitive function, a later study estimated the risk of hip and non-spine, non-hip fractures to be 66% greater in women with severe binocular visual field loss than in those with no visual field loss (Coleman et al. 2009).

Optometrists and falls risk assessments

In 2013 the authors carried out a prescribing and dispensing survey (unpublished) to gain an understanding of current dispensing and prescribing practices of General Optical Council-registered optometrists and dispensing opticians, when dealing with elderly patients or customers (≥65 years) at risk of falls. Part of the survey investigated whether optical professionals assessed falls risk, how confident they felt in doing this and what method of assessment they applied.

The response rate was lower than expected, in spite of a wide range of publicity both in paper journals and electronic media. This could indicate a lack of interest in the topic of falls, or the feeling that it is not directly relevant to daily practice. It could be argued that the survey results were subject to self-selection bias by respondents with an interest in falls research.

Of the 205 analysed responses, there were 154 optometrists (94 female, 60 male) and 51 dispensing opticians (36 female, 15 male). A total of 23.9% ($n = 49$) of respondents did not assess falls risk, 35.6% ($n = 73$) felt confident to do so and 40.5% ($n = 83$) were not confident.

Falls risk assessment methods

Respondents who had identified themselves as confident were asked how they assessed falls risk. Ten themes were identified from the responses (Figure 2).

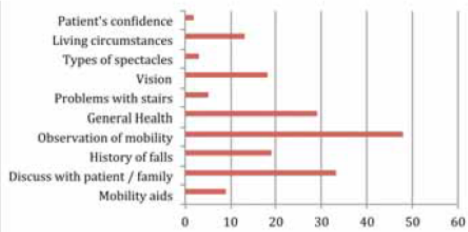

Figure 2. Thematic analysis of falls risk assessment modalities.

Falls risk assessment was undertaken primarily based on observation of patient mobility and discussion with the patient and family or carers. With only one practitioner reporting use of a specific falls risk assessment tool, the absence of a structured approach was apparent. In addition to the above categories, one practitioner referred to a senior member of staff for advice, and a further respondent used the experience gained from having a family member at risk of falls.

The type of spectacles worn was specifically mentioned by only two practitioners, with one other identifying whether the spectacles were broken in the course of a fall.

Chi-squared automatic interaction detection (CHAID) is a decision tree analysis model. This statistical method was chosen to investigate which parameters influenced the level of confidence in assessing falls risk. This method provides a hierarchical analysis of multiple variables.

The factors investigated were:

- gender
- years in practice
- practice environment
- profession
- supplementary qualifications
- number of >65s seen in an average week

- number of >65s with a visual acuity of 6/12 Snellen or less in an average week
- age in years
- employment status
- level of agreement with core statement

The main predictor of confidence was the number of patients seen in a week aged 65 and over with a visual acuity of 6/12 Snellen or less ($c^2 = 10.11$; df = 2; $P = 0.00$).

The majority of those who saw more than 10 such patients per week chose the 'confident to assess' category (55.8%). The majority of those who saw fewer than 10 such patients per week chose the 'not confident to assess' category (43.8%).

In both cases, the next defining variable was age. No other variables had a statistically significant influence on the chosen confidence level.

The decision tree analysis model, if used as a predictor, would correctly identify those 'not confident to assess' in 72.6% of cases.

Falls information

The majority of respondents indicated that they would benefit from further information about falls generally (75.9%), further information about the visual aspects of falls (87.9%), practice leaflets about falls generally (65.7%) and practice leaflets about the visual aspects of falls (79.7%). This indicates that there is a large interest base in additional knowledge regarding falls and their visual aspects.

In all, 85% of practitioners would welcome a quick and easy falls risk assessment tool to support them in practice.

Conclusions

The causes of falls are both varied and specific to each individual. The nature of falls risk differs between fallers and non-fallers and demands appropriately tailored falls prevention programmes. An increase in the elderly population, who contribute to the majority of hospital admissions as a result of injurious falls, demands falls risk reduction programmes across all identified risk areas.

Optical professionals should have an understanding of the role of vision, visual impairment and spectacle lens design with regard to falls risk to be able to provide sound prescribing and dispensing advice. Their role as primary health care providers could enable them to play an important role in falls awareness and falls risk reduction.

The reviewed literature illustrates the multifactorial nature of fall and the complexities in attributing specific risk or odds ratios to stand-alone visual factors. Studies vary not only in the type of visual impairment investigated, but also according to outcome data. Some studies report on falls, injurious falls or specific falls-related injury such as hip fracture. Others describe adaptive locomotion factors, such as postural stability, obstacle avoidance or foot and toe placement.

Falls are generally accepted as the outcome of a combination of contributory factors, with visual impairment widely recognised as one such. The role of reduced visual acuity is widely understood and reported on, both in academic research papers and public information leaflets. Along with acuity it is important to recognise that contrast sensitivity, visual fields and binocularity all play important intertwined roles.

Although there are publications that inform the practitioner about falls (College of Optometrists and BGS 2011; Elliott 2012), the majority of the respondents would still welcome further information for their own use, as well as practice leaflets. Identification or development of a suitable dedicated falls risk assessment tool could contribute to reducing the currently lacking structured approach to falls risk assessment in optical practice.

Summary

To understand the roles of vision and spectacle lens design in falls risk, it is helpful to have an appreciation of the multifactorial nature of falls. This review defines a fall, highlights the demographic and socioeconomic drives for falls reduction strategies and identifies a range of visual and non-visual falls risk factors. The role of spectacle lens design (single-vision, bifocal or progressive addition lenses) is complex and is outside the remit of this review.

The causes of falls are both varied and specific to each individual. The nature of falls risk, both non-visual and visual, differs between fallers and non-fallers and demands appropriately tailored falls prevention programmes. An increase in the elderly population, who contribute to the majority of hospital admissions as a result of injurious falls, requires falls risk reduction programmes across all identified risk areas.

Optical professionals provide a front-line contact with the elderly and are well placed to offer timely advice with regard to falls risk, particularly by identifying those with a change or reduction in vision. A recent survey by the authors identified the lack of a structured approach to falls risk assessment in optometric practice. The great majority of respondents would welcome further personal development information, practice leaflets and a quick and easy falls risk assessment tool for use in practice.

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Appendix 10 (cont.)

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CET multiple choice questions

This article has been approved for one non-interactive point under the GOC's Enhanced CET Scheme. The reference and relevant competencies are stated at the head of the article. To gain your point visit the College's website www.college-optometrists.org/oip and complete the multiple choice questions online. The deadline for completion is 31 July 2015.

1. The annual cost of social care for patients who have undergone hip replacement surgery is:

(a) £0.5 billion

(b) £0.6 billion

(c) £0.7 billion

(d) £0.8 billion

2. Which of the following patients would be eligible for registration as severely sight-impaired?

(a) 6/60 with moderate visual field contraction

(b) 6/24 with aphakia

(c) 4/60 with full field

(d) 6/36 with profoundly reduced visual field

3. Which of the following combination is incorrect about the risk factors that should be included in a multifactorial risk assessment for patients at risk of falling?

(a) Hypotension, footwear, dementia, syncope

(b) Labile blood pressure, footwear, psoriasis, arthritis

(c) Diabetes, arthritis, hypertension, incontinence

(d) Continence, reduced visual acuity, cognitive impairment, footwear

4. Which of the following is not true?

(a) Falls are more common in people who have previously suffered a fall

(b) Patients who suffer from osteoporosis are more likely to suffer injury from a fall than patients who do not suffer from the condition

(c) Patients who struggle to walk and talk simultaneously are at an increased risk of falling

(d) Regular podiatry appointments do not lower the risk of a fall

5. Which of the following advice is unlikely to reduce an individual's risk of falling?

(a) Turn on the lights if you visit the lavatory during the night

(b) Do not talk whilst you are walking

(c) Wear hip protectors

(d) Refrain from drinking alcohol

6. Which of the following statements is incorrect?

(a) There is an unequivocal link between the risk of falls and reduced visual acuity

(b) Reduced contrast sensitivity is a significant risk factor for falls

(c) Binocular central scotoma size in AMD is associated with reduced mobility

(d) Monocular visual field loss may increase the risk of falls by reducing stereopsis

● CPD Exercise

After reading this article can you identify areas in which your knowledge of falls risk assessment in optometric practice has been enhanced?

How do you feel you can use this knowledge to offer better patient advice?

Are there any areas you still feel you need to study and how might you do this?

Which areas outlined in this article would you benefit from reading in more depth, and why?

● Reflection

1. What impact has your learning had, or might it have, on:
   - your patients or other service users (eg those who refer patients to you, members of staff whom you supervise)?

Appendix 11 Avoiding slips and trips in our elderly patients

Additional Learning Material with MCQs for Association of British Dispensing Opticians' CET Conference, July 2012.

Additional Learning Material

ABDO CET Conference

29/30th September 2012

Avoiding Slips and Trips in our Elderly Patients

Anita Morrison-Fokken

Introduction

On first glance, it may seem that the topic of falls in the elderly population has no direct relevance to your daily practice as an optician. As a front line contact with the general public however, your awareness of falls risk factors could play a significant role in raising public awareness of falls reduction strategies, and moreover influence your lens dispensing recommendations.

This Additional Learning Material will highlight:

- the definition of a fall
- the demographics and socio-economic factors of falls
- non-visual falls risk factors
- vision related falls risk factors
- falls prevention strategies

What is a fall?

The Prevention of Falls Network Europe (PROFANE) Consensus group recommended a fall should be defined as "an unexpected event in which the participants come to rest on the ground, floor or lower level". [1]

In their 2010 updated Clinical Practice Guideline "Prevention of falls in older persons", the American Geriatrics Society and the British Geriatric Society keep their original definition of a fall as "an event whereby an individual unexpectedly comes to rest on the ground or another lower level *without known loss of consciousness.*"*[1] This is the same definition as used in their 2001 guidelines, which were referenced by the then National Institute for Clinical Excellence (NICE) in their 2004 Clinical Practice Guideline CG21. [2]

The randomised controlled trial VISIBLE [3] used the Kellogg definition that a fall is "unintentionally coming to the ground or some lower level *and other than as a consequence of sustaining a violent blow, loss of consciousness, sudden onset of paralysis as in a stroke or an epileptic seizure.*"* [4]

Lord[5] emphasises that although falls are generally thought to be "accidents", they are not in fact just "random events."

Types and Locations of falls

The Health Education Authority reported that "for older people accidents mainly occur in the home, contributing to 53% of injuries suffered by people aged 65-74 and 72% of injuries for people aged over 75. " The main cause of these injuries is falls. [6] Figure 1 shows the last recorded DTI location statistics.

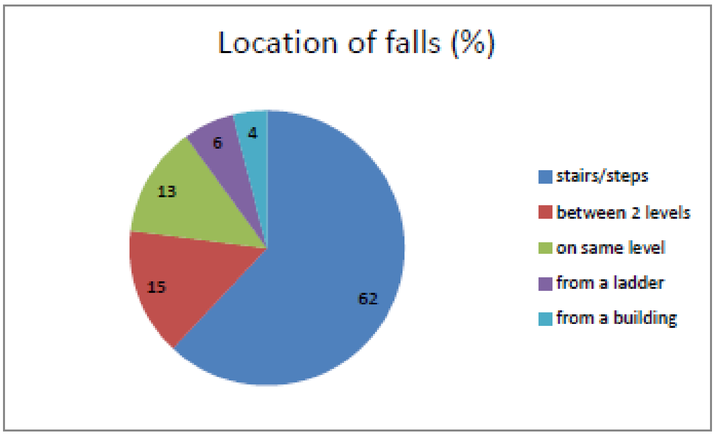

Figure 1: Location of falls after DTI "Avoiding slips, trips and broken hips" 2001

Other research[7] has identified four fall types:

- Indoor falls related to lavatory visits (hall and bathroom)
- Indoor falls during other activities of daily living
- Outdoor falls near the home during instrumental activities of daily living
- Outdoor falls away from home, occurring during walking, cycling and shopping for groceries

Older people have varying levels of fitness, but increasing age inevitably increases the risk of a fatal fall. [8] In the 75 – 84 year age group, falls are considered to be a significant cause of fatalities. In the over 85s this increases to become the main cause. Recent Hospital Episode statistics report that females aged 80 or over represented 30.9% of all fall-related admissions.[9]

Appendix 11 (cont.)

Demographics and socio-economic factors of falls

Falls have a large financial impact on health and social care resources, and can affect an older person's life greatly. Increased fear of further falls can limit physical activity, which in turn exacerbates frailty, social isolation and depression.

The British Orthopaedic Association estimated that the incidence of hip fracture will increase from 70,000 cases in 2007 to 101,000 cases in 2020.[10] In the UK, hip fractures are estimated to cost the NHS and Social Care Systems £2.3billion per year.[11]

Osteoporosis – a major risk factor in hip fracture - is not just a disease that affects women, and although 1 in 2 women over the age of 50 are reported to experience a fracture because of poor bone health, 1 in 5 men are also affected.

As mentioned previously, there is a real risk of death after a bone fracture, and it is estimated that 1,150 people are dying every month in the UK after a hip fracture. (11) The overall mortality in the first 12 months is greater however in men. Health Promotion England reported that up to 33% of all hip fracture patients die within twelve months of their accident, and 50% lose the ability to live independently. [12]

You can also research your local falls-related mortality statistics by visiting https://indicators.ic.nhs.uk/webview/ , and on the left of the screen selecting 'Compendium of Population Health Indicators' > 'Illness or condition' > 'Accidents and injury' > 'Mortality from accidental falls'. There are many different analyses, and you can choose which you would like to investigate further.

If you are further interested in NHS statistical information, www.hesonline.nhs.uk and the NHS Information Centre www.ic.nhs.uk are valuable resources.

The National Service Framework for Older People (Standard 6:Falls) describes a model for falls service provision. (13) Integrated falls services were to be implemented by local health authorities and social services by April 2005. I recommend finding out what services are available in your area, and how your patients can access them if required.

Our older generation is therefore disproportionately affected by falls. This age group is steadily increasing, and will place further demands on health and social care resources. The Office of National Statistics (www.ons.gov.uk) projects a 28% increase in those of pensionable age and a doubling of the over 80 age group in the period from 2010 to 2035. [13] Falls reduction strategies are therefore of major importance in managing this need.

Figure 2 clearly shows the age-related increase in admissions to hospital as a result of falls.

Appendix 11 (cont.)

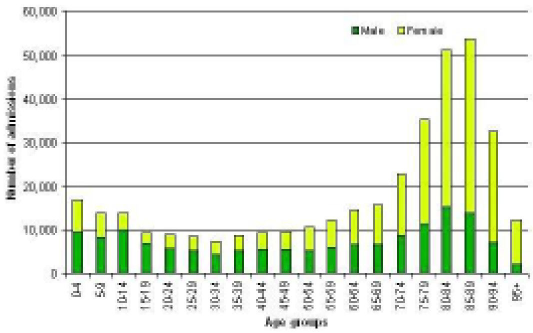

Figure 2. Graph to show the number of admissions to hospital for falls in 2007-2008
(Health and Social Care Information Centre www.hesonline.nhs.uk)

Non-visual falls risk factors

Falls risk factors are sometimes divided into extrinsic and intrinsic categories. Extrinsic factors are those not related to the individual's own physical and mental health capacities and can generally be easily amended, eg poor lighting in hallways etc.

Lord et al [14] identified 4 non-visual key risk factors, of which three are intrinsic:

- Dementia
- Depression
- Multiple medications
- Inappropriate footwear

Visual impairment was also identified as a risk factor, but we will look at this later.

The International Review of Interventions in Falls among Older People [15] further mentions dehydration, previous fall history, Parkinson's disease, diabetes, stroke, postural hypotension and an increasing sedentary lifestyle as risk factors. Balance is also not surprisingly implicated, with difficulties walking and the inability to balance on one leg being highlighted. Visual impairment in conjunction with other sensory loss - predominantly hearing - has been recognised as increasing fall risk. [16] Multi-tasking in the form of walking and talking at the same time is also a risk factor, and has been used in some risk assessment studies.

We have mentioned that the home is where most accidents happen. It is important to look at extrinsic factors here that can be remedied, such as poor lighting, trailing wires, clutter on stairs, and patterned carpets that obscure the step edge. (Figure 3)

Figure 3. Stair edge obscuration due to patterned carpet.

Vision-related falls risk factors

Many aspects of vision have been implicated as falls risk factors. Table 1 details a selection of studies that investigated the effects of different visual components.

	Stereo - deficiency	Visual Acuity	Contrast Sensitivity	Visual Fields	Not wearing glasses	Increased time since last eye exam
Ivers 2000 [17]	✓	✓			✓	✓
Beaver Dam Eye Study [18]	✓	✓	✓			
Freeman 2007 [19]	x	x	x	✓		
Anand 2003 [20]		✓	✓			
Harwood 2001 [21]		✓	✓			
Cumming 2007 [22]		x				
Ivers 1998 [23]		✓	✓	✓		
Squirrel 2005 [24]		✓				
Cummings [25]	✓	x	✓			
Wood [26]		✓	✓	x		

Table 1: Visual components of falls risk

Key: ✓ Found to increase falls risk

x Found not significant in increasing falls risk

The Blue Mountain Eye Study [23,27] reported that impaired vision and reduced visual fields were found to double the risk of falls and that "for those aged 75 or older, moderate visual impairment was associated with a nine-fold increase in risk of hip fracture during the subsequent two years"

5

Lens design

What is perhaps of more interest from a dispensing point of view is that some studies have found that those at risk of falls should be advised to wear single vision lenses, and not multifocals. Many of these studies have not been carried out by optical professionals, so it is perhaps not surprising that different definitions of multifocal lenses have been used. Bifocal and progressive addition lenses have been grouped together. (Table 2) The very different optical properties of these lenses have not been taken into account.

Study	
Johnson [28]	Multifocal = bifocal and PALs
Cumming [22]	Differentiated between bifocal and PALs
Anand[20]	No lens type differentiation
Lord [2914]	Multifocal = bifocal, trifocal and PALs
Ivers [17]	Bifocal only (No PAL wearers in study)
Campbell [30]	No lens type differentiation
Haran [3]	Multifocal = bifocal, trifocal and PALs

Table 2: Lens definitions used in studies

The correct definition of lens types can be found in BS EN ISO 13666:1999 document. (Still current at time of writing).

Regarding spectacle lens design, we find the following recommendations:

- "Older people may benefit from wearing nonmultifocal glasses when negotiating stairs and in unfamiliar settings outside the home." [14]
- "Use of single vision improves stepping precision and safety when elderly habitual multifocal wearers negotiate a raised surface. " [31]
- "A useful strategy to reduce falling in the older person might be to advise multifocal and distance single-vision spectacle wearers to flex their heads rather than just lower their eyes when looking downwards. " [28]
- "With appropriate counselling, provision of single lens glasses for older wearers of multifocal glasses who take part in regular outdoor activities is an effective falls prevention strategy." [3]

Unfortunately, the research is not absolutely prescriptive. Haran (4) further comments that the provision as in the last bullet point above could be "harmful, however, in multifocal glasses wearers with low levels of outdoor activity". Cumming [22] also finds that "in frail older people, comprehensive vision and eye assessment, with appropriate treatments, does not reduce and may even increase the risk of falls and fractures"

6

Advancing age increases the dependence on bifocal, trifocal and progressive addition lenses, as well as the prevalence of visual impairment and the risk of falls. Strategy with Vision [32] advised in a personal communication that the market share of bifocal lenses in the UK in 2010 was 12%, and that of progressive lenses 22%. This is a good third of all the lenses we dispense. The question we must pose is whether current studies provide enough evidence to differentiate between the optical effects of bifocal, trifocals or PALs with regard to increasing falls risk?

This forms the basis of my PhD research in the Department of Vision Sciences at Aston University.

I suggest reviewing a recent editorial by Elliott [33] and the AOP guidance issued in April 04, which stated "Other changes of lens form may affect the risk, such as moving from varifocals to bifocals or vice versa. For a well adapted wearer, switching from a multifocal to a single vision correction may cause some disorientation". The College of Optometrists has also produced a helpful overview document. [34]

Cumming [22] advises prescribing conservatively and giving advice about the need for caution when adapting to "new eyeglasses ". Experience tells us that we are indeed wise to alert our patients to adaptation issues when there are large prescription changes, such as change of axis orientation and cyl power, or if a different lens design is dispensed. As well as relying on your professional skills to ensure correct centration and fit characteristics, communication is key to informing your patients of potential issues, along with identifying which of your patients may have an increased fall risk.

Even though issued in a different context, we would be wise to take on board the following quote:

"For lack of guidance a nation falls..." Proverbs 11:14

Acknowledgements

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*Author's italics

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Appendix 11 (cont.)

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Appendix 11 (cont.)

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Date

Name

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If you don't submit online, post or fax your answers using this form

C-19888 Avoiding slips and trips additional learning– MCQs

1. Which definition of a fall is used by NICE in the Clinical Practice Guideline CG21?

- The PROFANE definition
- The Kellogg definition
- The visible trial definition
- The American Geriatrics Society & British Geriatrics Society definition

2. Which one of the following is an intrinsic fall factor?

- Poor lighting on stairs and in hallways
- Loose fitting slippers
- Multiple medications
- Patterned carpets that mask stair edges

3. According to the DTI report, where do most falls occur?

- From a ladder
- Outside during activities of daily living
- From stairs and steps
- On the same level

4. Which age group has the least number of hospital admissions as a result of falls?

- 80 - 84
- 30 - 34
- 90 - 94
- 0 - 4

5. Which statement is NOT true?

- Visual impairment is a recognised falls risk factor
- Bifocal lenses have been shown to reduce falls
- Visual field loss has been associated with increased falls risk factor
- Falls risk factor is increased when visual impairment is accompanied by hearing loss

6. Which statement is true?

- Prescribing conservatively and advising on adaptation issues is recommended
- We should advise our patients to look straight ahead when negotiating stairs if wearing PALs
- Stepping precision is improved when wearing bifocals
- Multifocals should always be prescribed to elderly presbyopes

Please give your opinion of this CET. This will help ABDO CET to plan and improve future CET provision. Add any other comments in the box.

- Excellent
- Good
- Acceptable
- Poor